# Appendix A: Hydrology and Geomorphology

## Identifying Environmental Flow Requirements for the Pecos River:
## Background Literature Review and Summary

Contents

# 1 Changes in Physical Process & Flows Resulting from Dams & Operations

Hydrology is a driver for geomorphic and biologic trends in arid river reaches: 1) arid rivers are most often sand bed dominated and 2) sand bed systems are quite dynamic. Large-scale factors, such as climatic wet and dry seasons, affect snowpack and precipitation patterns throughout watersheds. When engineered structures such as dams, levees, and bank stabilization methods are introduced, the underlying hydrology (mean discharge of water and sediment) is influenced. Cumulatively, over time, this generally results in a homogenization of the river (Poff et al. 2007) and a progressive decline in the diversity of structure and functions of both the aquatic and riparian ecosystems. This is owed to the decrease in ranges of water and sediment discharges, which are shown to drive diversity of river morphological features that are found there. Historically, the Pecos fits the arid river definition. It is largely a sand bed system that historically was braided and had the characteristic transverse bars.

The total drainage area at the Pecos' confluence with the Rio Grande is approximately 33,000 square miles (Carra 2007). The majority of the Pecos' tributaries flow in from the west - Gallinas River, the Rio Hondo, the Rio Felix, the Rio Penasco, the Delaware River, Independence Creek, Toyah Creek, and Comanche Creek. Entering the Pecos from the east are the tributaries Alamogordo, Taiban, Live Oak, and Howard (Hayter n.d.).

Surface hydrology represents the timing, magnitude and duration of flows through a watershed system. When traveling downstream in a watershed system, there are more and more tributary inputs and in-stream infrastructure. This culminates into spatial observations of the watershed system. Also, to be considered are temporal observations, resulting from climatic trends and development in the watershed.

## *1.1 River Reaches*

For the purposes of this document, the Pecos River was divided into three river reaches (Table 1; Figure 1). Reach A includes the headwaters to Santa Rosa Dam. Reach B is everything downstream of Santa Rosa Dam to Sumner Dam. Reach C, the longest reach, includes everything downstream of Sumner Dam to Brantley Dam. In some sections of this report, Reach C is further divided into three sub-reaches (C-1, C-2, C-3). These sub-reaches relate to how the U.S. Fish and Wildlife Service (USFWS) has traditionally divided up the river based on habitat quality (Horner 2020).

*Table 1: River reach information for the Pecos SRP.*

| | Location | Length | Elevation Drop | Overall Slope |
|---|---|---|---|---|
| **Reach A** | Headwaters – Santa Rosa Dam | 232 km<br>144 mi | 1,200 m<br>3,937 ft | 0.5% |
| **Reach B** | Santa Rosa Dam to – Sumner Dam | 87.7 km<br>54.5 mi | 122 m<br>400 ft | 0.1% |
| **Reach C** | Sumner Dam – Brantley Dam | 354 km<br>220 mi | 305 m<br>1,000 ft | 0.08% |

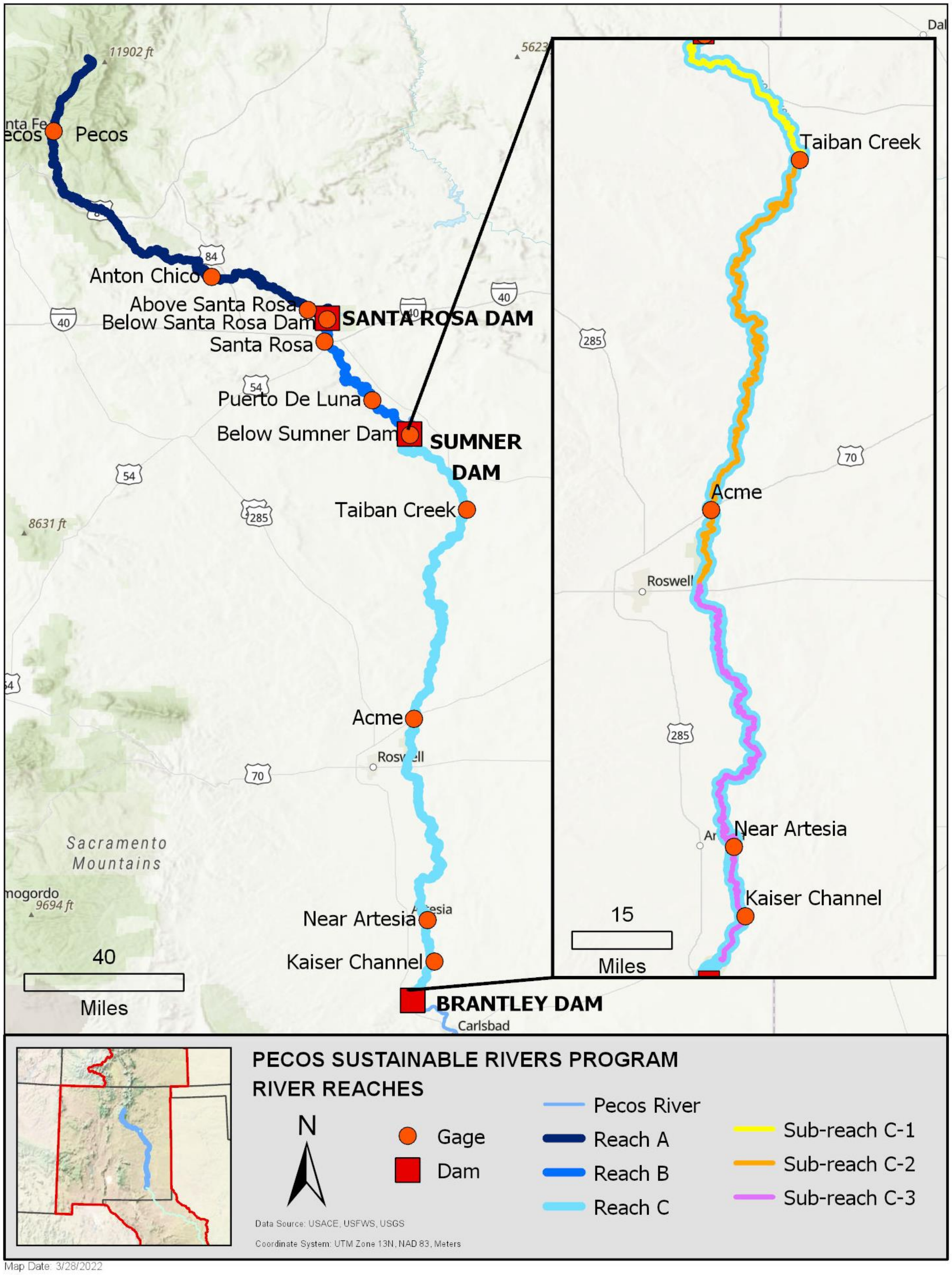



*Figure 1: The reaches and sub-reaches for the Pecos SRP Literature Review.*

As discussed above, the construction of dams has a significant impact on a river's natural hydrology and the watershed landscape. The dam acts as a physical barrier that stores inflows and manages outflowing discharges for specific purposes. The dam construction also affects the transport of sediment in the reach, again by acting as a physical barrier that stores sediment, but also by effecting riverine hydraulics that transport or stores sediment. Since 1880, the Pecos River has become increasingly fragmented due to sediment capture and flood control by dams, and base inflows being affected by groundwater withdrawal (Mussetter Engineering, Inc. 2001). The surface hydrology for the system is evaluated by two foci relevant to an environmental flows workshop: pre-dam versus post-dam hydrology changes and daily averaged seasonal representation.

The paired influence of sediment and hydrology may change a river's geometry and affect ecosystems that are sensitive to hydraulic shear forces, sediment transport regimes, or other geomorphologic patterns that affect water conveyance on land. This hydrologic analysis uses percent exceedance and annual peak discharge to analyze pre- and post-dam eras. Percent Exceedance describes the magnitude and duration of flows through a basin. The high-flow, less frequent events, can be used to characterize the flood regime of the basin. Certain ecological processes, such as vegetation development, are dependent on flood frequencies. Flood events may mobilize larger sediment and bed loads, affect the stability of vegetation, and influence the topography of the terrain that directs flows of less magnitude. The low-flow, more frequent events, demonstrate the base- and low- flows for a reach, demonstrating the frequency of dry periods.

While the Percent Exceedance can be used to demonstrate durations and magnitudes of discharge over several years or decades, the annual peak discharge is helpful in demonstrating trends over an annual basis. U.S. Geological Survey (USGS) gages were used as primary data sources to evaluate the system, the gages utilized are listed in Table 2 and shown in Figure 1.

*Table 2: USGS gages used for the Pecos SRP hydrology analysis.*

| ***Pecos River Gages*** | ***USGS Number*** | ***Period of Record*** | ***Analysis Reach*** |
|---|---|---|---|
| *Near Pecos, NM* | *08378500* | *10/1/1919* | *A* |
| *Near Anton Chico, NM* | *08379500* | *10/1/1910* | *A* |
| *Above Santa Rosa Lake* | *08382650* | *2/28/1976* | *A* |
| *Below Santa Rosa Dam* | *08382830* | *1/17/1980* | *B* |
| *Santa Rosa, NM* | *08383000* | *10/1/1912* | *B* |
| *Near Puerto de Luna, NM* | *08383500* | *5/1/1938* | *B* |
| *Below Sumner Dam, NM* | *08384500* | *10/1/1912* | *C* |
| *Below Taiban Creek* | *08385522* | *8/12/1992* | *C* |
| *Near Acme, NM* | *08386000* | *7/1/1937* | *C* |
| *Near Artesia, NM* | *08396500* | *10/1/1905* | *C* |
| *Kaiser Channel Near Lakewood, NM* | *08399500* | *5/16/1950* | *C* |

Lastly, the seasonal hydrology is evaluated based on hydrologic seasons that impact the ecology surrounding the Pecos Basin (Table 3). These hydrologic seasons coincide with changes in temperature and historic precipitation patterns that affected which species inhabit the areas surrounding and within the Pecos River.

| Table 3: Seasons used to evaluate seasonal hydrology for the Pecos SRP Literature Review. | |
|---|---|
| **Season** | **Starting Date** |
| Snowmelt runoff | January 27 – May 27 |
| Summer low flow | May 28 – July 25 |
| Monsoon | July 26 – September 4 |
| Fall-winter base flow | September 5 – January 26 |

The hydrologic data from USGS gages were synthesized into daily averaged data into three "eras". The eras are punctuated by dam construction:

- Pre-Sumner Dam (period of record to October 1937);
- Pre-Santa Rosa (October 1937 to 1979); and
- Modern (October 1979 to present).

October marks the beginning of the water year and does not necessarily coincide with the dam closure dates.

Following the surface hydrology analysis for each reach, there is a discussion on the changes in channel geometry and sediment transport in order to identify sub-reach trends that are occurring in each study reach. The channel geometry and sediment transport discussion uses historical aerial photography from 1997, 2011, 2016, and 2018 was used to measure and compare active channel width, active channel area, sinuosity, and assess channel plan view (e.g. channel migration, etc.). The objective is to link these trends with changes in morphological drivers: sediment and water supply; as a means to both characterize these reaches and to prepare for analyses of geomorphic trends that may be affected by environmental flows recommendations and analysis.

# 2 Reach A

Reach A extends from the headwaters to the Santa Rosa Reservoir Dam and is approximately 232 kilometers (144 miles) long. With an elevation drop of over 1,200 meters (3,937 ft), the overall slope of the reach is 0.5%.

The 2021 USBOR Basin Study summarizes Reach A –

> *"From its headwaters in the Sangre de Cristo Mountains, the Pecos River flows generally southeast, dropping in elevation from 11,700 ft at its source to about 4,800 ft upstream of Santa Rosa Reservoir (USFS 2002). The Pecos River above Santa Rosa Reservoir is perennial except for short reaches of intermittent flow between Anton Chico and Colonias. In these reaches, the river loses the entirety of its flow unless flows are very high (e.g., during snowmelt runoff season and after major storms). Much of this water ultimately rejoins the river further downstream. Average annual snowmelt runoff over the past 30 years has been approximately 50,000 to 60,000 acre-feet. Major*

*tributaries to this reach include the Rio Mora, Willow Creek, Glorieta Creek, Cow Creek, Tecolote Creek, and the Rio Gallinas."*

Reach A has three USGS gages that were used for its peak annual discharge evaluation. The Pecos, NM gage is the most upstream gage in the system (Figure 2). Though in some years the downstream gage at Anton Chico, NM experiences similar magnitudes of peak discharge, Anton Chico gage regularly exceeds the daily averaged data from the gage at Pecos, NM peak by approximately 3,000 cfs (Figure 3). The gage above Santa Rosa Lake generally follows the order of magnitude of the Anton Chico, however there are several years in the 2010s that greatly exceed the Anton Chico peaks, by as much as 9,000 cfs (Figure 4). The magnitude of the peak event has generally decreased over the period of record. The frequency of daily average discharge events exceeding 2000 cfs occurred approximately every 4 years, but from 1997 to 2019, 2000 cfs has only been exceeded twice.

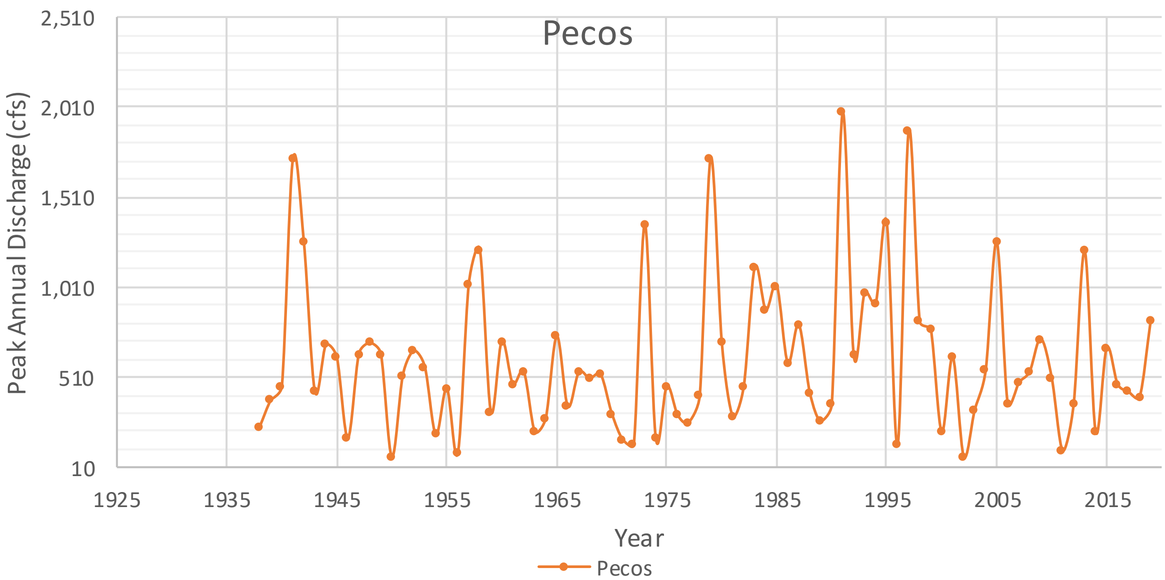



*Figure 2: Annual peak discharges for USGS gage Pecos River near Pecos, NM.*

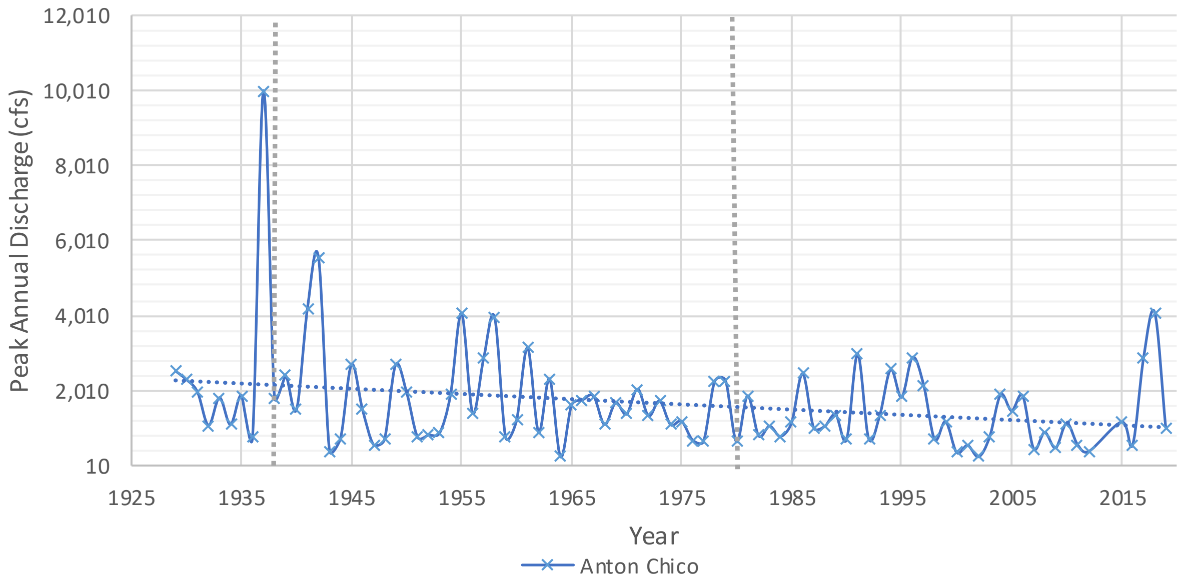



*Figure 3: Annual maximum daily averaged discharges for USGS gage Pecos River Near Anton Chico, NM.*

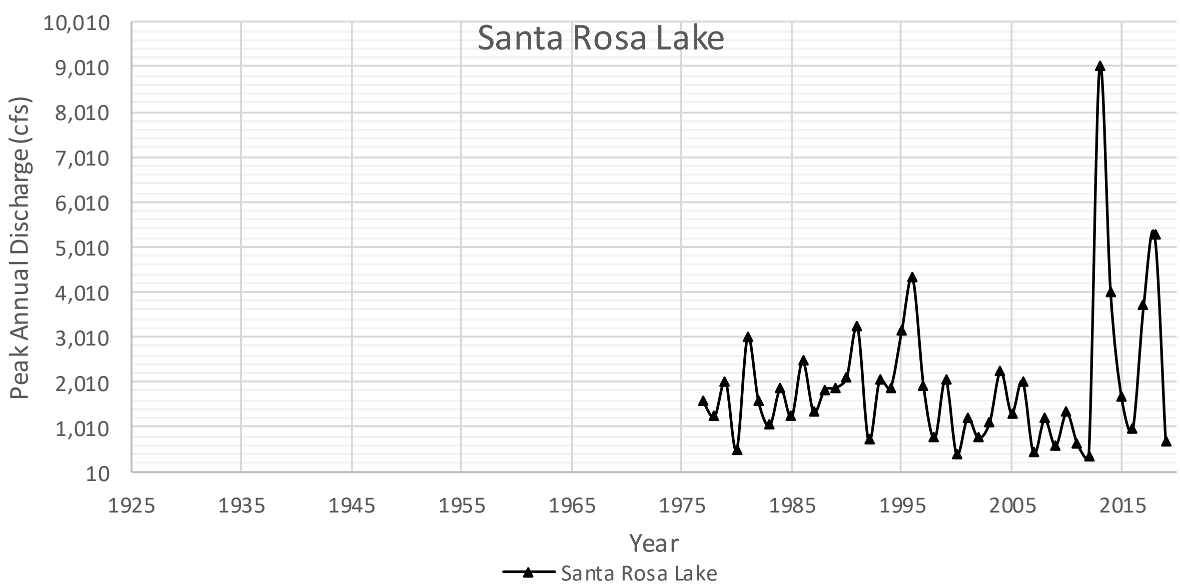



*Figure 4: Annual peak discharges for USGS gage Pecos River above Santa Rosa Lake.*

USGS also presents the maximum instantaneous discharge for each of its gaged sites. Often, these present a longer period of record than the daily-averaged data. Differences between the maximum daily averaged and the peak instantaneous data occur because flood frequency events can be "flashy" and rapidly attenuated over a few hours. The daily average usually shows an attenuated record of the peak discharge. The Pecos River near Anton Chico (USGS 08379500) has a demonstrable decrease in magnitude of peak events over time (Figure 5), with the last event exceeding 30,000 cfs occurring in the 1930s, and the last event exceeding 20,000 cfs occurring in the 1990s.

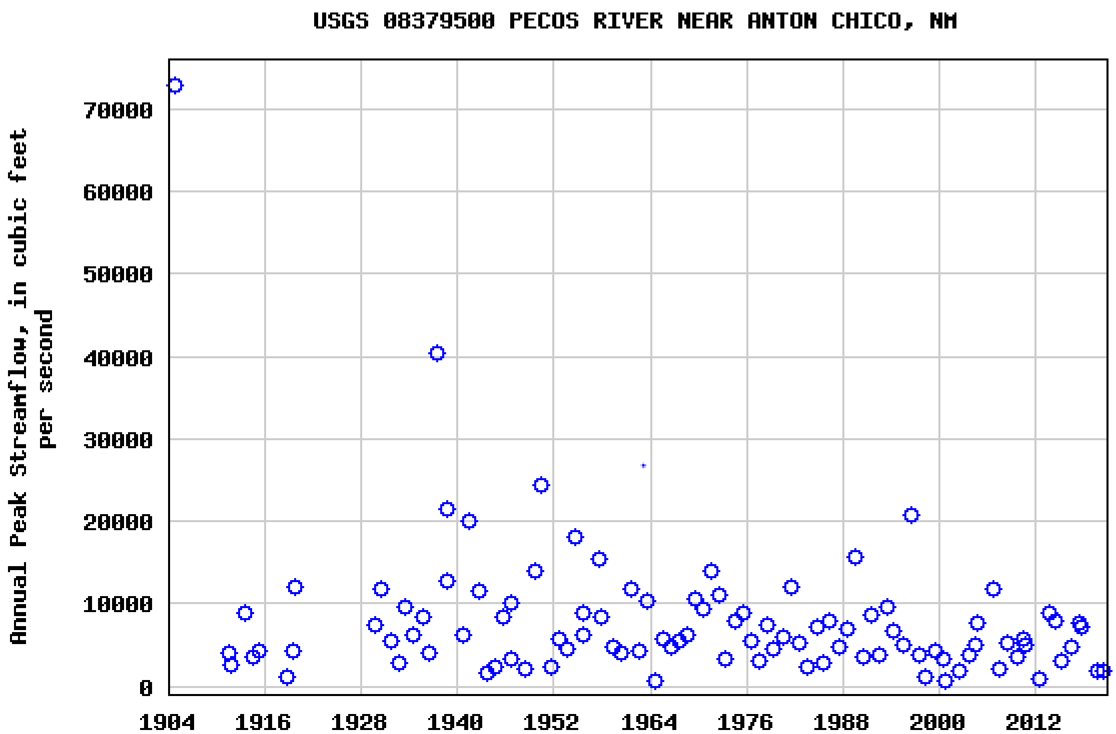


*Figure 5. Peak annual stream flow for Pecos River near Anton Chico, NM.*

Reach A has not been affected by upstream dam regulation, and therefore has only slight variance of daily averaged discharges over the course of the three eras (Figure 6). The maximum variance occurs in the beginning of the Fall-Winter base flow season, by approximately 100 cfs. This may be due to a late monsoon season occurring in the Pre-Sumner, from 1919 (the beginning of period of record for this gage) to 1937. The Pre-Sumner era is shorter than the other two, making it more prone to variance.

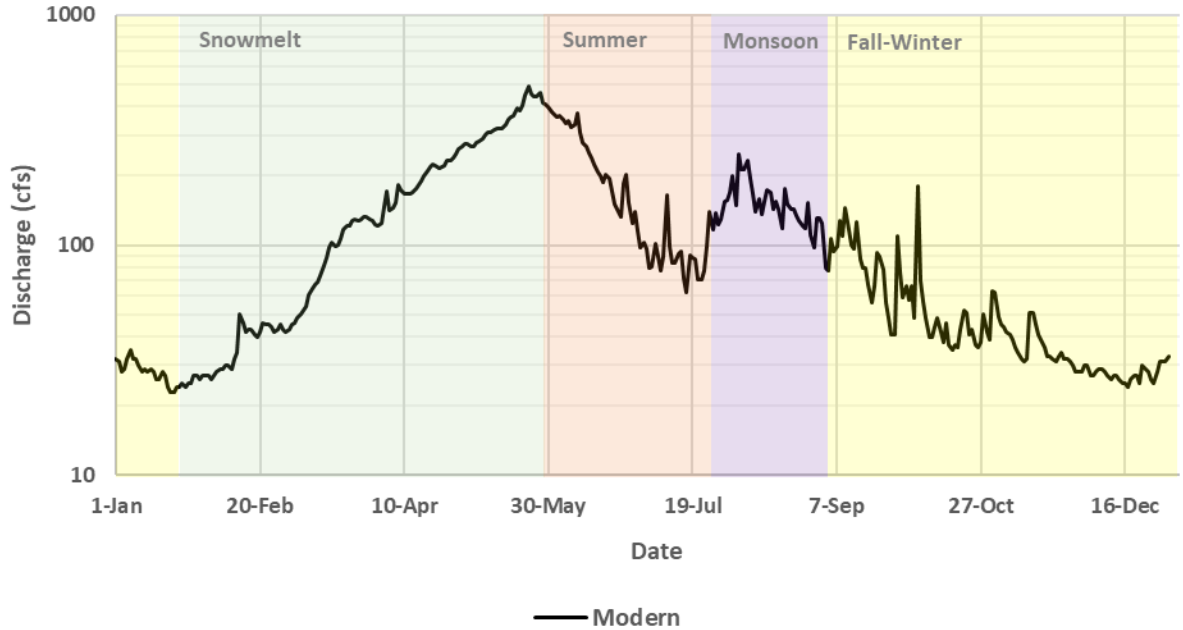



*Figure 6: Daily averaged data representing Reach A, from Pecos River at Anton Chico, NM (USGS 08379500)*

In terms of sediment movement, Reach A is confined by narrow canyon walls with a narrower valley bottom than either Reach B or C. There are five locations where substantial channel migration has occurred ranging from 90 to almost 700 ft. Two of the five locations were influenced by tributary inputs. No meander bend cutoffs were noted, only lateral migration. From 1997-2018, Reach A active channel area decreased by 25% and channel width decreased 29%. Sinuosity was nearly identical. Cross-section analysis (total of 2) noted a decrease in channel capacity at both cross-sections and a slight decrease in shear stress (force of moving water against the bed) at one of the two.

# 3 Reach B

Reach B is below Santa Rosa dam and just upstream of Sumner dam, it is affected by Santa Rosa Dam. Reach B was evaluated using the USGS gage of the Pecos River at Santa Rosa, NM (08383000) and Below Santa Rosa Dam (08382830) for the pre- and post-dam conditions, respectively. It is a relatively short reach of only 87.7 kilometers (54.5 miles) with an elevation drop of roughly 122 meters (400 ft) and an overall slope of 0.1%.

The USBOR summarizes water resources in this reach in the 2021 Pecos Basin Study –

> ” *From Santa Rosa Dam, the Pecos River flows about 60 miles southwards to Sumner Reservoir, at an elevation of just under 4,300 ft, near the Village of Fort Sumner. The springs near the town of Santa Rosa provide about 36,000 to 60,000 acre-feet of water annually to the river. Major tributaries to this stretch include numerous short, spring-fed creeks in the Santa Rosa area, Agua Negra, and Alamogordo Creek. The springs around Santa Rosa Reservoir provide a fairly consistent flow in this reach of the river.”*

The following percent exceedance curves show the pre-dam conditions sustaining lower flows for a greater percentage of the time (Figure 7). Prior to the construction of Santa Rosa Dam, 75% of daily averaged flows throughout the years were less than 100 cfs. In the post-Santa Rosa era (since 1980) a daily averaged discharge of less than 100 cfs occurs 85% of the time.

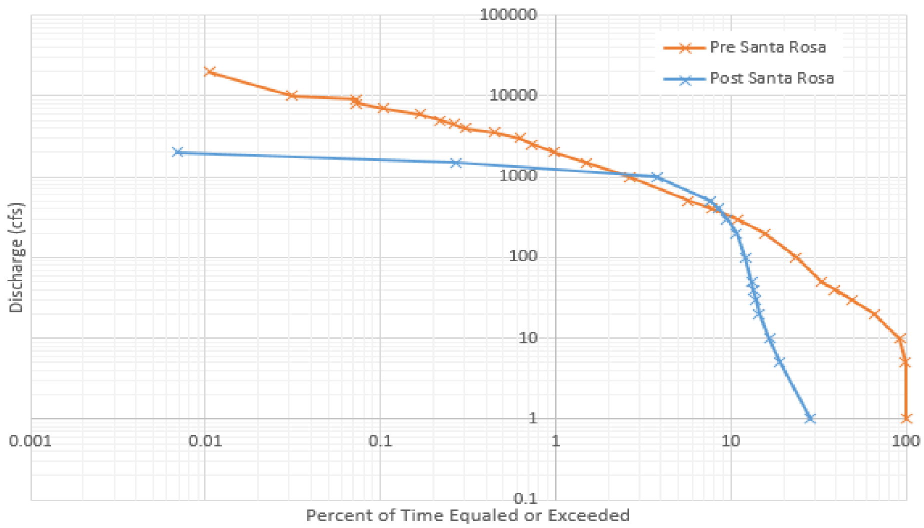



*Figure 7: Reach B daily average percent exceedance prior to and following installation of Santa Rosa Dam.*

More dramatically affected for Reach B are the high flow events. Prior to the construction of Santa Rosa, there were occurrences of daily averaged discharges exceeding 10,000 cfs. Though these events were infrequent over the recorded time period, with the period of record beginning in 1912, such events would be influential of vegetative and sediment distribution in the reach. Post-Santa Rosa conditions of a similar frequency, albeit over half an accumulated time period, 40 years, has a maximum event of 2,000 cfs. The 1% event after dam construction was found to be 1200 cfs. Prior to the construction of Santa Rosa Dam, the 2,000 cfs discharge would be exceeded 1% of the time. This indicates that the 1% peak event has been attenuated by a magnitude of 40% in Reach B.

For Reach B, the discharge related to the Santa Rosa Dam location is reflected by two USGS gages: Pecos River at Santa Rosa, NM (08383000) and Below Santa Rosa Dam (08382830; Figure 8). These are effectively near the same location, however using the Santa Rosa, NM allows for the period of record to extend back to 1928. The USGS gage at Puerto de Luna, NM is downstream of the Santa Rosa gage. Prior to the construction of Santa Rosa Dam, the magnitude of the peak events for Puerto de Luna, NM gage and the Santa Rosa gage were very similar. The maximum daily averaged discharge exceeded 10,000 cfs on three occasions throughout the period of record. Following the construction of Santa Rosa Dam, Puerta de Luna annual peak discharges continued to have greater magnitude than those upstream. Maximum averaged daily discharges generally continued a low-magnitude trend, with the maximum discharges from Santa Rosa not exceeding 2,000 cfs (Figure 9). Prior to the construction of the dam, 2,000 cfs would be the maximum daily averaged annual discharge about 20% of the time.

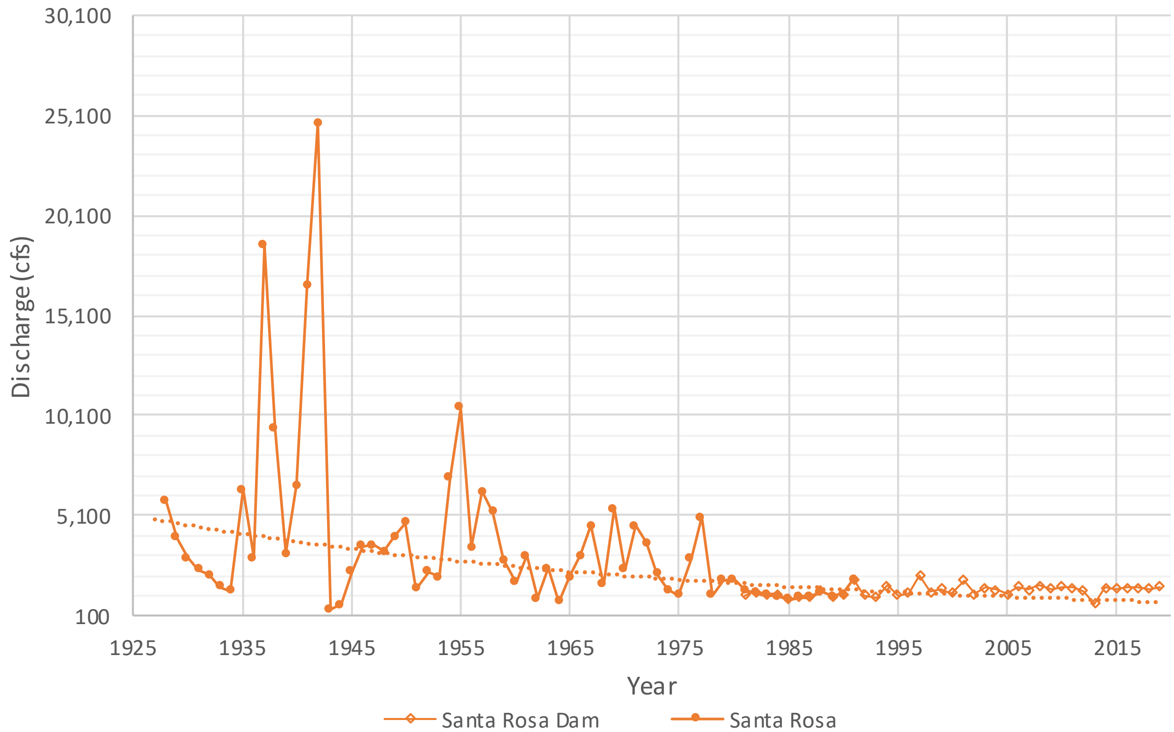



*Figure 8: Annual peak discharges for USGS gages in Reach B.*

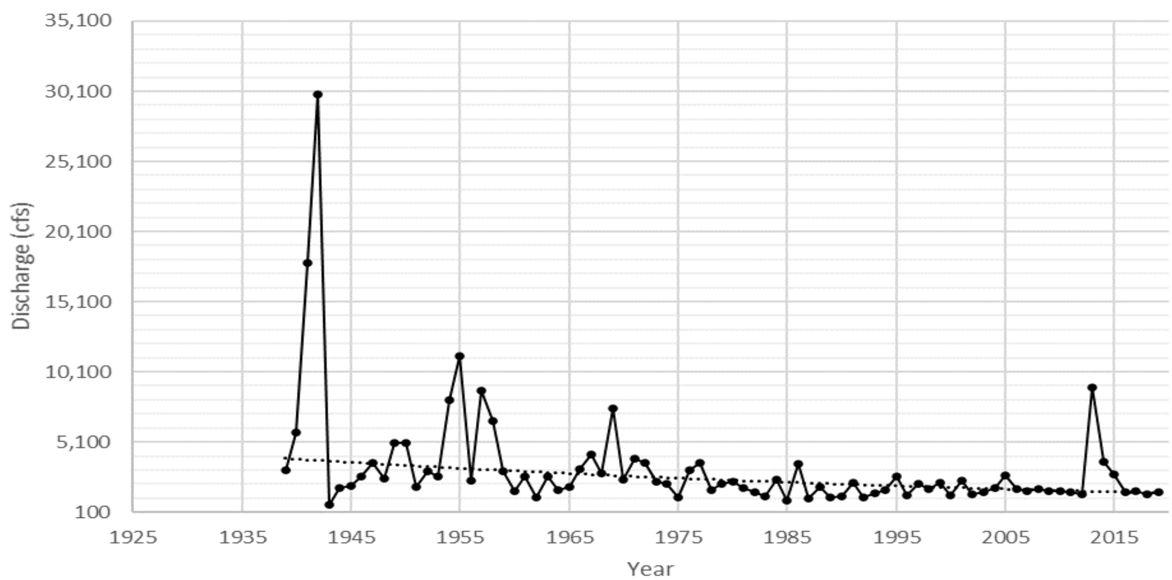



*Figure 9: Annual maximum daily average discharges for USGS gage Pecos River near Puerto de Luna, NM in Reach B.*

According to instantaneous peak data from USGS, the magnitude of peak discharges has decreased over the period of record (Figure 10). Prior to closure of Santa Rosa Dam, instantaneous peak events would exceed 10,000 cfs nearly 40% of the period of record with some events including 6 events ranging from 20,000 to 50,000 cfs. After closure the 10,000 cfs magnitude instantaneous events occurred 10% of the years.

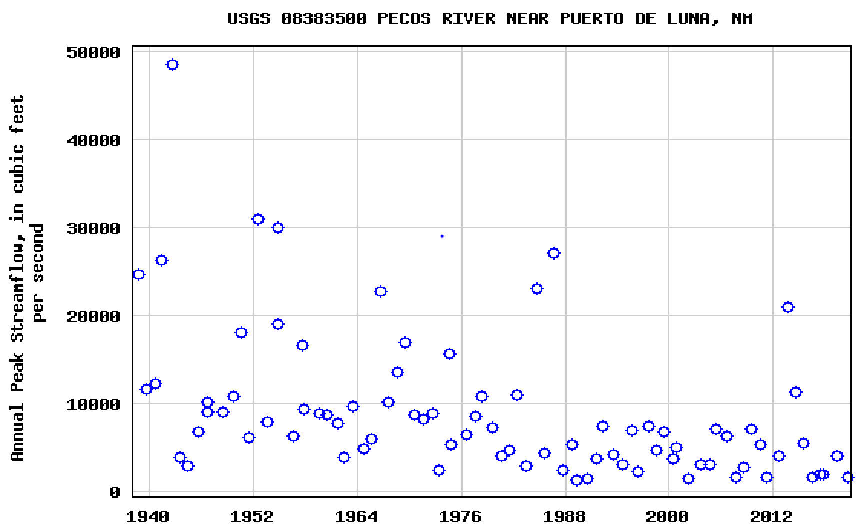


*Figure 10. Peak annual stream flow for Pecos River near Anton Chico, NM.*

Following the closure of Santa Rosa Dam, there is much more variation in the Fall-Winter baseflows, with discharges dropping from an average of 20-30 cfs, to 1 to 10 cfs. Generally, the Snowmelt season starts off with much higher discharges at the beginning of the season, with the average being 100 cfs in the Modern era, relative to a 20-30 cfs continuation of the baseflow. The summer and Monsoon seasons are constant at approximately 100-200 cfs, whereas prior to Santa Rosa Dam's closure, there would be peaks that increased the average to 400 cfs or more. (Figure 11)

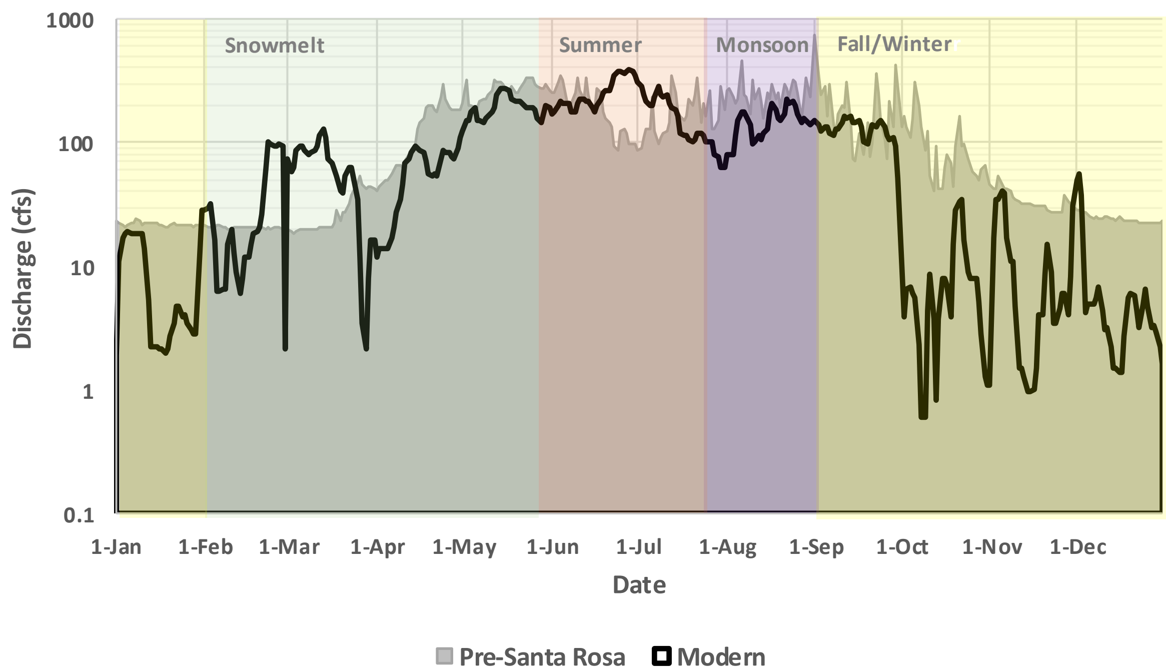


*Figure 11: Daily averaged data representing Reach B, from Pecos River near Santa Rosa, NM (USGS 08383000) and Below Santa Rosa Dam (USGS 08382830)*

Tetra Tech (2020) evaluated geomorphic characteristics of the Pecos River from Santa Rosa Dam to Lake Arthur, near the Eddy and Chavez County line south of Roswell New Mexico. Of these evaluations, Santa Rosa Dam to Puerto de Luna USGS gage falls within Reach B. This site is characterized as a straight, channelized channel that is confined to a narrow alluvial and terraced valley (Tetra Tech 2020).

Tetra Tech 2019 evaluated bed material and cross-sectional data. Just outside of Roswell, Reach B is within a wider valley bottom with less bank line vegetation and generally larger meander bends. There were no obvious indications of direct tributary influence. Reach B shows two locations where a meander migration occurred and one location where a man-made reconnection of a relic channel was constructed in 2009 and a meander cutoff occurred between 2011 and 2016. The meander migrations ranged from approximately 200 to over 530 ft. From 1997-2018, the active channel area of Reach B also decreased by 34% and channel width by 38%. Sinuosity was effectively unchanged here as well. There were three cross-sections evaluated in Reach B; two showed no change in channel capacity and one with a slight decrease. Shear stress was unchanged in all three. Bed gradations in Reach B also appear unchanged as sediment supplies are tributary derived.

USGS field-samples were analyzed to identify the magnitude of change in suspended sediment concentrations following the installation of dams throughout the study area. Figure 12 demonstrates changes from pre Santa Rosa (prior to 1981) to after at Puerto de Luna, Reach B. The pre-Santa Rosa Dam samples consisted of 59 discharge and sediment concentration measurement events, ranging from 1975 to 1980. Post-Santa Rosa Dam samples ranged from 1981 to 2011, and there were 112 monitoring events. Generally, the suspended sediment concentration has decreased per unit discharge. This is demonstrated in the Figure 12 by a steeper incline of the sediment/water relationship in the post-dam data than the pre-dam data, indicating that the cumulative discharge is increasing at a faster rate than cumulative sediment. For both the Pre- and Post-Santa Rosa curves, the largest increases in cumulative sediment discharge occurred in the time frame of June to September.

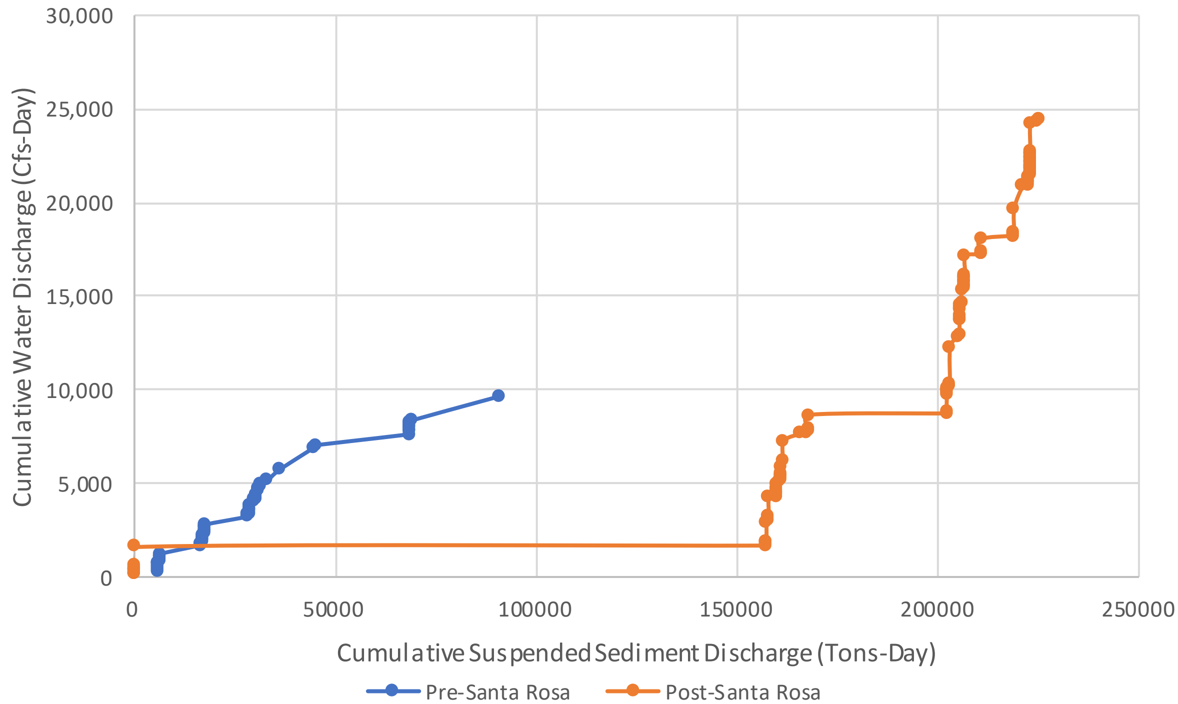



*Figure 12. Double-mass curve USGS gage at Puerto de Luna (08383500) comparing suspended sediment concentration to discharge.*

Sediment supply to the Pecos has declined in the post-dam period (Tetra Tech 2020). Bathymetric surveys of Sumner Reservoir (USBOR 2014) estimated the annual sedimentation rate between 1936 and 1989 (pre-Santa Rosa Dam) was approximately 1,170 acre-feet/year; however, in the post-Santa Rosa dam period (1989-2013) the sedimentation rate has progressively declined from approximately 76 acre-feet/year (1989-2001) to around 32 acre-feet/year (2001-2013). These measurements are only a relative estimate of changes in upstream sediment supply, as operations at the dam may affect sediment passing through the reservoir and compaction may affect total sediment estimates. The decline in sediment supply downstream of the dam has been documented in the 2016 Biological Opinion for the Carlsbad Project Water Operations, where USFWS associated habitat degradation with scour and sediment-poor releases from Sumner (USFWS, 2017). Sediment supply to the Pecos has shifted to storm-driven inputs from tributaries (MEI 2003). Considering the sensitive balance between Pecos hydrology/sediment transport capacity and tributary sediment supplies, it then becomes important to understand the spatial distribution and relative contributions of these tributaries.

# 4 Reach C

Reach C is affected by both Santa Rosa Dam and Sumner Dam. Reach length is approximately 354 kilometers (220 miles) with an elevation drop of roughly 305 meters (1,000 ft) and an overall slope of 0.08%.

The USBOR 2021 Pecos Basin Study describes Reach C as –

*"The Pecos River flows generally southward for approximately 120 miles through the broad plains of eastern New Mexico. In this reach, the river is typically fairly shallow and meanders across a relatively wide channel at low flows, featuring numerous sand bars and frequent sections of braided channels (Figure 3). At moderate flows, the river extends across the channel. In this reach, the Pecos River only overtops its banks and spills onto the surrounding floodplain in extreme floods. These characteristics continue to the downstream end of the reach near the USGS Acme Gage 08386000 north of the city of Roswell (Acme Gage) at U.S. Highway 70 just north of the city of Roswell. Major tributaries to this stretch of the river include Taiban Creek, Yeso Creek, and Salt Creek. This stretch of the river is perennial but prone to occasional drying during drought conditions.*

*Below the Acme Gage, the Pecos River flows through the Bitter Lake National Wildlife Refuge between U. S. Highway 70 and U.S. Highway 380. Within the refuge, the river retains a moderately active channel. From the refuge downstream to USGS Artesia Gage 08396500 near the city of Artesia (Artesia Gage), the river channel narrows and deepens, becoming more incised and confined to a single channel, but with a broad floodplain. A sometimes-significant source of water in this area is base inflow from the adjacent aquifer that has been as high as 120,000 acre-feet and as low as 15,000 acre-feet per year over the period of record (1905-1998). The Rio Hondo and Rio Felix are the largest tributaries to this reach.*

*Downstream of the Artesia Gage, the Pecos River flows about 25 miles through a broad floodplain to Brantley Reservoir. Rio Peñasco is the only significant tributary in this reach, though it and numerous small arroyos in the reach only flow after heavy rains. Several miles upstream of the Brantley Reservoir, the river enters the Kaiser Channel, a man-made canal that traverses the lakebed of the former McMillan Reservoir."*

Prior to the construction of Sumner Dam, the 2-year return flood at Artesia NM was 10,200 cfs; following the closure of Sumner Dam (1938-1996), the 2-year return flood is 2,900 cfs (Tetra Tech 2000). This evaluation was based on a log-Pearson Type III analysis, Bulletin 17B. The water management of Sumner Dam has also reduced the number of days per year where flows are less than 50 cfs. The 100-year peak flow event was reduced from 43,100 cfs prior to Sumner Dam, 22,800 cfs prior to construction of Santa Rosa Dam, and now to 1,620 cfs under current conditions (Mussetter Engineering, Inc. 2001).

Percent Exceedance figures for Reach C were recorded by Mussetter, 2002 (Figure 13). For Reach C, the duration of flows below 100 cfs were attenuated by the construction of Sumner Dam in 1937. Prior to Sumner Dam, 50% of the time, discharges in the Pecos would fall below 100 cfs, and about 60% of the time post Sumner dam. This indicates that water operations in the Pecos Reach have curtailed the duration of flows less than 100 cfs. Increased durations of these flows may support vegetation encroachment and stabilization of islands and bars. This change may also affect what vegetative species dominate the riparian zone.

The water operations following the installation of Sumner Dam did not appreciably affect the high-flow events for Reach C. However, following the construction of Santa Rosa Dam upstream, the magnitude of high-flow, low- frequency events were attenuated similar to what was demonstrated in Figure 13. Though Santa Rosa Dam is not within this reach, the regulation of water affects downstream hydrology.

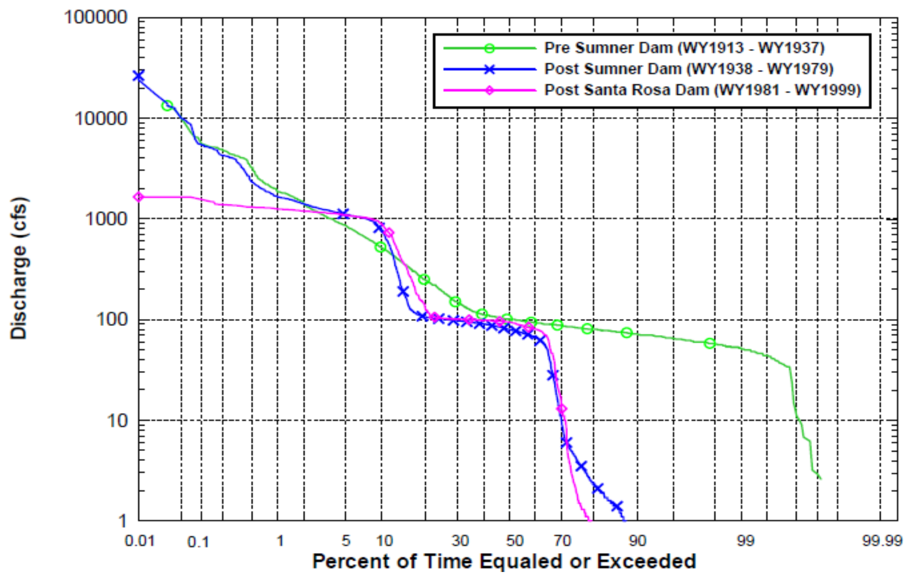



*Figure 13: Reach C percent exceedance following the installation of Sumner Dam and Santa Rosa Dam. Source: Mussetter Engineering, Inc. 2001, Figure 2.1*

For the modern era (Post-Santa Rosa), the longitudinal attenuation of water is represented in (Figure 14). It is shown that downstream USGS gages generally have the same percent chance exceedance when discharges are averaged on a daily basis. Acme, NM shows higher discharges than downstream and upstream gages, 30% of the time. For all four gages, the average daily discharge is less than 100 cfs for 70% of the time.

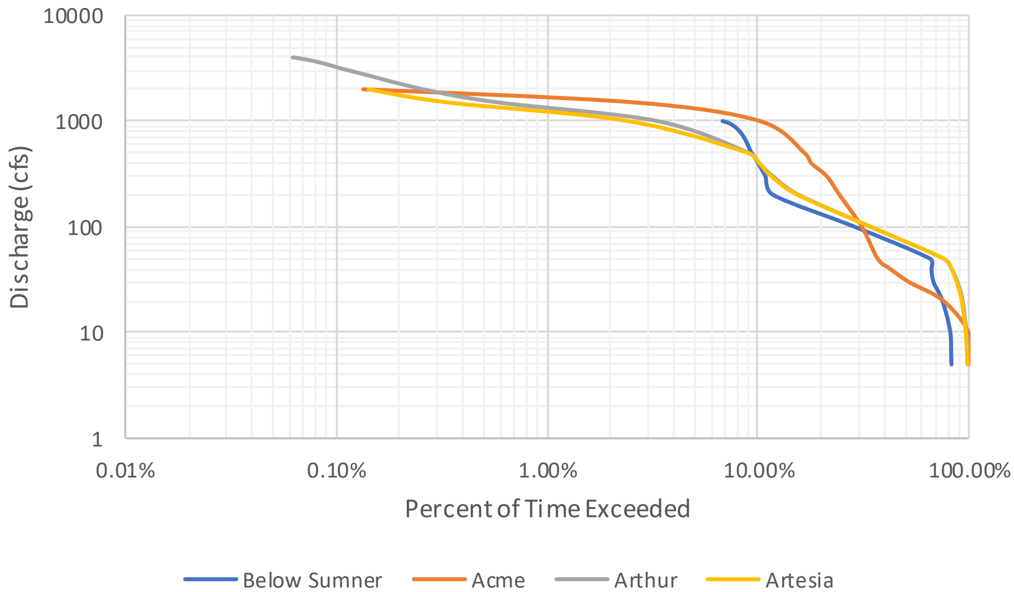



*Figure 14: Reach C profile of daily average discharges from Sumner to Brantley Dams from 1981 to 2019.*

Reach C, from Sumner Dam to Brantley Dam, is a much longer reach than the preceding two. Following the installation of Sumner Dam in 1937, annual discharge peaks continue to exceed 10,000 cfs on five occasions at Acme, NM. The peak events from the outflow of Sumner Dam were greatly attenuated, especially after 1946. Acme, Artesia and Kaiser gages showed relatively consistent peak annual discharges to those at Artesia before Sumner Dam's closure (Figures 15 - 17). Following the closure of Santa Rosa Dam in 1979, there has been one instantaneous peak discharge event exceeding 10,000 cfs throughout the reach – 12,300 cfs in Artesia in 1986. The maximum instantaneous discharge from Acme NM is 8,140 cfs, in 1991. Annual daily averaged maximums from Sumner, post- Santa Rosa, have been a steady 1,000 to 1,600 cfs for the time period (Figure 18). The decrease in all gages below Sumner may reflect a climatic trend of drying throughout the watershed.

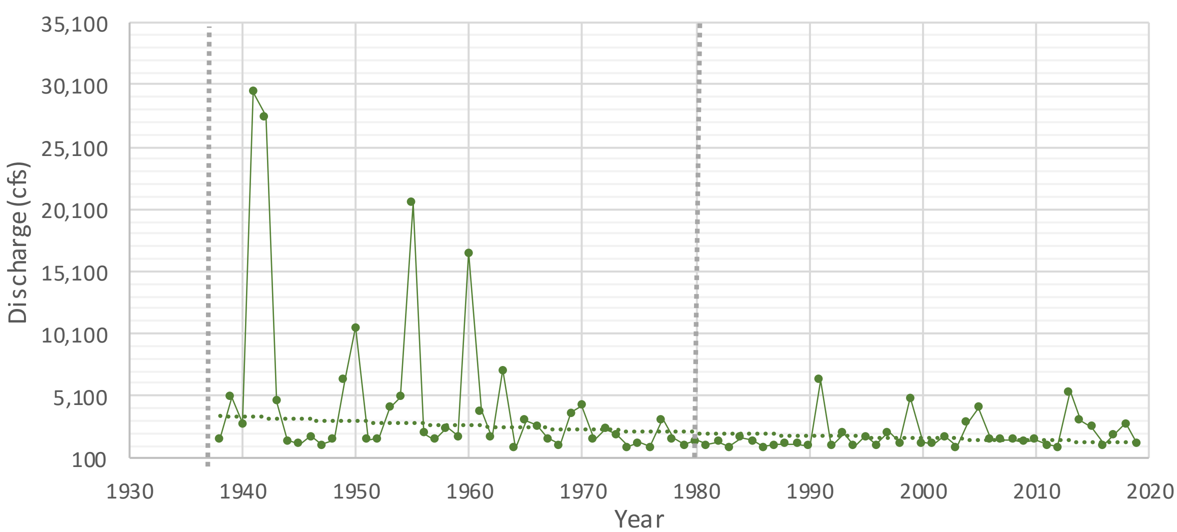



*Figure 15: Annual peak discharges for USGS gage for the Pecos River near Acme, NM in Reach C.*

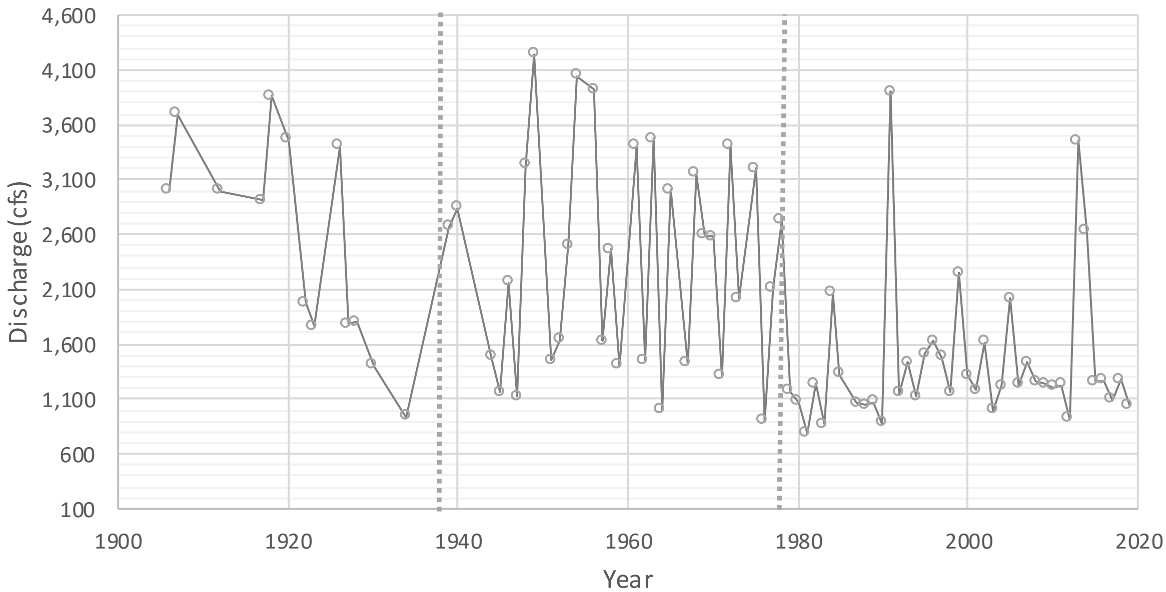



*Figure 16: Annual peak discharges for USGS gage for the Pecos River near Artesia, NM in Reach C.*

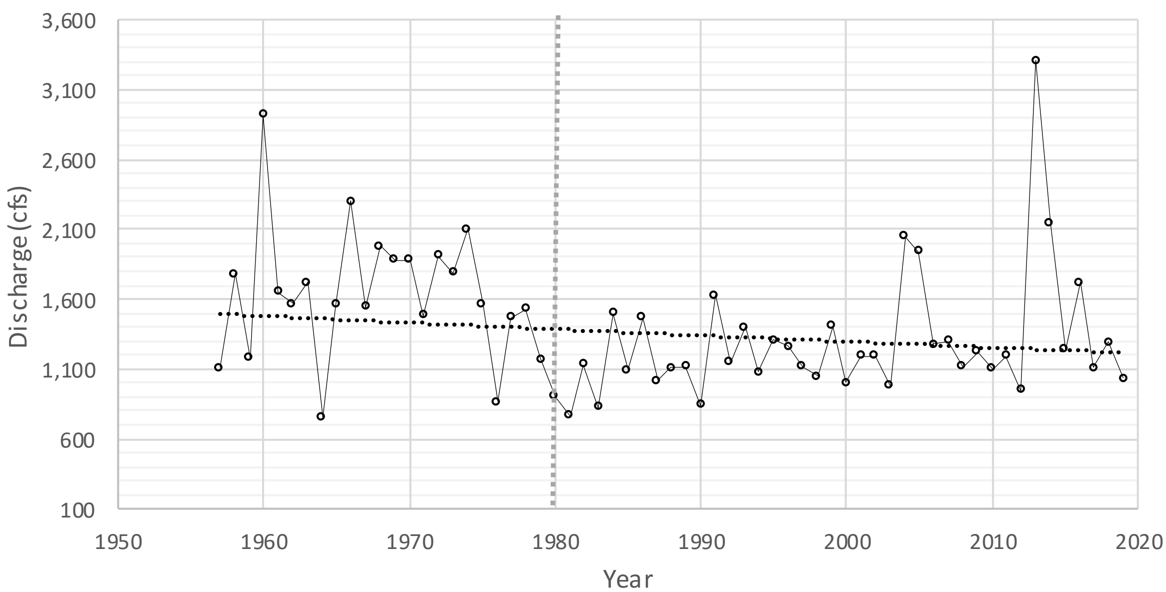



*Figure 17: Annual peak discharges for USGS gage for the Pecos River near Kaiser, NM in Reach C.*

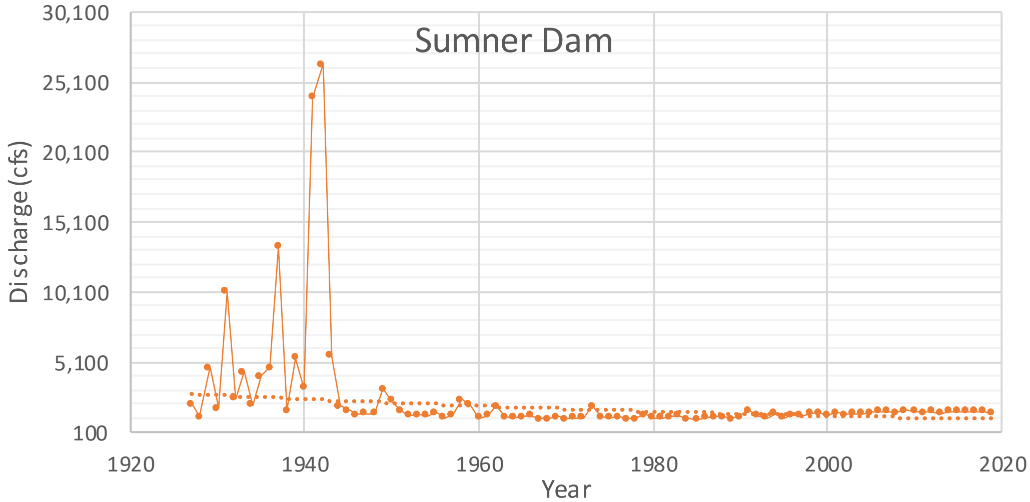



*Figure 18: Annual maximum daily averaged discharges for USGS gage Pecos River below Sumner Dam in Reach C.*

Mussetter (2001) observed that Sumner Dam operations mostly affect low-flow periods, and the Santa Rosa Dam has significant effects at high flows. The data presented here does not dispute that assessment, though following the construction of Santa Rosa Dam, low flows during the fall and winter season have been affected by extending the duration of low flow.

In observing the instantaneous peak discharge data from USGS, all gages have reduced magnitude in peak discharge events (Figure 19). The gage below Sumner was strongly affected by the closure of Sumner Dam. Acme and Artesia, NM have the highest instantaneous peak events after 1980. Generally, these instantaneous peaks are less than 10,000 cfs.

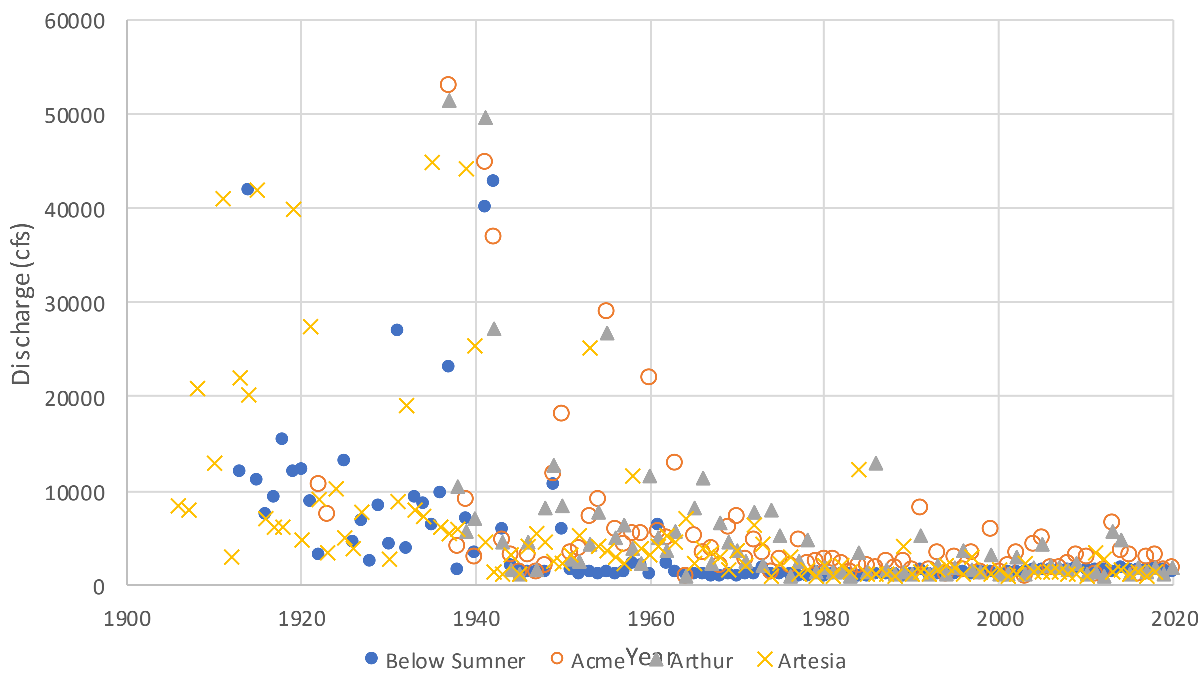



*Figure 19: Maximum annual instantaneous discharge events for USGS gages in Reach C.*

As one travels down the watershed, there is more likelihood for tributaries, inflows and seepage to affect the data. For Reach B, the upstream inflows were impacted directly by Santa Rosa Dam. For both the Pre-Sumner and Pre-Santa Rosa eras, there was greatest variation in the summer flows, more pronounced in the Pre-Sumner era. Generally, the Fall-Winter base flows and spring runoff had similar magnitude daily discharge averages.

For Reach C, the culminating downstream effects of tributaries, seepage and diversions may contribute to more variance in between the seasons. Reach C is regulated at its upstream boundary by Sumner Dam, as well as farther upstream by Santa Rosa Dam. Prior to Sumner's construction, average daily flows for the "Summer Low-Flow" season would be the highest, exceeding 1,000 cfs for much of the duration and at times exceeding 10,000 cfs. Prior to regulation at Sumner, the end of Monsoon season and the beginning of the Fall-Winter season flows would consistently fall below 100 cfs, whereas in more recent eras, the average was consistent at 200-300 cfs. Regulation following the construction of Sumner attenuates the winter flows to approximately 20-30 cfs, where before discharges during the Winter season was close to 100 cfs. (Figure 20)

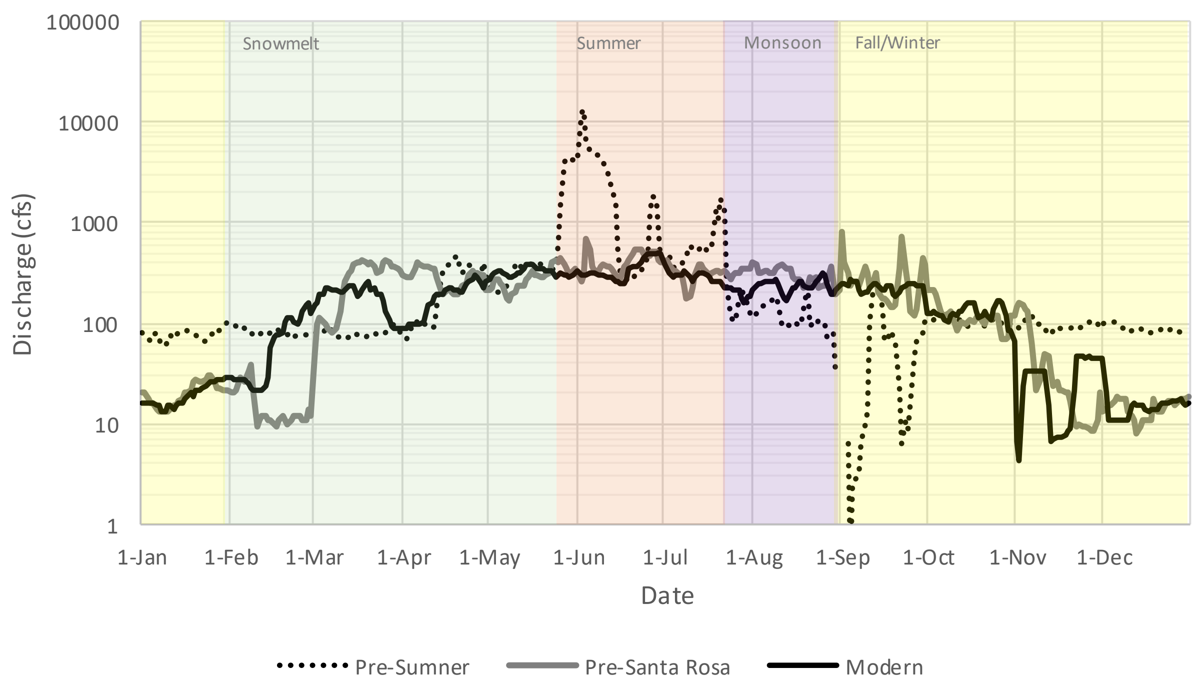



*Figure 20: Daily averaged data representing Reach C, from Pecos River below Sumner Dam (USGS 08384500)*

Reach C has been further divided into three subreaches that reflect how the U.S. Fish and Wildlife Service (Service) classifies habitat suitability for the threatened Pecos bluntnose shiner (*Notropis simus pecocensis*; shiner) which is typical of Great Plains, pelagic spawning fishes. Reach C subreaches defined by the Service are: Tailwater, Rangelands, and Farmlands. For the SRP, these are referred to as subreaches C-1, C-2, and C-3, respectively.

- Sub-reach C-1 (Tailwater) extends from Sumner Dam to the Taiban Creek confluence and is approximately 55 kilometers (34 miles) long.
- Sub-reach C-2 (Rangelands) begins at the Taiban Creek confluence and ends near the southern boundary of Bitter Lake National Wildlife Refuge (BLNWR), just east of Roswell, New Mexico.
- Sub-reach C-3 (Farmlands) begins near the southern boundary of BLNWR and ends at the Brantley Reservoir delta.

Tashjian (1997) evaluated geomorphic characteristics at six sites within Reach C and concluded that, while some minor changes in cross section data were noted, there was no net aggradational or degradational trends at any of the sites during the study period (1992-1997). Tetra Tech (2003) performed a series of sediment transport analyses that evaluated aggradation and degradation potential through BLNWR for existing conditions and three alternative flow scenarios that attempted to capture a range of disparate flow regimes. In addition, bedform modeling showed that at discharge rates of less than 100 $ft^3/s$ (cfs), ripples appear to be the dominant bedform. From 100-700 cfs, dunes were dominant and above 700 cfs upper flow regime bedforms (e.g. antidunes and cyclic steps) were predicted. Importantly, Sub-reach 3 (through BLNWR) was likely to aggrade and the Sub-reach 5 was expected to remain generally stable. Under all scenarios, a meandering planform was maintained. Finally, Mussetter Engineering (2004) was a study conducted in support of shiner habitat evaluations by Kehmeier et al. (2004). Four sites within shiner critical habitat were studied to relate the dynamics of meso- and macro-scale features to habitat availability. Model results showed that habitat availability depended on the presence of linguoid bars (a macroform) and that as flows increase the percentage of preferred habitat (mesoscale bedforms) decreases. There was no specific reference to what life stage was evaluated but it is assumed, considering the results, to be the motile stages More recent hydrologic and geomorphology studies were also performed by Tetra Tech (Tetra Tech 2019; Tetra Tech 2020). These collective efforts were initiated by the USFWS over concerns of physical habitat decline in Reach C. Observations over approximately the last 5-years suggested that some channel narrowing and degradation may be occurring and that the inferior habitat conditions within of the Farmlands subreach may be expanding northward.

*Table 4: Geomorphic characteristics of the Pecos River Reach C (adapted from tetra tech 2001).*

| Sub-Reach | Name | Sinusoity | Floodplain Top Width (Ft) | Channel Width (Ft) | D50 (Mm) | Channel Slope | Rosgen Classification, Additional Narrative |
|---|---|---|---|---|---|---|---|
| **1** | Below Taiban | 1.6 (moderate to high value) | 540 | 130 | Coarse Sand 0.61 | 0.07% | C5c -- single-thread channel; slightly entrenched; moderate to high width:depth; |
| **3** | Near Acme | 1.5 | 970 | 200 | Medium Sand 0.28 | 0.08% | D5c -- multiple channels; very high width:depth; |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **5A** | Near Dexter | 1.0 (moderate) | 200 | 90 | Fine Sand 0.2 | 0.03% | F5-- single-thread channel; entrenched; moderate to high width:depth; |
| **5B** | Near Artesia | 1.2 (moderate) | 104 | 65 | Fine Sand 0.21 | 0.12% | F5 -- single-thread channel; entrenched; moderate to high width:depth; |

### 4.1 Sub-reach C-1

The Taiban site has a broad valley floor bordered by two six-foot high terraces. As the river flows downstream beyond the gaging station, it meanders across the floodplain until it runs up against a bluff on the right (west) side of the valley. The site lacks significant formations of rock or bedrock and the riverbanks are composed of mildly cohesive sand, silt, clay mixtures characteristic of eastern New Mexico soils. In certain locations, lenses of thick, erosion resistant clay material were found in and along the riverbanks. Local tributary influences are Taiban Creek and the Fort Sumner Irrigation District return canals. Vegetation is characterized by upland areas having wild ryes and bunch grasses, mesquite, sage brush and an occasional cottonwood. Riparian vegetation along the banks is composed of tamarisk, Russian olive, and grasses. The width of the floodplain is approximately 3,000 ft between the terrace toes. The width of the channel at the floodplain cross section is 400 ft wide and has several island features located in the cross section. The survey crosses Taiban Creek twice in the tributary area, composed of deltaic deposits.

Due to sediment sequestration by upstream dams and relatively clear water releases below Sumner Dam, the riverbed in this reach is incised and armored consisting of gravel and cobble substrate. Lane's balance (QS ~ Qsds) suggests that as the bed material sediment supply is cut off (Qs reduced by the sediment sequestration) the slope (S) either needs to decrease or the bed material (ds) needs to increase. In terms of historical conditions, it is generally degraded aquatic habitat that is not suitable for native, pelagic spawning fishes such as the Pecos bluntnose shiner.

### 4.2 Sub-reach C-2

Sub-reach C-3 represents the best overall aquatic habitat within Reach C, and within the Upper Pecos as a whole. It is a key stronghold for the shiner and is more indicative of the historical, mobile sand-bed river system; there are numerous unregulated tributaries which provide sediment during monsoon events. Although sediment in the Pecos River is limited by upstream dams, tributary sediment loads in sub-reach 3 have reached a quasi-equilibrium with block release hydrology and thus a dynamic but generally stable channel planform.

The Near Acme site is located in a broad and open valley where the Pecos River meanders from the right (west) side of the valley across to the left (east) side of the valley. The gaging station is located on the right side of the valley on a bluff with bank materials composed of mildly cohesive sand, silt, clay mixtures characteristic of eastern New Mexico soils. The river turns across the valley toward the east bluff, which is formed from a geologic fault. Bank materials of the eastern bluff are composed of sand/silt/clay mixtures and large boulders. River flows have continually cut into the toe of the bluff and recently dislodged a large boulder, approximately five feet in diameter, which now rests at the toe of the slope. Vegetation includes seep willows and grasses along the banks and thin stands of mature tamarisk. Vegetation transitions into upland prairie and rye grasses and the occasional mesquite bush beyond the tamarisk stands. The primary tributary to the reach is Salt Creek, which joins the Pecos River in the Bitter Lake National Wildlife Refuge. Several other small ephemeral drainages are found throughout the study reach; however, their influence is minimal.

### 4.3 Sub-reach C-3

Sub-reach C-3 is generally more channelized than Sub-reach C-2 with a smaller shiner population. Historical channel planform activity is seen in aerial photography where the channel planform was a large meander bend. The river is bordered by several farms and has been channelized for infrastructure protection of the highway bridge throughout leaving a homogenous U shape as the cross-section geometry and a straight planform. Bank soil structure is composed of cohesive sand/silt/clay materials. The banks are heavily vegetated on both sides of the river, with tamarisk and Russian thistle. Beyond the tamarisk and the outer banks, the vegetation transitions into upland grasses, mesquite and more Russian thistle. Dense vegetation on the riverbanks has greatly increased soil strengths and reduced local bank erosion through establishment of dense root systems. Other vegetation noted includes tule (various species of bulrushes) thickets and an occasional Russian olive. Typically, tule stands are located on the interior portion of the gentle meander curve and are found in sandy substrates overlaying the more cohesive silts/fines and clay substrates. The primary tributary input to the Dexter reach is the Rio Hondo, whose confluence with the Pecos River is approximately 35.4 kilometers (22 miles) upstream from the gage station. The flow regime is influenced by flows from the Rio Hondo, releases from Sumner Dam, and thunderstorm activity. Other tributary influences include spring drainages and small ephemeral streams. Geomorphic investigations include the establishment of a cross section network having ten cross-sections. The Rosgen classification system is likely a poor tool in describing Pecos geomorphology for this reach due to the disturbed nature of the channel from channelization and the establishment of dense tamarisk stands on the riverbanks.

The Dexter site, Sub-reach C-3a, is located in a broad and very flat valley, however, the sub-reach is more channelized by levees and dense bank line vegetation that borders large areas of farmland. One location noted some limited channel migration of up to approximately 240 ft and two other locations showed oxbow cutoffs evident after 1997. No direct tributary effects were noted and one of the oxbow cutoffs was likely influenced by the Wichita Bridge located just downstream. The dense bank line and riparian vegetation in Reach C probably limits significant channel migration. From 1997-2018, the active channel area decreased by 38% and channel width decreased by 39%. Again, sinuosity was unchanged. Two cross-sections showed an increase in channel capacity. Although the vertical datum for the historical data could not be established the calculated depth is still accurate and comparable with the 2018 surveys. Shear stress and bed gradations are also effectively unchanged.

The Artesia site, Sub-reach C-3b, is located in a broad and flat valley. The left (east) side of the valley is bordered by gently sloped bluffs and the right side of the valley has a mild slope, which extends for 24 kilometers (15 miles) before encountering hill topography. Flow regime is influenced by releases from Sumner Dam, irrigation operations and thunderstorm activity. Local tributary influences include Walnut, Cottonwood, and Eagle Creeks from the west, as well as several small drainages off the bluff on the east side. The local meander pattern has been altered by river channelization downstream from the Hwy-82 Bridge. Depositional features (minor point bars) are found in this reach. Bank materials are composed of sand/silt/clay cohesive soil mixtures where the presence of riparian vegetation including grasses, tamarisk and an occasional Russian olive that further stabilizes the banks. Tamarisk are found throughout the study reach but the density is much less than that of the Dexter reach. Beyond the banks near the floodplain cross section, the vegetation type changes to desert bunch grasses and mesquite. Downstream from the bridge, vegetation beyond the main channel banks is dominated by tamarisk.

With respect to Sub-reach C-3, Mussetter Engineering (2001) contends that the channel was likely always relatively narrow and deep due to the silt and clay content of the streambanks. This is in contrast to Hoagstrom (2000) which posited that channel incision in Sub-reach 5 was due to upstream impoundments and sediment sequestration by dams. Regardless of the cause, poorer habitat conditions in this sub-reach currently dominate and, as no periodic monitoring of physical habitat is performed on the Pecos, it became necessary to evaluate current geomorphic trends in Sub-reach C-2– particularly in light of the recent drought sequences and lack of geomorphic data or analyses collected or performed in the last 20 years.

The field data collection component of Tetra Tech (2019) focused on four representative sites; three in Sub-reach 3(Bosque Draw, U.S. Highway 70, and Scout Camp) and one in Sub-reach C-3 (Dexter). These sites were chosen as geomorphic changes have been observed in recent years and they also span the transition zone between Sub-reach C-2 and Sub-reach C-3. Sampling included cross section surveys and bed material collected from 5 – 8 November 2018. Discharge ranged from 75-45 cfs as measured at the Acme gage (USGS 0838600 Pecos River Near Acme, NM).

Two types of cross-sections were surveyed: 1) repeat surveys of past cross-sections and 2) new cross-sections that will help establish a baseline at long-term shiner sampling sites where geomorphic changes have been noted. All cross-section surveys, repeat and new baseline, can be used to track potential future changes over time.

The USGS gage below Sumner Dam has field data collection of discharges and suspended sediment concentrations from, 1972 to 1988. The cumulative discharge and sediment load was calculated for two time periods: Pre-Santa Rosa (1972-1980) and modern era (1981 to 1988). The Pre-Santa Rosa had 730 data collection events, while the modern era had 1069 data collection events. Santa Rosa Dam is further upstream, Figure 21 demonstrates that suspended sediment transport patterns have been affected by the closure of Santa Rosa. The Post-Santa

Rosa data shows more clustering of sediment concentrations in the 10-100 mg/L over the range of sampled discharges following closure of Santa Rosa, indicating that the volume of suspended sediment transported per unit discharge is becoming more homogenous over a range of discharges. This is contrary to typical sediment transport relationships where bed material sediment transport capacity increases with water discharge. The trends are demonstrated in the double mass curve in Figure 21, with the modern era having a much steeper and linear increase in cumulative sediment per discharge measurement, which indicates less suspended sediment transported per discharge.

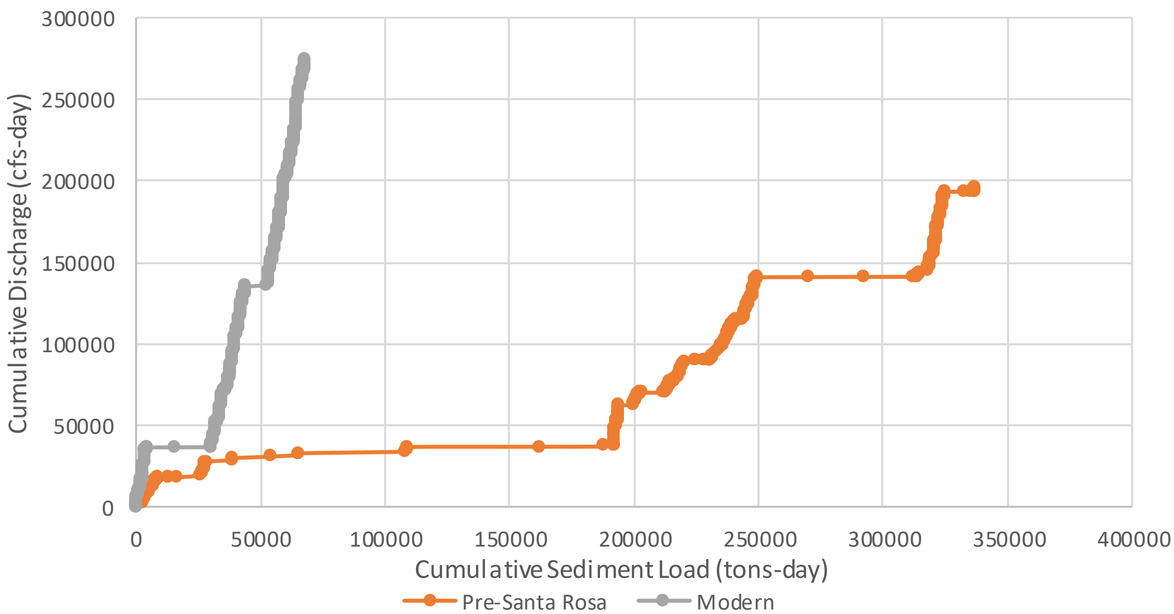



*Figure 21. USGS gage below Sumner Dam (08384500) comparing suspended sediment concentration to discharge.*

The field samples at the USGS gage in Acme, NM only represent the Post-Santa Rosa era. There were 73 data collection points from 1981 to 1998. For these field samples, the suspended sediment concentration increases with discharge similar to the sediment transport relationship at Puerto de Luna, prior to the closure of Santa Rosa Dam (Figure 22). This indicates that the sediment sequestration from upstream dams is not as pronounced. However, observations of changes in suspended sediment transport due to upstream dams is not possible for this period of record.

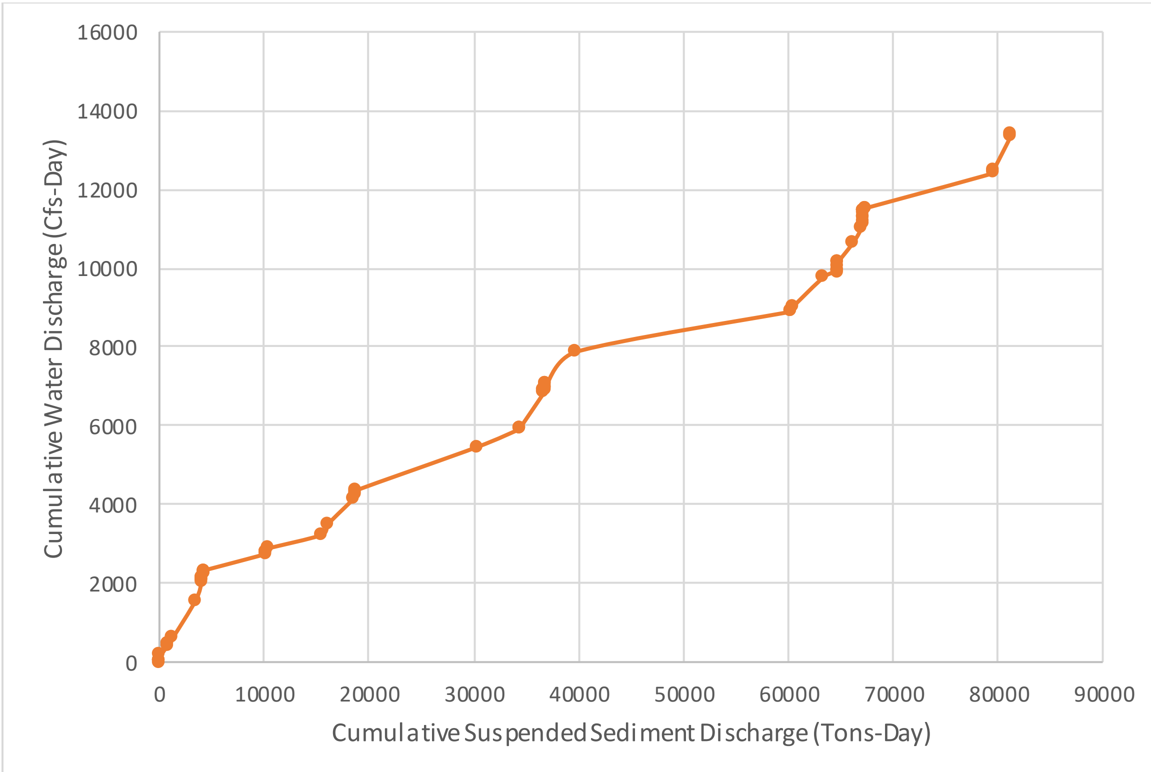



*Figure 22. USGS gage at Acme, NM (08386000) comparing suspended sediment concentration to discharge.*

Figure 23 shows the field-measured water quality samples that demonstrate the percentage of the fine-grained-sizes of the suspended sediment. Samples were collected in Puerto de Luna from 1975 to 2011; Below Sumner dam from 1979 to 1988; and in Acme from 1981 to 1998. Sumner Dam consistently has high proportions of fine-grained sediment throughout the range of sample discharges. This suggests that the dam is effective in sequestering the larger grains. Puerto de Luna and Acme show a distribution of larger sediment grain sizes as a more substantial fraction of the suspended sediment load over a range of discharges. This phenomenon may be occurring because Puerto de Luna and Acme gages may be influenced by tributary loadings. For Acme, the samples with a higher proportion of larger grain sizes were associated with discharges less than 35 cfs (1 m3/s) and were collected in February and May. Generally these samples were from 1981 to 1983, or immediately after closure of the Santa Rosa Dam. For Puerto de Luna, samples collected around 70 cfs had a 10% - 20% fine grained percentage, were collected from 1976 to 1978 (pre-closure of Santa Rosa Dam) during the spring runoff and in the winter months. Larger sediment fractions were also collected at the Puerto de Luna site in the late 1990s in the snowmelt season at discharges approaching 1000 cfs (30 m3/s). Otherwise, finer sediment dominates the suspended sediment load samples for all three sites. The dataset reflects post-Sumner data collection and is skewed to after the closure of Santa Rosa Dam. The reduction of frequency of coarser suspended sediment loads may indicate that the coarser sediment sources have reduced following the closure of Santa Rosa Dam. Bed load data has not been collected by the USGS at these field-monitoring stations.

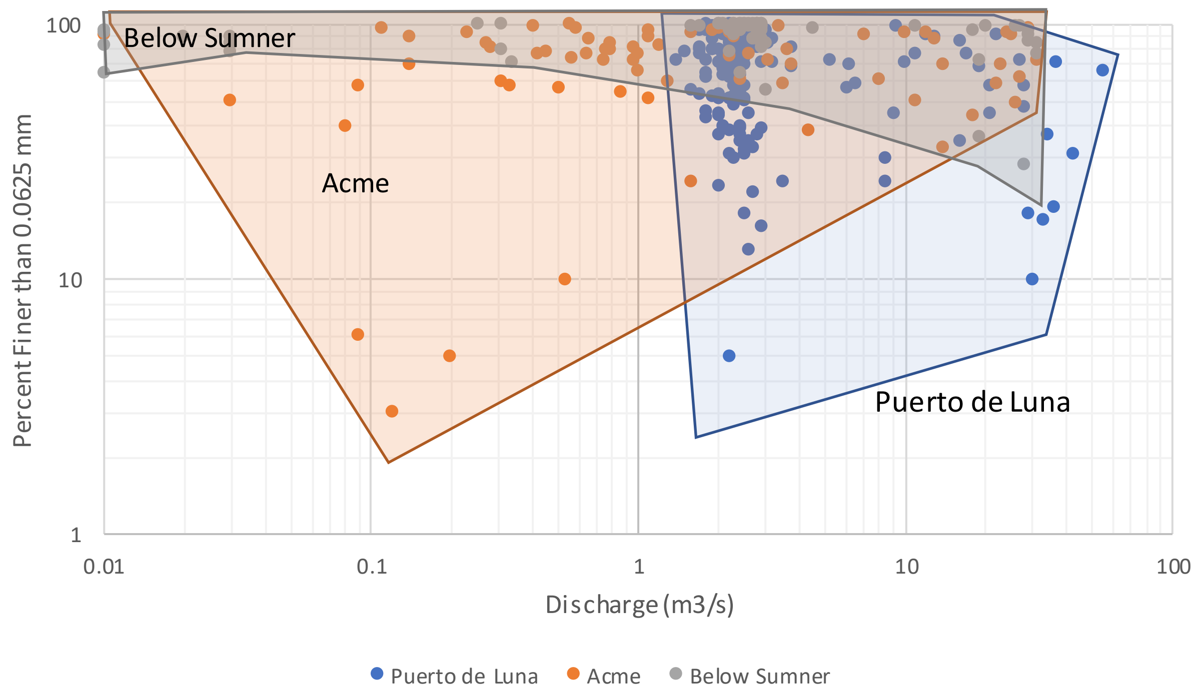



*Figure 23. Suspended sediment finer than very fine sand grain size for Puerto de Luna (08383500), Below Sumner Dam (08384500), and Acme (08386000). Distribution of data delineated with polygons.*

A larger contributor to the sediment supply are tributaries. Tetra Tech (2020) identified 50 tributaries in the study reach alone. These include named tributaries noted from the seamless 7.5-minute USGS quad maps and smaller tributaries identified through inspection of aerial photography. Unfortunately, the Rio Hondo is the only gaged tributary and numerous diversions as well as two flood control dams (collectively Two Rivers Flood Control Project) affect both water and sediment yield from the Rio Hondo drainage. Nor is it clear how much water and sediment the ungagged/unregulated tributaries actually contribute to the mainstem Pecos. Logically, the more tributaries in a given reach increases the probability of significant inputs. Tetra Tech (2020) addressed this by examining the number of spates being greater than 100 cfs in one day at five mainstem Pecos gages (whether during a block release or otherwise). Also identified were large events not occurring during a block release. The rationale here was that a sharp increase in discharge (i.e., 100 cfs in a 24-hour period) signifies a storm event large enough to produce a signal in the mainstem and is therefore significant in terms of both water and sediment contributions. Since mean daily discharge data was used in this analysis, even shorter duration spates (less than one day) are not represented well in this flow record aside from the skew a given peak flow, which is sensitive to duration, may have on the mean value. Because of this, the use of mean daily discharge can underestimate peak flow contributions, and thus sediment delivery, as sediment transport is non-linear with discharge (Tetra Tech 2020). Overall, however, this provides some valuable insight into the frequency, timing, and location of tributary inputs.

Table 5 shows that the Dunlap gage (USGS 08385630 Pecos River Near Dunlap, NM) recorded the most tributary events followed by the Acme gage. The months with the highest number of tributary events was July, August, and September coinciding with the North American Monsoon.

*Table 5: Total number of tributary events per gage, 2000-2019 (adapted from Tetra Tech 2020).*

| Gage | Number of Events (2000-2019) |
|---|---|
| Below Sumner gage | 0 |
| Taiban gage | 35 |
| Dunlap gage | 80 |
| Acme gage | 69 |
| NB Near Dexter gage | 49 |
| **Total** | **233** |

This relationship suggests that tributary flow is largely driven by monsoon events and years with a strong monsoon season should provide the most sediment inputs. Given the spatial heterogeneity of the mainstem signal, the flashy nature of most storm-driven hydrographs, and the basin's overall ability to attenuate fairly large events (Tetra Tech 2020), the variable storm tracks should result in more localized effects and not necessarily large-scale inputs. Exceptions to this are far more infrequent. Table 6 shows some large storm events that produced a mainstem signal at multiple gages which clearly delivered sizable quantities of sediment to multiple reaches.

*Table 6: Storms/high flow events (above 2,000 cfs) with a signal at multiple Pecos River mainstem gages (adapted from Tetra Tech 2020).*

| Date | Gage | Discharge (cfs) |
|---|---|---|
| 10/5/2004 | Taiban | 2,300 |
| 10/6/2004 | Acme | 4,190 |
| 10/7/2004 | Near Dexter | 4,620 |
| 9/12/2013 | Taiban | 4,590 |
| 9/12/2013 | Dunlap | 3,760 |
| 9/12/2013 | Acme | 5,470 |
| 9/13/2013 | Near Dexter | 9,110 |
| 9/14/2013 | Near Dexter | 9,350 |
| 9/14/2013 | Near Dexter | 7,240 |
| 5/24/2014 | Near Dexter | 2,310 |
| 5/25/2014 | Near Dexter | 3,860 |
| 5/23/2015 | Taiban | 2,470 |
| 5/24/2015 | Acme | 2630 |

In addition, an examination of the rating curves (the relationship between stage and discharge rate) at the five gages listed in Table 5 showed that there were no substantial changes to channel geometry suggesting that storm-driven tributary sediment inputs are sufficient and in equilibrium with Pecos block release hydrology. Mussetter Engineering (2004) observed that a significant portion of the sediment yield within the Pecos River is wash load, or fine sediment. The wash load likely deposits at low-flow conditions and "drapes" over existing bedforms (Mussetter Engineering, 2004).

Although there are certain areas where meander migrations or oxbow cutoffs have occurred, they are not common throughout the study reach. Reach C, being more channelized and thus having a more isolated floodplain, is ostensibly less dynamic in terms of avulsive behavior and net channel migration. Still, the generally uncommon result of reach-wide plan view changes suggests a pattern of relative stability throughout the study area. Reach-wide, the active channel area has decreased by 31% and the active channel has narrowed by 34% over the study period (1997-2018). In some locations, narrowing was the result of bank-attached bars while in others vegetation encroachment has channelized the reach. In addition, the average width continuously decreased over time and progressed in the downstream direction. Tetra Tech (2003) indicates that the block releases help maintain a wider channel than the alternative of lower magnitude releases of a longer duration. Higher discharge events disrupt vegetation encroachment that leads to bank aggradation and channel narrowing. Sinuosity was effectively unchanged and bed gradations, although lacking enough data to establish a clear pattern, seems unchanged as well. Channel capacity has decreased over the study period but remains capable of containing a typical block release.

### *4.4 Seepage and Tributaries*

Tetra Tech 2000 presents in-depth information about the tributaries and inflows to the Pecos River. The information from this report is summarized here (Table 7):

*Table 7. Tributaries for sub-reaches below Sumner Dam.*

| Location | Types of inflows or losses | Significant Places | Length |
|---|---|---|---|
| Santa Rosa to Puerto de Luna | Springs, dam releases, tributaries | Santa Rosa Dam, Rio Agua Negra, Arroyo San Juan de Dios; Arroyo Salado, Arroyo Guadalupe; Windmill Draw. | 34 miles |
| Sumner to Taiban Creek | Major springs, ephemeral tributaries and one small perennial tributaries | Sand Springs, Dark Canyon; Conejos Creek and Cedar Creek | 29 miles |
| Taiban Creek to Dunlap Gage | Insignificant ephermeral inputs | -- | 35 miles |
| Dunlap Gage to Acme Gage | Loses water | Bitter Lake Wildlife Refuge | 50 miles |
| Dexter to Lake Arthur Gage | Net losses are minimal. Groundwater base inflows, agricultural drainage ditches, tributary | Rio Felix | 29 miles |
| Lake Arthur to Artesia | Losses. Small base inflows | Roswell basin | 18 miles |
| Artesia to below Kaiser | Tributaries | Rio Penasco, Fourmile Draw, North Seven Rivers, South Seven Rivers. | 12 miles |

Tetra Tech's study also generated figures of the magnitude of inflow volumes for certain locations in Reach C. The base inflow volumes from Acme to Artesia showed gains due to groundwater base inflows, agricultural drainage, and the Rio Felix (Figure 24). This is interesting as the same report indicates that this reach generally loses water.

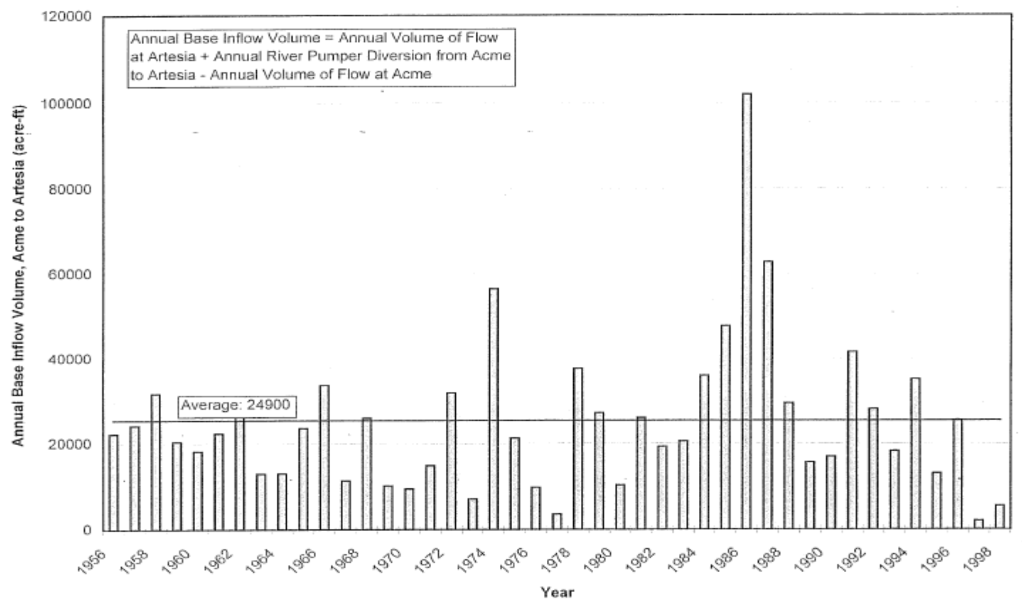



Figure G-1. Historical Annual Base Inflow Volumes, Acme to Artesia

*Figure 24. Base inflow volumes from Acme to Artesia. From Tetra Tech 2000.*

From a sub-section of the reach shown in Figure 25, the Lake Arthur to Artesia reach indicates that some years there are net gains from the reach or net losses. The magnitude of loss or gain are of a similar magnitude, but by the time of the end of the period of record, the frequency of net losses to occur were increasing.

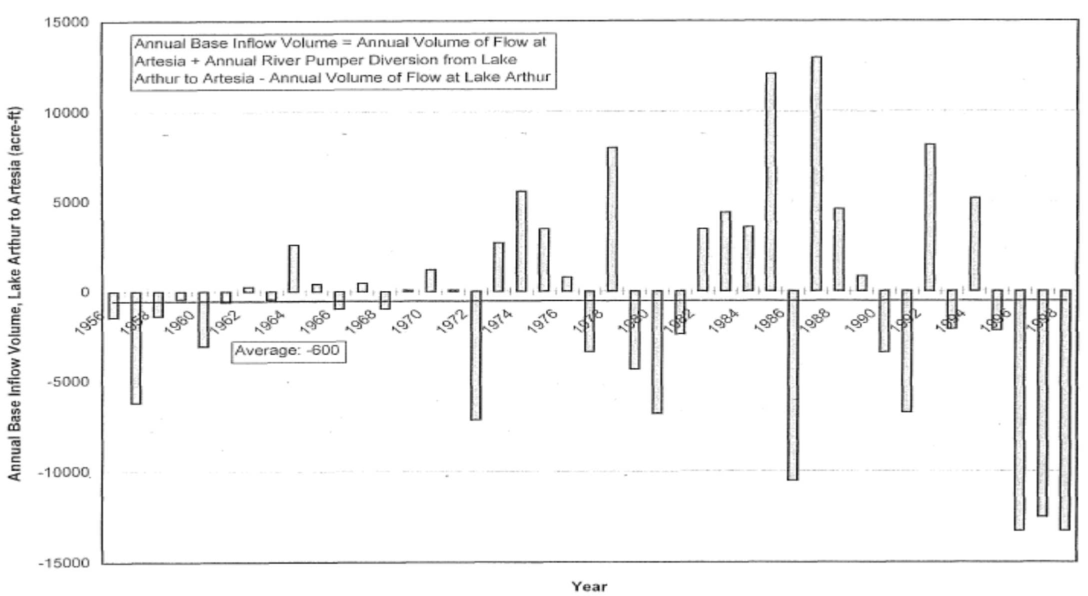



Figure G-3. Historical Annual Base Inflow Volumes, Lake Arthur to Artesia

*Figure 25. Base inflow volumes from Lake Arther to Artesia. From Tetra Tech 2000.*

The objective of the Tetra Tech 2000 report was to characterize inflows and outflows of Reach C in order to provide guidance for water operations for water managers and irrigators (Figure 26). Interestingly, the Tetra Tech report neglected return inflows from CID, perhaps because the magnitudes were not well measured. The crux of the study was finding effective discharges for water delivery, to minimize losses due to seepage.

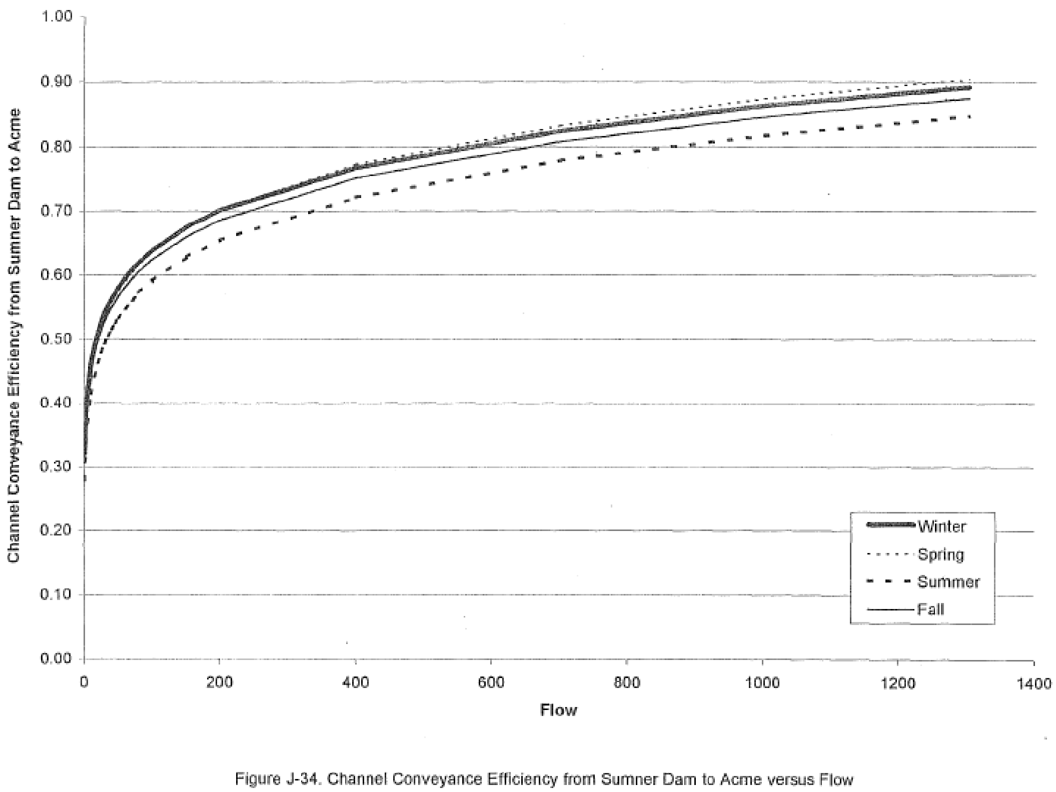
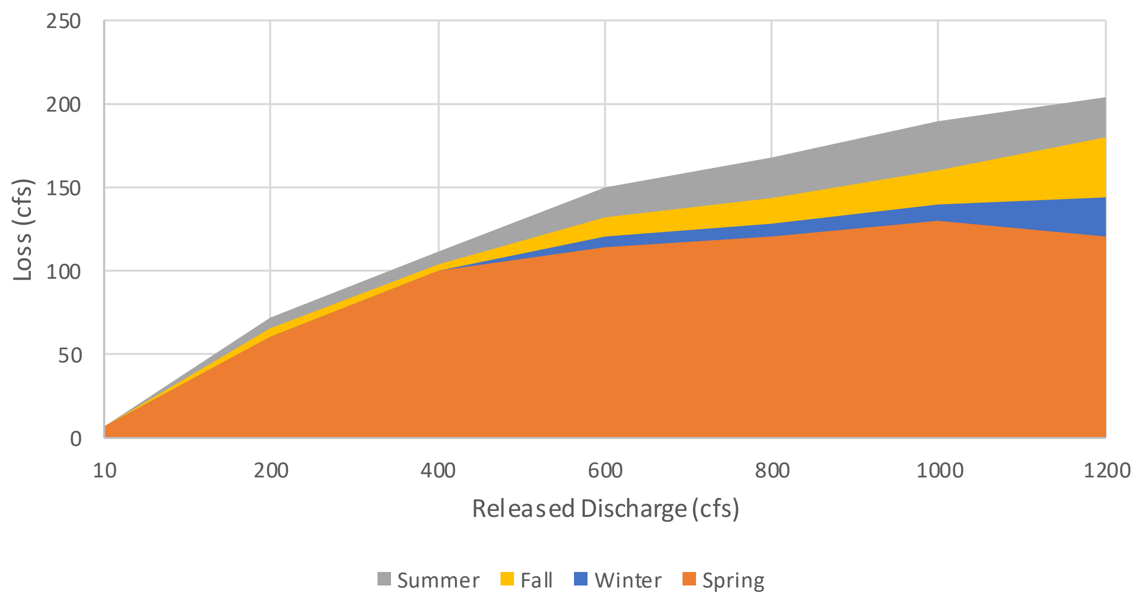



*Figure 26. Results of the effective water transport analysis from Tetra Tech 2000.*

Another way to visualize the loss data is in Figure 27 and accompanying table. The mechanism of losses have to do with infiltration rates of the wetted channel perimeter. As discharge increases, the proportion of water making contact with the wetted perimeter decreases.




| *Release Discharge (cfs)* | *Loss (cfs)* | | | |
|---|---|---|---|---|
| | *Winter* | *Spring* | *Summer* | *Fall* |
| *10* | 7 | 7 | 7 | 7 |
| *200* | 60 | 60 | 72 | 60 |
| *400* | 100 | 100 | 112 | 104 |
| *600* | 120 | 114 | 150 | 132 |
| *800* | 128 | 120 | 168 | 144 |
| *1000* | 140 | 130 | 190 | 160 |
| *1200* | 144 | 120 | 204 | 180 |

*Figure 27. Amount of discharge losses according to effectiveness coordinates found by Tetra Tech 2000.*

# Appendix B: Water Operations

## Identifying Environmental Flow Requirements for the Pecos River: Background Literature Review and Summary

Contents

# 1 DAMS AND RESERVOIRS

Santa Rosa Reservoir, Sumner Reservoir, and Brantley Reservoir are all authorized for flood control and irrigation water storage (Figure 1). All provide significantly more storage in their flood control pools (the maximum volume of water that can be stored for flood control purposes) than they do for irrigation. Any storage space above the conservation pool is reserved for flood control.

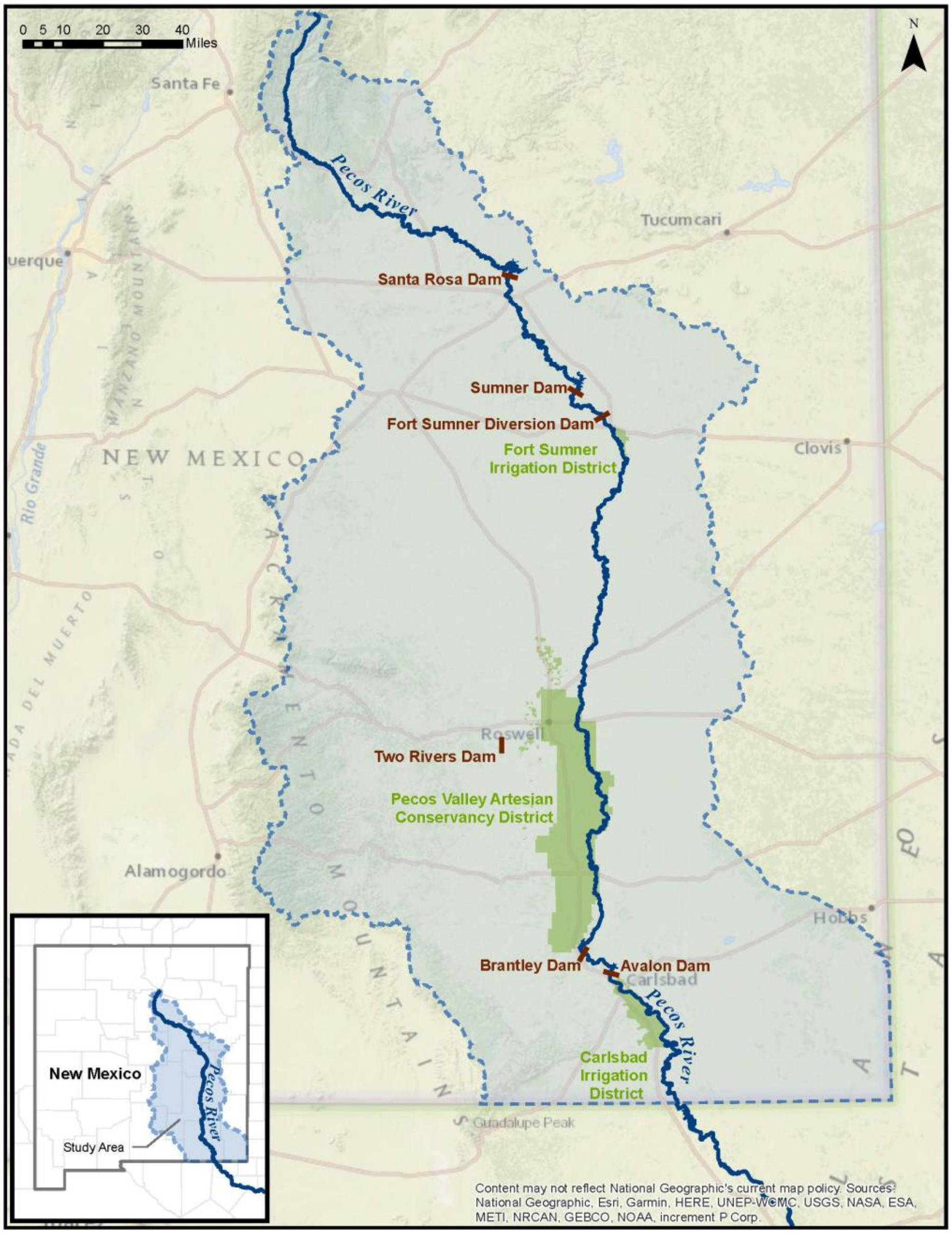


*Figure 1: Pecos River location (blue line). The Pecos River Basin is highlighted in blue. Irrigation districts are highlighted in green.*

While USBOR owns Sumner and Brantley Dams, under normal conditions, CID performs operations and maintenance of these dams and reservoirs. Under flood conditions, however, USACE assumes operation of Sumner and Brantley Dams. Table 1 gives further details of each dam.

*Table 1: Dams in the study area. All elevations are given in NAVD 88*

| | Santa Rosa Dam | Sumner Dam | Brantley Dam |
|---|---|---|---|
| **Owner** | USACE | USBOR | USBOR |
| **Authorized** | 1954 | 1935 | 1972 |
| **Opening Year** | 1979 | 1939 | 1987 |
| **Purpose** | Flood control, irrigation storage | Flood control, irrigation storage | Flood control, irrigation storage |
| **Construction Material** | Rolled Earth & Rock | Earth & Rockfill | Central concrete gravity section with earth sections on each side |
| **Drainage Area Above Project (sq mi)** | 2,630 | 1,483[1] | 13,208[2] |
| **Crest Length / Crest Width (ft)** | 1,950 / 36 | 3,675 / 30 | [3]See Below |
| **Top of Embankment Elevation (ft)** | 4,826.11 | 4,302.88 | 3,308 |
| **Conservation Elevation (ft)** | 4,749.55 | 4,262.88 | 3,272.60 |
| **Flood Control Storage (acre-ft)** | 167,000 | 53,000 | 189,700 |
| **Entitled Storage for Irrigation (acre-ft)** | 99,763 | 32,871 | 40,000 |
| **Sediment Reserve (acre-ft)** | 82,000 | 64,000 | 116,000 |
| **Minimum Pool (acre-feet)** | 0 | 2,500 | 2,000 |

[1] Drainage area between Santa Rosa Dam and Sumner Dam

[2] Drainage area between Sumner Dam and Brantley Dam excluding the area upstream of the Two Rivers Project on Rocky Arroyo and the Rio Hondo

[3] Total dam length is approximately 4 miles. The concrete section is 730 ft long and 143.5 ft high with the roadway elevation at 3,308.5 ft. The east wing dam is 12,059 ft long with a crest width of 24 ft and the crest elevation is 3,308 ft. The west wing dam is 8,020 ft long with a crest width of 24 ft and the crest elevation at 3,308 ft.

Hydropower is not a federally authorized purpose of Santa Rosa Dam and Lake, Sumner Dam and Lake, or Brantley Dam and Reservoir and there is currently no hydropower generation installed at these projects. Under an agreement with the Federal Energy Regulatory Commission, private entities are allowed to add hydropower to USACE and USBOR projects if those projects do not interfere with other project purposes or impact the safety of the dam.

## 1.1 Santa Rosa Dam and Lake

*All Elevations Are in NAVD 88*

Santa Rosa Dam is on the Pecos River in Guadalupe County, NM. The dam is approximately 9 river miles upstream of Santa Rosa, NM and approximately 757 river miles above the confluence of the Pecos River and the Rio Grande at Lake Amistad, TX. The project location is shown within the Pecos River Basin in Figure 1. Major tributaries originating in the headwaters area that drain into Santa Rosa Lake include the Upper Pecos (including Cow Creek), Tecolote Creek, the Gallinas River, and Canyon Blanco.

The authority for the construction of the Santa Rosa Dam and Lake Project is contained in the Flood Control Act of 1954, Section 203, Public Law 83-780, 83rd Congress, Second Session. The project was included as part of a comprehensive investigation of flood and water related problems on the Pecos River. The comprehensive report was published as House Document No. 339, 84th Congress, Second Session. Public Law 96-379, October 6, 1980 (S-1895) 68 Stat. 1260 authorized the project name to be changed from Los Esteros Dam to Santa Rosa Dam and Lake. Santa Rosa Dam and Lake is owned and operated by USACE.

USBOR owns all conservation storage in Santa Rosa Lake on behalf of CID. The project is generally operated to target storing water to the top of the water conservation storage entitlement that is calculated on an annual basis for CID by USBOR. Inflow is typically captured for storage during snowmelt runoff and storm events. During periods of high inflow, and when the conservation storage entitlement is exceeded, the project is operated for flood risk management. At the request of CID and the USBOR, block releases from Santa Rosa are used to move irrigation water to downstream reservoirs for reregulation and irrigation deliveries. Flood storage has never been exceeded at Santa Rosa Lake. On at least one occasion, the conservation irrigation storage at Santa Rosa Lake was essentially depleted, and there is no minimum pool at the lake.

Incidental benefits of the project include recreational use, and fish and wildlife enhancement.

## [redacted] *Typical Operations*

Santa Rosa Dam and Lake is operated to comply with approved operational guidelines and to achieve Congressionally authorized purposes. The process used by USACE to achieve this mission includes monitoring factors in antecedent, real-time, and forecasted weather conditions. USACE makes real-time operational decisions at its dams based on existing conditions, as well as upstream/downstream effects and works in close coordination with the Natural Resources Conservation Service, the National Weather Service, and the National Weather Service's West Gulf River Forecast Center (WGRFC). While USACE considers current and reasonably expected future conditions, decisions are normally made based on actual events and "water on the ground", not based on rainfall forecasts. Throughout the operational decision-making process, USACE coordinates with partners and stakeholders and keeps affected interests informed through weekly calls, individual updates, and press releases. There are many competing interests in the basin and USACE must constantly balance the needs of these stakeholders and the authorized purposes of Santa Rosa Dam and Lake.

Santa Rosa Dam and Lake is operated with the goal of capturing and storing enough water to fill the annual conservation storage entitlement volume. Unless actively operating for flood risk management, or actively releasing water at the request of CID and the USBOR, the project typically operates with no releases occurring through the dam's outlet works. All snowmelt, storm inflow, and base inflow is retained to fill the annual conservation storage entitlement. **There is neither a minimum storage pool or minimum required release at Santa Rosa Dam and Lake.**

Releases from the irrigation conservation pool by CID are achieved in the form of block releases that typically move from several thousand to tens of thousands of acre-feet of water to downstream storage over the period of several days to more than two weeks. The average release rate is typically from 1,000 cfs to 1,400 cfs, although lower release rates are utilized to avoid mobilizing sediment or drawing down the pool elevation too quickly due to potential concerns related to excessive draw down rates. Block Releases are further discussed in Section 3.3.

## [redacted] *Flood Operations*

Flood control along the Pecos River is the primary objective of Santa Rosa Dam and Lake. This is accomplished by temporarily storing floodwaters coming into Santa Rosa Lake until they can be released without creating damaging stages downstream of Santa Rosa Dam. Flood control operation of Santa Rosa Dam and Lake is completed as described in the Water Control Plan of the 2017 Santa Rosa Dam and Lake Water Control Manual, and the 1977 Pecos River Basin, New Mexico – Texas, Master Water Control Manual.

During typical operations when there is no release being made from Santa Rosa Dam, flood inflows upstream of Santa Rosa Lake are captured and stored so there is no contribution to any flooding that may be occurring downstream of the project. If a block release from Santa Rosa Dam is actively occurring and a significant rainfall event is expected to impact the Pecos River below the project, the outflow will often be reduced or terminated to prevent Santa Rosa Dam releases from contributing to downstream flooding. Data exchanges and coordination take place with the USBOR, NWS and WGRFC, and other downstream stakeholders. Lake level forecasts are made throughout the flood event using quantitative precipitation forecasts, quantitative rainfall estimates, and upstream USGS gage data. Pecos River Basin models are currently being developed to use the Corps Water Management System (CWMS) for modelling flood operations.

Water Management Section and Santa Rosa Project staff monitor lake levels and complete operational forecasts based on anticipated rainfall and lake inflow. If the lake elevation is forecasted to approach or exceed the top of the annual conservation entitlement storage, a decision is made regarding the necessity to begin releases in order to avoid exceeding the permitted annual storage volume. Because the actual maximum conservation storage would not be exceeded at this point, and storage is still forecast to be well below the bottom of Santa Rosa Project flood control space, the project would not be considered to be on the verge of entering into formal flood control operations. Storing water above the annual conservation entitlement storage is essentially a water rights issue involving CID, USBOR, and the NMOSE. Any releases made in this situation would be designed to move water out of Santa Rosa Lake as safely as possible without creating any increased flood risk to the downstream population.

If the lake elevation is forecast to approach or exceed the top of maximum conservation storage and potentially enter the Santa Rosa Project flood control space above elevation 4,778.61 ft, the project would be entering into formal flood control operations based on storage encroachment within the flood control pool. In this scenario, Water Management Section and Santa Rosa Project staff would follow the operations described by the Santa Rosa Dam and Lake water control plan. In general, the water control plan calls for operating to minimize storage within the flood space of Santa Rosa Lake and evacuating any flood storage as rapidly as downstream conditions permit. Since Santa Rosa Lake was designed to be operated along with Sumner Dam as an integral system for managing large floods on the Pecos River, the water control plan also calls for managing flood storage within both reservoirs such that flood storage in Santa Rosa Lake will be 3.6 times the flood storage within Sumner Lake, insofar as possible.

When making flood control releases, Santa Rosa is operated to control flows in the Pecos River to not exceed 13,000 cfs at the USGS Puerto de Luna gage and to not exceed 13,000 cfs as the computed inflow into Lake Sumner. In coordination with Sumner Dam and Lake during basin wide flooding, Sumner and Santa Rosa releases will be designed to control flows to not exceed 8,500 cfs as measured at the USGS gages at both Acme and Artesia.

## 1.2 Sumner Dam and Lake

*All Elevations Are in NAVD 88*

Sumner Dam (previously known as Alamogordo Dam and Reservoir) is located on the Pecos River in De Baca County, NM. The dam is approximately 21 miles upstream of the City of Fort Sumner, and about 711 river miles upstream of the confluence of the Pecos River and the Rio Grande. The project location is shown within the Pecos River Basin on Figure 1. Tributaries that drain into the Pecos between Santa Rosa Dam and Sumner Dam include the Rio Agua Negra, Borica Draw, Salado Creek, Arroyo San Juan de Dios, Arroyo Potrillo, and Alamogordo Creek.

Sumner Dam and Lake Sumner was authorized by the Secretary of the Interior under a finding of feasibility approved by the President of the United States of America on November 6, 1935, under the Federal USBOR laws. Sumner Dam is part of the USBOR's Carlsbad Project. USBOR retains ownership of the project, but the operation and maintenance of Sumner Dam has been transferred by agreement to the CID.

Sumner Dam was initially constructed to provide CID additional storage to supplement that of McMillan (breached and replaced by Brantley Dam and Lake) and Avalon Dam and Lake. The authorization for Santa Rosa Dam provided for an exchange of space between Lake Sumner and

Santa Rosa lake. The State Engineer's Findings and Order of September 22, 1972, transferred 176,500 acre-feet of CID storage, less the available space at Avalon, Brantley and Lake Sumner to Santa Rosa Lake. This transfer of conservation storage from Sumner Lake to Santa Rosa Lake replaced the conservation storage within Sumner Lake above elevation 4,262.88 that became dedicated to flood control storage under the authority of USACE. In addition to this initial transfer of conservation storage, there is a progressive transfer of the remaining conservation storage from Lake Sumner to Santa Rosa Lake as conservation storage space is lost to sediment deposition with Lake Sumner.

### [redacted] *Typical Operations*

As described in the *1971* (and amended 1974) *Memorandum of Understanding between the Department of the Interior Bureau of Reclamation and Department of the Army Corps of Engineers*, and the *1985 Letter of Understanding between Department of the Interior Bureau of Reclamation, Department of the Army Corps of Engineers, and Carlsbad Irrigation District*, USBOR is responsible for regulation of conservation storage (below elevation 4,262.88 ft or up to 20,000 acre-feet of conservation storage, whichever provides the greater volume) and operation of Sumner when storage is greater than 4,283.88 ft. USACE is responsible for the regulation of Sumner when storage is within the dedicated flood control pool, which is from the top of conservation storage as just defined up to elevation 4,283.88 ft. USBOR may also store an additional 20,000 acre-feet of seasonal winter storage within the dedicated flood control space at Sumner from 1 November through 30 April of each water year. This entire 20,000 acre-feet of seasonal winter storage must be evacuated by 30 April. USBOR has also eliminated the seasonal winter storage of the additional 20,000 acre-feet of water in order to prevent the storage of water against the closed radial gates.

### [redacted] *Flood Operations*

Sumner Dam and Lake Sumner is operated for irrigation storage and flood control within the restrictions and conditions imposed by the Flood Control Act of 1954, the New Mexico State Engineer's September 22, 1972, order and the *Pecos River Master's Manual*, dated November 30, 1987. Flood control operation at Sumner Dam is coordinated with Santa Rosa Dam to balance flood storage and prevent or minimize flooding and damages downstream.

Operation of Sumner Dam is completed by the CID and monitored by the USBOR and USACE as long as lake storage does not exceed the top of the conservation storage elevation 4,262.88 ft. Once Sumner storage enters the dedicated flood control pool, regulation of Sumner is completed under the direction of USACE as described in the standing approved Water Control Plan contained within the *1991 Sumner Dam and Lake Water Control Manual*, and the *1977 Pecos River Basin, New Mexico – Texas, Master Water Control Manual*. Control of the regulation of Sumner Dam reverts to the USBOR when Sumner storage exceeds elevation 4,283.88 ft, which is also the crest elevation of the lowest fuse plug in the emergency spillway.

During flood events, inflows originating upstream of Sumner Lake are captured and stored so that there is no contribution to any flooding that may be occurring from Sumner Dam downstream to Brantley Dam. If a release from Sumner Dam is actively occurring and a significant rainfall event is expected to impact the Pecos River below the project, the rate of release may be reduced or terminated to prevent Sumner Dam releases from contributing to downstream flooding. Data exchanges and coordination take place with the USBOR, National Weather Service and West Gulf River Forecast Center, and other downstream stakeholders. Lake level forecasts are made throughout the flood event using quantitative precipitation forecasts, quantitative rainfall estimates, and upstream USGS gage data. Pecos River Basin models are currently being developed to use the CWMS for modelling flood operations.

The goal of flood control operation at Sumner Dam is to minimize the capture of flood storage and to evacuate any stored flood water as rapidly as downstream conditions permit within the operating constraints at Santa Rosa Dam and Sumner Dam. Flood control releases from Santa Rosa Dam must be passed or re-regulated at Sumner Dam. Flood control storage used in Santa Rosa Lake and Sumner Lake will be proportionally balanced insofar as possible to assure that both projects maintain the same relative flood control capacity. The Santa Rosa Lake flood storage volume should be about 3.6 times the flood storage volume captured in Sumner Lake when both projects are in flood operation, if conditions permit. Flood control releases will limit the total Pecos River flow to 8,500 cfs at the Acme gage and Artesia gage below Sumner Dam to the greatest extent possible.

## 1.3 Brantley Dam and Lake

*All Elevations Are in NAVD 88*

Brantley Dam is located on the Pecos River in Eddy County, New Mexico, approximately 479 river miles upstream from the confluence of the Pecos and Rio Grande. The project is about 13 miles upstream from the city of Carlsbad, New Mexico. The project location is shown within the Pecos River Basin on Figure 1. Several major tributaries and numerous smaller tributaries drain into the Pecos River between Sumner Dam and Brantley Dam. Much of the land within the drainage area between Sumner Dam and Brantley Dam is located within hydrologically closed basins that do not contribute direct runoff to the Pecos River.

The Brantley Project was authorized for construction on October 20, 1972 by Public Law 92-514. The primary purposes of the Brantley Project are to provide improved safety of dams, flood control, and conservation storage for irrigation.

### [redacted] *Typical Operations*

As described in the *1988 Letter of Understanding between Department of the Interior Bureau of Reclamation, Department of the Army Corps of Engineers, and Carlsbad Irrigation District,* USBOR is responsible for regulation of recreation and irrigation storage (below elevation 3,272.60 ft) and the operation of Brantley when storage is within the surcharge space (greater than elevation 3,284.60 ft). USACE is responsible for the regulation of Brantley when storage is within the dedicated flood control space between elevations 3,272.60 ft and 3,284.60 ft.

The entitlement storage elevation at Brantley is calculated each year to adjust for estimated or actual measured sediment content. For Calendar Year 2020, Brantley's entitlement storage at elevation 3,256.29 ft was 42,602 acre-feet, which creates a surface area of 3,184 acres when the full entitlement storage is in the lake.

## [redacted] *Flood Operations*

Brantley Dam and Reservoir is operated for irrigation storage, recreation, and flood control within the restrictions and conditions imposed by the *Flood Control Act of 1954*, the *New Mexico State Engineer's September 22, 1972* order, and the *Pecos River Master's Manual*, dated 30 November 1987. Due to the large intervening drainage area below the upstream reservoirs and the relatively high channel capacity of the Pecos River through Carlsbad, New Mexico, Brantley Dam is generally intended to be operated for flood control independently of the upstream flood control projects at Two Rivers, Sumner, and Santa Rosa.

Operation of Brantley Dam and Reservoir is completed by the CID and monitored by the USBOR and USACE as long as lake storage does not exceed the top of the conservation storage elevation of 3,272.60 ft. Once Brantley storage enters the dedicated flood control pool, regulation of Brantley Dam is completed under the direction of USACE as described in the standing approved Water Control Plan contained within the *1995 Brantley Dam and Reservoir Water Control Manual*, and the *1977 Pecos River Basin, New Mexico – Texas, Master Water Control Manual*. Control of the regulation of Brantley Dam reverts to the USBOR when Brantley storage exceeds elevation 3,284.60 ft.

During flood events, inflows originating upstream of Brantley Reservoir are captured and stored so there is no contribution to any flooding that may be occurring downstream of the dam. If a release from Brantley Dam is actively occurring and a significant rainfall event is expected to impact the Pecos River below the project, the release outflow may be reduced or terminated to prevent Brantley Dam releases from contributing to downstream flooding. Data exchanges and coordination take place with the USBOR, NWS and WGRFC, and other downstream stakeholders. Lake level forecasts are made throughout the flood event using quantitative precipitation forecasts, quantitative rainfall estimates, and upstream USGS gage data. Pecos River Basin models are currently being developed to use the CWMS for modelling flood operations.

The goal of flood control operation at Brantley Dam and Reservoir is to minimize the capture of flood storage and to evacuate any stored flood water as rapidly as downstream conditions permit. Flood control regulation at Brantley Dam is intended to pass inflow up to the downstream channel capacity of 20,000 cfs through Carlsbad, NM. Flood water stored above elevation 3,272.60 ft is evacuated from storage at the maximum rate possible based on observed downstream conditions. Brantley Dam provides flood protection to the Pecos River Basin from Brantley Dam to Red Bluff Reservoir in Texas. During real-time flood control operation, the downstream control point for flood releases is the Pecos River below Dark Canyon Draw, at Carlsbad, NM.

# 2 RESERVOIR STORAGE

Reservoir storage varies annually and seasonally. Droughts can drastically reduce storage volumes, but storage levels can recover rapidly following an extreme storm. Figure 2 shows the relative storage amounts and seasonal and drought year variations. Note the immediate recovery after the drought of 2011-2013, due to a large regional storm.

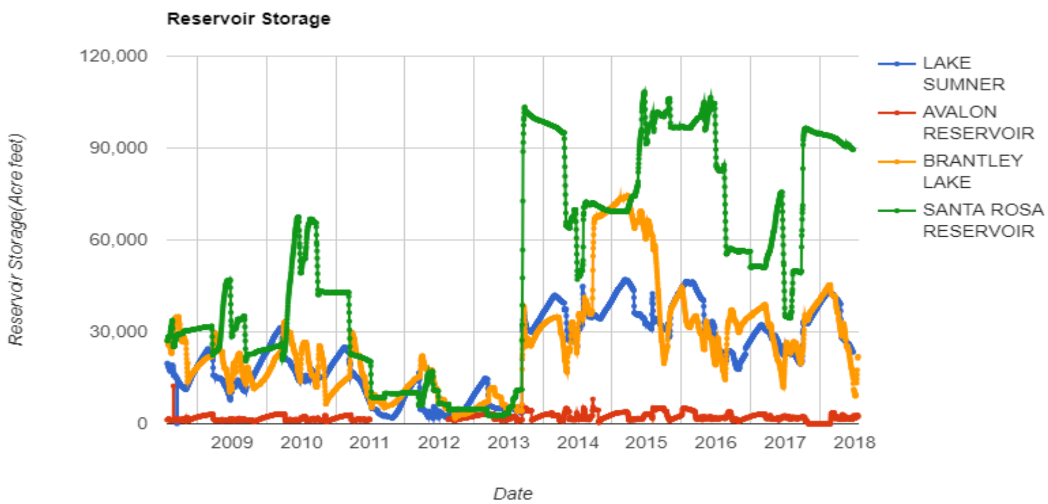



*Figure 2: Reservoir storages from 2009-2018 (data derived from USBOR 2019).*

# 3 IRRIGATION DISTRICTS

In 2010, approximately 135,000 acres of land were irrigated in the study area downstream of Sumner Reservoir. Of this acreage, roughly 25,000 acres were irrigated fully or partially from surface water supplies. Approximately 110,000 acres were farmed using groundwater from wells in the PVACD within the Roswell Artesian Basin. Two surface water irrigation districts, FSID and CID, divert surface water from the Pecos River. At the time of reporting, the FSID irrigates 6,000 acres, the CID irrigates 25,000 acres (Tetra Tech 2000). For this reason, FSID and CID will be the main focus of the Pecos Sustainable Rivers Study.

## 3.1 Fort Sumner Irrigation District

FSID is the most upstream irrigation district on the Pecos River, located below Sumner Dam. FSID is downstream of the Village of Fort Sumner on the east bank of the Pecos River, about 75 miles north of Roswell and about 20 river miles downstream of Sumner Reservoir. It extends southeast from the town of Fort Sumner for about 9 miles along the east side of the Pecos River (See Figure 1). Fort Sumner is the county seat and only incorporated municipality in DeBaca County.

FSID has no storage facilities or rights for storage but maintains an entitlement to divert up to 100 cfs of the “natural flow” of the Pecos River (Reynolds 1979). The construction of Alamogordo Dam (now Sumner Dam) in 1937 and Los Esteros Dam (now Santa Rosa Dam) in 1979 altered the flow regime of the river at the FSID diversion point, affecting how this “natural flow” is determined (Reynolds 1979).

Currently, the FSID entitlement is calculated by the NMOSE in two-week increments, using the average measured flow at the stream gage in Puerto de Luna (upstream of Sumner Reservoir), and adding in the net flows at Santa Rosa Reservoir (inflows-releases). This calculation estimates the “natural flow” of the Pecos River (i.e., the amount of water that would arrive at the Fort Sumner Diversion Dam if Sumner Reservoir and Santa Rosa Reservoir did not exist). Even when inflows into Santa Rosa Reservoir are minimal, numerous springs in the Santa Rosa area provide a fairly uniform baseflow to the Pecos River, typically ranging from about 60 to 100 cfs, depending on the time of year and precipitation (Reynolds 1979). FSID’s entitlement is limited to the March-October irrigation season, as well as two 8-day periods during the off season (Figure 3). FSID’s theoretical maximum entitlement is therefore 51,769 acre-feet, though in practice this is rarely achieved, as the natural flows of the river typically drop below 100 cfs for at least some portion of the irrigation season.

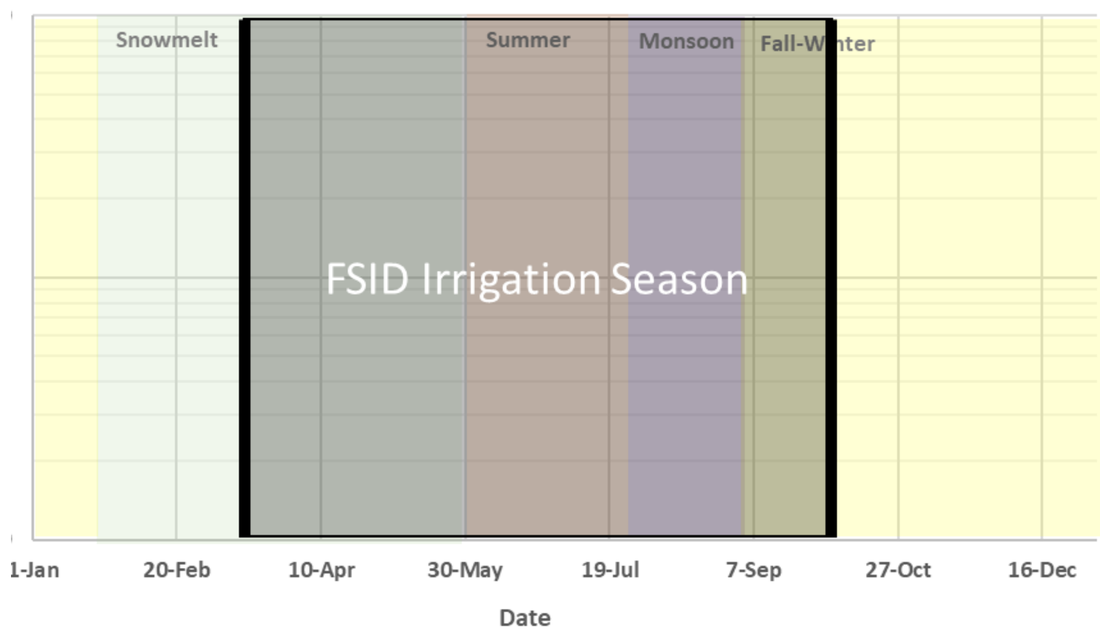



*Figure 3: FSID irrigation season runs from March to October as well as two 8-day periods during the off season.*

FSID is a run-of-the river operation that currently lacks options for water storage. FSID’s entitlement varies from year to year and over the course of the irrigation season, depending on conditions in the watershed. Since rainfall and entitlement availability is somewhat unpredictable, farmers may have difficulty planning or prioritizing crops at the beginning of an irrigation season. When farmers receive less water, those employing better practices are more successful, and others are incentivized to implement more efficient watering infrastructure and practices. Farmers can also adapt to lower entitlements by prioritizing water to the most productive fields and fallowing other fields.

A typical rotation cycle in FSID is 21 days, though the cycles can be shorter. This cycle works well for alfalfa, which can handle infrequent but substantial watering. The cycle length can inhibit crop diversification; however, as many other crops are ill-suited for this cycle, requiring more frequent, moderate watering (ARC 2016). As a result, most of the land in FSID is currently used to grow alfalfa.

Actual diversion amounts vary due to maintenance, irrigation requirements, storms, etc. This modeling study used 1950-2009 calculations to determine historical entitlements (Figure 4), and a value of 6,500 acres for the irrigated acreage. Actual FSID entitlements ranged from a low of 38,224 acre-feet in 1956 to the entire entitlement amount from 1992 to 1995 and from 1997 to 1999.

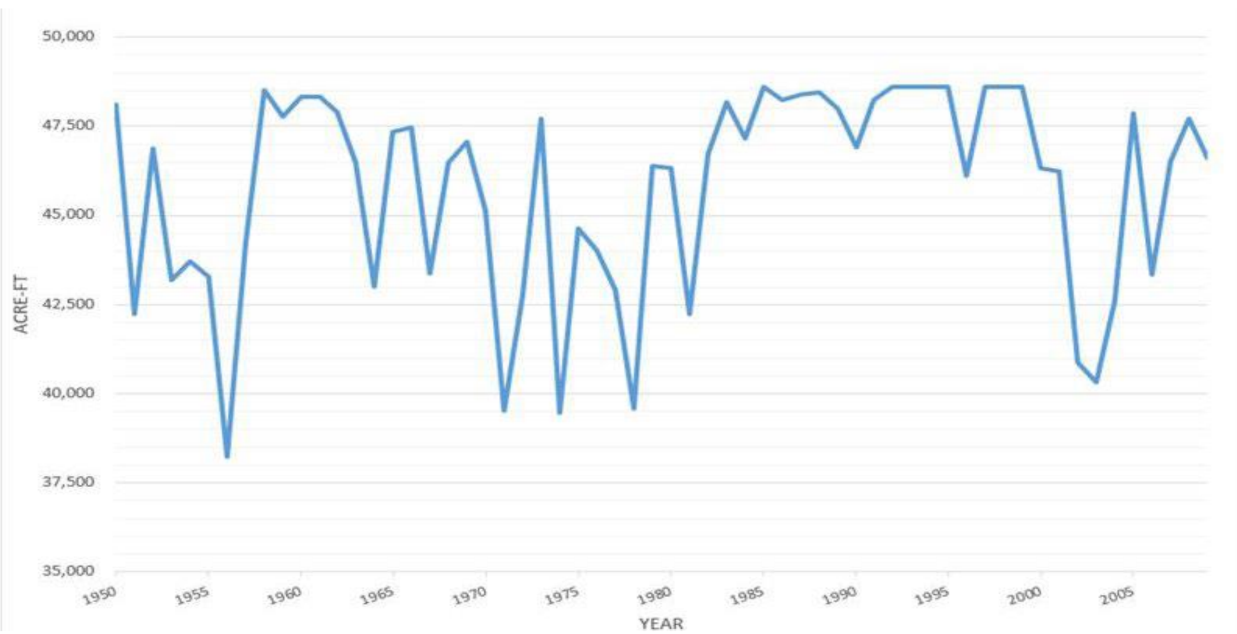



*Figure 4: Calculated historical FSID entitlements. Note that entitlements are different from actual use and do not account for additional limited winter diversions. Values range between 35,000 and 50,000 acre-feet (USBOR).*

FSID is committed to conserving water, has implemented water conservation measures in the past, and continues to look for opportunities to do so. Current actions being taken by FSID and its members include:

- Use of laser and global positioning software (GPS) technology for precision leveling and grading of fields by FSID farmers for more efficient water use

- Plans by FSID to install automatic head gates and telemetry in the near future
- Application for funding to develop a strategic plan to address assets, operations efficiency, etc.
- Continued organizing, preserving, and archiving the district's historical records to be ready for adjudication processes

## 3.2 Carlsbad Irrigation District

The CID main diversion is located at Avalon Dam downstream of Carlsbad and on the west side of the Pecos River. CID has the sole storage permit on the Pecos River, with storage in four reservoirs on the main stem of the river. CID operates Sumner, Brantley and Avalon Dams, which are maintained jointly by CID and USBOR. CID also holds the rights to conservation storage in Santa Rosa Reservoir (operated by USACE). Currently there is only CID water stored in Santa Rosa. At some point in the future there may be supplemental irrigation water for USBOR use stored in Santa Rosa. In any case, CID can call for their water in Santa Rosa at any time, limited only by dam safety concerns and weather conditions. There are no legal or operational regulations or constraints for release of CID's water to Sumner. CID could call for all the water that is in Santa Rosa Lake and drain the lake.

CID has been fully adjudicated and is authorized to divert 4.997 acre-feet per acre of water right per year (3.697 acre-feet per acre allotment at the farm, plus 1.3 acre-feet per acre of allowable carriage loss from Avalon Dam to the farm). CID land with adjudicated water rights totals 25,055 acres, allowing a total annual diversion of 125,200 acre-feet of water from the Pecos River. Since the Settlement, which mandated the purchase by NMISC of water rights associated with almost 4,500 acres of CID land, CID has typically irrigated approximately 15,000 to 20,000 acres of land. The model analyses in this study used 20,000 acres as the irrigated acreage. The volume of water that CID has diverted annually from the river, as measured by USGS Gage 08403500 (Carlsbad Main Canal), has fluctuated over the years, in part due to water availability, averaging 72,588 acre-feet (2.897 acre-feet per acre) from 1950-2009.

The following is an excerpt from Tetra Tech (2000) describing the irrigation demands in a typical year (Figure 5).

> *"The CID irrigation season typically runs from March 1st through October 31st, at the time of reporting, the allotments range from 100 to 375 cfs (Tetra Tech 2000). The most significant diversion begins in mid-March for the first irrigation of alfalfa and for pre-planting cotton; the next in mid-May for the second irrigation of alfalfa. In June, the diversion increases for the first irrigation of cotton and hay. During July and August, the diversion is continuous for irrigation of all crops. During early September, watering of new hay begins. Diversions gradually decrease as the irrigation season ends October 31st."*

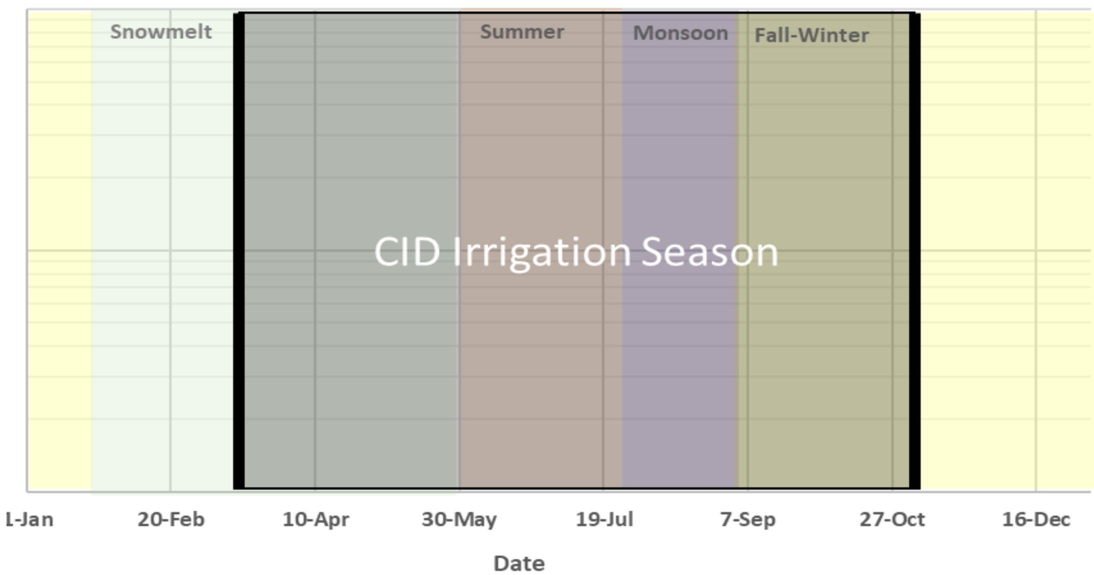



*Figure 5: CID irrigation season runs from March 1st – October 31st.*

CID allotments are measured by on-farm deliveries. The historical records of allotments from CID (1950-2009) show an average CID allotment of 2.47 acre-feet per acre on the farm (Figure 6). In 2016, CID was allotted the maximum amount of 3.697 acre-feet per acre. The volume of surface water that CID diverted in 2016 was 71,409 acre-feet as measured at the Main Canal (USGS Gage 08403500). CID irrigated 17,121 acres of land with this water (Ballard 2020).

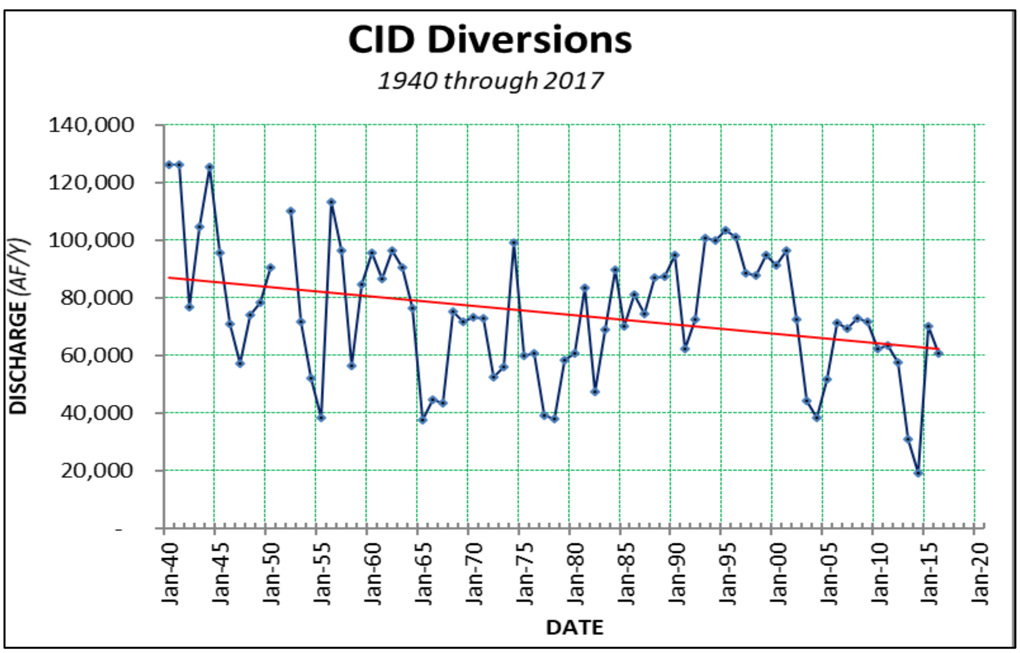



*Figure 6. CID Diversions 1940-2017 (USBOR XXXX).*

When CID's surface water supplies are low, farmers with supplemental wells can pump groundwater, if they do not exceed their total allotment. NMOSE has not permitted further rights to supplemental groundwater since 1972 (Hall 2002). This pumping decreases the volume of groundwater inflow to the Pecos River.

Although the four reservoirs can store a maximum of 176,500 acre-feet of irrigation storage, well over double CID's average annual diversions and almost 50% more than their maximum allowed annual use, the system lacks the ability to provide adequate storage during a multi-year drought. Once evaporation from reservoir surfaces and conveyance losses (incurred in moving water from the upper reservoirs to Brantley Reservoir) are accounted for, the effective amount of water stored for CID is substantially lower, and at full capacity the system stores approximately one year's worth of water for the district.

Rainfall patterns in the basin are highly variable. While a single extreme storm event can replenish the entire system and effectively end a drought in a few days, such storms cannot be depended on. Location of storms is also critical—an extreme storm between Sumner Reservoir and Brantley Reservoir could contain enough water to refill the system, but only 40,000 acre-feet could be stored due to Brantley Reservoir's conservation storage limits. Moreover, if the rainstorm is late in the irrigation season, farmers cannot use the water that year. For example, in 2013, CID had a significant rain event in September, and went from 0.8 acre-feet per acre allotment to begin the year, to a much higher allotment of 2.0 acre-feet at the end of the irrigation season. However, due to the timing of the storms, farmers could not make use of the higher allotment. Those with supplemental wells could pump during the drought but preparing for the next year was all that those without supplemental wells could do. Lack of resiliency to multi-year droughts is a significant challenge to CID operations, one that will be exacerbated should future conditions become drier and hotter with future climate change.

## 3.3 Block Releases

Block releases have been determined to be the most efficient, least loss way to deliver water from one reservoir to another in the Pecos Basin (CID, NMOSE, Stockton, TetraTech, etc). A fine scale look at block releases is shown in Figure 7 below.

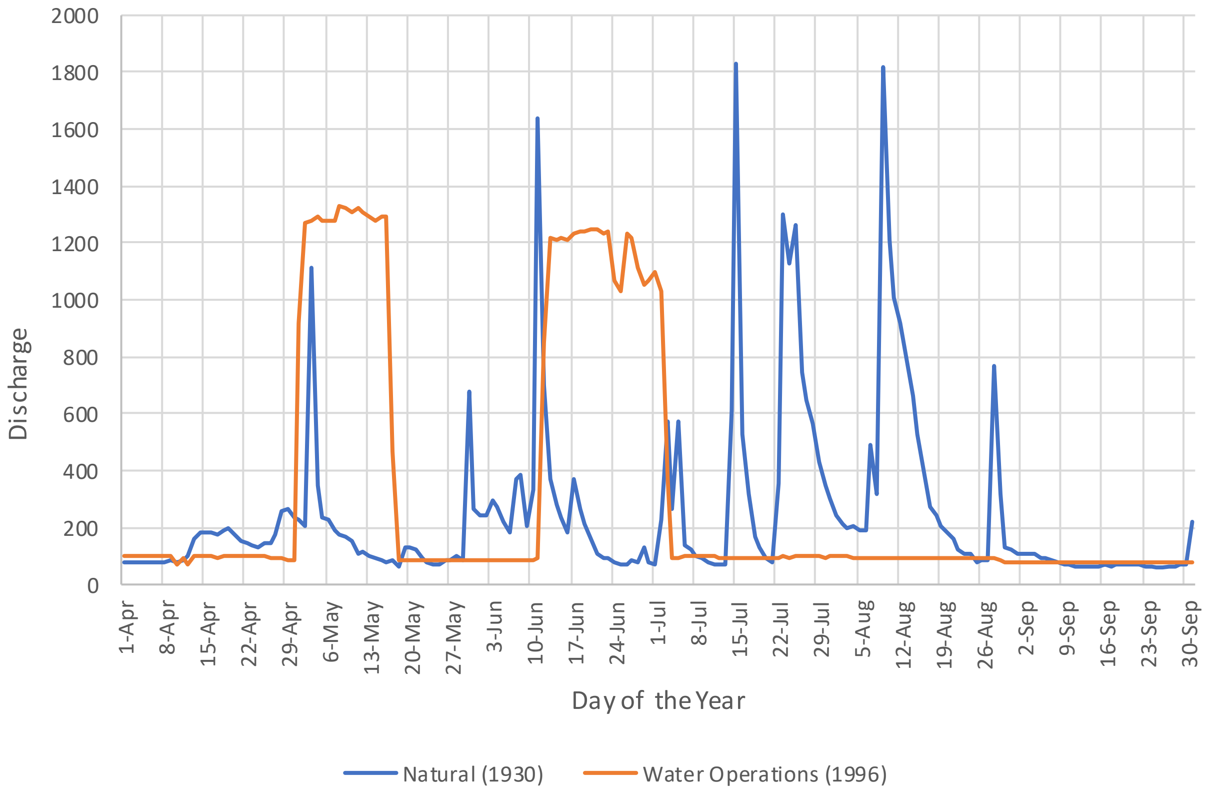



*Figure 7: Hydrograph comparison at Pecos River below Sumner Dam for prior to Sumner Dam's closure (Natural, 1930) and after Santa Rosa Dam's closure (Water Operations, 1996). 1930 and 1996 are selected as years representing the flow hydrograph before Sumner Dam was installed and after Santa Rosa Dam, respectively. The selected days are from April 1 to October 1, which would intersect the end of the snowmelt runoff, the entire summer and monsoon season, and one month of the fall/winter season. Both sets of data come from the USGS gage of the Pecos River below Sumner Dam, NM (08384500).*

The 1930 hydrograph or the "natural" hydrograph, shows several peak events occurring from the end of April to the end of September. The base flow would be approximately 100 cfs, with peaks ranging from 400 to 1800 cfs. The summer base flows (May to June) and the monsoon season base flows (July to August) would exceed 200 cfs. Notably, the peak events would ramp up rapidly, but would have a more gradual decrease in discharge over time than the Water Operations hydrograph. The number of peaks in the Water Operations hydrograph is less than the Natural hydrograph, and the peaks are sustained for a longer period of time. The baseflows for the Water Operations hydrograph stays consistent throughout all seasons at 100 cfs.

Block flow discharge rates are typically around 1,400 cfs for up to 15 days (mean of 8 days from 2000-2019); these agreed upon limits have been enacted to minimize Pecos bluntnose shiner egg and larval displacement. Being the dominant high-flow hydrology, block releases are responsible for majority of contemporary sediment transport and thus geomorphically most significant. The number of annual block releases varies depending on the available storage in the upper reservoirs and the call for water by downstream irrigators (CID) and can range from 1- 4 block releases/year. At the below Sumner gage, from 2006-2018, block releases average

53% of the total annual volume of the Pecos River, having a range of 25% - 69% (Tetra Tech 2020).

Lake Sumner is permitted to store up to 20,000 ac-ft of water in the joint use pool from November 1st to April 30th, this winter storage is required to be vacated by May 1st, usually as a block release a few days before the 30th.

Block releases from Sumner are regulated and best described in the 2017 Biological Opinion:
***Carlsbad Project Water Delivery***

*USBOR delivers Project water from storage in the Upper Reservoirs, consistent with applicable Federal and State laws, pursuant to contractual obligations to downstream irrigators. A block release is a high magnitude release of Project water from Sumner Reservoir, typically around 39.6 m3/s (1,400 cfs), which is used to most efficiently deliver water to Brantley Reservoir (USBOR 2017a: 19). It is a release of a relatively short duration (approximately 1-2 weeks; USBOR 2017a: 75) designed to minimize evaporative and seepage losses. Block releases will be used for Project water delivery. Mussetter (2004) presents the typical block release hydrograph for 2002-2003 year in the following figure (8):*

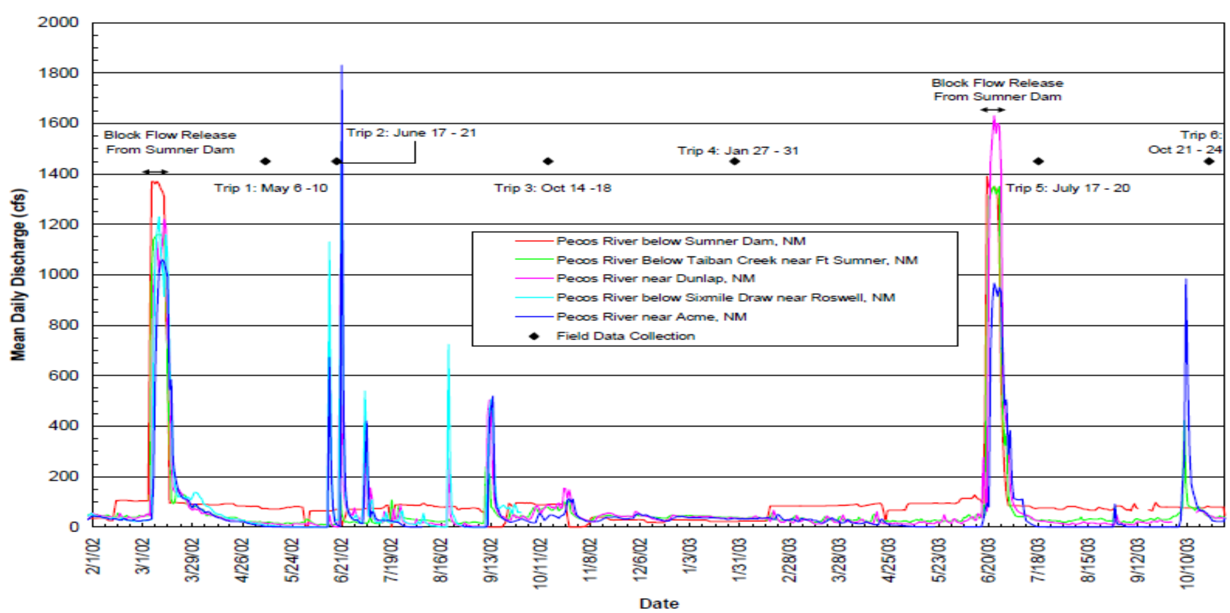



*Figure 8, Mean daily discharges at 5 USGS stream gages between Sumner Dam and Acme (1 Feb 2002 – 30 Oct 2003). Also shown are the times of the field data collection efforts for this study. Source: Mussetter 2004, Figure 4.8*

*Much of the motivation for high releases comes from Tetra Tech 2000, where dam releases underwent a conveyance efficiency analysis. The low flows of 20 cfs from Sumner had loss rates of 50% at Acme and 40% to Kaiser; while 1000 cfs in summer had loss rates of 82% at Acme to 74% at Kaiser. These efficiencies were seasonally and discharge dependent (Figure 9 (P-5); Tetra Tech 2000).*

| | Time | Discharge (cfs) |
|---|---|---|
| Sumner Release Begins 2/15/94 Begins: | 6:00 | 0.12 |
| Shoulder: | 7:00 | 344 |

Inflection: hour that flow begins to increase
Median: approximate mid-point of wave
Shoulder: hour that flow increase ends

| | Hours toTaiban | Discharge at Taiban (cfs) | Hours to above Acme | Discharge at above Acme (cfs) | Hours to near Acme | Discharge at near Acme (cfs) | Hours to Lake Arthur | Discharge at Lake Arthur (cfs) | Hours to Artesia | Discharge at Artesia (cfs) | Hours to Kaiser | Discharge at Kaiser (cfs) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Inflection | 21 | 13 | 80 | 6.3 | 92 | 22 | 138 | 36 | 150 | 64 | 158 | 50 |
| Median | 23 | 140 | 81 | 76 | - | - | 139 | 98 | 153 | 159 | 159 | 101 |
| Shoulder | 28 | 207 | 86 | 140 | 93 | 174 | 152 | 190 | 156 | 228 | 160 | 205 |

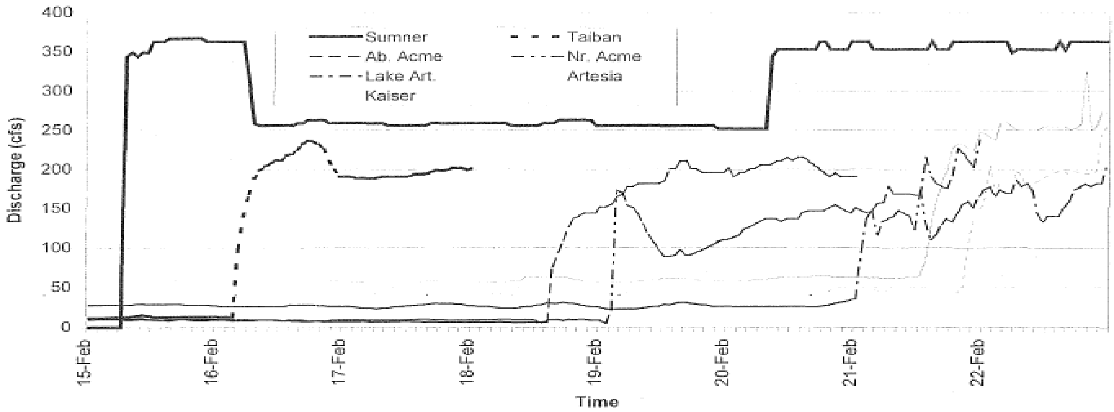



*Figure 9. Wave travel times and discharge attenuation from Taiban to Kaiser (15 Dec 1994 – 22 Dec 1994) Stop Releases. Source, Tetra Tech 2000, Figure P-5*

*The Proposed Action will continue to release stored water, consistent with 2016 Biological Opinion, as follows (USBOR 2017a: 19-20):*

- *Release stored water for the beneficial use of irrigation in a manner that does not constitute a wasteful use due to excessive losses through seepage and evaporation from the Upper Reservoirs to Brantley Reservoir (i.e., block releases);*
- *Manage the block release schedule from Sumner Reservoir, if possible, to alleviate any intermittency;*
- *Restrict the duration of block releases from Sumner Reservoir to a maximum of 15 days;*
- *Restrict the cumulative duration of block releases from Sumner Reservoir in a calendar year to a maximum of 65 days; and*
- *The number of days between block releases from Sumner Reservoir shall be no less than 14. (Note: maximum release from Sumner is ± 1,600 cfs at full winter storage)*

*USBOR also proposes that any remaining attributes of block releases (e.g., flow rates, irrigation demand) should be considered part of the Environmental Baseline (USBOR 2017a: 20).*

*As to the timing of the block releases CID can call for water whenever they feel that water is needed in a downstream reservoir throughout the year, following the rules above. However, the usual timing is just prior to May 1st, late June or early July, and late August or early September.*

The citation (USBOR 2017a) is the 2016 Biological Assessment provided to the USFWS for their 2016 Biological Opinion on the Pecos Bluntnose Shiner and Interior Least Tern. Carlsbad Project Water Operations, Consultation Number 02ENNM00-2016-F-0506.

# 4 FLEXIBILITY IN WATER RESOURCE OPERATIONS

USBOR only has flexibility in the use of supplemental water. That flexibility is in the volume of water used to maintain a continuous river as indicated by 5 cfs at the Acme gage. This flexibility only lasts until the supplemental water runs out or if there is not enough water in storage to provide supplemental water.

Currently the supplemental water is stored in Lake Sumner on a calendar year schedule, Bypass and FCP water acquired is available on January 1st, Forbearance water is acquired as FSID forgoes the water and is available once the water begins to accumulate in storage. All supplemental water in storage on December 31st reverts to CID. However, if storage of supplemental water becomes available in Santa Rosa Lake (USACE) the water on December 31st will be transferred from Sumner and increase USBOR's flexibility.

The only other way to increase flexibility is to work with the irrigation districts to develop changes in water movement in the basin.

The main laws, regulations, and agreements governing water use in the Pecos River Basin from Santa Rosa Reservoir to Brantley Lake follow:

- **New Mexico Water Law, 1907** - Defines beneficial use; first in time, first in right; water as property right; non-riparian water rights; all water in New Mexico belongs to the people, except that water that has been appropriated; etc.
- **Hope Community Ditch Decree, May 8, 1933** - Adjudicated water rights to lands situate in the counties of De Baca, Chaves, Lincoln, Eddy, and Otero
- **Pecos River Compact between NM and TX, 1949** - Sets the water delivery and accounting for Pecos Basin water delivery to Texas.
- **State Engineer's Findings and Order, October, 1972** - IN THE MATTER OF THE APPLICATION OF THE CARLSBAD IRRIGATION DISTRICT AND THE UN1T£D STATES DEPARTMENT OF THE INTERIOR, BUREAU OF RECLAMATION, FILE NO. 6, FOR A PERMIT TO TRANSFER IRRIGATION STORACE CAPACITY IN ALAMOGORDO DAM RESERVOIR TO LOS ESTEROS DAM AND LAKE: AND TO PROVIDE ADDITIONAL IRRIGATION STORAGE CAPACITY IN LOS ESTER0S DAM AND LAKE, this regulation details how water is to be stored in Los Esteros, renamed Santa Rosa Lake, as a transfer of irrigation storage from Alamogordo Reservoir, renamed Lake Sumner, to Santa Rosa Lake, the minimum pool in Sumner, and the two-week FSID allocation calculations.
- **US Supreme Court, Amended Decree, March 28, 1988** - Resolved issues of complaint by TX and set definite deliveries and penalties for non-delivery as outlined in the Compact, and appointed the Pecos River Water Master.
- **Letter from NM State Engineer Carl L. Singerland to Glen Brim, District (2) Supervisor, Roswell, 1990** - Letter instructs Mr. Brim on how to exactly calculate the FSID two-week allotment.

- **Pecos Settlement Agreement, 25 March 2003** - Entered into this 25th day of March 2003 by and between the state of New Mexico ex rel. The State Engineer; the New Mexico Interstate Stream Commission; the United States of America, Department of the Interior, Bureau of Reclamation; the Carlsbad Irrigation District; and the Pecos Valley Artesian Conservancy District.
- **Pecos River Adjudication Settlement Negotiations, March 10, 2003** - Model Evaluation of Proposed Settlement Terms Final Report Prepared by: John Carron, Ph.D. Hydrosphere Resource Consultants, Inc.
- **Pecos River Master's Manual, July 28. 2003 Version** - This revised edition of the Peens River Master's Manual was compiled from the edition dated November 30, 1987, which was .marked as "Texas Exhibit No. 18". In the revised edition, modifications have been added to the text of the Manual. And a few minor changes in presentation style have been made. The edition was prepared. By the River Master and submitted to the Technical Representatives of New Mexico and Texas for review and approval. Comments received in a joint letter from the states dated May 14, 2003 have been incorporated into the revision.
- **Carlsbad Project Water Operations and Water Supply Conservation Final Environmental Impact Statement June 2006, USBR/NMISC** - This document was completed as the NEPA component of the 2006 Biological Opinion for the Pecos Bluntnose Shiner and the Interior Least Tern.
- **Pecos River Hydrology and Water Operations Reference Manual, Stockton, June 2011** - A detailed report of how the water in the Pecos Basin, from Santa Rosa Lake to Carlsbad, NM, is allocated and used.
- **Final Biological Opinion for the Carlsbad Project Water Operations and Water Supply Conservation, 2016-2026, USFWS, December 2017** - Replaces previous biological opinions, current Biological Opinion that details the conditions and flows needed in the Pecos River below Lake Sumner and the Acme gage (currently on the US Highway 70 Bridge north of Roswell, NM), and Interior Least Tern habitat at Brantley Lake and to promote the survival of the Pecos Bluntnose Shiner.

# Appendix C: Water Quality

**Identifying Environmental Flow Requirements for the Pecos River:**

**Background Literature Review and Summary**

The construction of dams and reservoirs have increased dramatically over the past century has resulted in a drastic reduction in the number of free-flowing rivers (Benke 1990). Currently, only 23% of rivers globally longer than 1,000 kilometers flow uninterrupted to the ocean (Grill et al. 2019). The most basic impact of impoundments on the hydrologic cycle is the dramatic increase in residence times, with an estimated 3X increase in the mean age of river water over the last century (Vörösmarty 1997). The increase in residence times by impoundments has significant implications for downstream transport of sediments (Vörösmarty et al. 2003, Syvitski et al. 2005), salinity and nutrients (Kelly 2001, Teodoru and Wehrli 2005, Cook et al. 2010), and organic matter (Mulholland and Elwood 1982, Kraus et al. 2011, Sobek et al. 2012). In addition, dams also influence the downstream thermal regime of rivers, however, the direction, magnitude, and longitudinal extent of these changes varies due to the configuration of the outlet works, physical characteristics, and storage volume (Preece and Jones 2002, Caissie 2006, Olden and Naiman 2010). The surface water withdrawals and returns in fragmented river networks also impact the thermal regime (Walker 1985, Van Horn et al. In review), salinity (Walker and Thoms 1993, Jolly et al. 2001, Dahm et al. 2013), and nutrients (Mortensen et al. 2016, Bicknell et al. 2020). Despite these ecological impacts, dams and surface water diversions provide consumptive benefits (Jackson et al. 2001) and are heavily relied upon for water storage, water delivery, and to buffer against drought in the southwestern U.S. (Grimm et al. 1997, MacDonald 2010, Dettinger et al. 2015, Udall and Overpeck 2017, Bennett et al. 2019) and other arid and semi-arid regions globally (Genxu and Guodong 1999, Kingsford 2000, Mukherjee et al. 2010).

Within the Pecos Basin, fresh water provides consumptive benefits including water for livestock watering and irrigation (USBOR and NMISC 2006b, NMWCC 2017). Non-consumptive benefits within the basin include flood control, sediment retention, recreation, wastewater discharge, and habitat for biota (USBOR and NMISC 2006b, USACE 2017, NMED 2020b). Some benefits, such as irrigation and flood control, are achieved by major changes to the natural flow regime, specifically water storage dams and water diversions (Robertson 1997, Yuan et al. 2007), groundwater pumping (Lingle and Linford 1961), and the return and reuse of irrigation water (Houston et al. 2019). These hydrological changes often have negative effects or trade-offs with other instream benefits, such as supporting diverse aquatic assemblages and ecosystem processes (Dudley and Platania 2007, Hoagstrom et al. 2008, Hoagstrom 2009, Pease and Delaune 2021) and maintaining suitable water quality for consumptive use (Houston et al. 2019). Water quantity and quality on the Pecos River are also influenced by natural processes including the Pacific Decadal Oscillation (Yuan et al. 2007), El Niño-Southern Oscillation (Molles and Dahm 1990), saline surface water and groundwater additions (Yuan and Miyamoto 2005, Houston et al. 2019), rock-water interactions and salt deposits in the Permian Basin (Hoagstrom 2009, Houston et al. 2019), and evaporative losses (Hoagstrom 2009, Houston et al. 2019). The goals of this section are to 1) summarize the spatial and temporal variability in salinity within the basin, 2) identify biological and ecological implications of increased salinity, 3) document the impacts of a block release from Santa Rosa Reservoir on water quality, and 4) summarize the mercury impairments within the basin and the influence of reservoirs on the mercury cycle.

Elevated salinity within the Pecos River throughout much of its length is a concern for consumptive use (Houston et al. 2019) and the aquatic ecosystem (Hoagstrom 2009, Pease and Delaune 2021). As a result, numerous investigations have evaluated the spatial and temporal variability in salinity or Total Dissolved Solids (TDS) within the Pecos Basin (Yuan and Miyamoto 2005, USBOR and NMISC 2006b, Yuan et al. 2007, Hoagstrom 2009, Houston et al. 2019). Salinity and TDS are considered synonymous, as both refer to the total ionic concentration of dissolved minerals in water. Specific conductance (SC; conductance at 25 °C), a water quality parameter commonly measured in the field, correlates with the total dissolved major-ion concentrations and often with a single dissolved-ion concentrations (Hem 1970), and supplements analytical determination of TDS (Miller et al. 1988). A strong relationship between SC and TDS on the Pecos River at 6 stations above Santa Rosa to Orla (USBOR and NMISC 2006a).

A recent analysis of salinity, TDS, SC, additional water quality data from surface-water and groundwater samples, streamflow measurements, and geophysical logs provided additional insight regarding sources and assessment of salinity in the Pecos Basin (Houston et al. 2019). In summary, longitudinal sources of salinity inputs to the Pecos River in New Mexico during winter baseflow conditions include springs discharging into include El Rito Creek, inflow from Bitter Lake National Wildlife Refuge, inflow from the Rio Hondo, outflow of Lee Lake, and the Malaga Bend region of the Pecos River (Figure 1; Houston et al. 2019). The most notable spatial increase in salinity on the Pecos River in New Mexico was the sub-reach between Acme and Artesia (Houston et al. 2019), and is attributed to sources (e.g., groundwater inflow, inflow from surface-water features) with isotopically different sources than the main stem of the Pecos River (Houston et al. 2019). Longitudinal monitoring during additional hydrologic periods (e.g., snowmelt, monsoon storm, summer baseflow) would further refine the sources of salinity to the Pecos Basin.

Considerable within-site temporal variability in salinity on the Pecos River has also been observed. For example, the TDS flux measured at Santa Rosa, Puerto De Luna, Sumner, and Acme have been positively correlated with stream discharge, and influenced by reservoir releases, inflow, and storage (Yuan et al. 2007). Recent high-frequency measurements of discharge and SC during block releases directly downstream of Santa Rosa Dam have also documented a reduction in SC with an increase in discharge (Reale 2016). Similarly, releases greater than 1000 cfs from Sumner dam have been found to reduce the longitudinal increase in SC (USBOR and NMISC 2006a).

Regardless of the timing or source, salinization within the Pecos River in New Mexico and Texas has negatively impacted the aquatic ecosystem ranging from biodiversity to food webs. For example, benthic macroinvertebrate diversity in a high salinity reach of the Pecos River was less than a reach that received freshwater inflow (Davis 1980). Elevated salinity on the Pecos has also been attributed to declines in fish diversity (Davis 1986, Rhodes and Hubbs 1992, Linam and Kleinsasser 1996, Hoagstrom 2009, Pease and Delaune 2021), with a shift in dominance to euryhaline fishes that are more typical of coastal estuaries (Davis 1986) or saline wetlands and springs proximal to the Pecos River (Hoagstrom 2009). Salinization in the Pecos River, along with reduced flows, have been attributed to the reduction in allochthonous inputs along with shortened and less diverse food chains (Pease and Delaune 2021). Within the Sub-reach C-3 (Farmland Reach; i.e., Roswell to Brantley Reservoir delta), salinization may affect the habitat suitability of federally listed Pecos Bluntnose Shiner (*Notropis simus pecocensis*) for all life stages (USFWS 2017). In contrast to other ecological indicators, blooms of golden algae were associated with periods of low SC (< 15,000 µS/cm) and a wide range of nutrient (nitrogen and phosphorus) concentrations, whereas blooms observed at greater SC occurred at only mid-to-high nutrient concentrations (Israël et al. 2014).

In addition to salinity, the alternation of the natural flow regime on the Pecos River is likely to influence other water quality parameters. Beginning in the summer of 2020, the Corps in collaboration with the University of New Mexico (UNM) began collecting year-round and high-frequency water quality data (i.e., temperature, pH, SC, dissolved oxygen (DO), and turbidity) on the Pecos River upstream (~ 2.3 km downstream of USGS No. 08382650), immediately downstream (~ 40 m downstream of USGS No. 08382830), and ~ 12.5 km downstream (I-40 crossing) of Santa Rosa Reservoir (Figure 1). This study provides the opportunity to assess episodic, seasonal, and interannual trends in water quality and in-stream ecosystem processes and the influence of water operations (e.g., water storage and block releases) at Santa Rosa Reservoir on the observed variability. Due to the preliminary status of the study data from a single block release was evaluated for this report.

*Figure 1: High-frequency water quality stations on the Pecos River upstream (2.3 km downstream of USGS No. 08382650; left), immediately downstream (40 m downstream of USGS No. 08382830; center), and 12.5 km downstream (i.e., Interstate-40 crossing; right) of Santa Rosa Reservoir, New Mexico during summer base-flow conditions (USACE).*

The September 2020 block release began on 28-Sept and ended on 2-Oct and resulted in a transfer of approximately 4,000 acre-ft of water from Santa Rosa Reservoir to Sumner Lake. The peak discharge and average discharge during the block release were 728 and 501 cfs, respectively (Figure 2). The abrupt and dramatic increase in discharge altered water quality immediately downstream of the dam and at the I-40 crossing, compared to pre-release values and the site upstream of the reservoir. SC decreased at both downstream sites during the release and did not recover to pre-release values for 10-15 days following the conclusion of the release. The diel temperature flux at the upstream site was nearly two times greater than the downstream sites prior to and following the release and could be attributed gains in groundwater (Caissie 2006) and coldwater seepage from the hypolimnion (Olden and Naiman 2010). A decrease in water temperature and dampening of the diel signal was observed at the site immediately downstream of the dam and to a lesser extent at the I-40 site. The thermal regime at both sites recovered immediately to pre-release levels. While turbidity increased by approximately 50 NTU during the release, which is greater than the threshold (i.e., < 10 NTU above background) established by the NMWCC (2017). The elevated turbidity from the release likely reduced light transmission reducing primary production (Izagirre et al. 2008) and substantial visible contrast with the natural appearance. However, turbidity levels quickly recovered to pre-release values within 3-4 days.

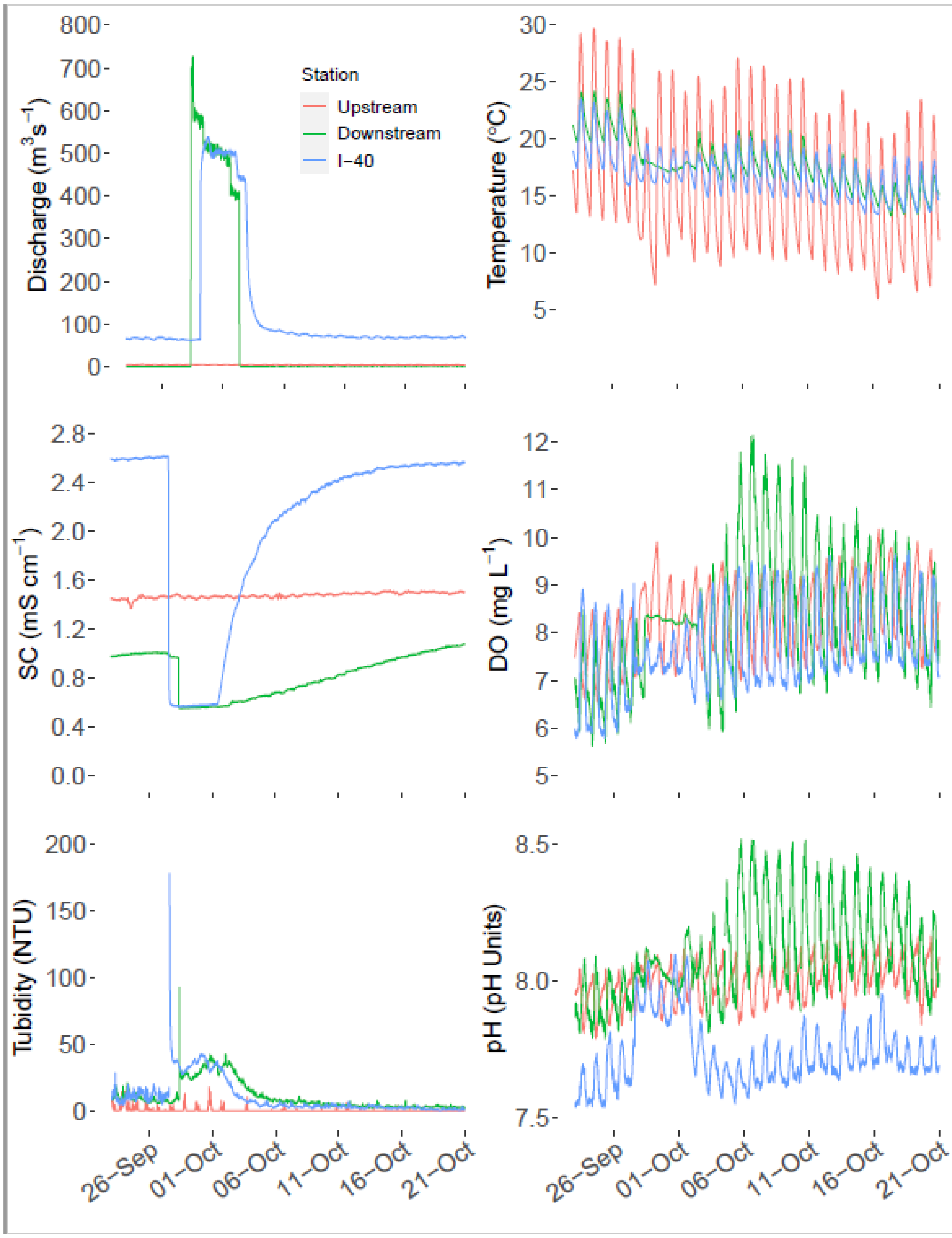



*Figure 2: High-frequency water temperature, pH, SC, dissolved oxygen (DO), and turbidity collected on the Pecos River immediately upstream, immediately downstream, and 12.5 km downstream (i.e., Interstate-40 crossing) of Santa Rosa Reservoir, New Mexico during the September 2020 block release. Discharge data from proximal streamflow gages were obtained from the USGS were utilized (i.e., gage No. 08382650, 08382830, 08383500).*

High-frequency diel DO signals can be used to estimate stream metabolism (Mulholland et al. 2005, Dodds 2007), a functional metric of river health (Young et al. 2008) and responds to disturbances following controls floods downstream of dam (Uehlinger et al. 2003) and drought (Acuña et al. 2005). Where gross primary production (GPP) elevates and ecosystem respiration (ER) reduces to DO signal, respectively. As part of the Corps-UNM study, a single-station metabolism model using StreamMetabolizer (Appling et al. 2018) will be utilized in the future. For the interim, the amplitude and timing of the DO and temperature signals provide a preliminary understanding of the effects of the block release on stream metabolism (Figure 3). At the upstream site DO was out of phase with water temperature throughout the study period, suggesting that the physiochemical relationship of water temperature and oxygen solubility was controlling the DO signal. The low turbidity and open canopy at this site throughout the study period suggests that light availability was not limiting GPP (Izagirre et al. 2008). The small diel DO oscillations are surprising, as low and stable flows have been found to enhance GPP (Acuña et al. 2011). At the site immediately downstream, DO was also out of phase with water temperature prior to the block release but shifted to in phase following the block release. This shift suggests biological controls (i.e., primary production and ecosystem respiration) were regulating the DO signal post-release. While at the I-40 site, DO was in phase with water temperature prior to and following the block release, suggesting that biological controls remained dominant throughout the study period. Overall, the increase in discharge likely stimulated stream metabolism downstream of Santa Rosa Reservoir, and has been observed by others following moderate increases in discharge (Stevenson 1990, Humphrey and Stevenson 1992).

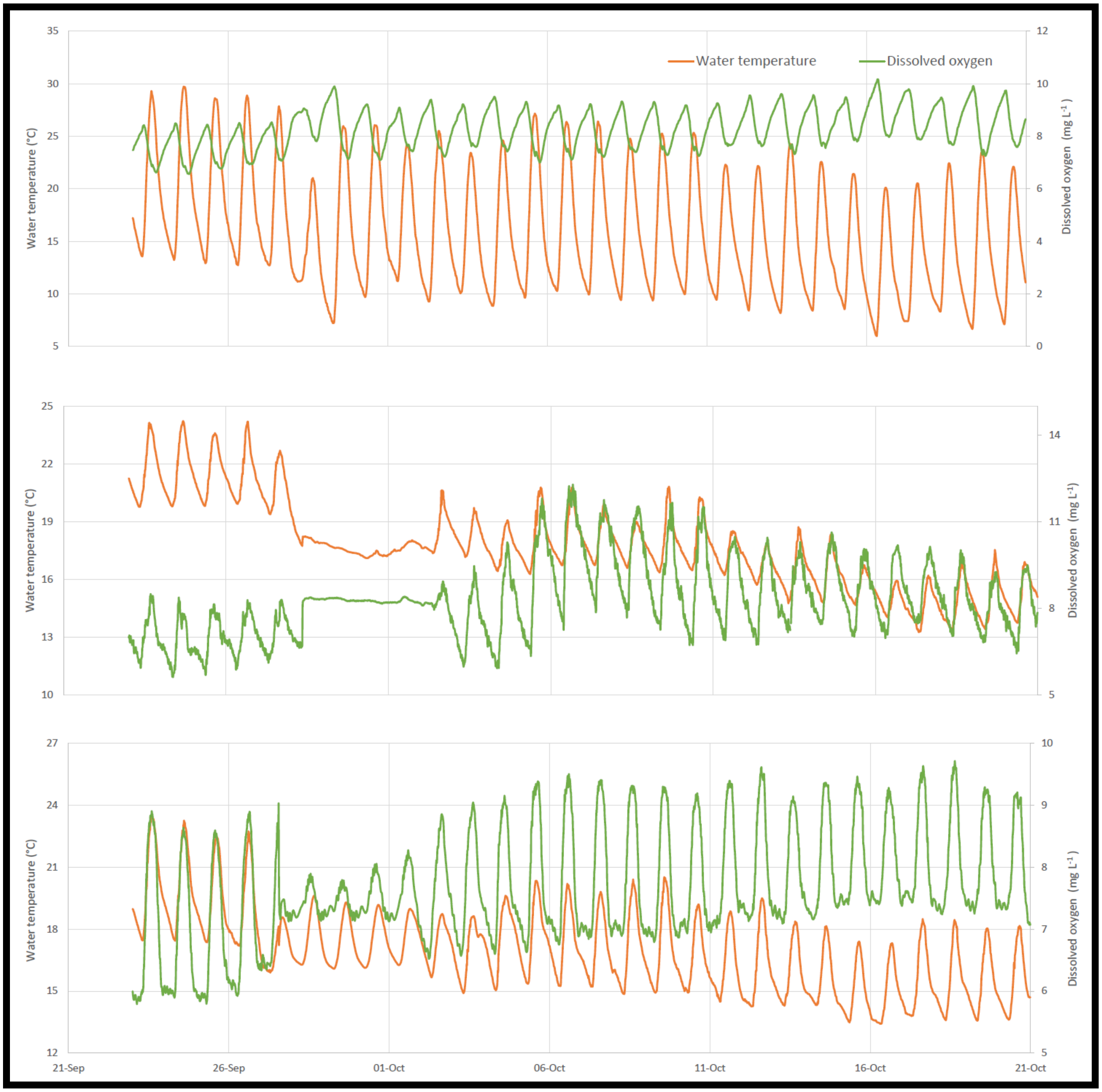



*Figure 3: High-frequency water temperature and dissolved oxygen (DO) collected on the Pecos River immediately upstream (top), immediately downstream (middle), and 12.5 km downstream (bottom) of Santa Rosa Reservoir during the September 2020 block release.*

In summary, the 2020 block release had short-term (days to weeks) impacts on downstream water quality and stimulated stream metabolism following the release, despite a relatively short duration and peak discharge. More prolonged impacts following block releases below Santa Rosa Reservoir are likely, given that releases often exceed 1,000 $ft^3$ $s^{-1}$ and persist for several weeks. Future monitoring of water quality during longer duration block releases and reservoir storage will provide the opportunity to further evaluate the influence of water management operations on water quality and in-stream ecosystem processes within the Pecos River.

In addition to water quality, mercury has been a well-studied within the Pecos River Basin. All three reservoirs within the study area (Santa Rosa, Sumner, and Brantley) are listed as impaired (NMED 2020a) for elevated mercury concentrations (i.e., > 0.3 mg methyl mercury kilogram$^{-1}$), resulting in fish consumption advisories for multiple species (NMED et al. 2020). Greystone (1998) investigated the longitudinal gradient of total and methyl mercury in water, sediment, and fish tissue along the Pecos River. Their results, based on a detection limit less than the water quality standard (i.e. 0.005 µg/L), showed that total mercury remained below the standard throughout the upper basin. Total mercury in fine and course sediment remained also remained well below the current EPA freshwater sediment screening benchmark (180 ng/g). Elevated mercury in water was only found at a site just north of Acme and indicates a mercury source between there and Sumner Lake, the next upstream site. This finding is of particular importance because this site is within designated critical habitat for Pecos Bluntose Shiner. All fish tissue samples, which were comprised of primarily of whole-body cyprinids, exceeded the EPA's Human Heath Criteria for mercury (0.00015 mg kilogram $^{-1}$). The authors conclude that because ambient mercury concentrations are low in water and sediment the biota in the Pecos River are bioaccumulating mercury. However, a longitudinal trend in biota tissue downstream of Santa Rosa was not observed; and therefore, not likely adversely affecting Pecos Bluntnose shiner (Greystone 1998, USFWS 2017) and the reservoir is functioning as a sediment and mercury sink. High-frequency water quality and discrete total suspended solids, total mercury, and methyl mercury monitoring suggest that sediment and mercury are not being transported downstream during a low-pool block release (Reale 2016).

As documented in this section, impoundments, water operations, and natural sources in the Pecos Basin influence riverine water quality and in-stream ecosystem processes temporally and longitudinally. Strategic water storage and flow regime restoration using the existing reservoir network could be used to reduce salinization, possibly reducing the dominance of euryhaline fishes and promoting the native fish assemblage. However, Santa Rosa, Sumner, and Brantley reservoirs also function as mercury sink, providing an ecosystem service downstream and should be taken into consideration if flow regime restoration is implemented.

**References:**

Acuña, V., I. Muñoz, A. Giorgi, M. Omella, F. Sabater, and S. Sabater. 2005. Drought and postdrought recovery cycles in an intermittent Mediterranean stream: structural and functional aspects. Journal of the North American Benthological Society **24**:919-933.

Acuña, V., C. Vilches, and A. Giorgi. 2011. As productive and slow as a stream can be—the metabolism of a Pampean stream. Journal of the North American Benthological Society **30**:71-83.

Appling, A. P., R. O. Hall Jr, C. B. Yackulic, and M. Arroita. 2018. Overcoming equifinality: Leveraging long time series for stream metabolism estimation. Journal of Geophysical Research: Biogeosciences **123**:624-645.

Benke, A. C. 1990. A perspective on America's vanishing streams. Journal of the North American Benthological Society **9**:77-88.

Bennett, K. E., V. C. Tidwell, D. Llewellyn, S. Behery, L. Barrett, M. Stansbury, and R. S. Middleton. 2019. Threats to a Colorado river provisioning basin under coupled future climate and societal scenarios. Environmental Research Communications **1**:095001.

Bicknell, K., P. J. Regier, D. Van Horn, K. Feeser, and R. Gonzales-Pinzon. 2020. Linking Hydrobiogeochemical Processes and Management Techniques to Close Nutrient Loops in an Arid River. Frontiers in Water **2**.

Caissie, D. 2006. The thermal regime of rivers: a review. Freshwater Biology **51**:1389-1406.

Cook, P. L., K. T. Aldridge, S. Lamontagne, and J. Brookes. 2010. Retention of nitrogen, phosphorus and silicon in a large semi-arid riverine lake system. Biogeochemistry **99**:49-63.

Dahm, C. N., D. J. Van Horn, J. K. Reale, R. Candelaria-Ley, and C. S. Reale. 2013. Continuous water quality monitoring of the Rio Grande and Rio Chama. University of New Mexico, Submitted to the U.S. Army Corps of Engineers, Albuquerque, NM.

Davis, J. R. 1980. Species composition and diversity of benthic macroinvertebrate populations of the Pecos River, Texas. The Southwestern Naturalist:241-256.

Davis, J. R. 1986. Faunal characteristics of a saline stream in the northern Chihuahuan Desert. Chihuahuan Desert Research Institute.

Dettinger, M., B. Udall, and A. Georgakakos. 2015. Western water and climate change. Ecological Applications **25**:2069-2093.

Dodds, W. K. 2007. Trophic state, eutrophication and nutrient criteria in streams. Trends in ecology & evolution **22**:669-676.

Dudley, R. K., and S. P. Platania. 2007. Flow regulation and fragmentation imperil pelagic-spawning riverine fishes. Ecological Applications **17**:2074-2086.

Genxu, W., and C. Guodong. 1999. Water resource development and its influence on the environment in arid areas of China—the case of the Hei River basin. Journal of Arid Environments **43**:121-131.

Greystone. 1998. Assessment of mercury transport into and out of the Santa Rosa Reservoir and its effects on the Pecos Bluntnose Shiner in the Pecos River, New Mexico. Prepared for: U.S. Army Corps of Engineers, Albuquerque District.

Grimm, N. B., A. Chacón, C. N. Dahm, S. W. Hostetler, O. T. Lind, P. L. Starkweather, and W. W. Wurtsbaugh. 1997. Sensitivity of aquatic ecosystems to climatic and anthropogenic changes: The Basin and Range, American Southwest and Mexico. Hydrological processes **11**:1023-1041.

Hem, J. D. 1970. Study and interpretation of the chemical characteristics of natural water, U.S. Geological Survey Water-Supply Paper 1473.

Hoagstrom, C. W. 2009. Causes and impacts of salinization in the lower Pecos River. Great Plains Research:27-44.

Hoagstrom, C. W., J. E. Brooks, and S. R. Davenport. 2008. Spatiotemporal population trends of Notropis simus pecosensis in relation to habitat conditions and the annual flow regime of the Pecos River, 1992–2005. Copeia **2008**:5-15.

Houston, N. A., J. V. Thomas, P. B. Ging, A. P. Teeple, D. E. Pedraza, and D. S. Wallace. 2019. Pecos River Basin salinity assessment, Santa Rosa Lake, New Mexico, to the confluence of the Pecos River and the Rio Grande, Texas, 2015. 2328-0328, US Geological Survey.

Humphrey, K. P., and R. J. Stevenson. 1992. Responses of Benthic Algae to Pulses in Current and Nutrients during Simulations of Subscouring Spates. Journal of the North American Benthological Society **11**:37-48.

Israël, N. M., M. M. VanLandeghem, S. Denny, J. Ingle, and R. Patiño. 2014. Golden alga presence and abundance are inversely related to salinity in a high-salinity river ecosystem, Pecos River, USA. Harmful Algae **39**:81-91.

Izagirre, O., U. Agirre, M. Bermejo, J. Pozo, and A. Elosegi. 2008. Environmental controls of whole-stream metabolism identified from continuous monitoring of Basque streams. Journal of the North American Benthological Society **27**:252-268.

Jackson, R. B., S. R. Carpenter, C. N. Dahm, D. M. McKnight, R. J. Naiman, S. L. Postel, and S. W. Running. 2001. Water in a changing world. Ecological Applications **11**:1027-1045.

Jolly, I., D. Williamson, M. Gilfedder, G. Walker, R. Morton, G. Robinson, H. Jones, L. Zhang, T. Dowling, and P. Dyce. 2001. Historical stream salinity trends and catchment salt balances in the Murray–Darling Basin, Australia. Marine and Freshwater Research **52**:53-63.

Kelly, V. J. 2001. Influence of reservoirs on solute transport: a regional-scale approach. Hydrological processes **15**:1227-1249.

Kingsford, R. T. 2000. Ecological impacts of dams, water diversions and river management on floodplain wetlands in Australia. Austral Ecology **25**:109-127.

Kraus, T. E., B. A. Bergamaschi, P. J. Hernes, D. Doctor, C. Kendall, B. D. Downing, and R. F. Losee. 2011. How reservoirs alter drinking water quality: organic matter sources, sinks, and transformations. Lake and Reservoir Management **27**:205-219.

Linam, G. W., and L. J. Kleinsasser. 1996. Relationship between fishes and water quality in the Pecos River, Texas. Texas Parks and Wildlife Dept., Resource Protection Division River Studies Report.

Lingle, R. T., and D. Linford. 1961. Pecos River Commission of New Mexico and Texas: A report of a decade of progress, 1950-1960. Rydal Press, Santa Fe, NM.

MacDonald, G. M. 2010. Water, climate change, and sustainability in the southwest. Proceedings of the National Academy of Sciences **107**:21256-21262.

Miller, R. L., W. L. Bradford, and N. E. Peters. 1988. Specific conductance: theoretical considerations and application to analytical quality control. U.S. Geological Survey Water-Supply Paper 2311.

Molles, M. C., and C. N. Dahm. 1990. A perspective on El Niño and La Niña: global implications for stream ecology. Journal of the North American Benthological Society **9**:68-76.

Mortensen, J. G., R. González-Pinzón, C. N. Dahm, J. Wang, L. H. Zeglin, and D. J. Van Horn. 2016. Advancing the food-energy–water nexus: closing nutrient loops in arid river corridors. Environmental Science & Technology **50**:8485-8496.

Mukherjee, S., Z. Shah, and M. D. Kumar. 2010. Sustaining urban water supplies in India: increasing role of large reservoirs. Water resources management **24**:2035-2055.

Mulholland, P. J., and J. W. Elwood. 1982. The role of lake and reservoir sediments as sinks in the perturbed global carbon cycle. Tellus **34**:490-499.

Mulholland, P. J., J. N. Houser, and K. O. Maloney. 2005. Stream diurnal dissolved oxygen profiles as indicators of in-stream metabolism and disturbance effects: Fort Benning as a case study. Ecological Indicators **5**:243-252.

NMED. 2020a. 2020-2022 State of New Mexico Clean Water Act Section 303(d)/ Section 305(b) integrated report. Surface Water Quality Bureau, New Mexico Environment Department, Santa Fe, NM.

NMED. 2020b. NPDES individual permits.

NMED, NMDOH, and NMGF. 2020. New Mexico fish consumption advisory table. State of New Mexico, Santa Fe, New Mexico.

NMWCC. 2017. State of New Mexico Standards for Interstate and Intrastate Streams. New Mexico Environment Department, Santa Fe, New Mexico.

Olden, J. D., and R. J. Naiman. 2010. Incorporating thermal regimes into environmental flows assessments: modifying dam operations to restore freshwater ecosystem integrity. Freshwater Biology **55**:86-107.

Pease, A., and K. Delaune. 2021. Dried and salted: Cumulative impacts of diminished flows and salinization on Lower Pecos River food webs. TNHC-Publications. Desert Fishes Council.

Preece, R. M., and H. A. Jones. 2002. The effect of Keepit Dam on the temperature regime of the Namoi River, Australia. River Research and Applications **18**:397-414.

Reale, J. K. 2016. Santa Rosa Reservoir block release water quality and chemistry monitoring report. U. S. Army Corps of Engineers, Albuquerque District, Albuquerque, New Mexico.

Rhodes, K., and C. Hubbs. 1992. Recovery of Pecos River fishes from a red tide fish kill. The Southwestern Naturalist:178-187.

Robertson, L. 1997. Water operations on the Pecos River, New Mexico and the Pecos bluntnose shiner, a federally listed minnow. Page 407 *in* H. W. Greydanus and S. S. Anderson, editors. Competing Interests in Water Resources-Searching for Consensus, U.S. Committee on Irrigation and Drainage, Washington, D.C.

Sobek, S., T. DelSontro, N. Wongfun, and B. Wehrli. 2012. Extreme organic carbon burial fuels intense methane bubbling in a temperate reservoir. Geophysical Research Letters **39**.

Stevenson, R. J. 1990. Benthic algal community dynamics in a stream during and after a spate. Journal of the North American Benthological Society **9**:277-288.

Syvitski, J. P., C. J. Vörösmarty, A. J. Kettner, and P. Green. 2005. Impact of humans on the flux of terrestrial sediment to the global coastal ocean. Science **308**:376-380.

Teodoru, C., and B. Wehrli. 2005. Retention of sediments and nutrients in the Iron Gate I Reservoir on the Danube River. Biogeochemistry **76**:539-565.

Udall, B., and J. Overpeck. 2017. The twenty-first century Colorado River hot drought and implications for the future. Water Resources Research **53**:2404-2418.

Uehlinger, U., B. Kawecka, and C. Robinson. 2003. Effects of experimental floods on periphyton and stream metabolism below a high dam in the Swiss Alps (River Spöl). Aquatic Sciences **65**:199-209.

USACE. 2017. Appendix B: Santa Rosa Dam and Lake water control manual. Pecos River Basin master water control manual, U.S. Army Corps of Engineers, Albuquerque District.

USBOR, and NMISC. 2006a. Appendix 4: water quality. Carlsbad Project Water Operations and Water Supply Conservation Final Environmental Impact Statement, Albuquerque Area Office, Bureau of Reclamation, Albuquerque, New Mexico. https://www.usbr.gov/uc/albuq/library/eis/carlsbad/feis/CarlsbadVol2Appendices.pdf.

USBOR, and NMISC. 2006b. Carlsbad Project Water Operations and Water Supply Conservation Final Environmental Impact Statement. Albuquerque Area Office, Bureau of Reclamation, Albuquerque, New Mexico. https://www.usbr.gov/uc/albuq/library/eis/carlsbad/feis/CarlsbadFEISVol1.pdf.

USFWS. 2017. Final biological opinion for the Carlsbad Project water operations and water supply conservation, 2016-2026. New Mexico Ecological Services Field Office, Albuquerque, New Mexico. Consultation Number 02ENNM00-2016-F-0506.

Van Horn, D. V., J. K. Reale, and T. P. Archdeacon. In review. Water quality in three potential refugia in an arid-land river: assessing suitability to sustain fish populations Aquatic Sciences.

Vörösmarty, C. J., M. Meybeck, B. Fekete, K. Sharma, P. Green, and J. P. Syvitski. 2003. Anthropogenic sediment retention: major global impact from registered river impoundments. Global and planetary change **39**:169-190.

Walker, K. 1985. A review of the ecological effects of river regulation in Australia. Perspectives in Southern Hemisphere Limnology:111-129.

Walker, K., and M. Thoms. 1993. Environmental effects of flow regulation on the lower River Murray, Australia. Regulated Rivers: Research & Management **8**:103-119.

Young, R. G., C. D. Matthaei, and C. R. Townsend. 2008. Organic matter breakdown and ecosystem metabolism: functional indicators for assessing river ecosystem health. Journal of the North American Benthological Society **27**:605-625.

Yuan, F., and S. Miyamoto. 2005. Dominant processes controlling water chemistry of the Pecos River in American southwest. Geophysical Research Letters **32**.

Yuan, F., S. Miyamoto, and S. Anand. 2007. Changes in major element hydrochemistry of the Pecos River in the American Southwest since 1935. Applied Geochemistry **22**:1798-1813.

# Appendix D: Avian Species

## Identifying Environmental Flow Requirements for the Pecos River: Background Literature Review and Summary

CONTENTS

# 1 Pecos River Basin Birds

| Avian Species Common Name | Where Located | | | Habitat/Behavior Type | | | | Temporal Nature | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Reach A | Reach B | Reach C | Shore or Wading | Riparian Forest | Predator/ Scavenger | Grasses/ Chapparal | Resident | Migratory | Breeding | Winter |
| Black-bellied Whistling-Duck | | x | x | x | | | | | | x | |
| Snow Goose | x | x | x | x | | | | | | | x |
| Ross's Goose | x | x | x | x | | | | | | | x |
| Greater White-fronted Goose | x | x | x | x | | | | | x | | |
| Brant | | | x | x | | | | | x | | |
| Cackling Goose | x | x | x | x | | | | | | | x |
| Canada Goose | x | x | x | x | | | | x | | | |
| Trumpeter Swan | | | x | x | | | | | x | | |
| Tundra Swan | | | x | x | | | | | x | | |
| Wood Duck | x | x | x | x | | | | | | | x |
| Garganey | | | x | x | | | | | x | | |
| Blue-winged Teal | x | x | x | x | | | | | | x | |
| Cinnamon Teal | x | x | | x | | | | | | x | |
| Blue-winged/Cinnamon Teal | x | x | | x | | | | | | x | |
| Northern Shoveler | x | x | x | x | | | | | | | x |
| Gadwall | x | x | x | x | | | | x | | | x |
| Eurasian Wigeon | | | x | x | | | | | x | | |
| American Wigeon | x | x | x | x | | | | | | | x |
| Mallard | x | x | x | x | | | | | | | x |
| Mallard (Domestic type) | | x | x | x | | | | | | | |
| Northern Pintail | x | x | x | x | | | | | | | x |
| Green-winged Teal | x | x | x | x | | | | | | | x |
| teal sp. | x | x | x | x | | | | | | | |
| Canvasback | x | x | x | x | | | | | | | x |
| Redhead | x | x | x | x | | | | | | | x |
| Ring-necked Duck | x | x | x | x | | | | | | | x |
| Greater Scaup | | x | x | x | | | | | x | | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Lesser Scaup | x | x | x | x | | | | | | | x |
| Surf Scoter | x | x | x | x | | | | | x | | |
| White-winged Scoter | x | x | x | x | | | | | x | | |
| Black Scoter | | x | | x | | | | | x | | |
| Long-tailed Duck | | x | x | x | | | | | x | | |
| Bufflehead | x | x | x | x | | | | | | | x |
| Common Goldeneye | x | x | x | x | | | | | | | x |
| Barrow's Goldeneye | | | x | x | | | | | x | | |
| Hooded Merganser | x | x | x | x | | | | | | | x |
| Common Merganser | x | x | x | x | | | | | | | x |
| Red-breasted Merganser | x | x | x | x | | | | | x | | |
| Common/Red-breasted Merganser | x | x | x | x | | | | | | | |
| Ruddy Duck | x | x | x | x | | | | x | | x | x |
| duck sp. | x | x | x | x | | | | | | | |
| Northern Bobwhite | x | x | x | | | | x | x | | | |
| Scaled Quail | x | x | x | | | | x | x | | | |
| Gambel's Quail | x | | | | | | x | x | | | |
| Ring-necked Pheasant | | | x | | | | x | x | | | |
| Dusky Grouse | x | | | | | | x | | ? | | |
| Wild Turkey | x | x | x | | | | x | x | | | |
| Pied-billed Grebe | x | x | x | x | | | | x | | | |
| Horned Grebe | x | x | x | x | | | | | x | | ? |
| Red-necked Grebe | | x | | x | | | | | x | | |
| Eared Grebe | x | x | x | x | | | | | | | x |
| Western Grebe | x | x | x | x | | | | | x | | x |
| Clark's Grebe | x | x | x | x | | | | | x | | x |
| Western/Clark's Grebe | x | x | | x | | | | | | | |
| Rock Pigeon | x | x | x | | | | x | x | | | |
| Band-tailed Pigeon | x | | x | | | | x | | | ? | |
| Eurasian Collared-Dove | x | x | x | | | | x | x | | | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| White-winged Dove | x | x | x | | x | | | x | | x | |
| Mourning Dove | x | x | x | | G | | | | | | |
| Groove-billed Ani | | | x | | x | | | | | x | far south (TX) |
| Greater Roadrunner | x | x | x | | x | | x | x | | | |
| Yellow-billed Cuckoo | x | x | x | | x | | | | | x | |
| Lesser Nighthawk | | | x | | | | x | | | x | |
| Common Nighthawk | x | x | x | | x | | x | | | | |
| Common Poorwill | x | x | x | | | | x | | | x | |
| Chimney Swift | x | | | | G | | | | | x | |
| White-throated Swift | x | | | | x | | | | | | |
| Rivoli's Hummingbird | x | | | | x | | | | | | |
| Black-chinned Hummingbird | x | x | x | | x | | | | | x | |
| Broad-tailed Hummingbird | x | x | x | | x | | | | x | x | |
| Rufous Hummingbird | x | x | x | | x | | | | x | | |
| Calliope Hummingbird | x | | | | x | | | | x | | |
| hummingbird sp. | x | x | | | x | | | | | | |
| Virginia Rail | | x | x | x | | | | | x | x | |
| Sora | | x | x | x | | | | | x | | |
| Common Gallinule | | | x | x | | | | x | | | |
| American Coot | x | x | x | x | | | | x | | | |
| Sandhill Crane | x | x | x | x | | | | | x | | x |
| Black-necked Stilt | | x | x | x | | | | | | x | |
| American Avocet | x | x | x | x | | | | | | x | |
| Black-bellied Plover | x | x | x | x | | | | | x | | |
| American Golden-Plover | | | x | x | | | | | x | | |
| Snowy Plover | | x | x | x | | | | | | x | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Semipalmated Plover | x | x | x | x | | | | | x | | |
| Piping Plover | x | | x | x | | | | | x | ? | |
| Killdeer | x | x | x | x | x | | | x | | | |
| Upland Sandpiper | | x | x | x | | | | | x | | |
| Whimbrel | | | x | x | | | | | x | | |
| Long-billed Curlew | | x | x | x | | | | | x | x | |
| Hudsonian Godwit | | | x | x | | | | | x | | |
| Marbled Godwit | x | x | x | x | | | | | x | | |
| Ruddy Turnstone | | x | x | x | | | | | x | | |
| Red Knot | | | x | x | | | | | x | | |
| Stilt Sandpiper | | x | x | x | | | | | x | | |
| Curlew Sandpiper | | | x | x | | | | | x | | |
| Sanderling | | x | x | x | | | | | x | | |
| Dunlin | | | x | x | | | | | x | | |
| Baird's Sandpiper | x | x | x | x | | | | | x | | |
| Little Stint | | | x | x | | | | | x | | |
| Least Sandpiper | | x | x | x | | | | | x | | x |
| White-rumped Sandpiper | | x | x | x | | | | | x | | |
| Buff-breasted Sandpiper | | | x | x | | | | | x | | |
| Pectoral Sandpiper | x | x | x | x | | | | | x | | |
| Semipalmated Sandpiper | | | x | x | | | | | x | | |
| Western Sandpiper | | x | x | x | | | | | x | | |
| peep sp. | x | x | | x | | | | | | | |
| Short-billed Dowitcher | | | x | x | | | | | x | | |
| Long-billed Dowitcher | | x | x | x | | | | | x | | x |
| Wilson's Snipe | x | x | x | x | | | | | | | x |
| Wilson's Phalarope | x | x | x | x | | | | | x | | |
| Red-necked Phalarope | x | x | x | x | | | | | x | | |
| Red Phalarope | | x | x | x | | | | | x | | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Spotted Sandpiper | x | x | x | x | | | | | x | x | |
| Solitary Sandpiper | x | x | x | x | | | | | x | | |
| Greater Yellowlegs | x | x | x | x | | | | | x | | x |
| Willet | x | x | x | x | | | | | x | | |
| Lesser Yellowlegs | | x | x | x | | | | | x | | |
| Greater/Lesser Yellowlegs | | x | x | x | | | | | | | |
| shorebird sp. | | x | x | x | | | | | | | |
| Long-tailed Jaeger | | x | x | x | | | | | x | | |
| Pomarine Jaeger | x | | x | x | | | | | x | | |
| Parasitic Jaeger | | | x | x | | | | | x | | |
| Jaeger sp. | x | | x | x | | | | | x | | |
| Black-legged Kittiwake | | | x | x | | | | | x | | |
| Sabine's Gull | x | x | x | x | | | | | x | | |
| Bonaparte's Gull | x | x | x | x | | | | | x | | x |
| Little Gull | | x | | x | | | | | x | | |
| Laughing Gull | | x | x | x | | | | | x | | |
| Franklin's Gull | x | x | x | x | | | | | x | | |
| Black-tailed Gull | | | x | x | | | | | x | | |
| Heemann's Gull | | | x | x | | | | | ? | | |
| Ring-billed Gull | x | x | x | x | | | | | x | | x |
| California Gull | x | x | x | x | | | | | x | | |
| Lesser Black-backed Gull | | | x | x | | | | | x | | |
| Herring Gull | x | x | x | x | | | | | x | | x |
| Iceland Gull | | x | | x | | | | | x | | |
| Glaucous-winged Gull | | | x | x | | | | | ? | | |
| Glaucous Gull | | x | x | x | | | | | x | | x |
| gull sp. | x | x | x | x | | | | | | | |
| Least Tern | | | x | x | | | | | x | x | |
| Gull-billed Tern | | | x | x | | | | | ? | | |
| Caspian Tern | | x | x | x | | | | | x | | |
| Black Tern | x | x | x | x | | | | | x | | |
| Common Tern | x | x | x | x | | | | | x | | |
| Forster's Tern | x | x | x | x | | | | | x | | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Sterna sp. | x | x | x | x | | | | | | | |
| tern sp. | | x | x | x | | | | | | | |
| Black Skimmer | | | x | x | | | | | ? | | |
| Red-throated Loon | x | x | x | x | | | | | ? | | |
| Pacific Loon | x | x | x | x | | | | | ? | | |
| Common Loon | x | x | x | x | | | | | x | | |
| Yellow-billed Loon | | | x | x | | | | | ? | | |
| Wood Stork | | | x | x | | | | | ? | | |
| Magnificent Frigatebird | | | x | x | | | | | ? | | |
| Anhinga | | | x | x | | | | | ? | | |
| Neotropic Cormorant | x | x | x | x | | | | | x | x | |
| Double-crested Cormorant | x | x | x | x | | | | x | x | | |
| American White Pelican | x | x | x | x | | | | | x | | |
| Brown Pelican | x | x | x | x | | | | | x | x | |
| American Bittern | | | x | x | | | | | x | | |
| Least Bittern | | | x | x | | | | | x | x | |
| Great Blue Heron | x | x | x | x | | | | x | | | |
| Great Egret | x | x | x | x | | | | x | x | | |
| Snowy Egret | x | x | x | x | | | | x | x | | |
| Little Blue Heron | | | x | x | | | | | x | | |
| Tricolored Heron | | x | x | x | | | | | x | | |
| Reddish Egret | | x | x | x | | | | | x | | |
| Cattle Egret | | x | x | x | | | | | | x | |
| white egret sp. | | x | x | x | | | | | | | |
| Green Heron | x | x | x | x | | | | | | x | |
| Black-crowned Night-Heron | x | x | x | x | | | | x | | x | |
| Yellow-crowned Night-Heron | | | x | x | | | | | x | ? | |
| White Ibis | | | x | x | | | | | x | ? | |
| Glossy Ibis | | | x | x | | | | | x | ? | |
| White-faced Ibis | x | x | x | x | | | | | x | x | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Roseate Spoonbill | | | x | x | | | | | ? | ? | |
| Turkey Vulture | x | x | x | | | x | x | | x | x | |
| Osprey | x | x | x | | | x | | | x | | x |
| White-tailed Kite | | | x | | x | x | x | ? | | | |
| Swallow-tailed Kite (rare visitor?) | | ? | ? | | x | x | | | ? | | |
| Golden Eagle | x | x | x | | x | x | | x | x | | x |
| Mississippi Kite | x | x | x | | x | x | | | x | x | |
| Northern Harrier | x | x | x | | x | x | x | x | x | | x |
| Sharp-shinned Hawk | x | x | x | | | x | often in conifers | x | x | | x |
| Cooper's Hawk | x | x | x | | x | x | | x | x | | x |
| Northern Goshawk | x | | | | | x | conifers | ? | x | | x |
| Bald Eagle | x | x | x | x | x | x | | | x | | x |
| Harris's Hawk | | | x | | x | x | x | x | | | |
| Common Black Hawk | ? | x | x | | x | x | | | x | x | |
| Broad-winged Hawk | x | x | x | | x | x | | | x | | |
| Swainson's Hawk | x | x | x | | x | x | x | | x | x | |
| Zone-tailed Hawk | | ? | x | | x | x | | | x | x | |
| Red-tailed Hawk | x | x | x | | x | x | x | x | | | |
| Rough-legged Hawk | | x | x | | | x | x | | x | | x |
| Ferruginous Hawk | x | x | x | | | x | x | x | x | | x |
| Barn Owl | x | x | x | | | x | x | x | | | |
| Western Screech-Owl | | | x | | x | x | | x | | | |
| Great Horned Owl | x | x | x | | x | x | | x | | | |
| Burrowing Owl | x | x | x | | | x | x | x | | x | |
| Long-eared Owl | | | x | | x | x | | x | | | x |
| Northern Pygmy-Owl | ? | | ? | | x | x | conifers | ? | | | |
| Northern Saw-whet Owl | x | | | | x | x | conifers | ? | | | x |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Belted Kingfisher | x | x | x | | x | | | x | | | x |
| Williamson's Sapsucker | x | | x | | x | | | ? | | | ? |
| Yellow-bellied Sapsucker | | | x | | x | | | | | | x |
| Red-naped Sapsucker | x | x | x | | x | | | ? | ? | ? | |
| Lewis's Woodpecker | x | | x | | x | | | | | | ? |
| Red-headed Woodpecker | x | x | x | | x | | | x | | x | |
| Acorn Woodpecker | x | | | | x | | | x | | | |
| American Three-toed Woodpecker ?? | x | | | | x | | | | | | |
| Downy Woodpecker | x | x | x | | x | | | x | | | |
| Ladder-backed Woodpecker | x | x | x | | x | | | x | | | |
| Hairy Woodpecker | x | | x | | x | | | x | | | |
| Northern Flicker | x | x | x | | x | | | x | | | x |
| Crested Caracara | | | x | | | | x | x | | | |
| American Kestrel | x | x | x | | x | x | x | x | | | |
| Merlin | x | x | x | | | x | | | | | x |
| Peregrine Falcon | x | x | x | | | x | | | x | | |
| Prairie Falcon | x | x | x | | | x | | x | | | x |
| Olive-sided Flycatcher | x | x | x | | x | | | | x | ? | |
| Western Wood-Pewee | x | x | x | | x | | | | x | x | |
| Western/Eastern Wood-Pewee | | x | | | x | | | | | | |
| Willow Flycatcher | x | x | x | | x | | | | x | ? | |
| Alder/Willow Flycatcher (Traill's Flycatcher) | | x | | | x | | | | x | | |
| Least Flycatcher | x | x | x | | x | | | | x | | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Hammond's Flycatcher | x | x | x | | x | | | | x | | |
| Gray Flycatcher | x | x | x | | x | | x | | x | ? | |
| Dusky Flycatcher | x | x | x | | x | | | | x | ? | |
| Cordilleran Flycatcher | x | x | x | | x | | | | x | ? | |
| Empidonax sp. | x | x | x | | x | | | | | | |
| Black Phoebe | x | x | x | | x | | | x | x | | |
| Eastern Phoebe | x | x | x | | x | | | | x | | |
| Say's Phoebe | x | x | x | | | | x | x | x | x | |
| Vermilion Flycatcher | | x | x | | x | | | | | ? | |
| Ash-throated Flycatcher | x | x | x | | x | | | | | x | |
| Great Crested Flycatcher | | | x | | x | | | | ? | ? | |
| Great Kiskadee | | | x | | x | | | ? | | | |
| Piratic Flycatcher | | | x | | x | | | | | x | |
| Cassin's Kingbird | x | x | x | | x | | | | x | x | |
| Western Kingbird | x | x | x | | x | | | | x | x | |
| Cassin's/Western Kingbird | x | x | x | | x | | | | | | |
| Eastern Kingbird | | x | x | | x | | | | x | x | |
| Scissor-tailed Flycatcher | | x | x | | x | | | | x | x | |
| White-eyed Vireo | | | x | | x | | | | ? | ? | |
| Bell's Vireo | | x | x | | x | | | | | x | |
| Hutton's Vireo | | | x | | x | | | ? | | | |
| Yellow-throated Vireo | | x | | | x | | | | ? | ? | |
| Cassin's Vireo | x | x | x | | x | | | | x | | |
| Blue-headed Vireo | | | x | | x | | | | x | | |
| Plumbeous Vireo | x | x | x | | x | | | | x | ? | |
| Philadelphia Vireo | | x | x | | x | | | | x | | |
| Warbling Vireo | x | x | x | | x | | | | x | ? | |
| Red-eyed Vireo | | | x | | x | | | | x | | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Loggerhead Shrike | x | x | x | | x | | x | x | | | |
| Northern Shrike | | x | x | | x | | x | | x | | x |
| Loggerhead/Northern Shrike | | x | | | x | | x | | | | |
| Canada Jay | x | | | | x | | | ? | | | |
| Pinyon Jay | x | x | x | | | | Pinyon/Oak | x | | | x |
| Steller's Jay | x | x | x | | | | conifer/pine-oak | x | | | |
| Blue Jay | | x | x | | | | oak-pines | x | | | x |
| Woodhouse's Scrub-Jay | x | x | x | | | | P/J | x | | | x |
| Black-billed Magpie | x | | | | x | | x | x | | | |
| Clark's Nutcracker | x | | | | | | conifers | x | | | |
| American Crow | x | x | x | | x | x | x | x | | | x |
| Chihuahuan Raven | x | x | x | | | x | x | x | | | |
| Common Raven | x | x | x | | x | x | x | x | | | |
| raven sp. | | x | x | | | x | | | | | |
| Black-capped Chickadee | x | | | | x | | | x | | | |
| Mountain Chickadee | x | x | x | | x | | conifers | ? | | | ? |
| Juniper Titmouse | x | x | x | | x | | P/J | x | | | |
| Verdin | | | x | | x | | | x | | | |
| Horned Lark | x | x | x | | | | x | x | | | |
| Northern Rough-winged Swallow | x | x | x | | x | | x | | | x | |
| Purple Martin | x | | | | x | | | | x | | |
| Tree Swallow | x | x | x | | x | | | | x | ? | |
| Violet-green Swallow | x | x | x | | x | | | | x | x | |
| Bank Swallow | x | x | x | | x | | | | x | x | |
| Barn Swallow | x | x | x | | x | | x | | x | x | |
| Cliff Swallow | x | x | x | | x | | x | | x | x | |
| Cave Swallow | | | x | | x | | | | | x | |
| swallow sp. | x | x | x | | x | | | | | | |
| Bushtit | x | x | x | | x | | x | x | | | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Golden-crowned Kinglet | x | x | x | | x | | spruce/conifers | | x | | x |
| Ruby-crowned Kinglet | x | x | x | | x | | conifers | | x | | x |
| Red-breasted Nuthatch | x | x | x | | x | | conifers | | x | | x |
| White-breasted Nuthatch | x | x | x | | x | | | x | | | x |
| Pygmy Nuthatch | x | | x | | x | | pines | ? | | | ? |
| Brown Creeper | x | x | x | | x | | most woodland types | | x | | x |
| Blue-gray Gnatcatcher | x | x | x | | x | | | | x | | |
| Rock Wren | x | x | x | | | | rocky canyons, slopes | x | | | |
| Canyon Wren | x | x | x | | | | cliffs, canyons | x | | | |
| House Wren | x | x | x | | x | | | | x | x | |
| Pacific Wren | | | x | | | | dense conifers | | x | | |
| Winter Wren | x | x | x | | x | | | | x | | |
| Sedge Wren | | | x | | x | | sedge marshes | | x | | |
| Marsh Wren | x | x | x | | x | | cattails/bullrush | | | | x |
| Carolina Wren | x | x | x | | x | | | x | | | |
| Bewick's Wren | x | x | x | | x | | | x | | | |
| Cactus Wren | | | x | | | | cactus/yuccas | x | | | |
| American Dipper | x | | | high mtn streams | x | | | ? | ? | | ? |
| European Starling | x | x | x | | x | | x | x | | | |
| Gray Catbird | x | x | x | | x | | | | x | x | |
| Curve-billed Thrasher | x | x | x | | x | | x | x | | | |
| Brown Thrasher | x | x | x | | x | | x | | x | x | x |
| Crissal Thrasher | x | | x | | x | | | ? | | | |
| Sage Thrasher | x | x | x | | | | x | | x | | x |
| Northern Mockingbird | x | x | x | | x | | x | x | | | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Eastern Bluebird | x | x | x | | x | | x | x | x | | x |
| Western Bluebird | x | x | x | | x | | x | x | x | | x |
| Mountain Bluebird | x | x | x | | x | | x | x | x | | x |
| Townsend's Solitaire | x | x | x | | x | | also conifers | ? | x | | x |
| Varied Thrush | | | x | | x | | also conifers | | x | | x |
| Swainson's Thrush | x | x | x | | x | | spruce forests/dense streamside | | x | | |
| Hermit Thrush | x | x | x | | x | | | | x | ? | x |
| Wood Thrush | | | x | | x | | | | ? | | |
| American Robin | x | x | x | | x | | x | x | | | |
| Northern Wheatear | | | x | | | | x | | x | | |
| Cedar Waxwing | x | x | x | | x | | x | | x | | x |
| Phainopepla | | | x | | | | x | x | ? | | |
| House Sparrow | x | x | x | | x | | x | x | | | |
| American Pipit | x | x | x | | | | x | | x | | x |
| Sprague's Pipit | | | x | | | | x | | x | | ? |
| Evening Grosbeak | x | x | x | | x | | conifers | | x | | x |
| Pine Grosbeak | x | | | | x | | conifers | ? | ? | | ? |
| House Finch | x | x | x | | x | | x | x | | | |
| Purple Finch | | | x | | x | | | | x | | ? |
| Cassin's Finch | x | | | | x | | conifers | | x | | x |
| Red Crossbill | x | x | x | | x | | conifers | ? | | | x |
| Pine Siskin | x | x | x | | x | | conifers | ? | x | | x |
| Lesser Goldfinch | x | x | x | | x | | | x | x | x | |
| American Goldfinch | x | x | x | | x | | x | x | x | | x |
| Lapland Longspur | | | x | | x | | lakeshores in winter | | | | x |
| Chestnut-collared Longspur | x | x | x | | | | x | | x | | x |
| McCown's Longspur | x | x | x | | | | x | | x | | x |
| longspur sp. | | x | x | | | | | | | | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Cassin's Sparrow | x | x | x | | | | x | | x | x | |
| Grasshopper Sparrow | | x | x | | x | | x | | x | x | |
| Chipping Sparrow | x | x | x | | x | | x | | x | x | x |
| Clay-colored Sparrow | x | x | x | | x | | x | | x | | |
| Black-chinned Sparrow | x | | x | | | | x | ? | x | ? | ? |
| Field Sparrow | | x | x | | x | | x | | x | | x |
| Brewer's Sparrow | x | x | x | | | | x | | x | | ? |
| Spizella sp. | x | x | x | | | | | | | | |
| Black-throated Sparrow | x | x | x | | | | x | x | ? | x | |
| Lark Sparrow | x | x | x | | x | | x | x | x | x | x |
| Lark Bunting | x | x | x | | | | x | | x | x | x |
| American Tree Sparrow | x | ? | | | x | | | | x | | x |
| Fox Sparrow | x | x | x | | x | | x | | x | | |
| Dark-eyed Junco | x | x | x | | | | x | | x | | x |
| White-crowned Sparrow | x | x | x | | x | | | | x | | x |
| White-throated Sparrow | x | x | x | | x | | | | x | | x |
| Golden-crowned Sparrow | | | x | | x | | | | x | ? | ? |
| Harris's Sparrow | | | x | | x | | x | | x | | ? |
| Sagebrush Sparrow (Sage sparrow?) | x | x | x | | | | x | | x | ? | x |
| Vesper Sparrow | x | x | x | | | | x | | x | | x |
| Savannah Sparrow | x | x | x | | | | x | | x | | x |
| Song Sparrow | x | x | x | | x | | | ? | x | | x |
| Lincoln's Sparrow | x | x | x | | x | | | | x | | x |
| Swamp Sparrow | | x | x | | x | | | | x | | x |
| Canyon Towhee | ? | x | x | | | | x | x | | | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Rufous-crowned Sparrow | x | x | x | | | | x | x | | | |
| Green-tailed Towhee | x | x | x | | x | | also foothills/ mtns. | | x | | x |
| Spotted Towhee | x | x | x | | x | | x | x | | | x |
| Eastern Towhee | | | x | | x | | | | | | ? |
| sparrow sp. | x | x | x | | x | | | | | | |
| Yellow-breasted Chat | x | x | x | | x | | | | x | x | |
| Yellow-headed Blackbird | x | x | x | | x | | | | x | x | x |
| Bobolink | | x | x | | x | | | | ? | | |
| Western Meadowlark | x | x | x | | | | x | x | | | |
| Eastern Meadowlark | | x | x | | | | | x | x | x | |
| Western/Eastern Meadowlark | x | x | x | | | | x | | | | |
| Orchard Oriole | | x | x | | | | x | | | | |
| Bullock's Oriole | x | x | x | | x | | | | x | x | |
| Bullock's/Baltimore Oriole | | x | | | x | | | | | | |
| Baltimore Oriole | | | x | | x | | | | x | ? | |
| Scott's Oriole | | | x | | | | agave-yucca mixed w/oaks | | x | x | |
| Red-winged Blackbird | x | x | x | | x | | | x | | | |
| Bronzed Cowbird | | | x | | | | x | | | ? | |
| Brown-headed Cowbird | x | x | x | | x | | x | x | x | x | |
| Rusty Blackbird | | x | x | | x | | | | x | | x |
| Brewer's Blackbird | x | x | x | | x | | x | x | x | | x |
| Common Grackle | x | x | x | | x | | x | | x | x | |
| Great-tailed Grackle | x | x | x | | x | | x | x | x | x | |
| blackbird sp. | x | x | x | | | | | | | | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Ovenbird | x | x | x | | x | | | | x | | |
| Northern Waterthrush | x | x | x | | x | | | | x | | |
| Worm-eating Warbler | | | x | | x | | | | ? | | |
| Blue-winged Warbler | x | x | x | | x | | | | x | | |
| Golden-winged Warbler | | ? | ? | | x | | | | ? | | |
| Black-and-white Warbler | | ? | ? | | x | | | | ? | | |
| Prothonotary Warbler | | | ? | | x | | | | ? | | |
| Tennessee Warbler | | | x | | x | | | | x | | |
| Orange-crowned Warbler | x | x | x | | x | | | | x | ? | x |
| Lucy's Warbler | | ? | x | | x | | | | x | | |
| Nashville Warbler | x | x | x | | x | | | | x | | |
| Virginia's Warbler | x | x | x | | x | | x | | x | ? | |
| MacGillivray's Warbler | x | x | x | | x | | | | x | | |
| Kentucky Warbler | | x | x | | x | | | | x | | |
| Common Yellowthroat | x | x | x | | x | | | | x | x | |
| Hooded Warbler | x | x | x | | x | | | | x | | |
| American Redstart | x | x | x | | x | | | | x | | |
| Northern Parula | x | x | x | | x | | | | ? | | |
| Magnolia Warbler | ? | x | x | | x | | conifers | | ? | | |
| Bay-breasted Warbler | | | x | | x | | | | ? | | |
| Blackburnian Warbler | | | x | | x | | | | ? | | |
| Yellow Warbler | x | x | x | | x | | | | x | x | |
| Chestnut-sided Warbler | | x | x | | x | | | | x | | |
| Blackpoll Warbler | | x | x | | x | | | | ? | | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Black-throated Blue Warbler | x | x | x | | x | | | | ? | | |
| Palm Warbler | | | x | | x | | | | ? | | |
| Pine Warbler | | | x | | x | | pine trees | | ? | | |
| Yellow-rumped Warbler | x | x | x | | x | | conifers | | x | | x |
| Yellow-throated Warbler | | | x | | x | | | | ? | | |
| Grace's Warbler | ? | | | | x | | pine-oaks | | | ? | |
| Black-throated Gray Warbler | x | x | x | | x | | P-J-oaks | | x | ? | |
| Townsend's Warbler | x | x | x | | x | | tal conifers | | x | | |
| Black-throated Green Warbler | | | x | | x | | | | x | | |
| Wilson's Warbler | x | x | x | | x | | | | x | ? | |
| Hepatic Tanager | x | x | x | | x | | mountains /foothills | | x | ? | |
| Summer Tanager | x | x | x | | x | | | | x | x | |
| Scarlet Tanager | ? | ? | ? | | x | | | | ? | | |
| Western Tanager | x | x | x | | x | | mixed conifer | | x | x | |
| Northern Cardinal | ? | ? | x | | x | | | x | | | |
| Pyrrhuloxia | | ? | x | | x | | x | x | | | ? |
| Rose-breasted Grosbeak | x | x | x | | x | | | | x | | |
| Black-headed Grosbeak | x | x | x | | x | | | | x | x | |
| Rose-breasted/Black-headed Grosbeak | | | | | | | | | | | |
| Blue Grosbeak | x | x | x | | x | | | | x | x | |
| Lazuli Bunting | x | x | x | | x | | | | x | x | |
| Indigo Bunting | x | x | x | | x | | x | | x | x | |
| Lazuli/Indigo Bunting | x | x | x | | x | | | | | | |
| Painted Bunting | | x | x | | x | | x | | x | ? | |
| Dickcissel | x | x | x | | | | x | | x | x | |

# 2 Reach A eBird Observances 1937 – 2020

eBird Menu

« Start Over

# Bird Observations

**Date Range:** Change Date

Jan-Dec, 1937-1979

Change Location [ Santa Fe NF - Panchuela Campground ] [ Pecos NHP--South Pasture trail (open weekends only) ] [ Santa Fe NF - Holy Ghost Campground ] [ Santa Rosa Lake SP ] [ Tererro General Store area ] [ Monastery Lake ] [ Villanueva Bridge over Pecos River ] [ Pecos NHP ] [ Villanueva SP ] [ Cowles Ponds ] [ Santa Fe NF - Jacks Creek Campground ]

Updated ~10 hr(s) ago.

27 species (+1 other taxa)

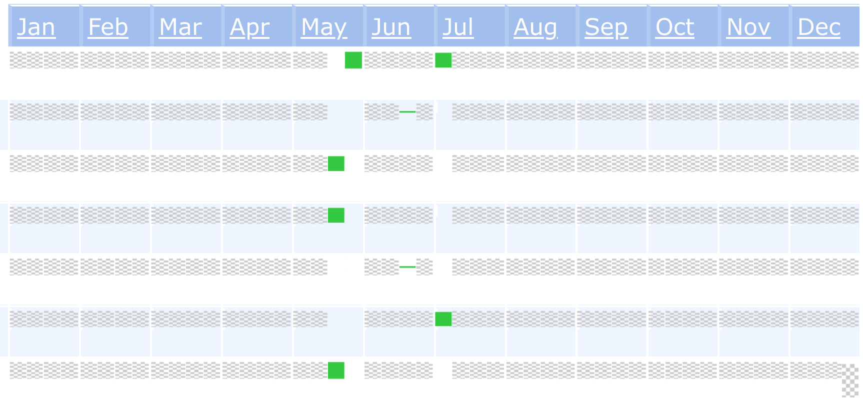
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

- Dusky Grouse
- Red-naped Sapsucker
- Northern Flicker
- Canada Jay
- Pinyon Jay
- Common Raven
- raven sp.
- Black-capped Chickadee
- Mountain Chickadee
- Violet-green Swallow
- Barn Swallow
- Cliff Swallow
- Ruby-crowned Kinglet
- White-breasted Nuthatch
- Rock Wren

Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

- House Wren
- Bewick's Wren
- American Dipper
- Western Bluebird
- Mountain Bluebird
- American Robin

27 species (+1 other taxa)




- Pine Siskin
- Lesser Goldfinch
- Chipping Sparrow
- Dark-eyed Junco
- Canyon Towhee
- Green-tailed Towhee
- Yellow-rumped Warbler

**KEY:** | = insufficient data | = rare to widespread

Download Histogram Data

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Menu

« Start Over

# Bird Observations

**Date Range:** Change Date

Jan-Dec, 1979-2020

Change Location [ Santa Fe NF - Panchuela Campground ] [ Pecos NHP--South Pasture trail (open weekends only) ] [ Santa Fe NF - Holy Ghost Campground ] [ Santa Rosa Lake SP ] [ Tererro General Store area ] [ Monastery Lake ] [ Villanueva Bridge over Pecos River ] [ Pecos NHP ] [ Villanueva SP ] [ Cowles Ponds ] [ Santa Fe NF - Jacks Creek Campground ]

Updated ~10 hr(s) ago.

265 species (+37 other taxa)

Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

- Snow Goose
- Ross's Goose
- Snow/Ross's Goose
- Greater White-fronted Goose
- Canada Goose
- Cackling/Canada Goose
- Wood Duck
- Blue-winged Teal
- Cinnamon Teal
- Blue-winged/Cinnamon Teal
- Northern Shoveler
- Gadwall
- American Wigeon
- Mallard
- Northern Pintail

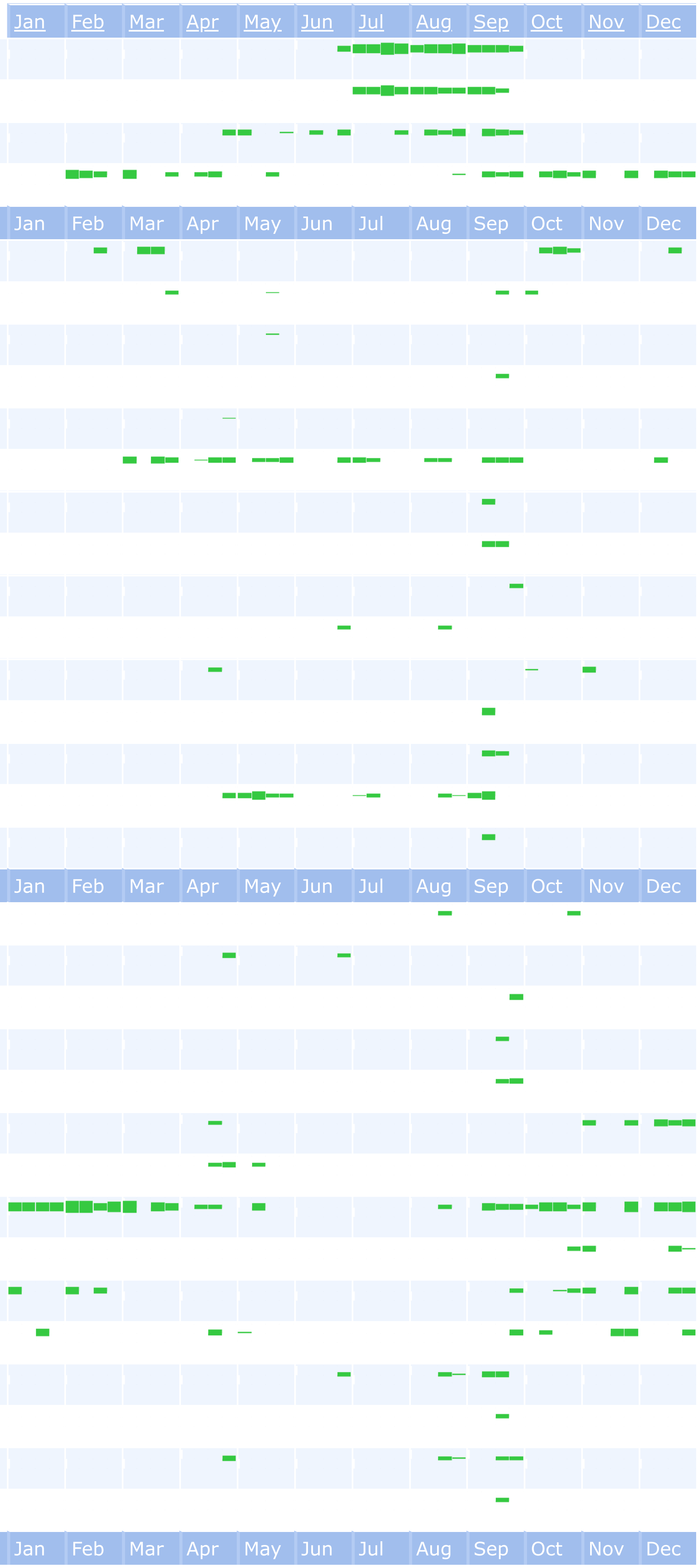
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

- Green-winged Teal
- teal sp.
- Canvasback
- Redhead
- Ring-necked Duck
- Lesser Scaup

265 species (+37 other taxa)

- Surf Scoter
- White-winged Scoter
- Bufflehead
- Common Goldeneye
- Hooded Merganser
- Common Merganser
- Red-breasted Merganser
- Common/Red-breasted Merganser
- Ruddy Duck
- duck sp.
- Northern Bobwhite
- Scaled Quail
- Gambel's Quail
- Dusky Grouse
- Wild Turkey
- Pied-billed Grebe
- Horned Grebe
- Eared Grebe
- Western Grebe
- Clark's Grebe
- Western/Clark's Grebe
- Rock Pigeon
- Band-tailed Pigeon
- Eurasian Collared-Dove
- White-winged Dove
- Mourning Dove
- Greater Roadrunner
- Yellow-billed Cuckoo
- Common Nighthawk
- Common Poorwill
- Chimney Swift
- White-throated Swift
- Rivoli's Hummingbird
- Black-chinned Hummingbird
- Broad-tailed Hummingbird

265 species (+37 other taxa)




- Rufous Hummingbird
- Calliope Hummingbird
- hummingbird sp.
- American Coot
- Sandhill Crane
- American Avocet
- Black-bellied Plover
- Semipalmated Plover
- Piping Plover
- Killdeer
- Marbled Godwit
- Baird's Sandpiper
- Pectoral Sandpiper
- peep sp.
- Wilson's Snipe
- Wilson's Phalarope
- Red-necked Phalarope
- Spotted Sandpiper
- Solitary Sandpiper
- Greater Yellowlegs
- Willet
- Pomarine Jaeger
- jaeger sp.
- Sabine's Gull
- Bonaparte's Gull
- Franklin's Gull
- Ring-billed Gull
- California Gull
- Herring Gull
- gull sp.
- Black Tern
- Common Tern
- Forster's Tern
- Common/Forster's Tern

265 species (+37 other taxa)

Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

- Sterna sp.
- Red-throated Loon
- Pacific Loon
- Common Loon
- Neotropic Cormorant
- Double-crested Cormorant
- Neotropic/Double-crested Cormorant
- American White Pelican
- Brown Pelican
- Great Blue Heron
- Great Egret
- Snowy Egret
- Green Heron
- Black-crowned Night-Heron
- heron sp.

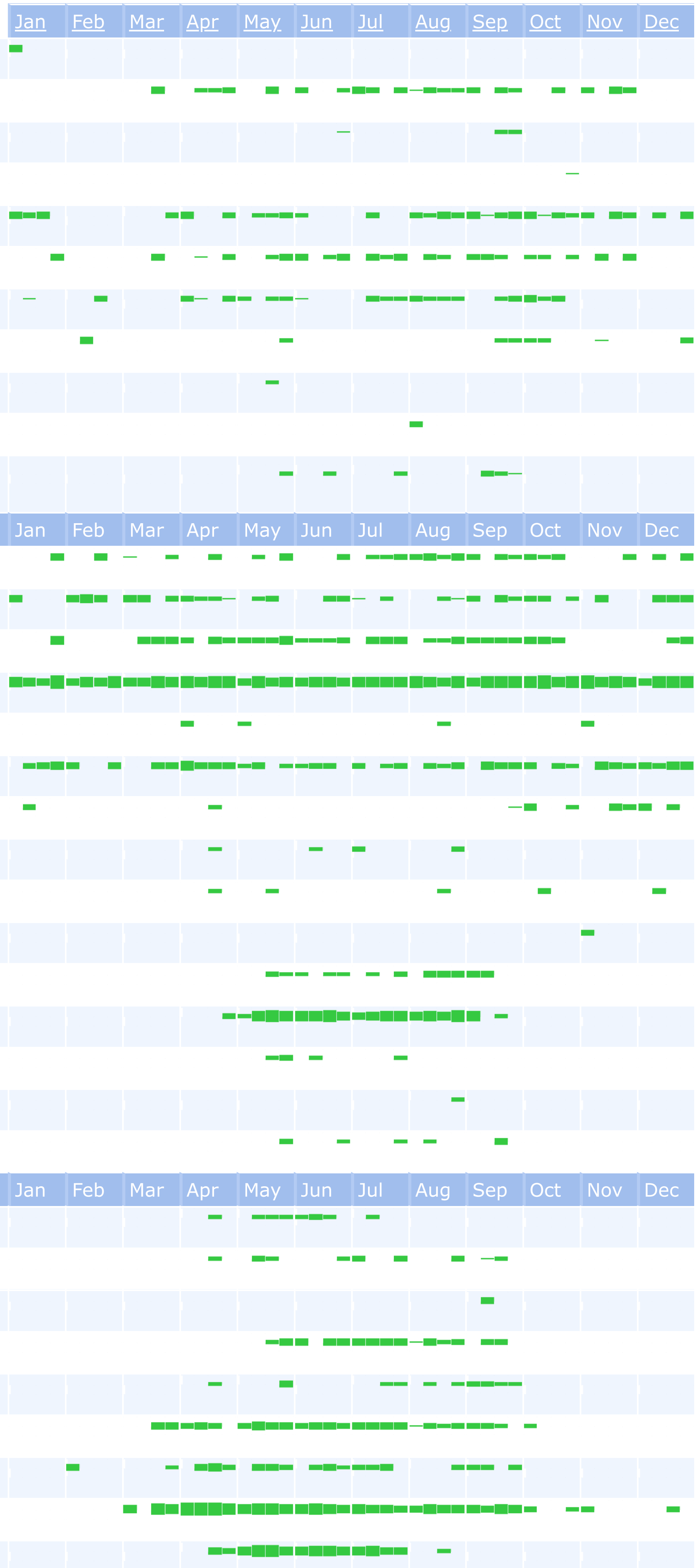
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

- White-faced Ibis
- Turkey Vulture
- Osprey
- Golden Eagle
- Mississippi Kite
- Northern Harrier
- Sharp-shinned Hawk
- Cooper's Hawk
- Sharp-shinned/Cooper's Hawk
- Northern Goshawk
- Accipiter sp.
- Bald Eagle
- Common Black Hawk
- Broad-winged Hawk
- Swainson's Hawk

Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

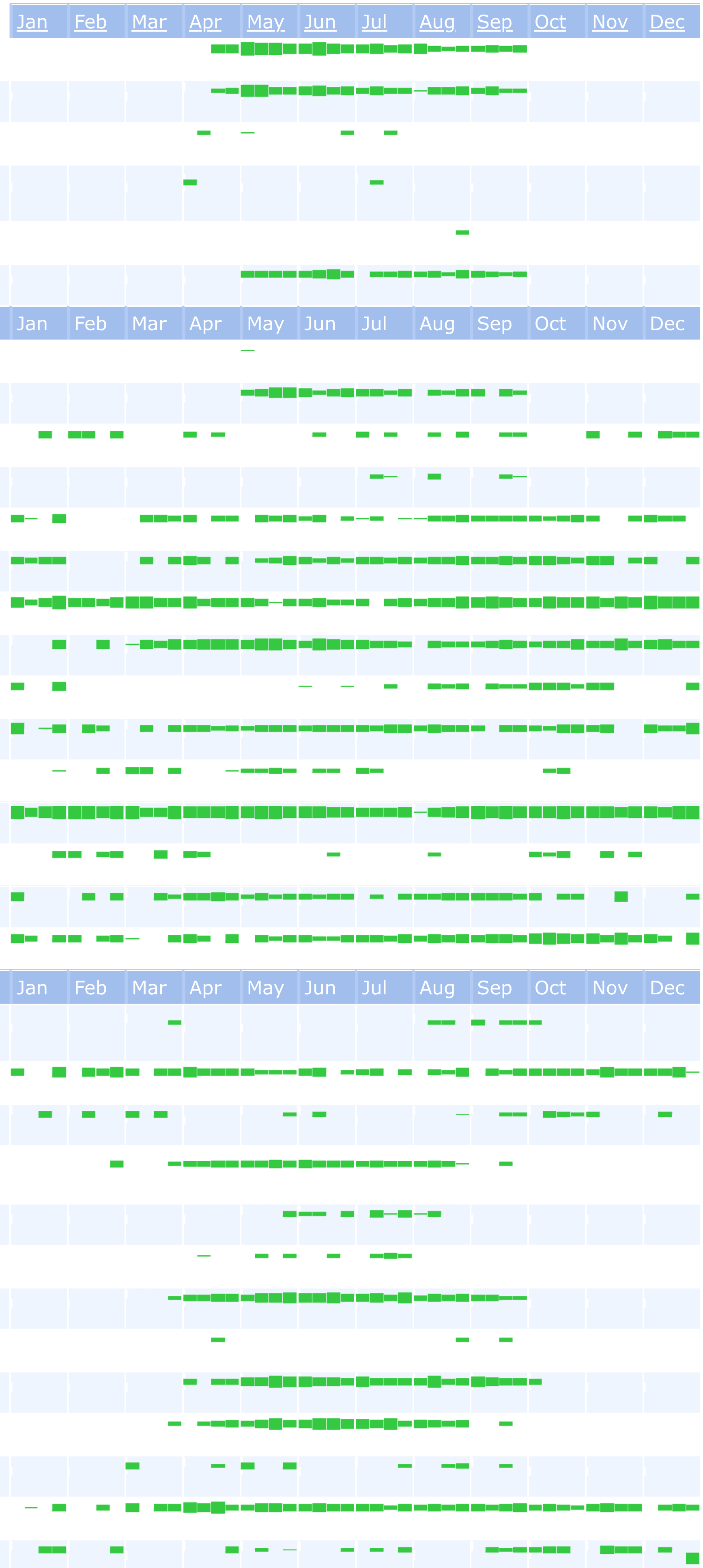
- Red-tailed Hawk
- Ferruginous Hawk
- Buteo sp.
- hawk sp.

265 species (+37 other taxa)




Barn Owl
Great Horned Owl
Northern Pygmy-Owl
Northern Saw-whet Owl
Belted Kingfisher
Williamson's Sapsucker
Red-naped Sapsucker
Lewis's Woodpecker
Red-headed Woodpecker
Acorn Woodpecker
American Three-toed Woodpecker
Downy Woodpecker
Ladder-backed Woodpecker
Hairy Woodpecker
Northern Flicker
woodpecker sp.
American Kestrel
Merlin
Peregrine Falcon
Prairie Falcon
large falcon sp.
Olive-sided Flycatcher
Western Wood-Pewee
Willow Flycatcher
Least Flycatcher
Hammond's Flycatcher
Gray Flycatcher
Dusky Flycatcher
Hammond's/Dusky Flycatcher
Cordilleran Flycatcher
Empidonax sp.
Black Phoebe
Eastern Phoebe
Say's Phoebe
Ash-throated Flycatcher

265 species (+37 other taxa)




- Cassin's Kingbird
- Western Kingbird
- Cassin's/Western Kingbird
- flycatcher sp. (Tyrannidae sp.)
- Cassin's Vireo
- Plumbeous Vireo
- Cassin's/Plumbeous Vireo
- Warbling Vireo
- Loggerhead Shrike
- Canada Jay
- Pinyon Jay
- Steller's Jay
- Woodhouse's Scrub-Jay
- Black-billed Magpie
- Clark's Nutcracker
- American Crow
- Chihuahuan Raven
- Common Raven
- raven sp.
- Black-capped Chickadee
- Mountain Chickadee
- Black-capped/Mountain Chickadee
- Juniper Titmouse
- Horned Lark
- Northern Rough-winged Swallow
- Purple Martin
- Tree Swallow
- Violet-green Swallow
- Bank Swallow
- Barn Swallow
- Cliff Swallow
- swallow sp.
- Bushtit
- Golden-crowned Kinglet

265 species (+37 other taxa) | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec

Ruby-crowned Kinglet
Red-breasted Nuthatch

Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec

White-breasted Nuthatch
Pygmy Nuthatch
Brown Creeper
Blue-gray Gnatcatcher
Rock Wren
Canyon Wren
House Wren
Winter Wren
Pacific/Winter Wren
Marsh Wren
Carolina Wren
Bewick's Wren
Cactus Wren
American Dipper
European Starling

Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec

Gray Catbird
Curve-billed Thrasher
Brown Thrasher
Crissal Thrasher
Sage Thrasher
Northern Mockingbird
Eastern Bluebird
Western Bluebird
Mountain Bluebird
Townsend's Solitaire
Swainson's Thrush
Hermit Thrush
American Robin
Cedar Waxwing
House Sparrow

Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec

American Pipit
Evening Grosbeak

265 species (+37 other taxa)

Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

Pine Grosbeak
House Finch
Cassin's Finch
Red Crossbill
Pine Siskin
Lesser Goldfinch
American Goldfinch
Chestnut-collared Longspur
McCown's Longspur
Cassin's Sparrow
Chipping Sparrow
Clay-colored Sparrow
Black-chinned Sparrow

Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

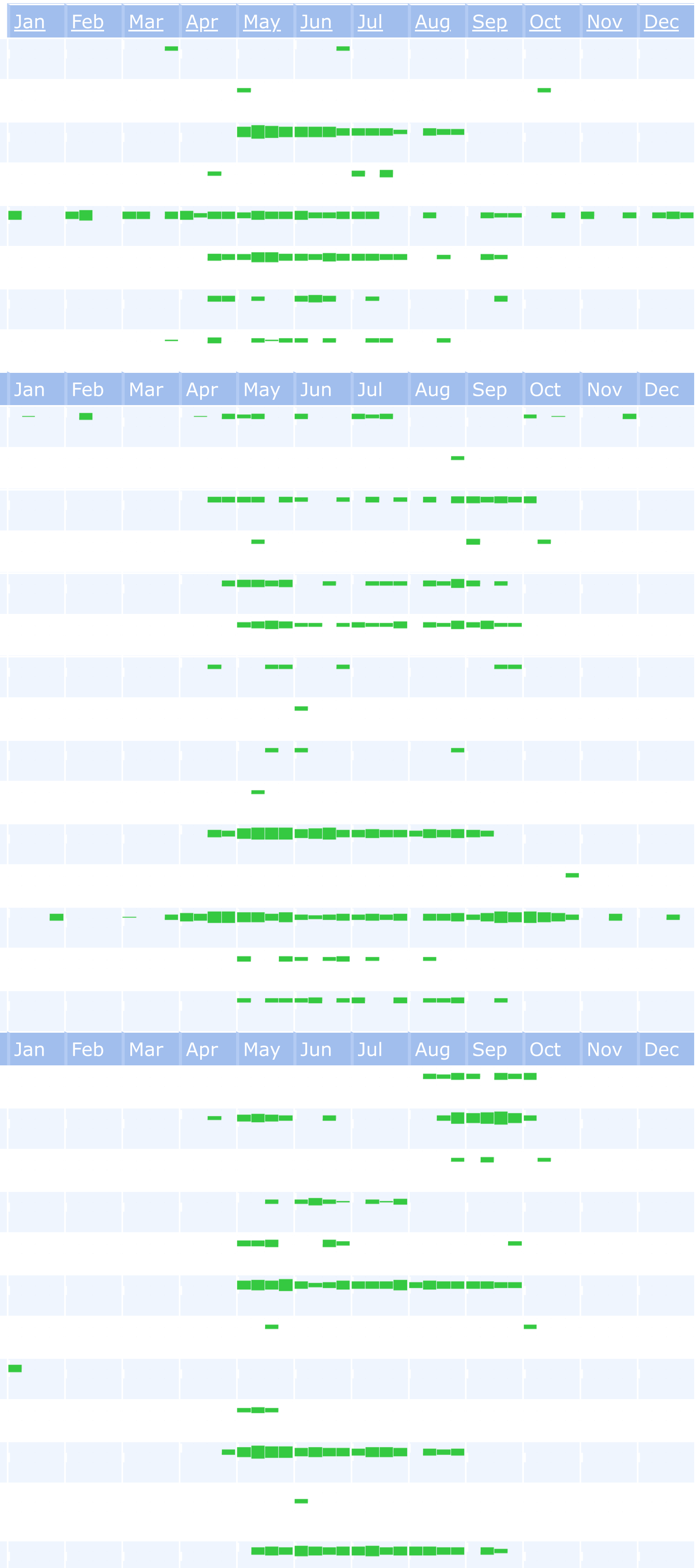
Brewer's Sparrow
Spizella sp.
Black-throated Sparrow
Lark Sparrow
Lark Bunting
American Tree Sparrow
Fox Sparrow
Dark-eyed Junco
White-crowned Sparrow
White-throated Sparrow
Vesper Sparrow
Savannah Sparrow
Song Sparrow
Lincoln's Sparrow
Canyon Towhee

Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

Rufous-crowned Sparrow
Green-tailed Towhee
Spotted Towhee
sparrow sp.
Yellow-breasted Chat
Yellow-headed Blackbird
Western Meadowlark

265 species (+37 other taxa)

- Eastern Meadowlark
- Western/Eastern Meadowlark
- Bullock's Oriole
- Scott's Oriole
- Red-winged Blackbird
- Brown-headed Cowbird
- Brewer's Blackbird
- Common Grackle
- Great-tailed Grackle
- Northern Waterthrush
- Orange-crowned Warbler
- Nashville Warbler
- Virginia's Warbler
- MacGillivray's Warbler
- Common Yellowthroat
- Hooded Warbler
- American Redstart
- Northern Parula
- Yellow Warbler
- Black-throated Blue Warbler
- Yellow-rumped Warbler
- Grace's Warbler
- Black-throated Gray Warbler
- Townsend's Warbler
- Wilson's Warbler
- warbler sp. (Parulidae sp.)
- Hepatic Tanager
- Summer Tanager
- Western Tanager
- Northern Cardinal
- Pyrrhuloxia
- Rose-breasted Grosbeak
- Black-headed Grosbeak
- Rose-breasted/Black-headed Grosbeak
- Blue Grosbeak



265 species (+37 other taxa) | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec

Lazuli Bunting

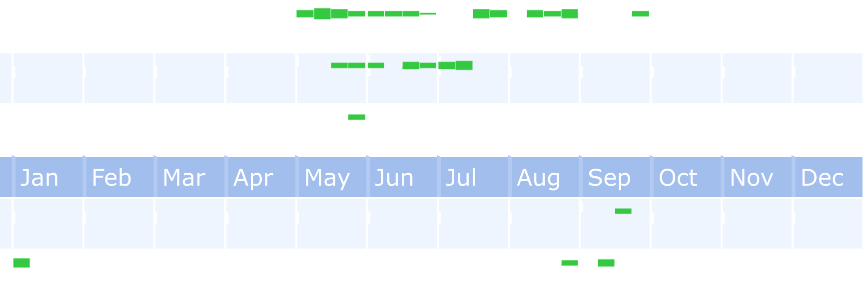
Indigo Bunting

Passerina sp.

Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec

Dickcissel

passerine sp.



**KEY:** = insufficient data | = rare to widespread

Download Histogram Data

# 3 Reach B eBird Observances 1937 – 2020

eBird Menu

« Start Over

# Bird Observations

**Date Range:** Change Date

Jan-Dec, 1937-1979

Change Location [ Sumner Lake SP ] [ Sumner Lake SP- Eastside CG ] [ Pecos River in Santa Rosa ] [ Pecos Watershed Education Center at Rock Lake Hatchery ] [ Park Lake - Santa Rosa ] [ Santa Rosa Power Dam Park ]

Updated ~16 hr(s) ago.

17 species (+0 other taxa)

Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

- Canada Goose
- Blue-winged Teal
- Cinnamon Teal
- Pied-billed Grebe
- Rock Pigeon
- Killdeer
- Turkey Vulture
- Sharp-shinned Hawk
- Swainson's Hawk
- Ladder-backed Woodpecker
- Western Kingbird
- Loggerhead Shrike
- Common Raven
- Juniper Titmouse
- Horned Lark

Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

- Northern Rough-winged Swallow
- Curve-billed Thrasher

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eBird Menu

« Start Over

# Bird Observations

**Date Range:** Change Date

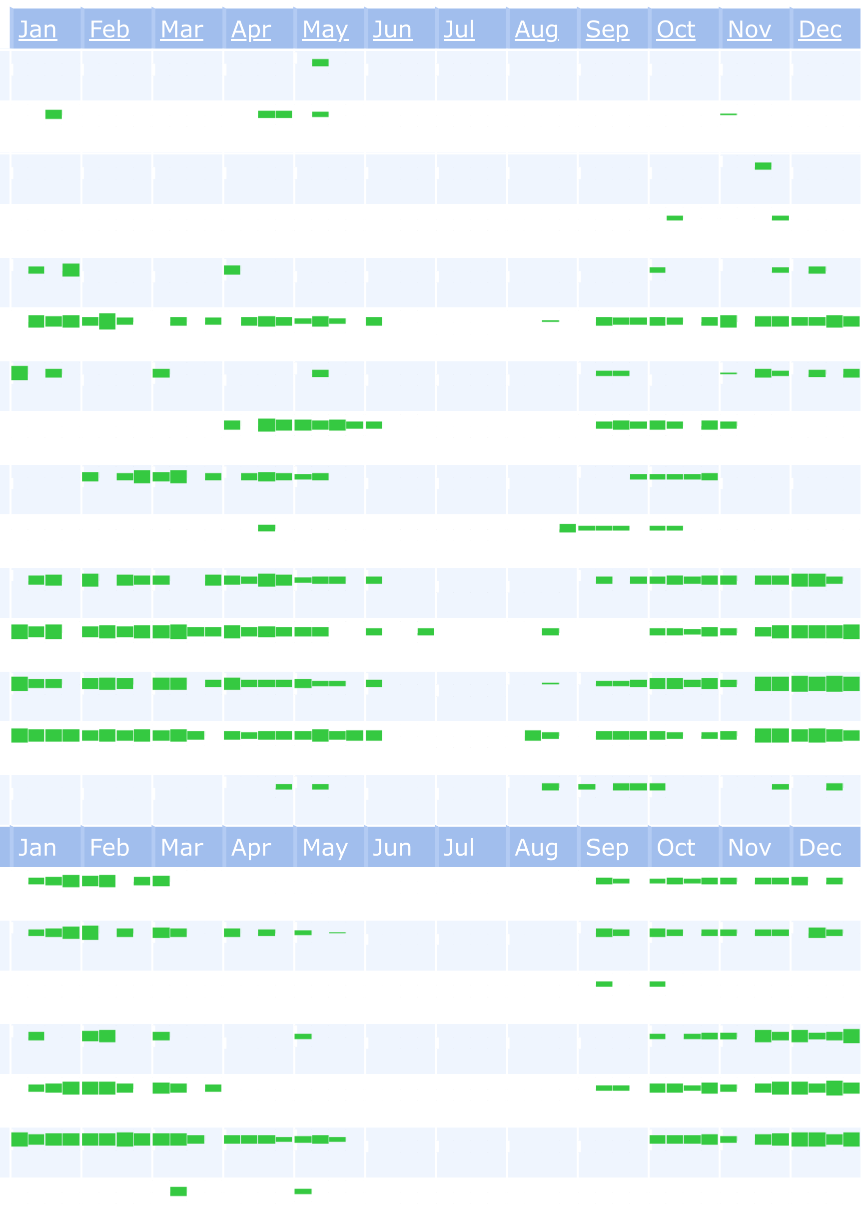
Jan-Dec, 1979-2020

Change Location [ Sumner Lake SP ] [ Sumner Lake SP- Eastside CG ] [ Pecos River in Santa Rosa ] [ Pecos Watershed Education Center at Rock Lake Hatchery ] [ Park Lake - Santa Rosa ] [ Santa Rosa Power Dam Park ]

Updated ~16 hr(s) ago.

290 species (+29 other taxa)

Black-bellied Whistling-Duck
Snow Goose
Ross's Goose
Greater White-fronted Goose
Cackling Goose
Canada Goose
Wood Duck
Blue-winged Teal
Cinnamon Teal
Blue-winged/Cinnamon Teal
Northern Shoveler
Gadwall
American Wigeon
Mallard
Mallard (Domestic type)
Northern Pintail
Green-winged Teal
teal sp.
Canvasback
Redhead
Ring-necked Duck
Greater Scaup



290 species (+29 other taxa)

Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

- Lesser Scaup
- Surf Scoter
- White-winged Scoter
- Black Scoter
- Long-tailed Duck
- Bufflehead
- Common Goldeneye
- Hooded Merganser

Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

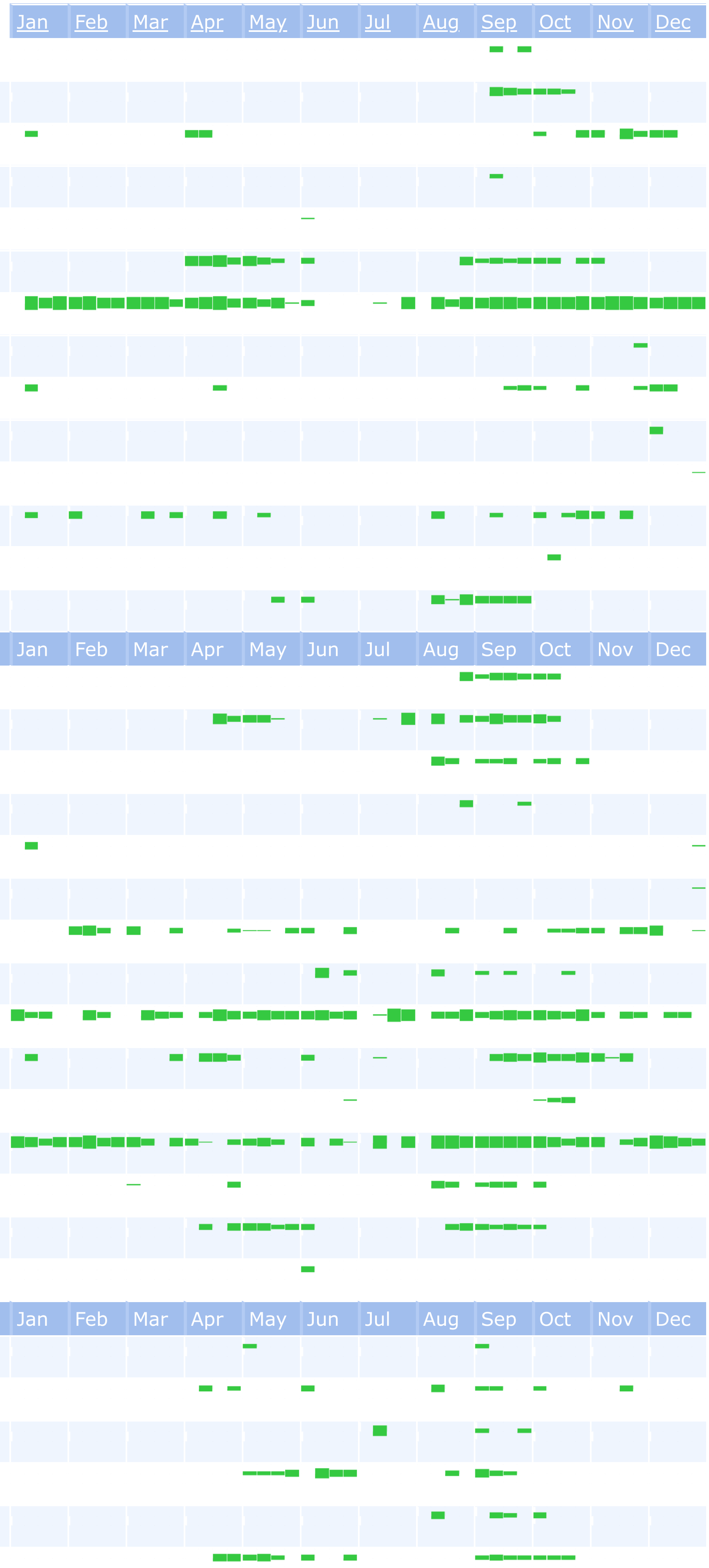
- Common Merganser
- Red-breasted Merganser
- Common/Red-breasted Merganser
- Ruddy Duck
- duck sp.
- Northern Bobwhite
- Scaled Quail
- Wild Turkey
- Pied-billed Grebe
- Horned Grebe
- Red-necked Grebe
- Eared Grebe
- Western Grebe
- Clark's Grebe
- Western/Clark's Grebe

Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

- Rock Pigeon
- Eurasian Collared-Dove
- White-winged Dove
- Mourning Dove
- Greater Roadrunner
- Yellow-billed Cuckoo
- Common Nighthawk
- Common Poorwill
- Black-chinned Hummingbird
- Broad-tailed Hummingbird
- Rufous Hummingbird
- hummingbird sp.

| 290 species (+29 other taxa) | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Virginia Rail | | | | | | | | | | | | |
| Sora | | | | | | | | | | | | |
| American Coot | | | | | | | | | | | | |
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| Sandhill Crane | | | | | | | | | | | | |
| Black-necked Stilt | | | | | | | | | | | | |
| American Avocet | | | | | | | | | | | | |
| Black-bellied Plover | | | | | | | | | | | | |
| Snowy Plover | | | | | | | | | | | | |
| Semipalmated Plover | | | | | | | | | | | | |
| Killdeer | | | | | | | | | | | | |
| Upland Sandpiper | | | | | | | | | | | | |
| Long-billed Curlew | | | | | | | | | | | | |
| Marbled Godwit | | | | | | | | | | | | |
| Ruddy Turnstone | | | | | | | | | | | | |
| Stilt Sandpiper | | | | | | | | | | | | |
| Sanderling | | | | | | | | | | | | |
| Baird's Sandpiper | | | | | | | | | | | | |
| Least Sandpiper | | | | | | | | | | | | |
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| White-rumped Sandpiper | | | | | | | | | | | | |
| Pectoral Sandpiper | | | | | | | | | | | | |
| Western Sandpiper | | | | | | | | | | | | |
| peep sp. | | | | | | | | | | | | |
| Long-billed Dowitcher | | | | | | | | | | | | |
| Wilson's Snipe | | | | | | | | | | | | |
| Wilson's Phalarope | | | | | | | | | | | | |
| Red-necked Phalarope | | | | | | | | | | | | |
| Red Phalarope | | | | | | | | | | | | |
| Spotted Sandpiper | | | | | | | | | | | | |
| Solitary Sandpiper | | | | | | | | | | | | |
| Greater Yellowlegs | | | | | | | | | | | | |
| Willet | | | | | | | | | | | | |
| Lesser Yellowlegs | | | | | | | | | | | | |
| Greater/Lesser Yellowlegs | | | | | | | | | | | | |
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| shorebird sp. | | | | | | | | | | | | |

290 species (+29 other taxa)

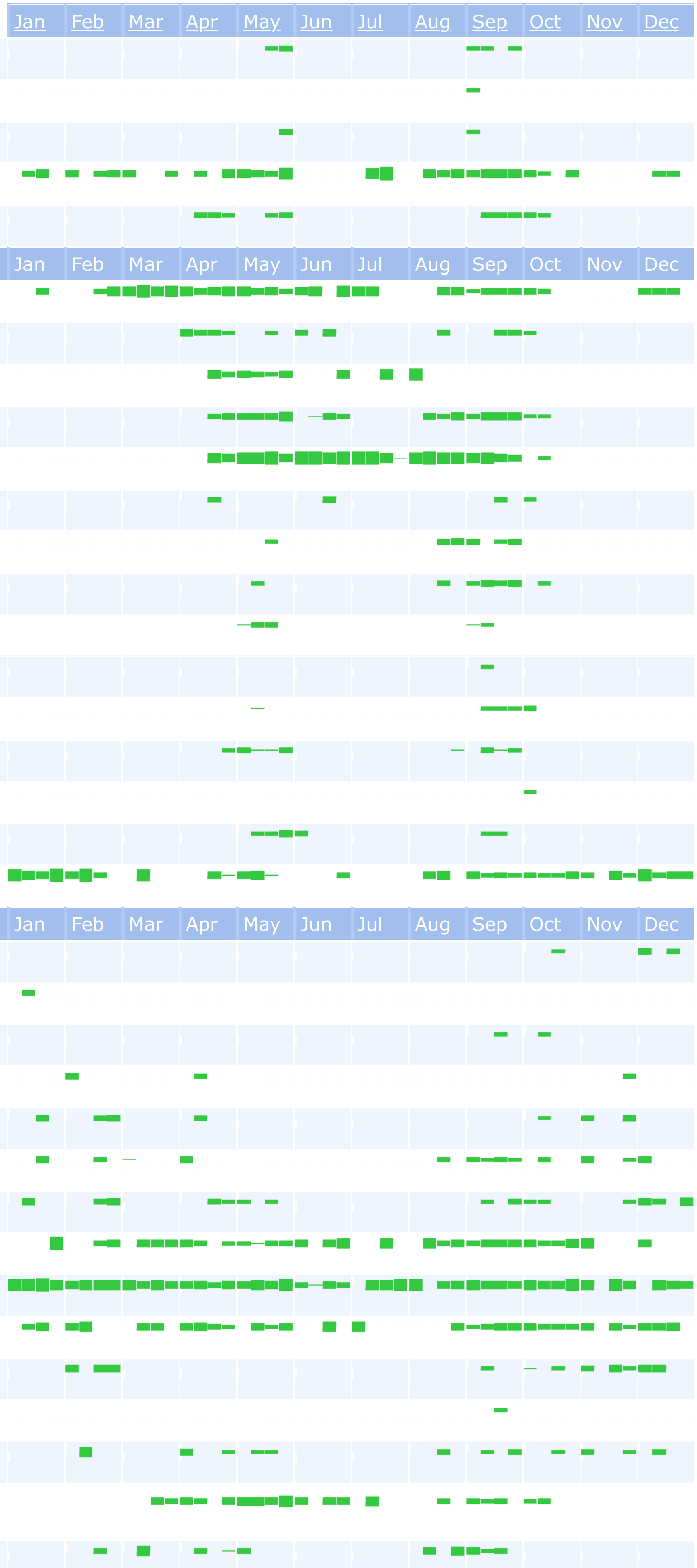



- Long-tailed Jaeger
- Sabine's Gull
- Bonaparte's Gull
- Little Gull
- Laughing Gull
- Franklin's Gull
- Ring-billed Gull
- California Gull
- Herring Gull
- Iceland Gull
- Glaucous Gull
- gull sp.
- Caspian Tern
- Black Tern
- Common Tern
- Forster's Tern
- Sterna sp.
- tern sp.
- Red-throated Loon
- Pacific Loon
- Common Loon
- Neotropic Cormorant
- Double-crested Cormorant
- American White Pelican
- Brown Pelican
- Great Blue Heron
- Great Egret
- Snowy Egret
- Tricolored Heron
- Reddish Egret
- Cattle Egret
- white egret sp.
- Green Heron
- Black-crowned Night-Heron
- White-faced Ibis

290 species (+29 other taxa)


- Turkey Vulture
- Osprey
- Swallow-tailed Kite
- Golden Eagle
- Mississippi Kite
- Northern Harrier
- Sharp-shinned Hawk
- Cooper's Hawk
- Bald Eagle
- Common Black Hawk
- Broad-winged Hawk
- Swainson's Hawk
- Zone-tailed Hawk
- Red-tailed Hawk
- Ferruginous Hawk
- Great Horned Owl
- Belted Kingfisher
- Red-naped Sapsucker
- Red-headed Woodpecker
- Downy Woodpecker
- Ladder-backed Woodpecker
- Northern Flicker
- American Kestrel
- Merlin
- Peregrine Falcon
- Prairie Falcon
- Olive-sided Flycatcher
- Western Wood-Pewee
- Western/Eastern Wood-Pewee
- Willow Flycatcher
- Alder/Willow Flycatcher (Traill's Flycatcher)
- Least Flycatcher
- Hammond's Flycatcher
- Gray Flycatcher

290 species (+29 other taxa)




- Dusky Flycatcher
- Cordilleran Flycatcher
- Empidonax sp.
- Black Phoebe
- Eastern Phoebe
- Say's Phoebe
- Vermilion Flycatcher
- Ash-throated Flycatcher
- Cassin's Kingbird
- Western Kingbird
- Cassin's/Western Kingbird
- Eastern Kingbird
- Scissor-tailed Flycatcher
- Bell's Vireo
- Yellow-throated Vireo
- Cassin's Vireo
- Plumbeous Vireo
- Philadelphia Vireo
- Warbling Vireo
- Loggerhead Shrike
- Northern Shrike
- Loggerhead/Northern Shrike
- Pinyon Jay
- Steller's Jay
- Blue Jay
- Woodhouse's Scrub-Jay
- American Crow
- Chihuahuan Raven
- Common Raven
- raven sp.
- Mountain Chickadee
- Juniper Titmouse
- Horned Lark
- Northern Rough-winged Swallow
- Tree Swallow

290 species (+29 other taxa)

| Species | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Violet-green Swallow | | | | | | | | | | | | |
| Bank Swallow | | | | | | | | | | | | |
| Barn Swallow | | | | | | | | | | | | |
| Cliff Swallow | | | | | | | | | | | | |
| swallow sp. | | | | | | | | | | | | |
| Bushtit | | | | | | | | | | | | |
| Golden-crowned Kinglet | | | | | | | | | | | | |
| Ruby-crowned Kinglet | | | | | | | | | | | | |
| Red-breasted Nuthatch | | | | | | | | | | | | |
| White-breasted Nuthatch | | | | | | | | | | | | |
| Brown Creeper | | | | | | | | | | | | |
| Blue-gray Gnatcatcher | | | | | | | | | | | | |
| Rock Wren | | | | | | | | | | | | |
| Canyon Wren | | | | | | | | | | | | |
| House Wren | | | | | | | | | | | | |
| Winter Wren | | | | | | | | | | | | |
| Marsh Wren | | | | | | | | | | | | |
| Carolina Wren | | | | | | | | | | | | |
| Bewick's Wren | | | | | | | | | | | | |
| Cactus Wren | | | | | | | | | | | | |
| European Starling | | | | | | | | | | | | |
| Gray Catbird | | | | | | | | | | | | |
| Curve-billed Thrasher | | | | | | | | | | | | |
| Brown Thrasher | | | | | | | | | | | | |
| Sage Thrasher | | | | | | | | | | | | |
| Northern Mockingbird | | | | | | | | | | | | |
| Eastern Bluebird | | | | | | | | | | | | |
| Western Bluebird | | | | | | | | | | | | |
| Mountain Bluebird | | | | | | | | | | | | |
| Townsend's Solitaire | | | | | | | | | | | | |
| Swainson's Thrush | | | | | | | | | | | | |
| Hermit Thrush | | | | | | | | | | | | |
| American Robin | | | | | | | | | | | | |
| Cedar Waxwing | | | | | | | | | | | | |


290 species (+29 other taxa)
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
House Sparrow
American Pipit
Evening Grosbeak
House Finch
Red Crossbill
Pine Siskin
Lesser Goldfinch
American Goldfinch
Chestnut-collared Longspur
McCown's Longspur
longspur sp.
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Cassin's Sparrow
Grasshopper Sparrow
Chipping Sparrow
Clay-colored Sparrow
Field Sparrow
Brewer's Sparrow
Spizella sp.
Black-throated Sparrow
Lark Sparrow
Lark Bunting
American Tree Sparrow
Fox Sparrow
Dark-eyed Junco
White-crowned Sparrow
White-throated Sparrow
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Vesper Sparrow
Savannah Sparrow
Song Sparrow
Lincoln's Sparrow
Swamp Sparrow
Canyon Towhee
Rufous-crowned Sparrow
Green-tailed Towhee
Spotted Towhee

290 species (+29 other taxa)

Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

- sparrow sp.
- Yellow-breasted Chat
- Yellow-headed Blackbird
- Bobolink
- Western Meadowlark
- Eastern Meadowlark
- Western/Eastern Meadowlark
- Orchard Oriole
- Bullock's Oriole
- Bullock's/Baltimore Oriole
- Scott's Oriole
- Red-winged Blackbird
- Brown-headed Cowbird
- Rusty Blackbird
- Brewer's Blackbird
- Common Grackle
- Great-tailed Grackle
- blackbird sp.
- Ovenbird
- Northern Waterthrush
- Golden-winged Warbler
- Black-and-white Warbler
- Orange-crowned Warbler
- Nashville Warbler
- Virginia's Warbler
- MacGillivray's Warbler
- Kentucky Warbler
- Common Yellowthroat
- Hooded Warbler
- American Redstart
- Northern Parula
- Magnolia Warbler
- Yellow Warbler
- Chestnut-sided Warbler
- Blackpoll Warbler


**KEY:** | = insufficient data | = rare to widespread

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# 4 Reach C eBird Observances 1937 – 2020

eBird Menu

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# Bird Observations

**Date Range:** Change Date

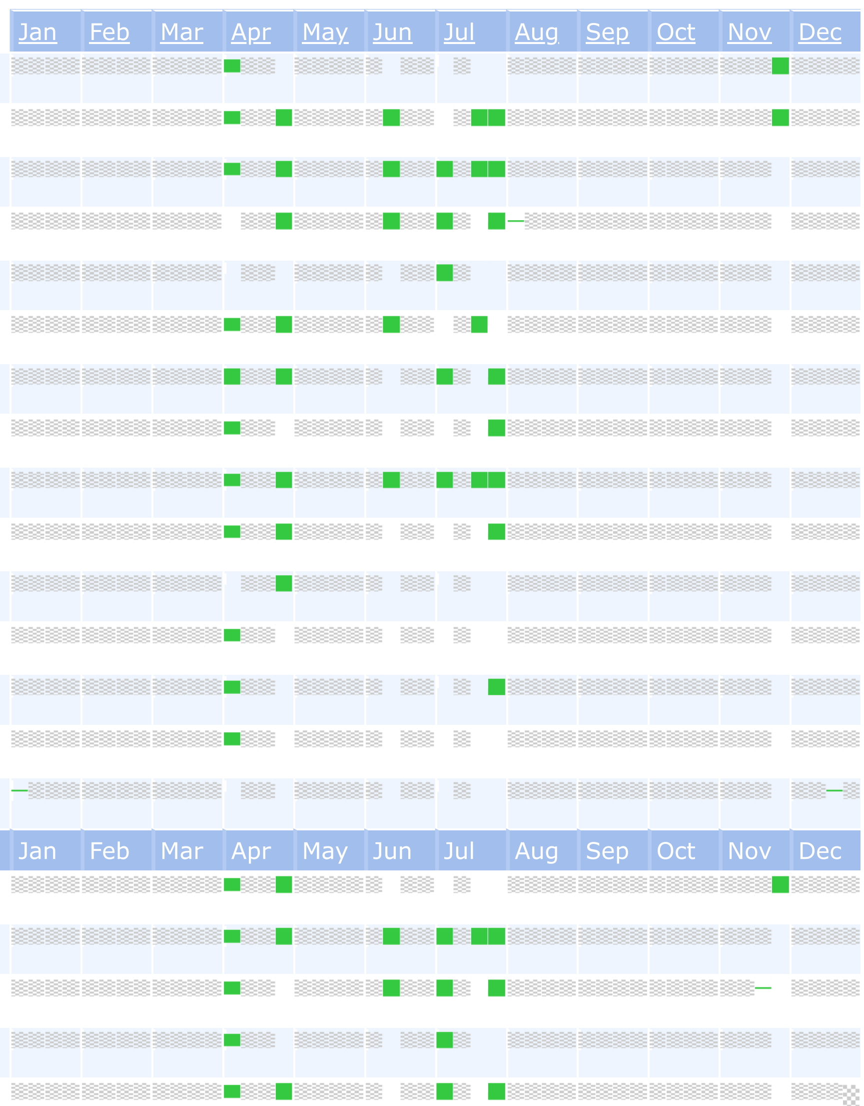
Jan-Dec, 1939-1979

Change Location [ Pecos River - Below Sumner Dam ] [ W.S. Huey Waterfowl Management Area ] [ Bosque Redondo Park ] [ Brantley Lake SP--campground ] [ Bitter Lake NWR -- parking between units 5 & 6 ] [ Bottomless Lakes SP ] [ Bitter Lakes NWR - Visitor Center ] [ Brantley Lake SP ] [ Brantley Lake SP--Cheapskate Pt. ] [ McMillan Dam wetlands ] [ Bitter Lake NWR - Sandhill Crane Overlook ] [ Brantley Reservoir ] [ Bitter Lake NWR--Farm (NMAR) ] [ Bitter Lake NWR ] [ Brantley Lake SP--Rocky Bay ] [ Bitter Lake NWR - Pajaro Bird Blind ] [ Southern Brantley Lake from Dam Ridge ] [ Lake McMillan ] [ Bitter Lake NWR-- OxBow ]

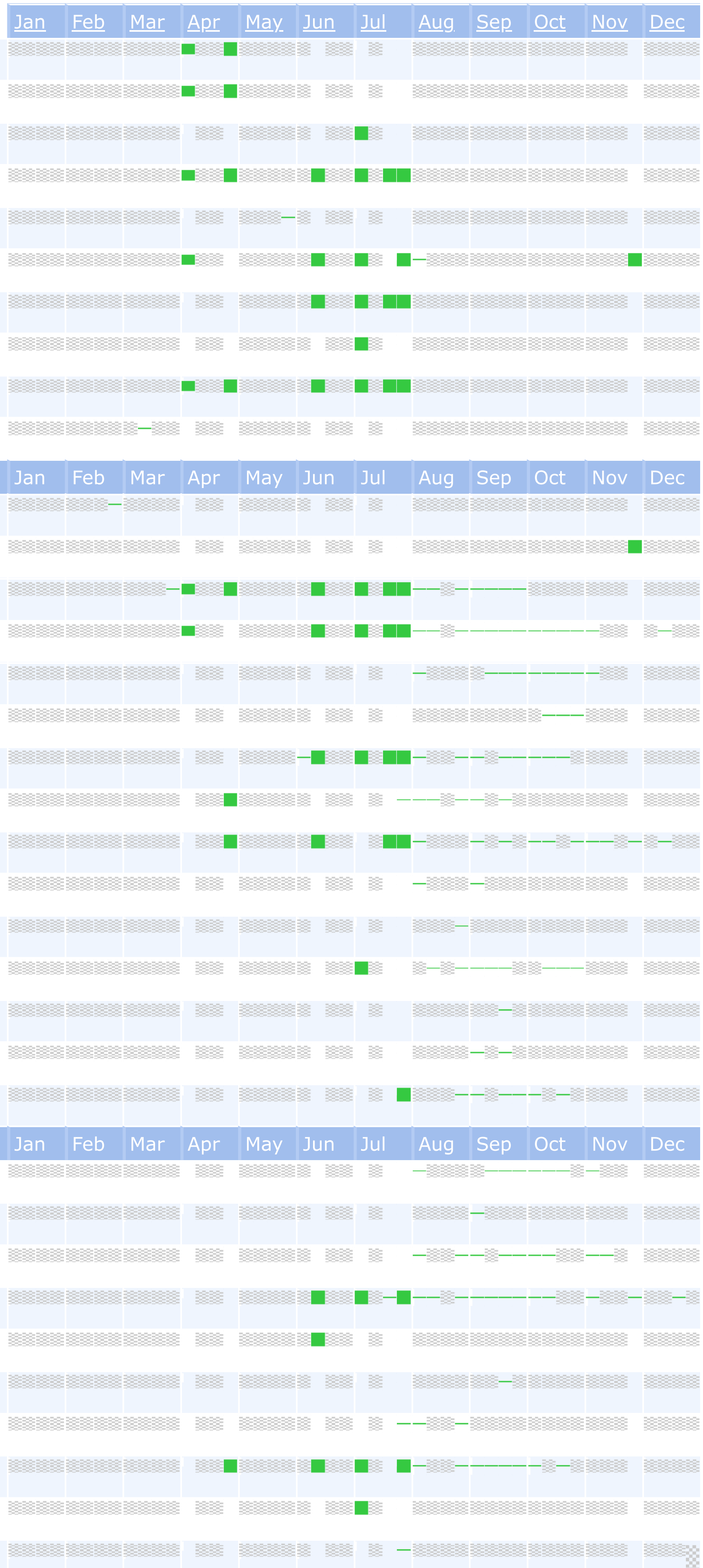
Updated ~16 hr(s) ago.

131 species (+4 other taxa)

Snow Goose
Canada Goose
Blue-winged Teal
Cinnamon Teal
Blue-winged/Cinnamon Teal
Northern Shoveler
Gadwall
American Wigeon
Mallard
Northern Pintail
Green-winged Teal
Canvasback
Redhead
Lesser Scaup
Harlequin Duck
Bufflehead
Ruddy Duck
Scaled Quail
Ring-necked Pheasant
Pied-billed Grebe



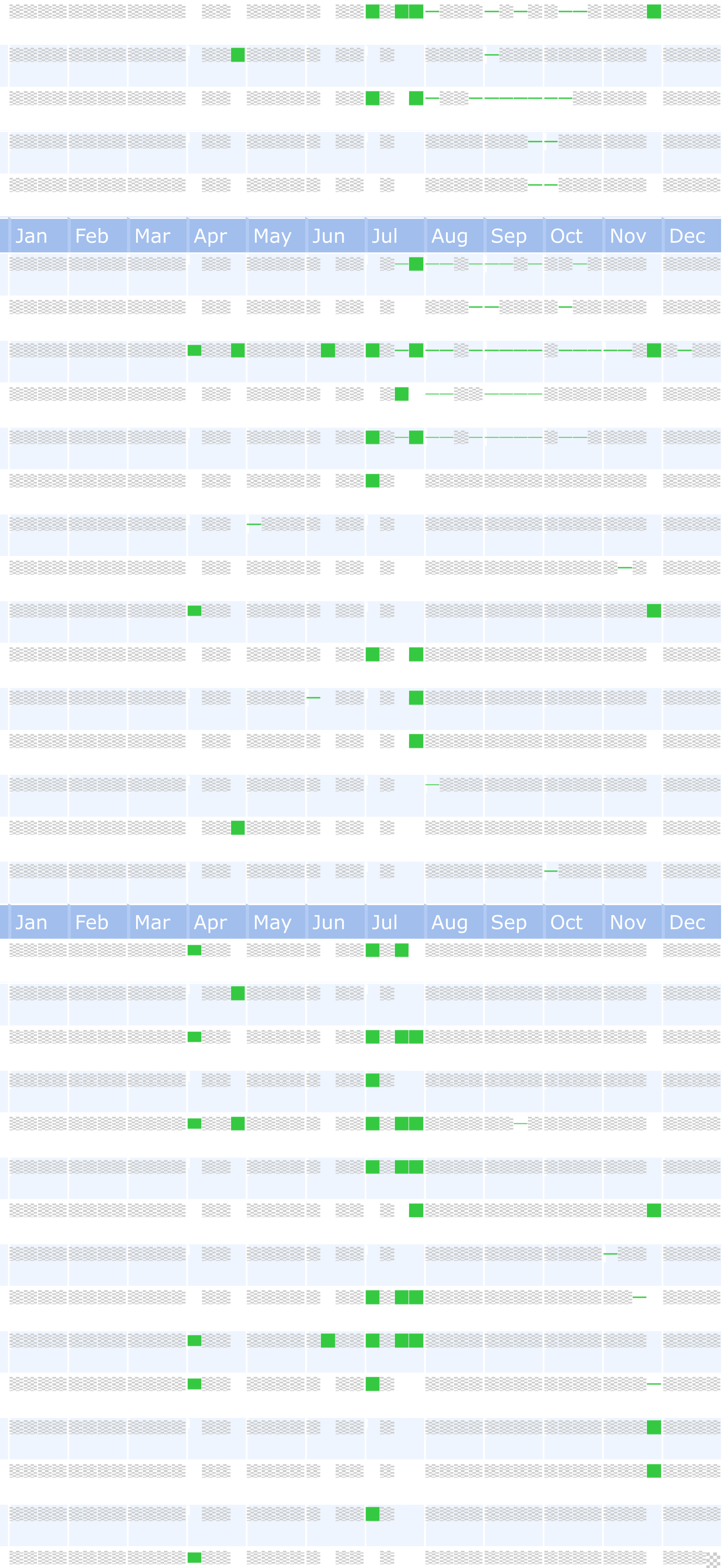
131 species (+4 other taxa)




- Eared Grebe
- Western Grebe
- White-winged Dove
- Mourning Dove
- Groove-billed Ani
- Greater Roadrunner
- Common Nighthawk
- Virginia Rail
- American Coot
- Purple Gallinule
- Yellow Rail
- Sandhill Crane
- Black-necked Stilt
- American Avocet
- Black-bellied Plover
- American Golden-Plover
- Snowy Plover
- Semipalmated Plover
- Killdeer
- Upland Sandpiper
- Whimbrel
- Long-billed Curlew
- Marbled Godwit
- Red Knot
- Stilt Sandpiper
- Sanderling
- Dunlin
- Baird's Sandpiper
- Least Sandpiper
- White-rumped Sandpiper
- Pectoral Sandpiper
- Semipalmated Sandpiper
- Western Sandpiper
- peep sp.
- Short-billed Dowitcher

131 species (+4 other taxa)

Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec



- Long-billed Dowitcher
- Wilson's Snipe
- Wilson's Phalarope
- Red-necked Phalarope
- Red Phalarope

Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

- Spotted Sandpiper
- Solitary Sandpiper
- Greater Yellowlegs
- Willet
- Lesser Yellowlegs
- Greater/Lesser Yellowlegs
- Pomarine Jaeger
- Laughing Gull
- Ring-billed Gull
- Least Tern
- Black Tern
- Forster's Tern
- Black Skimmer
- Common Loon
- Magnificent Frigatebird

Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

- Double-crested Cormorant
- American Bittern
- Great Blue Heron
- Great Egret
- Snowy Egret
- Green Heron
- Black-crowned Night-Heron
- White Ibis
- White-faced Ibis
- Turkey Vulture
- Northern Harrier
- Sharp-shinned Hawk
- Cooper's Hawk
- Swainson's Hawk
- Great Horned Owl

131 species (+4 other taxa)

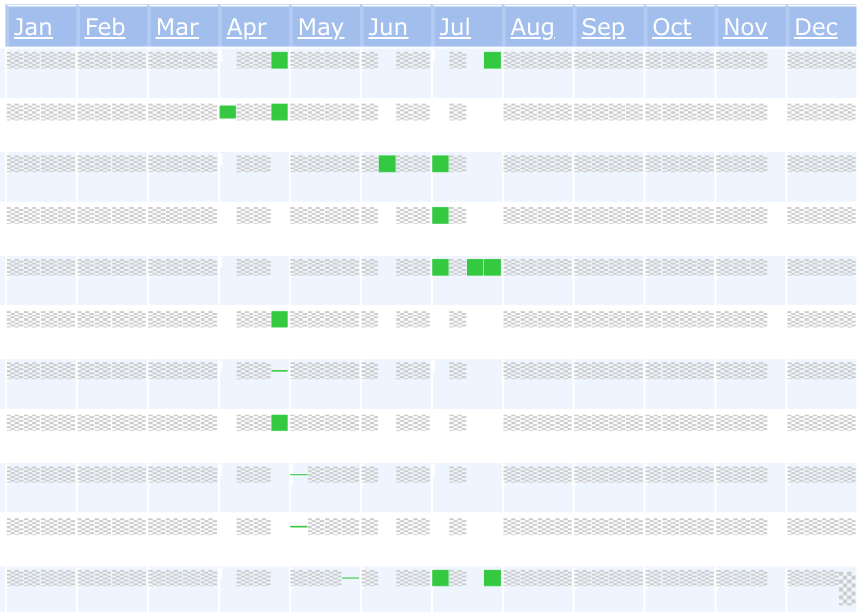
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

Burrowing Owl
Belted Kingfisher
Lewis's Woodpecker
Ladder-backed Woodpecker
Northern Flicker
American Kestrel
Say's Phoebe
Western Kingbird
Loggerhead Shrike
Clark's Nutcracker
Chihuahuan Raven
Horned Lark
Northern Rough-winged Swallow
Tree Swallow
Barn Swallow

Cliff Swallow
Sedge Wren
Cactus Wren
Crissal Thrasher
Northern Mockingbird
House Sparrow
Evening Grosbeak
House Finch
Cassin's Sparrow
Black-throated Sparrow
Lark Sparrow
American Tree Sparrow
White-crowned Sparrow
LeConte's Sparrow
Yellow-headed Blackbird

Western Meadowlark
Eastern Meadowlark
Bullock's Oriole
Red-winged Blackbird

131 species (+4 other taxa)




- Brown-headed Cowbird
- Brewer's Blackbird
- Great-tailed Grackle
- blackbird sp.
- Common Yellowthroat
- Yellow-rumped Warbler
- Yellow-throated Warbler
- Wilson's Warbler
- Painted Redstart
- Scarlet Tanager
- Blue Grosbeak

**KEY:** | = insufficient data | = rare to widespread

Download Histogram Data

eBird

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# Bird Observations

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Updated ~16 hr(s) ago.

| 380 species (+68 other taxa) | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Black-bellied Whistling-Duck | | | | | | | | | | | | |
| Snow Goose | | | | | | | | | | | | |
| Ross's Goose | | | | | | | | | | | | |
| Snow/Ross's Goose | | | | | | | | | | | | |
| Greater White-fronted Goose | | | | | | | | | | | | |
| Domestic goose sp. (Domestic type) | | | | | | | | | | | | |
| Brant | | | | | | | | | | | | |
| Cackling Goose | | | | | | | | | | | | |
| Canada Goose | | | | | | | | | | | | |
| Trumpeter Swan | | | | | | | | | | | | |
| Tundra Swan | | | | | | | | | | | | |
| Wood Duck | | | | | | | | | | | | |
| Garganey | | | | | | | | | | | | |
| Blue-winged Teal | | | | | | | | | | | | |
| Cinnamon Teal | | | | | | | | | | | | |
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| Blue-winged x Cinnamon Teal (hybrid) | | | | | | | | | | | | |
| Blue-winged/Cinnamon Teal | | | | | | | | | | | | |
| Northern Shoveler | | | | | | | | | | | | |
| Gadwall | | | | | | | | | | | | |

380 species (+68 other taxa) Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

Eurasian Wigeon
American Wigeon
Mallard
Mallard (Domestic type)
Mexican Duck
Mallard x Mexican Duck (hybrid)
Mallard/Mexican Duck
Northern Pintail
Green-winged Teal
teal sp.
dabbling duck sp.

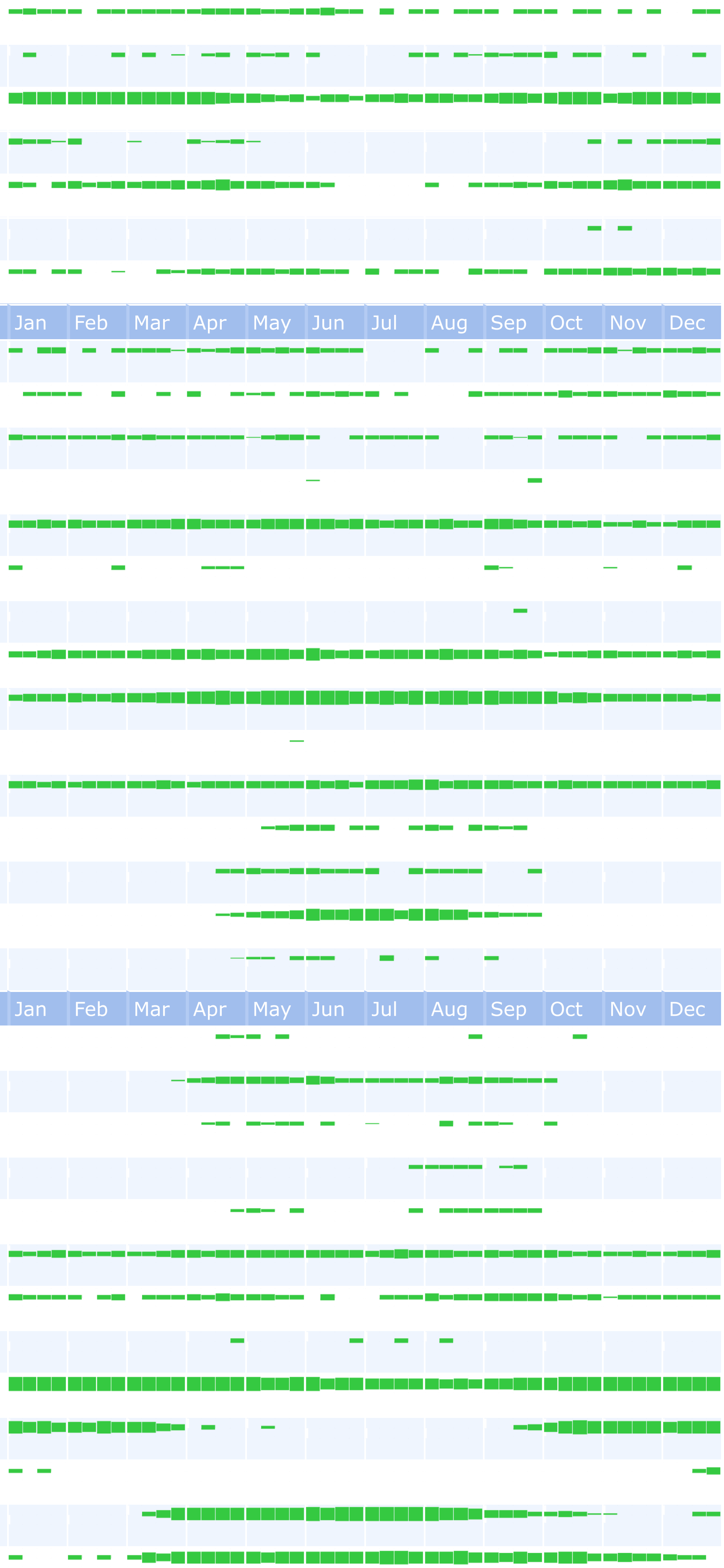
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

Canvasback
Redhead
Ring-necked Duck
Greater Scaup
Lesser Scaup
Greater/Lesser Scaup
Aythya sp.
Surf Scoter
White-winged Scoter
Long-tailed Duck
Bufflehead
Common Goldeneye
Bufflehead x Common Goldeneye (hybrid)
Barrow's Goldeneye
Hooded Merganser

Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

Common Merganser
Red-breasted Merganser
Common/Red-breasted Merganser
Ruddy Duck
duck sp.
waterfowl sp.
Northern Bobwhite
Scaled Quail

380 species (+68 other taxa)




| Species | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ring-necked Pheasant | | | | | | | | | | | | |
| Wild Turkey | | | | | | | | | | | | |
| Pied-billed Grebe | | | | | | | | | | | | |
| Horned Grebe | | | | | | | | | | | | |
| Eared Grebe | | | | | | | | | | | | |
| Horned/Eared Grebe | | | | | | | | | | | | |
| Western Grebe | | | | | | | | | | | | |

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Clark's Grebe | | | | | | | | | | | | |
| Western/Clark's Grebe | | | | | | | | | | | | |
| Rock Pigeon | | | | | | | | | | | | |
| Band-tailed Pigeon | | | | | | | | | | | | |
| Eurasian Collared-Dove | | | | | | | | | | | | |
| Inca Dove | | | | | | | | | | | | |
| Common Ground Dove | | | | | | | | | | | | |
| White-winged Dove | | | | | | | | | | | | |
| Mourning Dove | | | | | | | | | | | | |
| Groove-billed Ani | | | | | | | | | | | | |
| Greater Roadrunner | | | | | | | | | | | | |
| Yellow-billed Cuckoo | | | | | | | | | | | | |
| Lesser Nighthawk | | | | | | | | | | | | |
| Common Nighthawk | | | | | | | | | | | | |
| nighthawk sp. | | | | | | | | | | | | |

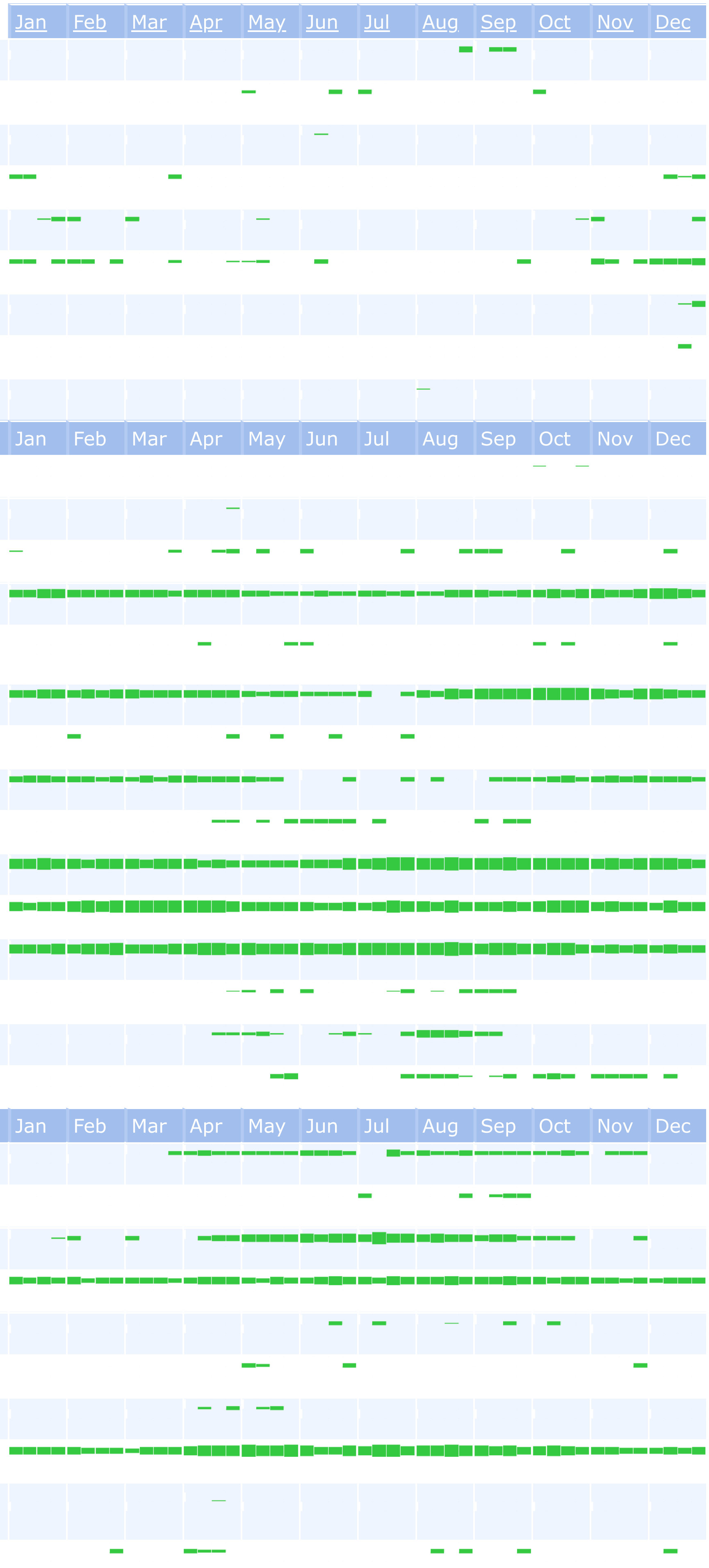
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Common Poorwill | | | | | | | | | | | | |
| Black-chinned Hummingbird | | | | | | | | | | | | |
| Broad-tailed Hummingbird | | | | | | | | | | | | |
| Rufous Hummingbird | | | | | | | | | | | | |
| hummingbird sp. | | | | | | | | | | | | |
| Virginia Rail | | | | | | | | | | | | |
| Sora | | | | | | | | | | | | |
| Common Gallinule | | | | | | | | | | | | |
| American Coot | | | | | | | | | | | | |
| Sandhill Crane | | | | | | | | | | | | |
| Common Crane | | | | | | | | | | | | |
| Black-necked Stilt | | | | | | | | | | | | |
| American Avocet | | | | | | | | | | | | |

380 species (+68 other taxa)

| Species | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Black-bellied Plover | | | | | | | | | | | | |
| American Golden-Plover | | | | | | | | | | | | |
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| Snowy Plover | | | | | | | | | | | | |
| Semipalmated Plover | | | | | | | | | | | | |
| Piping Plover | | | | | | | | | | | | |
| Killdeer | | | | | | | | | | | | |
| Mountain Plover | | | | | | | | | | | | |
| Upland Sandpiper | | | | | | | | | | | | |
| Whimbrel | | | | | | | | | | | | |
| Long-billed Curlew | | | | | | | | | | | | |
| Hudsonian Godwit | | | | | | | | | | | | |
| Marbled Godwit | | | | | | | | | | | | |
| Ruddy Turnstone | | | | | | | | | | | | |
| Red Knot | | | | | | | | | | | | |
| Stilt Sandpiper | | | | | | | | | | | | |
| Curlew Sandpiper | | | | | | | | | | | | |
| Sanderling | | | | | | | | | | | | |
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| Dunlin | | | | | | | | | | | | |
| Baird's Sandpiper | | | | | | | | | | | | |
| Little Stint | | | | | | | | | | | | |
| Least Sandpiper | | | | | | | | | | | | |
| White-rumped Sandpiper | | | | | | | | | | | | |
| Buff-breasted Sandpiper | | | | | | | | | | | | |
| Pectoral Sandpiper | | | | | | | | | | | | |
| Semipalmated Sandpiper | | | | | | | | | | | | |
| Western Sandpiper | | | | | | | | | | | | |
| Semipalmated/Western Sandpiper | | | | | | | | | | | | |
| peep sp. | | | | | | | | | | | | |
| Short-billed Dowitcher | | | | | | | | | | | | |
| Long-billed Dowitcher | | | | | | | | | | | | |
| Short-billed/Long-billed Dowitcher | | | | | | | | | | | | |
| Wilson's Snipe | | | | | | | | | | | | |
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| Wilson's Phalarope | | | | | | | | | | | | |


380 species (+68 other taxa)
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Red-necked Phalarope
Red Phalarope
phalarope sp.
Spotted Sandpiper
Solitary Sandpiper
Greater Yellowlegs
Willet
Lesser Yellowlegs
Greater/Lesser Yellowlegs
shorebird sp.
Pomarine Jaeger
Parasitic Jaeger
Long-tailed Jaeger
jaeger sp.
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Black-legged Kittiwake
Sabine's Gull
Bonaparte's Gull
Laughing Gull
Franklin's Gull
Black-tailed Gull
Heermann's Gull
Ring-billed Gull
California Gull
Herring Gull
Lesser Black-backed Gull
Glaucous-winged Gull
Glaucous Gull
gull sp.
Least Tern
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Gull-billed Tern
Caspian Tern
Black Tern
Common Tern
Forster's Tern
Common/Forster's Tern

380 species (+68 other taxa)



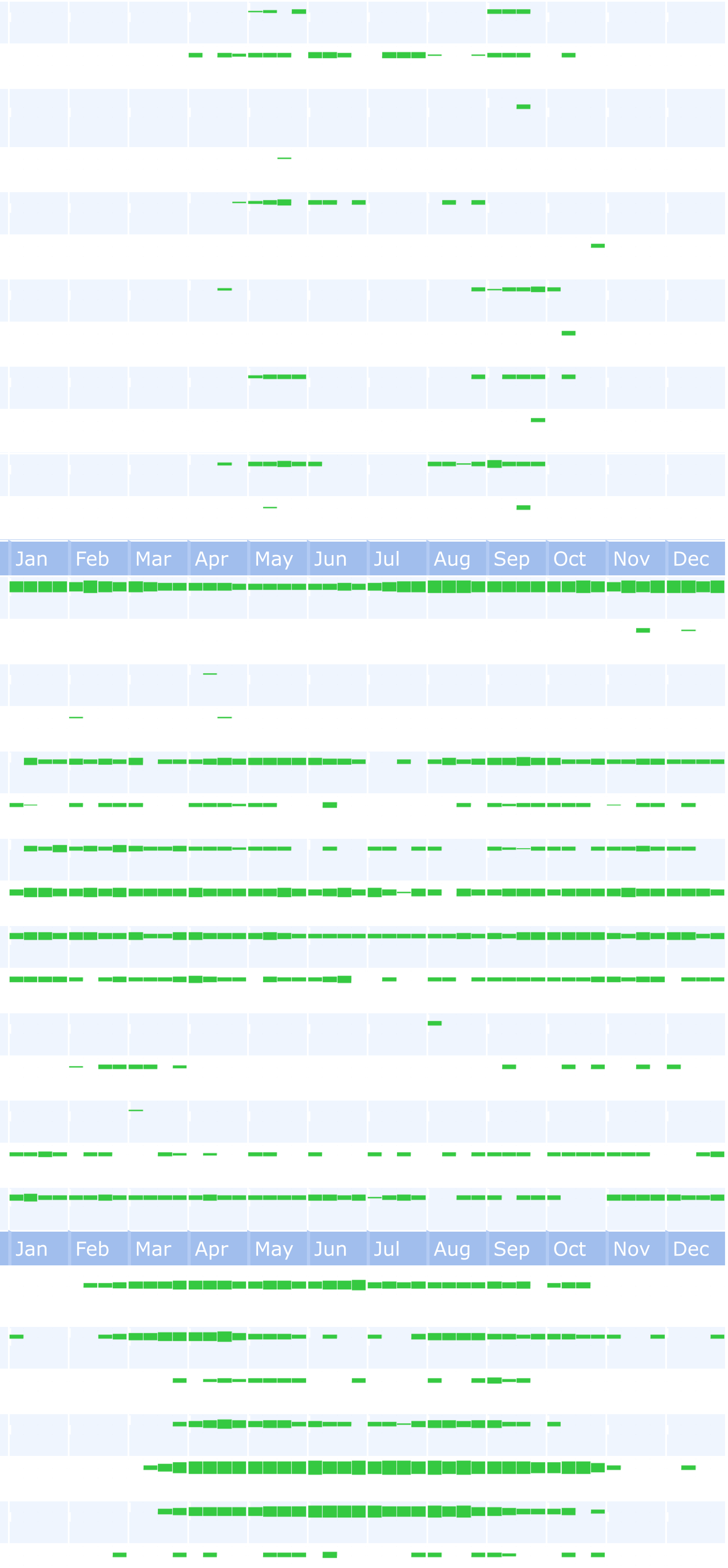

Sterna sp.
tern sp.
Black Skimmer
Red-throated Loon
Pacific Loon
Common Loon
Yellow-billed Loon
loon sp.
Wood Stork
Magnificent Frigatebird
Anhinga
Neotropic Cormorant
Double-crested Cormorant
Neotropic/Double-crested Cormorant
American White Pelican
Brown Pelican
American Bittern
Least Bittern
Great Blue Heron
Great Egret
Snowy Egret
Little Blue Heron
Tricolored Heron
Reddish Egret
Cattle Egret
white egret sp.
Green Heron
Black-crowned Night-Heron
Yellow-crowned Night-Heron
White Ibis
Glossy Ibis
White-faced Ibis
Glossy x White-faced Ibis (hybrid)
Glossy/White-faced Ibis


380 species (+68 other taxa)
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Roseate Spoonbill
Turkey Vulture
Osprey
White-tailed Kite
Golden Eagle
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Mississippi Kite
Northern Harrier
Sharp-shinned Hawk
Cooper's Hawk
Sharp-shinned/Cooper's Hawk
Accipiter sp.
Bald Eagle
Harris's Hawk
Broad-winged Hawk
Swainson's Hawk
Red-tailed Hawk
Rough-legged Hawk
Ferruginous Hawk
Buteo sp.
hawk sp.
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Barn Owl
Western Screech-Owl
Great Horned Owl
Burrowing Owl
Long-eared Owl
owl sp.
Belted Kingfisher
Williamson's Sapsucker
Yellow-bellied Sapsucker
Red-naped Sapsucker
Lewis's Woodpecker
Red-headed Woodpecker
Downy Woodpecker
Ladder-backed Woodpecker
Hairy Woodpecker

| 380 species (+68 other taxa) | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Downy/Hairy Woodpecker | | | | | | | | | | | | |
| Northern Flicker | | | | | | | | | | | | |
| Crested Caracara | | | | | | | | | | | | |
| American Kestrel | | | | | | | | | | | | |
| Merlin | | | | | | | | | | | | |
| Peregrine Falcon | | | | | | | | | | | | |
| Prairie Falcon | | | | | | | | | | | | |
| large falcon sp. | | | | | | | | | | | | |
| small falcon sp. | | | | | | | | | | | | |
| falcon sp. | | | | | | | | | | | | |
| Olive-sided Flycatcher | | | | | | | | | | | | |
| Western Wood-Pewee | | | | | | | | | | | | |
| Western/Eastern Wood-Pewee | | | | | | | | | | | | |
| Willow Flycatcher | | | | | | | | | | | | |
| Least Flycatcher | | | | | | | | | | | | |
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| Hammond's Flycatcher | | | | | | | | | | | | |
| Gray Flycatcher | | | | | | | | | | | | |
| Dusky Flycatcher | | | | | | | | | | | | |
| Hammond's/Dusky Flycatcher | | | | | | | | | | | | |
| Cordilleran Flycatcher | | | | | | | | | | | | |
| Pacific-slope/Cordilleran Flycatcher (Western Flycatcher) | | | | | | | | | | | | |
| Empidonax sp. | | | | | | | | | | | | |
| Black Phoebe | | | | | | | | | | | | |
| Eastern Phoebe | | | | | | | | | | | | |
| Say's Phoebe | | | | | | | | | | | | |
| Vermilion Flycatcher | | | | | | | | | | | | |
| Ash-throated Flycatcher | | | | | | | | | | | | |
| Great Crested Flycatcher | | | | | | | | | | | | |
| Great Kiskadee | | | | | | | | | | | | |
| Piratic Flycatcher | | | | | | | | | | | | |
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| Cassin's Kingbird | | | | | | | | | | | | |
| Western Kingbird | | | | | | | | | | | | |
| Cassin's/Western Kingbird | | | | | | | | | | | | |

380 species (+68 other taxa)

Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec



- Eastern Kingbird
- Scissor-tailed Flycatcher
- flycatcher sp. (Tyrannidae sp.)
- White-eyed Vireo
- Bell's Vireo
- Hutton's Vireo
- Cassin's Vireo
- Blue-headed Vireo
- Plumbeous Vireo
- Philadelphia Vireo
- Warbling Vireo
- Red-eyed Vireo

Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

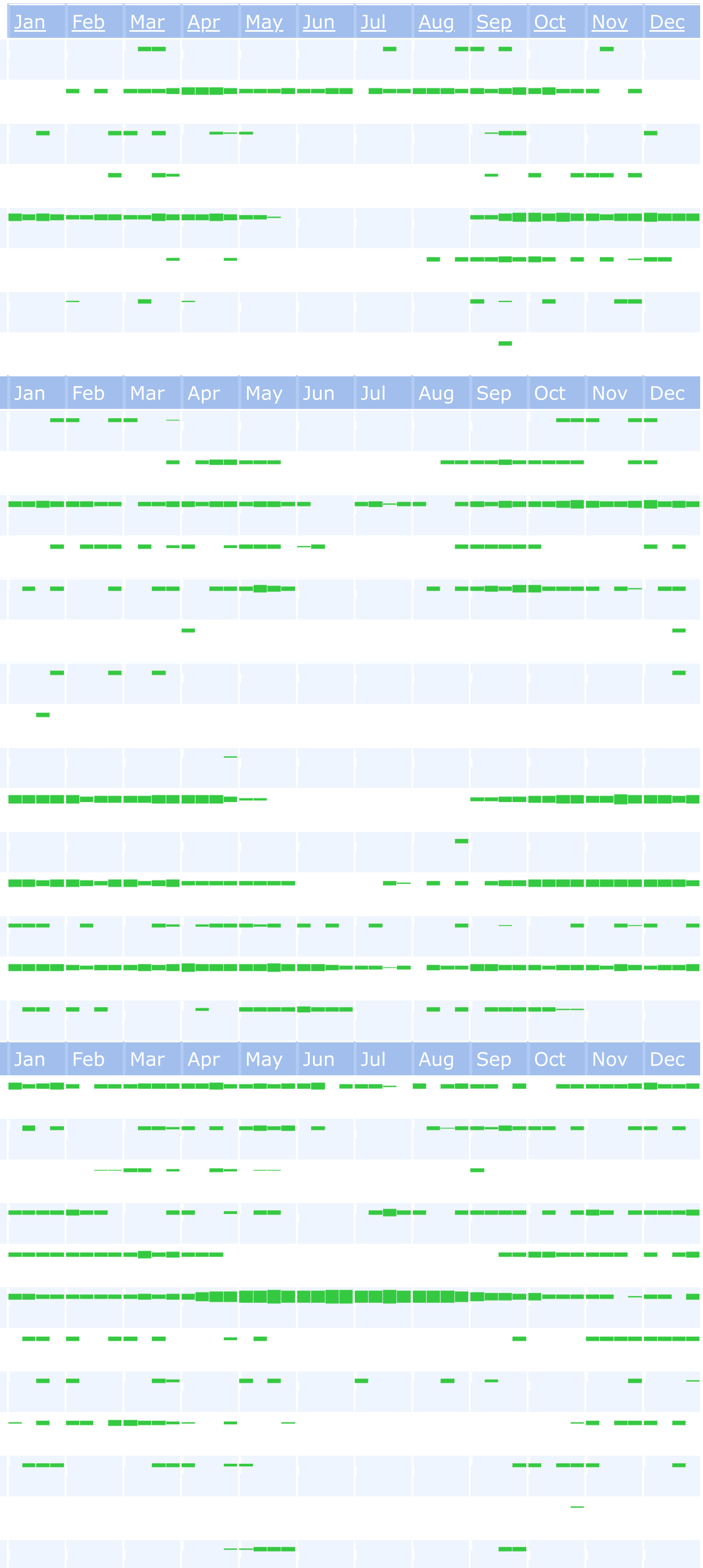
- Loggerhead Shrike
- Northern Shrike
- Pinyon Jay
- Steller's Jay
- Blue Jay
- Woodhouse's Scrub-Jay
- American Crow
- Chihuahuan Raven
- Common Raven
- raven sp.
- crow/raven sp.
- Mountain Chickadee
- Juniper Titmouse
- Verdin
- Horned Lark

Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

- Northern Rough-winged Swallow
- Tree Swallow
- Violet-green Swallow
- Bank Swallow
- Barn Swallow
- Cliff Swallow
- Cave Swallow

380 species (+68 other taxa)

Cliff/Cave Swallow
swallow sp.
Bushtit
Golden-crowned Kinglet
Ruby-crowned Kinglet
Red-breasted Nuthatch
White-breasted Nuthatch
Pygmy Nuthatch
Brown Creeper
Blue-gray Gnatcatcher
Rock Wren
Canyon Wren
House Wren
Pacific Wren
Winter Wren
Pacific/Winter Wren
Sedge Wren
Marsh Wren
Carolina Wren
Bewick's Wren
Cactus Wren
European Starling
Gray Catbird
Curve-billed Thrasher
Brown Thrasher
Long-billed Thrasher
Crissal Thrasher
Sage Thrasher
Northern Mockingbird
Eastern Bluebird
Western Bluebird
Mountain Bluebird
Townsend's Solitaire
Varied Thrush
Swainson's Thrush

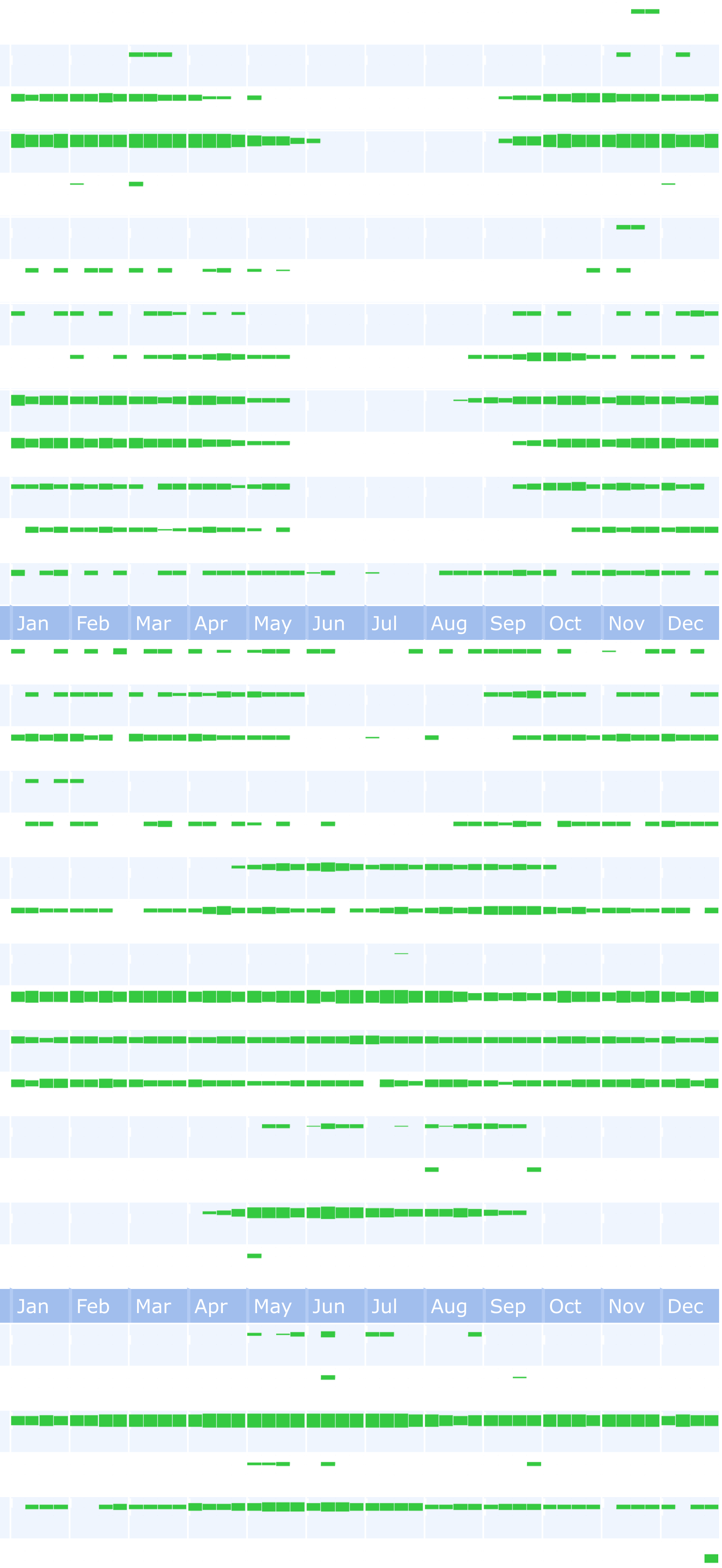


380 species (+68 other taxa)

Hermit Thrush
Catharus sp.
Wood Thrush
American Robin
Northern Wheatear
Cedar Waxwing
Phainopepla
House Sparrow
American Pipit
Sprague's Pipit
Evening Grosbeak
House Finch
Purple Finch
Haemorhous sp.
Red Crossbill
Pine Siskin
Lesser Goldfinch
American Goldfinch
Spinus sp. (goldfinch sp.)
Lapland Longspur
Chestnut-collared Longspur
McCown's Longspur
longspur sp.
Cassin's Sparrow
Grasshopper Sparrow
Chipping Sparrow
Clay-colored Sparrow
Black-chinned Sparrow
Field Sparrow
Brewer's Sparrow
Spizella sp.
Black-throated Sparrow
Lark Sparrow
Lark Bunting

380 species (+68 other taxa)

Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec



American Tree Sparrow
Fox Sparrow
Dark-eyed Junco
White-crowned Sparrow
Golden-crowned Sparrow
Harris's Sparrow
White-throated Sparrow
Sagebrush Sparrow
Vesper Sparrow
Savannah Sparrow
Song Sparrow
Lincoln's Sparrow
Swamp Sparrow
Canyon Towhee

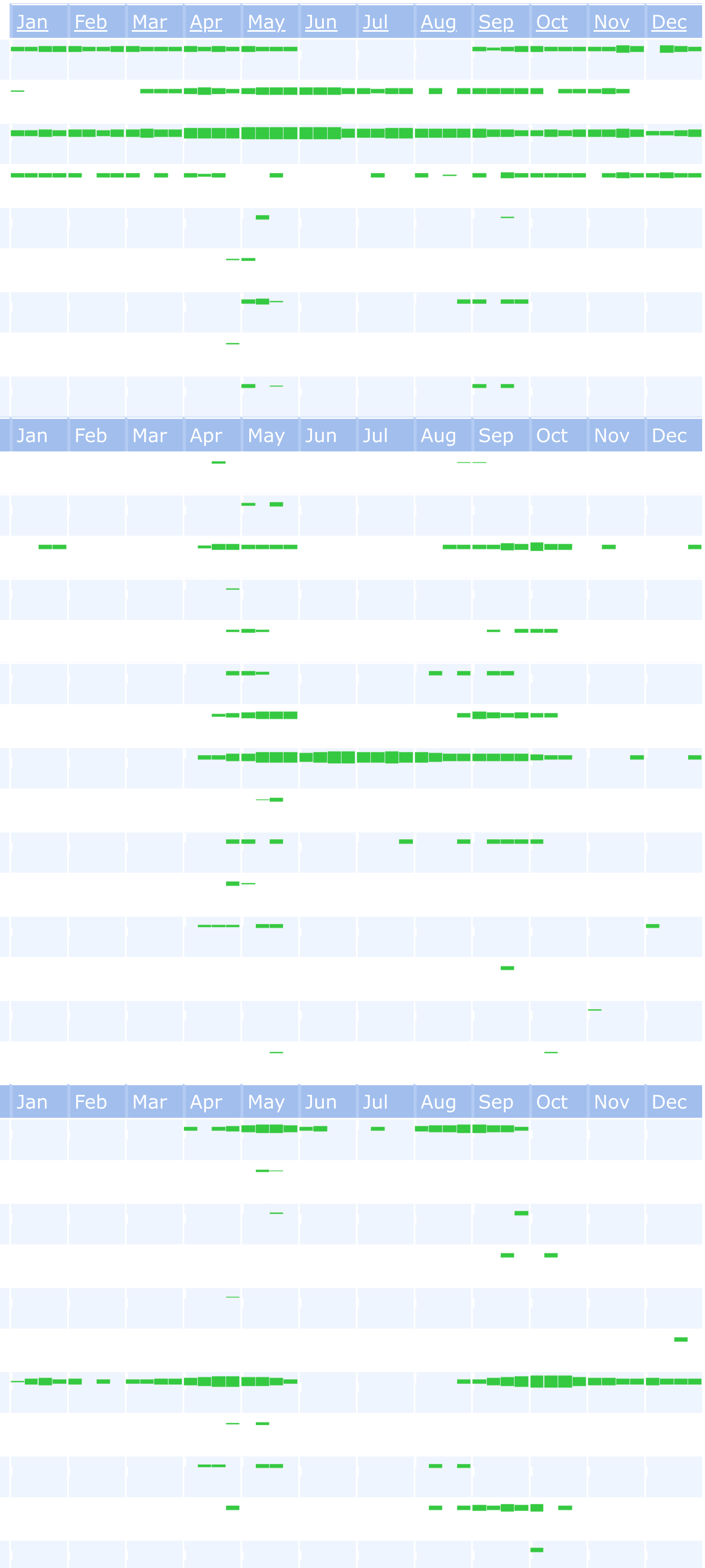
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

Rufous-crowned Sparrow
Green-tailed Towhee
Spotted Towhee
Eastern Towhee
sparrow sp.
Yellow-breasted Chat
Yellow-headed Blackbird
Bobolink
Western Meadowlark
Eastern Meadowlark
Western/Eastern Meadowlark
Orchard Oriole
Hooded Oriole
Bullock's Oriole
Baltimore Oriole

Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

Scott's Oriole
new world oriole sp.
Red-winged Blackbird
Bronzed Cowbird
Brown-headed Cowbird
Rusty Blackbird

380 species (+68 other taxa)




- Brewer's Blackbird
- Common Grackle
- Great-tailed Grackle
- blackbird sp.
- Ovenbird
- Worm-eating Warbler
- Northern Waterthrush
- Blue-winged Warbler
- Black-and-white Warbler
- Prothonotary Warbler
- Tennessee Warbler
- Orange-crowned Warbler
- Lucy's Warbler
- Nashville Warbler
- Virginia's Warbler
- MacGillivray's Warbler
- Common Yellowthroat
- Hooded Warbler
- American Redstart
- Cape May Warbler
- Northern Parula
- Magnolia Warbler
- Bay-breasted Warbler
- Blackburnian Warbler
- Yellow Warbler
- Chestnut-sided Warbler
- Blackpoll Warbler
- Black-throated Blue Warbler
- Palm Warbler
- Pine Warbler
- Yellow-rumped Warbler
- Yellow-throated Warbler
- Black-throated Gray Warbler
- Townsend's Warbler
- Black-throated Green Warbler


**KEY:** | = insufficient data | = rare to widespread

Download Histogram Data