Salinas Valley Water Project Flow Monitoring Report: 10-Year Review

Operational Seasons 2010 - 2019

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Executive Summary

This report evaluates the effectiveness of operations related to the *Salinas Valley Water Project* (SVWP) *Flow Prescription for Steelhead Trout* (Flow Prescription) over the first 10 years of operation of the Salinas River Diversion Facility (SRDF) from 2010 to 2019. The report examines migration opportunities for adult and juvenile steelhead as well as the Monterey County Water Resources Agency's (Agency) execution of the provisions in the Flow Prescription. The goal of this report is to provide a detailed accounting of Flow Prescription operations between 2010 and 2019 as a starting point for further discussions regarding reoperation of the Nacimiento and San Antonio Reservoirs to meet the long-term goals of the SVWP and inform the development of the Salinas River Habitat Conservation Plan.

The Flow Prescription contains a series of thresholds that define conditions suitable for adult South-Central California Coast steelhead trout (*Oncorhynchus mykiss*) (hereafter referred to as steelhead) upstream migration and juvenile and kelt outmigration as well as spawning and rearing below Nacimiento dam. Triggers based on reservoir storage, Salinas River Lagoon status (i.e., mouth open or closed to the ocean), and natural flow conditions in the Salinas River watershed and tributaries are used to determine the timing and magnitude of reservoir release actions to supplement natural flow conditions and enhance steelhead passage opportunities. The primary goal of the Flow Prescription is to ensure that SVWP operations do not result in a decrease in steelhead migration opportunities when compared to historical baseline conditions.

The Flow Prescription identifies migration targets (i.e., number of adult and juvenile steelhead passage days) for three normal water year categories based on historical conditions for each corresponding normal water year category. Water years are categorized as wet, normal, or dry based on unimpaired streamflow observed in the Arroyo Seco watershed. Normal year types are further broken down into wet-normal, normal, and dry-normal to help refine migration targets. Because wet years by their nature provide ample migration opportunities and because very few migration opportunities existed historically during dry years, passage day targets were only developed for normal category year types. Table ES-1 shows the water year type and the passage day target based on historical conditions for each of the first 10 years of SRDF operations. Because of natural variability, even among hydrologically similar years, the intent of the Flow Prescription is to meet passage day targets as an average across a 10-year operational period.

Table ES-1. Water Year Categories and Passage Day Targets for 2010-2019.

SRDF Operational Season	Year Type Calculated from USGS Streamflow	Passage Day Target Based on Historical Conditions
2010	Wet	N/A
2011	Wet-Normal	73
2012	Dry	N/A
2013	Dry-Normal	16
2014	Dry	N/A
2015	Dry	N/A
2016	Dry-Normal	16
2017	Wet	N/A
2018	Dry	N/A
2019	Wet	N/A

The first 10 years of operations under the Flow Prescription were predominately dry. Six of the first 10 years were classified as dry or dry-normal with extended drought conditions persisting from 2012 through 2016. The extended drought was the defining hydrologic factor during the 10-year evaluation period and limited both upstream and downstream steelhead migration opportunities.

The Agency complied with the terms of the Flow Prescription throughout the 10-year evaluation period. Over the first 10 years of operation, the Flow Prescription largely performed as intended. One of the goals of the Flow Prescription was to provide the median number of historical annual passage days in the lower Salinas River for each water year type, and all water year types combined, across a 10-year average, within a 10 percent variance. The Agency achieved adult upstream passage, on average across all water year types for the 10-year evaluation period, and for the wet-normal year (2011). It did not achieve adult upstream passage in the two dry-normal years. Adult passage in wet years and dry years were as expected in the Flow Prescription: precipitation during wet years provided enough water to enable substantial passage opportunities, whereas there were no passage opportunities during dry years. Smolt outmigration, as defined by the Flow Prescription, was achieved in five of the 10 years evaluated in this report.

The Agency is planning to use this analysis to inform its evaluation of the current Flow Prescription during the ongoing development of the Salinas River Habitat Conservation Plan. The Agency believes the existing Flow Prescription framework is a solid starting place, but it should be evaluated in the context of improved analytical tools, additional years of data, changing hydrologic conditions, and lessons learned from the historic drought conditions that occurred after the first 10-years of implementation. The Agency recommends evaluating the following:

- Stream depth and flow requirements for adult steelhead upstream passage

- Stream depth and flow requirements for juvenile steelhead outmigration
- Methodology for determining steelhead passage day targets
- Stream depth and flow requirements for spawning and rearing habitat
- Alternative migration pathways in and out of the Salinas River system

The evaluation of the first 10 years of SRDF operations under the Flow Prescription as defined by this report provides a starting point and guidance for further investigations into operational strategies for Agency projects and the analysis of project impacts to steelhead in the Salinas River watershed.

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Introduction

The Monterey County Water Resources Agency (Agency) is a flood control and water resources management agency whose mission and approach balances water supply, flood protection, and environmental sensitivity. The Agency owns and operates a range of flood control, water supply, groundwater augmentation, and hydroelectric facilities. The Agency manages flood and stormwater through its operations at the Nacimiento and San Antonio Dams, conserves such waters through percolation and storage, monitors groundwater extraction, and supports groundwater recharge of the Salinas Valley (Figure 1).

In 2002, the Agency Board of Directors certified the Final EIR/EIS and applied to the U.S. Army Corps of Engineers (Corps) for a permit to construct the Salinas Valley Water Project (SVWP). The SVWP consists of three components:

1. The Nacimiento Dam Spillway Modification.
2. Reoperation of Nacimiento and San Antonio reservoirs.
3. The Salinas River Diversion Facility (SRDF).

The Agency coordinated construction of the SVWP from 2008 through 2010. The project was the culmination of multiple decades of planning, engineering, and public involvement. The objectives of the SVWP are to:

- Halt seawater intrusion;
- Provide adequate water supplies to meet current and future (2030) water needs; and
- Improve the hydrologic balance of the Salinas Valley Groundwater Basin.

During the permitting process for the SVWP, the National Oceanic and Atmospheric Administration's National Marine Fisheries Service (NMFS) initiated a formal Endangered Species Act (ESA) Section 7 consultation with the Corps on the issuance of a permit for the SVWP. This consultation resulted in the Agency authoring the *Salinas Valley Water Project Flow Prescription for Steelhead Trout* (Flow Prescription) in 2005 and incorporating it into the project description. The Flow Prescription defines flow requirements and operational targets for managing South-Central California Coast steelhead trout (*Oncorhynchus mykiss*) (hereafter referred to as steelhead) in the Salinas River.

The Flow Prescription was developed in coordination with NMFS with the goal of providing steelhead migration opportunities within the lower Salinas River Basin from the Arroyo Seco and Nacimiento Rivers to Monterey Bay at similar frequency and magnitude as existed prior to the

SVWP. The timing and magnitude of prescribed flows is based on observations of steelhead behavior in nearby watersheds as well as the professional opinion of fisheries experts and NMFS. Reservoir releases made under the Flow Prescription for steelhead migration are designed to supplement or extend natural hydrologic events that might encourage migratory behavior in steelhead. Triggers were developed based on water year type, time of year, natural streamflow, reservoir storage, and other hydrologic conditions that help the Agency determine the appropriate actions and timing to meet the goals of the Flow Prescription.

The Flow Prescription was incorporated into the 2007 NMFS Biological Opinion (BO) which became the guiding document for reservoir releases during the course of Salinas Valley Water Project operations. Many of the provisions of the of the BO were later incorporated into the State of California Water Rights licenses and permits held by the Agency.

In a letter dated February 20, 2019, NMFS formally withdrew the 2007 BO and associated incidental take statement. The Agency continues to operate the SVWP under the terms of the BO that were incorporated into Water Rights licenses and permits until a long-term solution to incidental take coverage is developed.

Many of the goals of the Flow Prescription are based on achieving historical fish passage conditions over a 10-year period. The conclusion of the 2019 SRDF Operational Season marked the end of the first 10 years of SVWP operations under the Flow Prescription and BO. Even though the BO was withdrawn by NMFS before the first 10-years had been completed, the Agency opted to perform a review of the first 10 years of operations.

This report evaluates the effectiveness of the Flow Prescription to provide passage for adult and juvenile steelhead as well as the Agency's execution of the provisions in the Flow Prescription. The goal of this report is to provide a detailed accounting of Flow Prescription operations between 2010 and 2019 as a starting point for further discussions regarding reoperation of the Nacimiento and San Antonio Reservoirs to meet the long-term goals of the SVWP and inform the development of the Salinas River Habitat Conservation Plan.

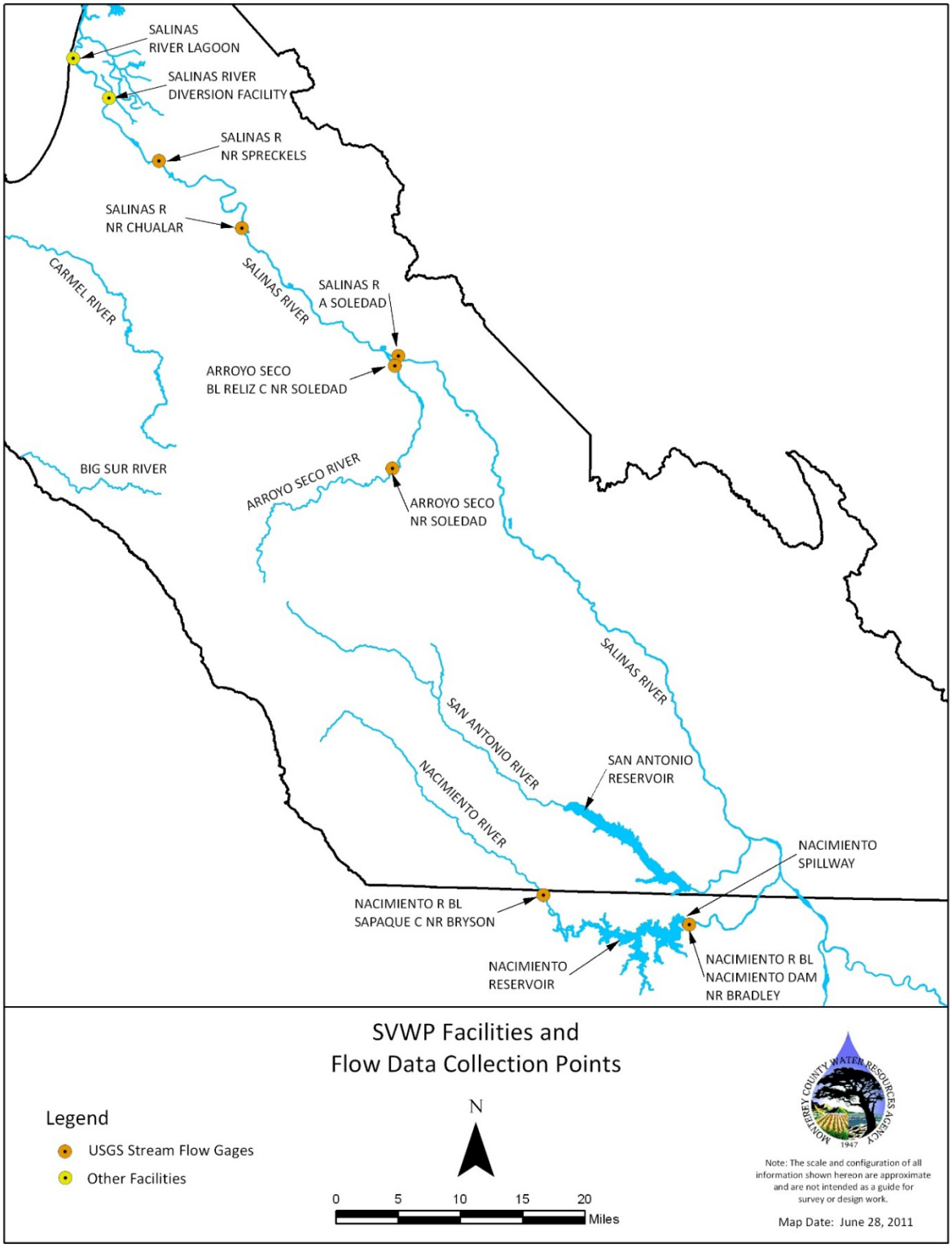

Figure 1. SVWP facilities and flow data collection points.

Background

The Agency has operated the SVWP in accordance with the 2005 Flow Prescription and 2007 BO since 2010 to facilitate up and downstream steelhead passage. This is accomplished by providing water releases from Nacimiento and San Antonio Dams based on water year conditions, water availability, and established hydrologic triggers at various locations within the basin. Flow Prescription actions are specific to adult and juvenile steelhead migratory life stages and were developed to provide conditions suitable for migration to the lower Salinas River basin including the Arroyo Seco, lower Nacimiento River, and Monterey Bay. Currently, the highest quality accessible habitat for steelhead spawning and rearing is in the Arroyo Seco River basin; releases from Nacimiento and San Antonio Reservoirs are designed to occur when the likelihood of providing passage opportunities to the Arroyo Seco River are high.

Salinas River Steelhead

Oncorhynchus mykiss are known for having a particularly diverse set of life history strategies, compared to other Pacific salmonids, exhibiting both resident, migratory, and anadromous forms. Anadromous variants, known as steelhead, migrate to the ocean as juveniles to mature whereas residents, known as rainbow trout, remain in freshwater for the entirety of their lives. Anadromous steelhead can produce resident offspring, just as resident rainbow trout can produce anadromous offspring, and the two life-history variants are known to interbreed. In general, South-Central California Coast steelhead rear in freshwater for one to three years before migrating to the ocean where they spend one to four years maturing before returning to spawn in freshwater (NMFS 2013). Juvenile migration to the ocean typically occurs in late winter and spring and adults return to freshwater and spawn between November and March. Eggs incubate within gravel redds from three to eight weeks depending upon water temperatures (NMFS 2013). Fry emerge from gravels between two and six weeks after hatchings. Steelhead, unlike salmon of the same genus (*Oncorhynchus*), are iteroparous, meaning that they can spawn more than once in their lifetime. Repeat spawning in the South-Central California Coast DPS has not been thoroughly investigated and its unknown how many individuals exhibit repeat spawning and how this may impact population dynamics (NMFS 2013).

Unique to the South-Central California Coast DPS is a steelhead life history type termed “lagoon-anadromous,” in which juveniles migrate downstream and over-summer in seasonal lagoons. As occurs at the mouth of the Salinas River, it is common for some river estuaries to become cut-off from the ocean during the summer by sandbars creating a seasonal lagoon and preventing lagoon-anadromous juveniles from completing their seaward migration (NMFS 2013). This life history strategy may give individuals an advantage as they grow larger before entering the ocean environment, when accessible, thereby increasing their likelihood of survival and probability of returning as adults to spawn. In some cases, presumably when the sandbar does not open and enable juveniles to enter the ocean, juveniles feed and grow in the estuary or lagoon before

migrating upstream to spawn. Expression of the "lagoon-anadromous" life history has been observed in the Salinas River during years when the estuary is blocked by a sandbar and disconnected from the ocean. Steelhead were observed migrating downstream to the lagoon where they spent several months before migrating upstream to freshwater (Cuthbert and Hellmair 2012, Hagar Environmental Science 2011). It is unclear how prominent the lagoon-anadromous or estuary life history strategy is in the Salinas Basin.

Steelhead are generally classified as winter or summer-run ecotypes depending on when they return to freshwater to spawn. Salinas River steelhead are winter run and generally migrate upstream between December and April and spawn shortly after (Stillwater Sciences 2020). This timing is dependent on environmental conditions such as hydraulic connectivity and water quality such as temperature. Specifically, fish must be able to pass the sandbar at the river's mouth and instream flows must be high enough for fish to reach spawning areas. Adult steelhead migration into the Salinas River is dependent on access and sufficient water in the Salinas River to accommodate upstream movement. It is common for a sandbar at the mouth of the lagoon to entirely block access to the Salinas River. The Agency manages lagoon connectivity to the ocean by grading or excavating a drainage channel across the beach and lowering the sandbar to facilitate a lagoon breach if lagoon water elevation, Salinas River flows, and rain conditions indicate that agricultural land or homes surrounding the lagoon are in imminent danger of flooding. The initial breach most frequently occurs in conjunction with winter storms between in December and January but can occur anytime between October and June. River flow may recede to low levels between storms and, depending on tide and wave conditions, the mouth may close again for periods of time with subsequent natural or artificial opening (Hagar Environmental Science 2015) (Figure 2).

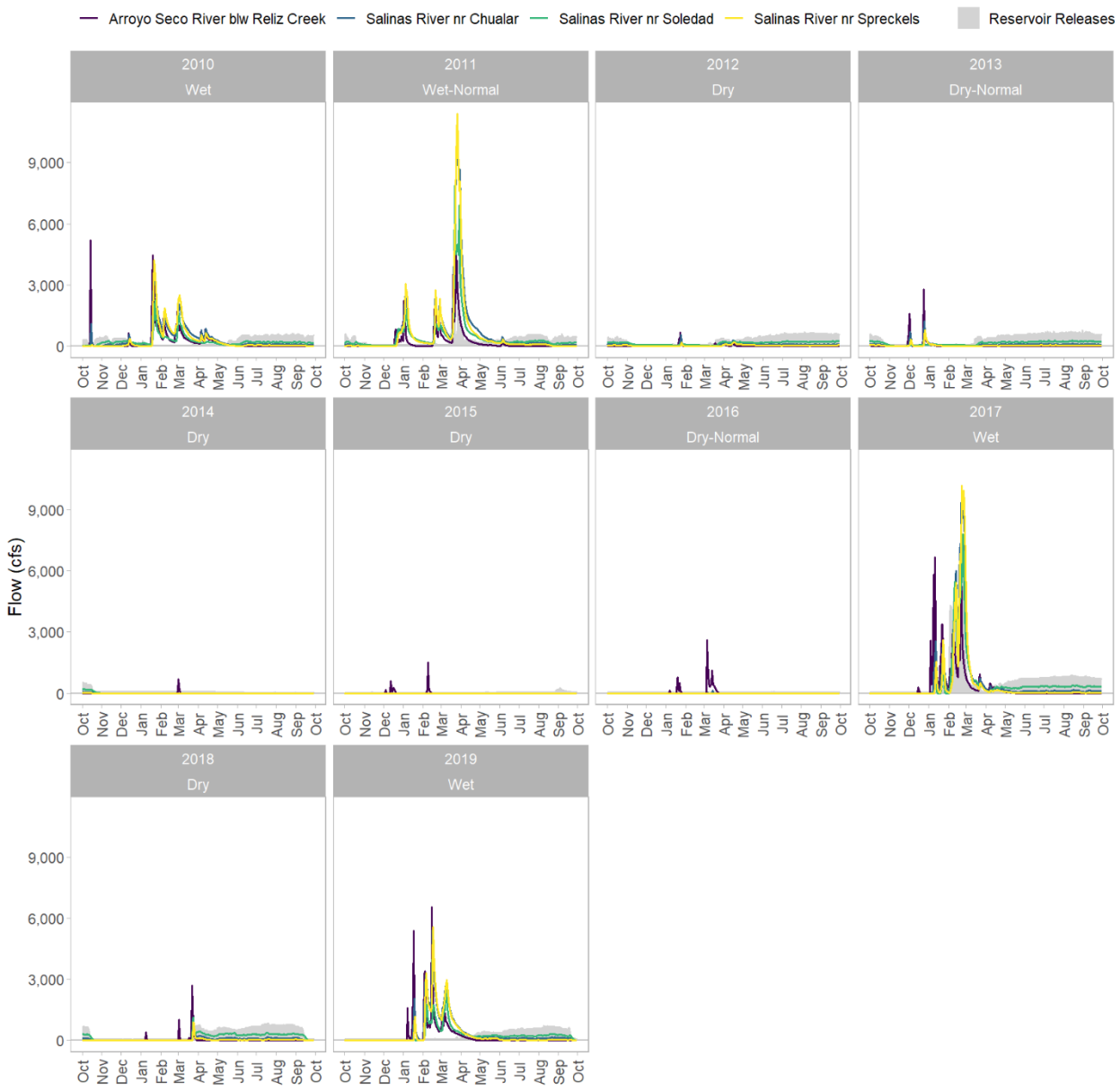

Figure 2. Stream flow summaries for selected flow monitoring locations in the Salinas River Basin. Reservoir releases are included as the grey shaded area. Water year type is indicated below the water year label in each panel.

Flow Prescription

Adult Steelhead Upstream Migration

The Flow Prescription defines adult steelhead upstream passage conditions as *"five or more consecutive days of a mean daily stream flow of at least 260 cfs as measured at the Salinas River*

near Chualar USGS stream gage, when the Salinas River Mouth at the Salinas River Lagoon is open to the ocean."

The period of adult steelhead upstream migration is defined as January 1 through March 31 and natural flows are augmented by releases from Nacimiento and San Antonio Reservoirs between February 1 and March 31 when the following conditions are met (Figure 3):

- Combined storage at Nacimiento and San Antonio Reservoirs is at least 220,000 acre-feet (AF);
- Flows on the Arroyo Seco River near Soledad (USGS stream gage 11152000) are greater than or equal to 340 cfs; and
- Flows on the Arroyo Seco River below Reliz Creek (USGS stream gage 11152050) are greater than 173 cfs.

Reservoir releases during the adult migration period are designed and operated to provide the median number of annual passage days in the lower Salinas River that occurred historically within a 10-percent variance and averaged over a 10-year period (Table 1). Specifically, the 2005 Flow Prescription and 2007 BO define the criteria needed to achieve adult upstream passage as "*on a 10-year average, the number of upstream passage days for the hydrologic year-type indicated in Table 1* [as shown in Table 1, below] *with a 10 percent variance*." The 2007 BO clarifies this achievement criteria by providing the following example "*e.g., the average number of passage days for all of the dry normal years within a 10-year period would be at least 14* [i.e., 14 days, rather than 16 days, to account for a 10 percent variance]." To further clarify, the Agency aims to provide the average number of historical annual passage days in the lower Salinas River for each water year type, and all water year types combined, across a 10-year period, with a 10 percent variance.

During dry and dry-normal years augmentation from reservoir releases may be necessary to meet passage requirements, although historically little or no adult upstream passage occurred during dry years. As such, during dry years zero passage days are required. During normal water years natural flows may be sufficient to meet passage requirements and reservoir augmentation may not be necessary. During wet and wet-normal years, natural flow conditions are typically sufficient to provide ample passage opportunities without additional reservoir augmentation.

Finally, for adult passage to occur, the Salinas Lagoon must be open to the ocean during the migration period. According to the Flow Prescription, the Salinas River lagoon is expected to remain open and accessible to migrating adult steelhead when sustained flow at the Salinas River near Spreckels USGS stream gage is between 80 and 150 cfs.

Table 1. Upstream adult migration historical passage days at Salinas River near Spreckels USGS Stream Flow Gage (1949-1994) (sources, 2005 Flow Prescription and 2007 BO).

Water Year Type	Median Number of Historical Upstream Passage Days, Jan 1 – Mar 31 (*±10%)*
Dry	0
Dry-Normal	16 (*2*)
Normal	47 (*5*)
Wet-Normal	73 (*7*)
Wet	0
All year types	27 (*3*)

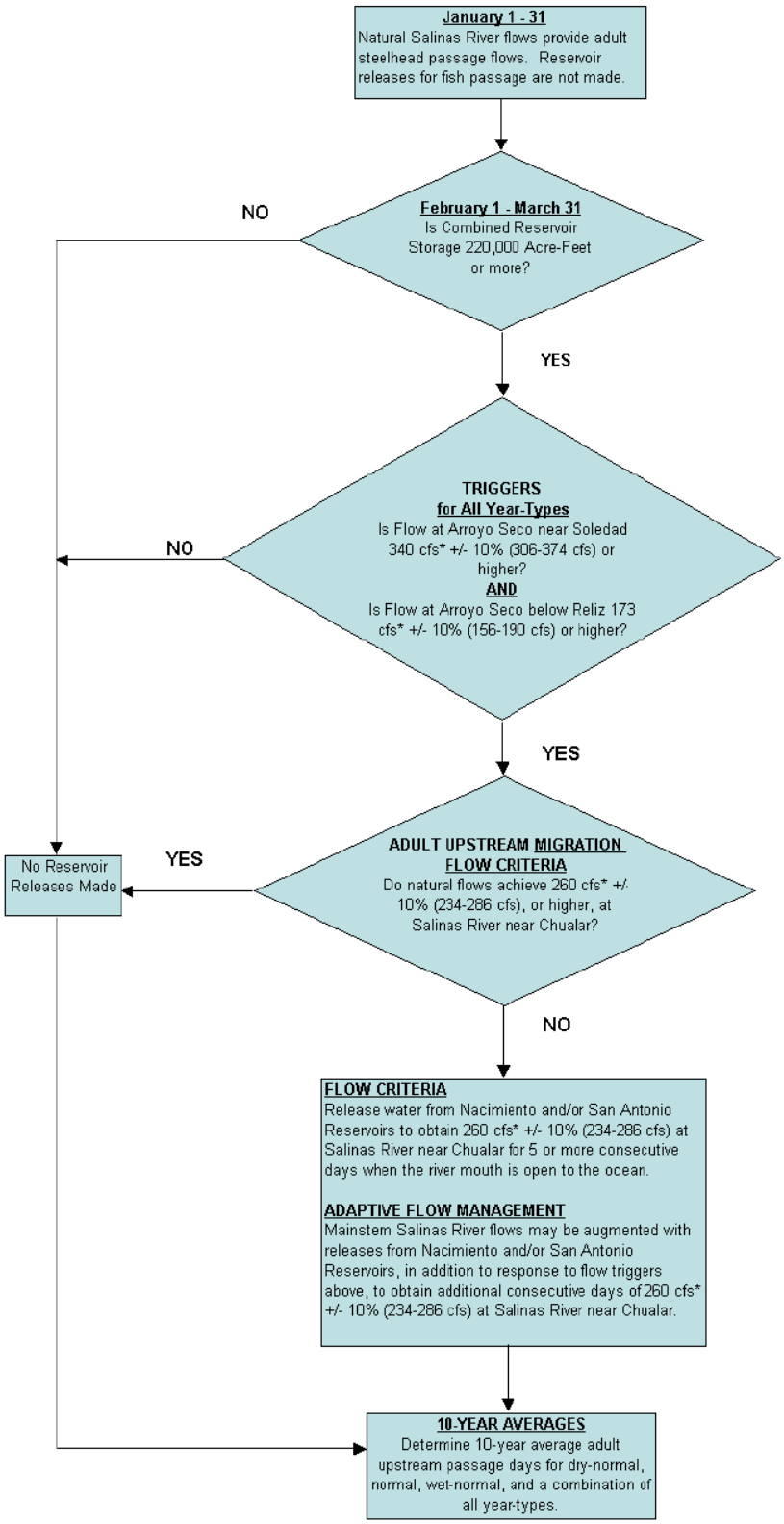

Figure 3. Adult upstream migration flow triggers. Figure from the 2005 Flow Prescription.

Steelhead Smolt Downstream Migration

Flow augmentation for steelhead smolt downstream migration as described in the Flow Prescription would occur between April 1 and May 15 (Figure 4). The majority of smolts are expected to migrate from the Arroyo Seco River with a small proportion originating from the Nacimiento River. This timing was determined based on migration timing observed in other Central California Coast streams. A precise relationship between stream flow levels and smolt downstream migration has not been determined for the Arroyo Seco and Salinas Rivers. For the Arroyo Seco, flow must reach the Salinas River mainstem during the migration period for smolts to migrate successfully. For the Salinas River it is estimated that meeting the minimum upstream migration threshold of 150 cfs at the Salinas River near Spreckels USGS stream gage, which correlates to 260 cfs at the Salinas River near Chualar, would provide suitable passage conditions for smolts migrating to the ocean. Analysis of historical data show that during the peak outmigration period, when flow at the USGS stream gage on the Arroyo Seco below Reliz Creek near Soledad is 1 cfs or more, flow at the USGS stream gage on the Salinas River near Spreckels is expected to exceed 148 cfs 95% of the time during normal year-types. Therefore, the minimum flow requirements for steelhead smolt outmigration have been identified in the Flow Prescription as 1 cfs or more at the USGS stream gage Arroyo Seco below Reliz Creek near Soledad and 150 cfs or more at the USGS stream gage Salinas River near Spreckels. During normal year types, flow augmentation in the form of block flows would occur if certain conditions are met.

Block Flow

To facilitate the downstream migration of smolts and rearing juvenile steelhead in the Salinas River during normal category water years (dry-normal, normal, and wet-normal) the Agency provides block flow releases when the following triggers are met between March 15th and May 31st of each normal year (Figure 5):

- Combined storage in Nacimiento and San Antonio reservoirs is 150,000 AF or more on March 15th, and
- Flow of 125 cfs or higher at the USGS stream gage Nacimiento River below Sapaque Creek near Bryson; **or**,
- Flow of 70 cfs or higher at the USGS stream gage Arroyo Seco below Reliz Creek near Soledad.

If triggered, a block flow would require a mean daily stream flow greater than or equal to 700 cfs at the USGS stream gage Salinas River at Soledad for five consecutive days, followed by an additional 20 to 40 days of a mean daily stream flow greater than or equal to 300 cfs at the USGS stream gage Salinas River near Spreckels. Block flows are not required during dry or wet years because not enough water is available or natural flows are sufficient to provide passage conditions for smolts, respectively.

During the development of the Flow Prescription, the Salinas Valley Integrated Ground and Surface Water Model (SVIGSM) was used to evaluate the effectiveness of Flow Prescription operations with the goal of maintaining historical levels of fish migration opportunities. A combination of an SVIGSM simulation between 1949 and 1994 and the application of block flow triggers to the historical record between 1995 and 2005 resulted in normal category years occurring in 26 of 57 years or 46% of the period of record (Table 2). Block Flow conditions were met in 18 of 26 or 69% of normal category years. It should also be noted that the SVIGSM simulation period of 1985 – 1994 which included the drought period between 1987 and 1991 contained only one normal category year and no Block Flow triggers.

The modeled occurrence of normal category years and block flow triggers showed significant differences for 10-year simulation periods between 1949 and 1994 as well as the historical period of 1995-2005 representing the wide range of climate variability experienced in the Salinas River watershed (Table 2). The historical period from 1995 to 2005 was one of the wettest periods on record with large flooding events occurring in both 1995 and 1998. Every year during that 11-year period was categorized as a wet or normal year type. During the 1949-1994 simulation period, the occurrence of normal category years ranged between 1 and 6 within 10-year simulation periods and block flow occurrence ranged between 0 and 4 within the same periods. The conditions experienced during the current study period between 2010 and 2019 do not stand out as anomalous when compared to the 1949-1994 simulation period.

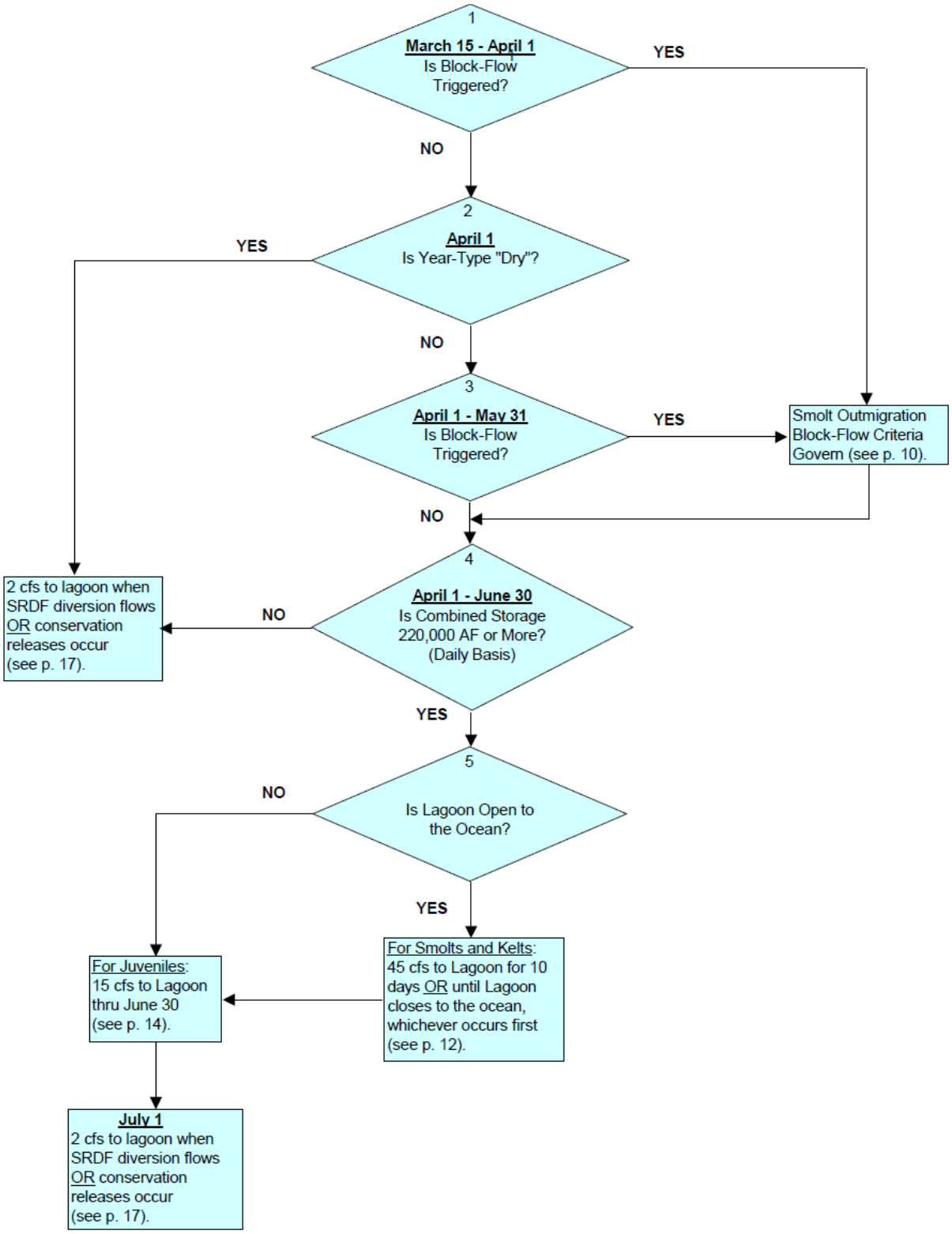

Figure 4. Smolt downstream migration flow triggers. Figure from the 2005 Flow Prescription.

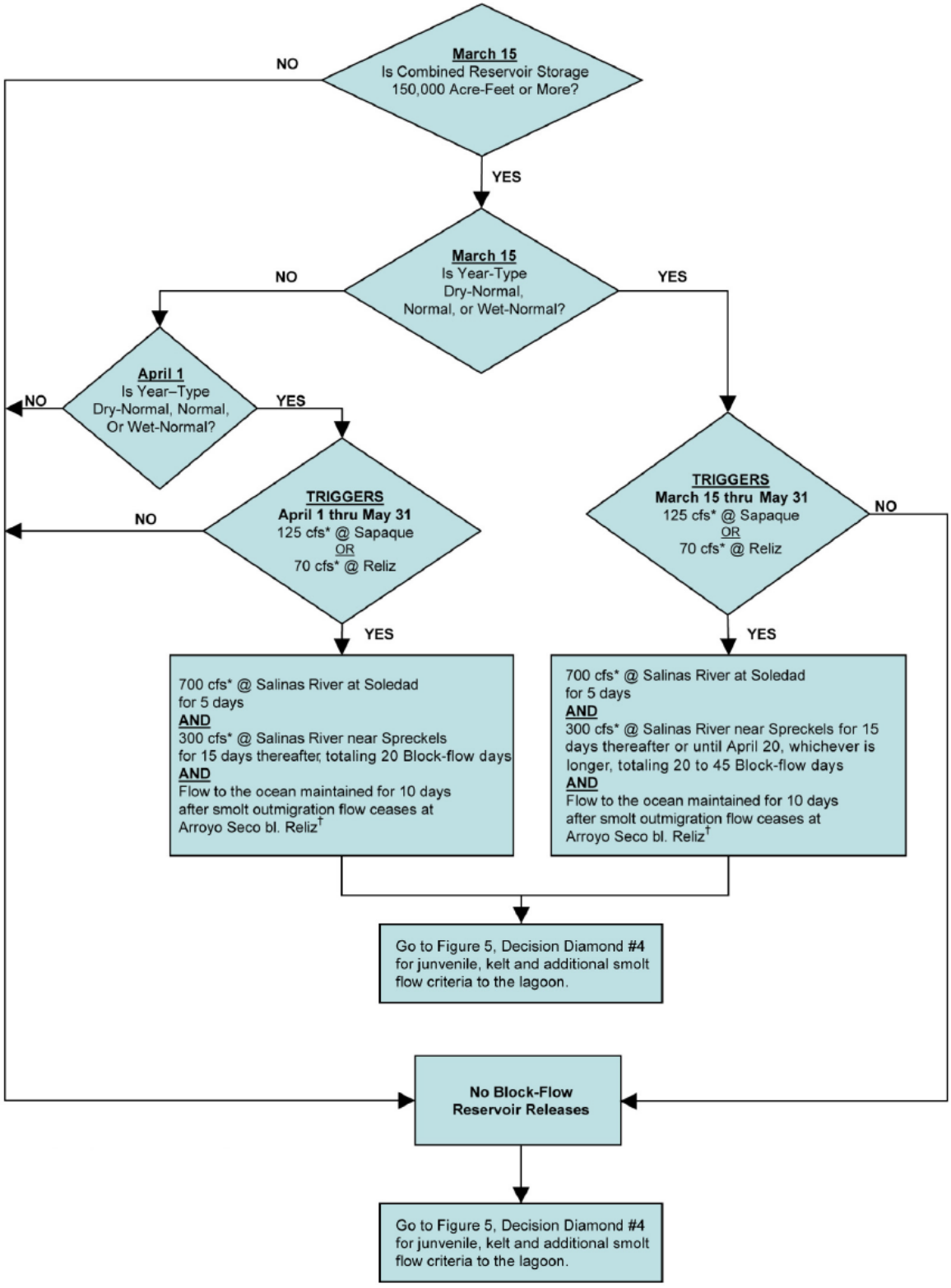

Figure 5. Smolt outmigration block flow triggers. Figure from the 2005 Flow Prescription.

Table 2. Modeled and historical occurrence of smolt outmigration block-flow triggers from the 2005 Flow Prescription.

Period	No. of Normal-Category Years	No. of Years Block Flow Occurred	Percent of Normal-Category Years when Block Flow Occurred	Comments
1949-1994	**18**	**12**	**67%**	*SVIGSM Simulation - 46 year period*
1995-2005	**8**	**6**	**75%**	**Application of Triggers to Historical Record**
1949-2005	**26**	**18**	**69%**	**Combination of Rows 1 and 2 above**
1949-1958	6	3	50%	SVIGSM Simulation - 10-year period
1959-1968	4	3	75%	SVIGSM Simulation - 10-year period
1949-1968	10	6	60%	SVIGSM Simulation - 20-year period
1969-1978	4	4	100%	SVIGSM Simulation - 10-year period
1959-1978	8	7	88%	SVIGSM Simulation - 20-year period
1949-1978	14	10	71%	SVIGSM Simulation - 30-year period
1979-1988	3	2	67%	SVIGSM Simulation - 10 year period
1969-1988	7	6	86%	SVIGSM Simulation - 20-year period
1959-1988	11	9	82%	SVIGSM Simulation - 30 year period
1949-1988	17	12	71%	SVIGSM Simulation - 40-year period
1985-1994	1	0	0%	SVIGSM Simulation - Last 10-year period of model

Methods

Year Type Category Determination

Flow Prescription actions are designed to mimic historical migration opportunities based on water year type. Therefore, it was necessary to develop a method to categorize years by hydrologic conditions for comparison. The following process is used to categorize years by hydrologic conditions to determine a year type and to help guide operational actions and targets for fish migration. Year type for a given water year (WY) is determined based on the exceedance probability of the mean stream flow for the water year in cubic feet per second (cfs) at the USGS *Arroyo Seco near Soledad* stream gage (Figure 1).

To calculate year type category boundaries, mean annual flow is calculated for each year of approved USGS streamflow data. The mean annual flows are ranked in descending order and plotting positions are assigned to each year. Streamflow values corresponding to the 25th, and

75th percentile are the boundaries between wet, normal, and dry categories (Figure 6). Normal year types are then subcategorized into wet-normal, normal, and dry-normal categories. The normal water year sub-categories are used to evaluate adult steelhead upstream passage opportunities over a 10-year average.

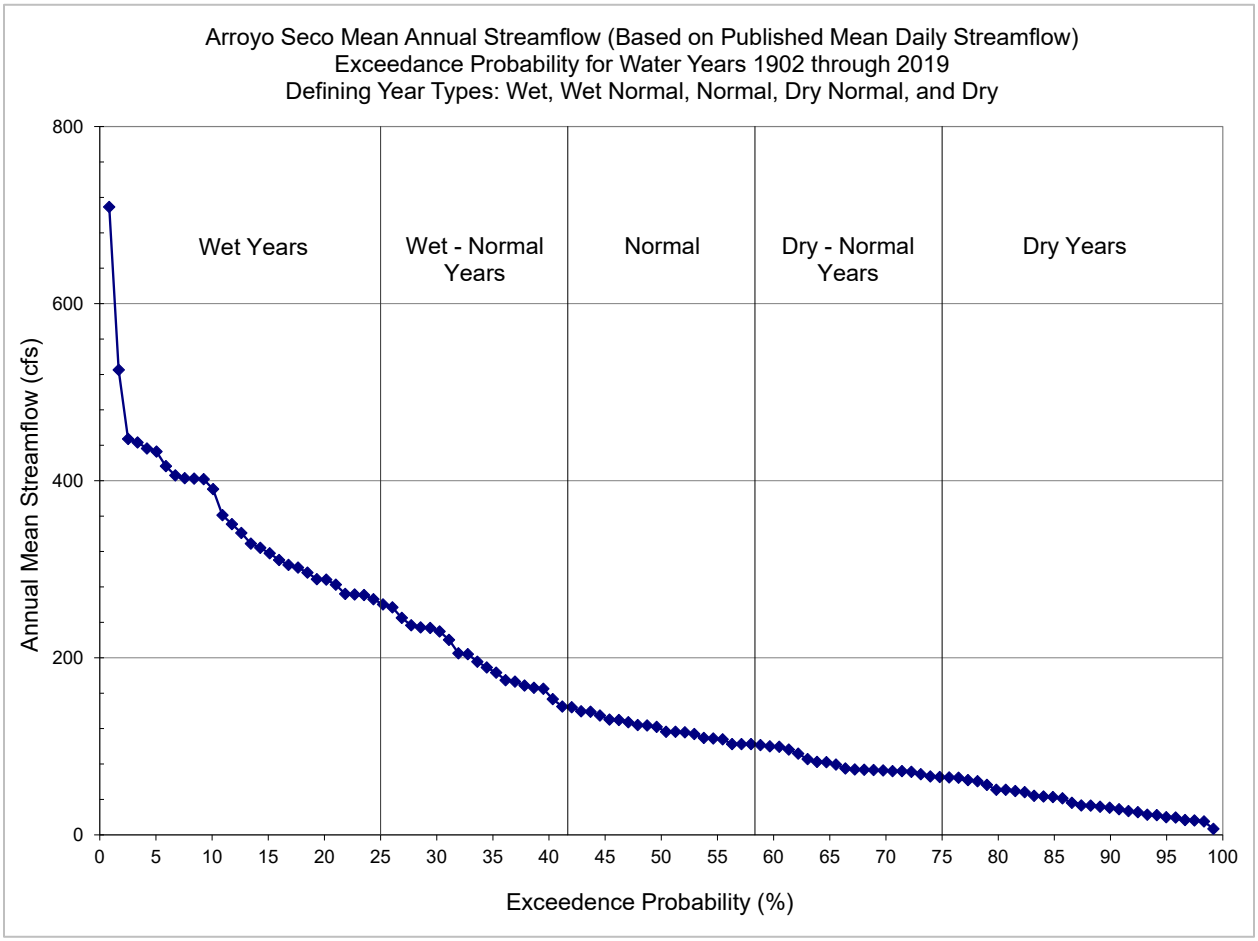

Figure 6. Exceedance probability of mean annual streamflow and year type boundaries.

Year Type Forecast

Water year types are used to determine operational actions and evaluate steelhead migration opportunities relative to historical years with similar hydrologic conditions. In accordance with the Flow Prescription, year type determinations have been made each year since 2010 to determine the activation of triggers for block-flow releases for smolt outmigration. Because year type is a trigger for some operational actions, it must be determined early enough in the water year to guide those actions during optimal steelhead migration periods. This requires making a year type forecast prior to the end of the rainy season. Year type forecasts are prepared on March 15th and April 1st of each water year with the goal of accurately predicting the current year type

classification. To forecast the year type, a mean annual streamflow average is calculated to each forecast date and a forecast factor is applied to adjust the partial year mean to represent the entire water year. The result is a forecast mean annual flow and associated year type for the water year.

The accuracy of this forecast methodology was tested by comparing year type forecasts to the approved period of record of mean daily streamflow at the Arroyo Seco near Soledad USGS stream gage. Mean annual flow forecasts were calculated for the entire period of record, 1902-2019. Forecasts for years prior to the operation of the SVWP were calculated using approved streamflow data through March 14th of each year to generate a March 15th forecast and through March 31st of each year to generate an April 1st forecast. Calculated mean annual flows for the forecast dates were applied to the 2010 year type categories to determine a wet, normal, or dry year type. Forecasts spanning the SVWP period under review (2010-2021) were original calculations made each operational season using available provisional streamflow data which was subsequently compared to approved streamflow data spanning the entire water year. Water year classifications (wet, normal, dry) were assigned for March 15th, April 1st, and the complete water year.

Cumulative Adult and Juvenile Passage Opportunities

To evaluate the effectiveness of the Flow Prescription in providing adult and smolt steelhead passage opportunities, the average number of fish passage days needed to evaluate achievement criterion for the 10-year period was calculated as described in the 2005 Flow Prescription and 2007 BO and the number of passage days achieved was calculated according to the criteria described in the previous sections. Detailed summary statistics and plots were produced for each year during the period under review and compared to trends across water year types. Calculations were made to determine the number of days during each operational year, across water year type categories; the number of days flows and reservoir storage exceed established thresholds; the number of days the lagoon was open and accessible to up and downstream migrants; how long the Arroyo Seco River was connected to the ocean during each migration window; and, if reservoir releases were made to augment migration. The data were examined to determine if additional passage days were achieved outside of the Flow Prescription migration periods. Finally, fish monitoring data collected during the study period were reviewed to provide perspective on passage conditions in addition to meeting the Flow Prescription criteria.

Results

Year Type Forecasts

Actual calculated year type boundaries that directly affect operations have shown little change from year to year, despite of a wide range of mean annual flow values (Figure 7). This is likely due in part to the large sample size of mean annual flow values used in the calculations; Arroyo Seco near Soledad streamflow records date back to 1902. Between 2010 and 2019, the flow value boundary separating wet and normal year types varied by 3 cfs (257 cfs to 260 cfs) while the flow value boundary demarcating dry and normal year types varied by 4 cfs (65 cfs to 69 cfs). The methodology used to predict water year types was accurate 86% and 89% on March 15 and April 1, respectively, for water years 1902 to 2019 (Figure 8 and Figure 9)(Table B - 1).

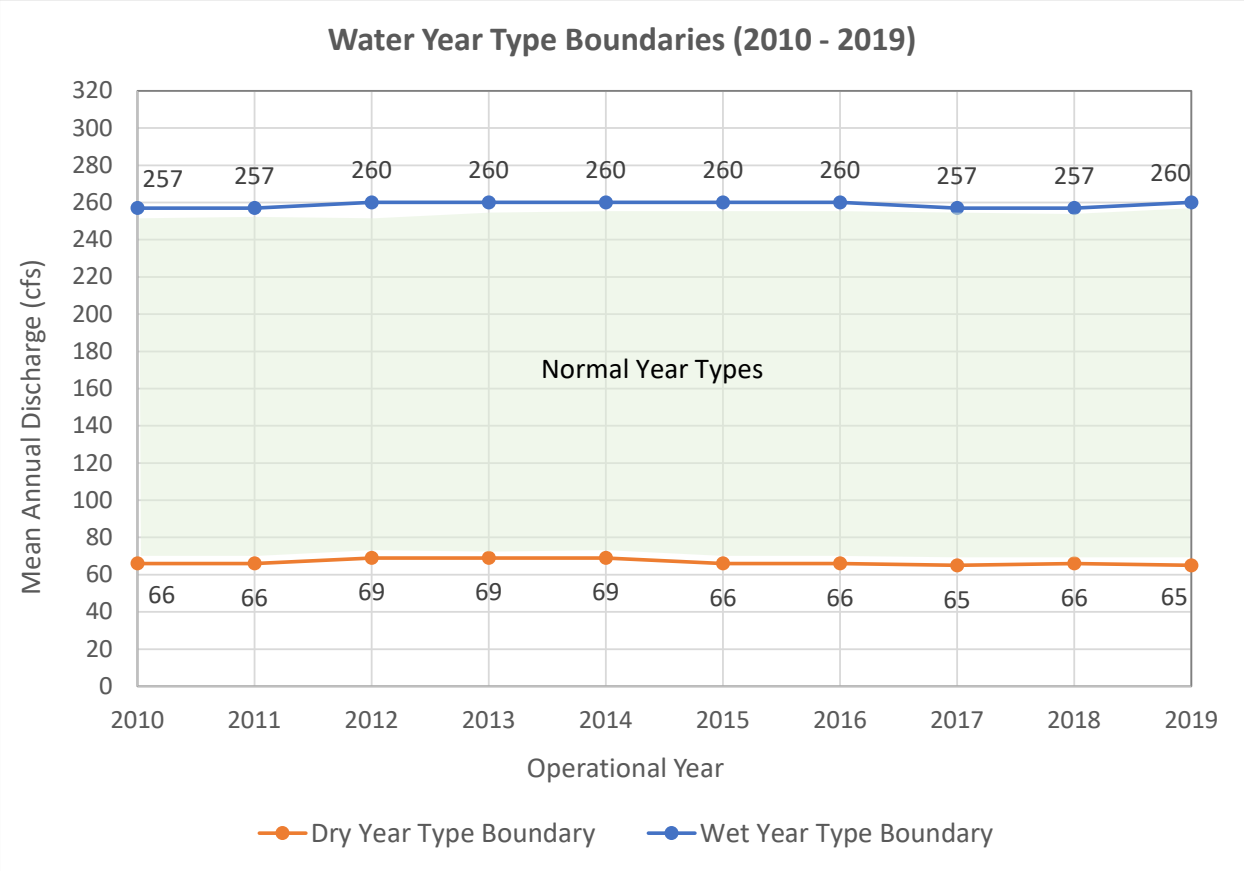

Figure 7. Water year type boundaries 2010-2019.

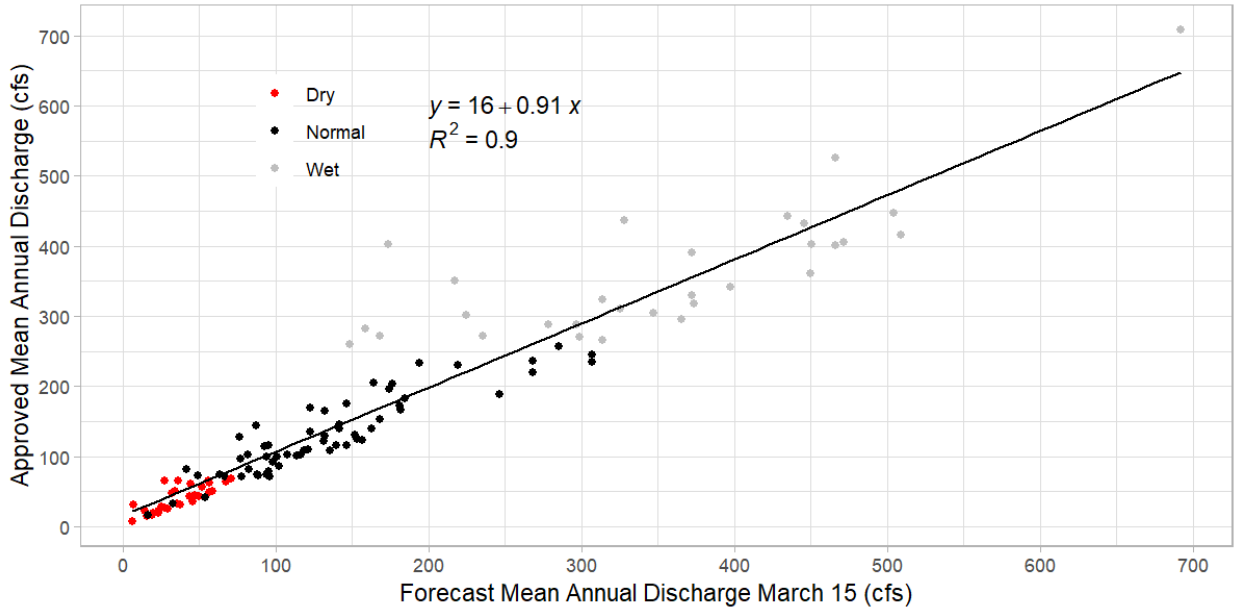

Figure 8. Relationship between forecasted mean annual discharge on March 15 and approved mean annual discharge from 1902 to 2019. Water year types are indicated by color and a linear trend line; fitted linear equation and R^2 value are also provided.

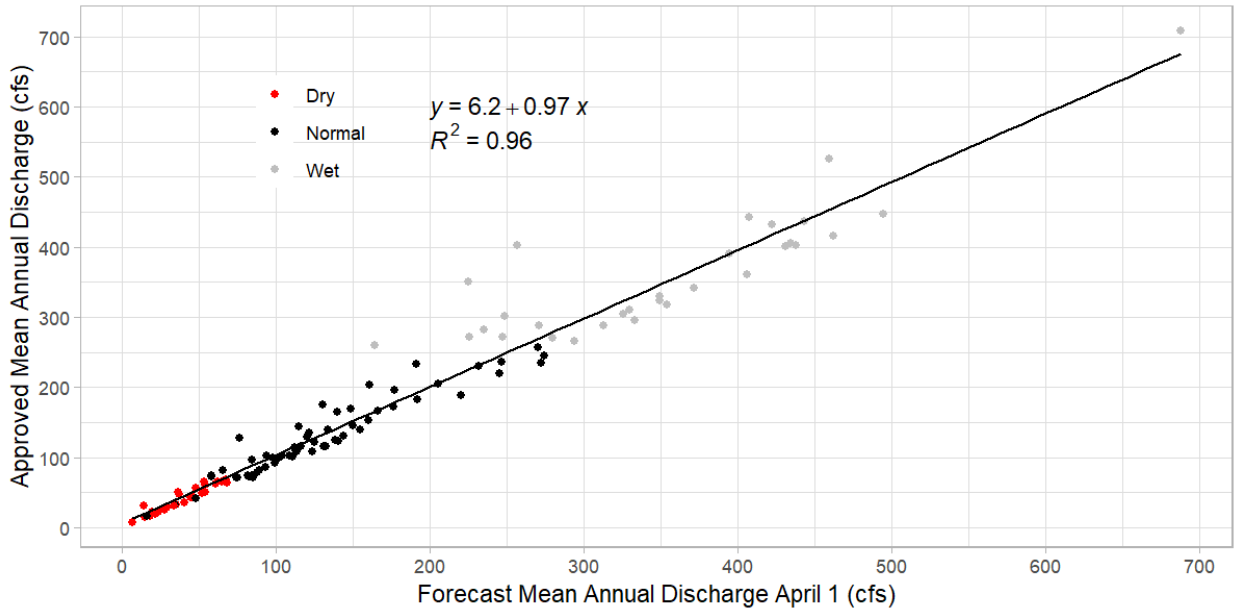

Figure 9. Relationship between forecasted mean annual discharge on April 1 and approved mean annual discharge from 1902 to 2019. Water year types are indicated by color and a linear trend line; fitted linear equation and R^2 value are also provided.

Flow Forecasts

Over the first ten years of SVWP operation (2010-2019) year type forecasts made on March 15th and April 1st accurately forecasted the year type in 90% of years (Appendix B). There was one year (2011) in which the observed mean annual discharge based on approved USGS streamflow data indicated a year type that differed from the forecasts. Both the March 15th and April 1st forecasts predicted a wet-normal year type while the observed mean annual flow resulted in a wet year type classification. A series of late storms in the spring of 2011 resulted in the higher-than-forecast mean annual flow that exceeded the wet year type threshold. Operationally 2011 was treated as a wet-normal year type, resulting in the activation of triggers requiring block flow releases for smolt outmigration. Forecast year types for all other water years during the ten-year period of review agreed with year types based on observed streamflow data spanning the entire water year.

Between water years 2010 and 2019 three years were classified as wet years (2010, 2017 and 2019), four were classified as dry years (2012, 2014, 2015, and 2018), one was classified as wet-normal (2011), and two were classified as dry-normal years (2013 and 2016) (Table 3).

Table 3. Adult steelhead upstream passage days by operational season.

Water Year	Type	Passage Days Required	Days Lagoon was Open	Days Flow at Chualar >= 260 cfs	Total Passage Days	Reservoir Releases Made to Augment Natural Flows
2010	Wet	N/A	70	72	70	No
2011	Wet-Normal	73	90	70	70	No
2012	Dry	N/A	0	1	0	No
2013	Dry-Normal	16	27	0	0	No
2014	Dry	N/A	0	0	0	No
2015	Dry	N/A	0	0	0	No
2016	Dry-Normal	16	0	0	0	No
2017	Wet	N/A	79	75	72	Yes*
2018	Dry	N/A	7	4	0	Yes
2019	Wet	N/A	72	63	61	No

* Reservoir releases in 2017 were done in response to rising reservoir levels and flood concerns.

Evaluation of Steelhead Passage Opportunities (2010 – 2019)

The following section includes an evaluation of how and when flow augmentation was performed over the 10-year period to support adult and smolt steelhead migration in the Salinas River basin and an assessment of adult upstream passage. Discussion of steelhead passage is organized by life stage (adult upstream, kelt and juvenile downstream) by water year type because the type of water year affects adult and juvenile passage and how the Agency augments flows under the Flow Prescription. This document is focused on the Flow Prescription components related to steelhead migration and reservoir operations. Additional parameters are discussed in the annual Flow Monitoring Reports which are available on the Agency web site.

Adult Steelhead Upstream Migration

Dry Water Years

Water years 2012, 2014, 2015, and 2018 were classified as dry and did not provide passage for adults as defined in the Flow Prescription (Figure 10). Except for 2018, flow augmentation did not occur during dry years because triggers were not met due to a combination of low flows, low reservoir storage, and the lagoon only opening briefly (Figure 10 and Figure 11). During the entire 2014 and 2015 operational periods the lagoon never opened and flows at Chualar were at or near zero.

During dry years, instream flows on the Arroyo Seco are restricted to short periods driven exclusively by rainfall (Figure 11). In 2014 and 2015, small pulses in flow were observed on the Arroyo Seco that did not reach the Salinas River. Similarly, releases from Nacimiento and San Antonio Reservoirs did not reach Chualar in 2014 and 2015 (Figure 12).

During the four dry water years, the Arroyo Seco River was connected to the ocean during the upstream migration period for a total of 15 days, seven occurred during the 2018 adult migration period (Table 4). This reveals that under dry conditions it is exceedingly difficult to maintain connectivity between the Arroyo Seco River and the ocean due to lagoon accessibility and water availability. Excessive amounts of water would need to be released during dry years to ensure the Arroyo Seco River remains connected to the ocean and adult fish are able to reach spawning habitats in the upper basin. Moreover, the flow events that occurred on the Arroyo Seco River in 2014 and 2015 were so short lived that providing additional flows in the mainstem Salinas River to connect the system to the ocean would have benefited upstream passage minimally for a very short period.

Small peak flow events may provide brief opportunities for adult upstream passage, such as those that occurred in 2012 and 2018. For example, between April 14 and April 18, 2012, the lagoon opened for 22 days, flows averaged 254 cfs at Chualar, and exceeded 250 cfs for four days peaking at 270 cfs on April 14. Adult steelhead were observed at the Salinas River Wier from January 26

through the end of March when the survey period ended (Cuthbert and Hellmair 2012) (Figure 13). Given that the lagoon was not connected to the ocean prior to the April flow event, adult steelhead could have taken advantage of the open lagoon and flow conditions to migrate upstream in April, although this is at the end of their known migration period. Furthermore, because the lagoon was not open before mid-April, adult steelhead observed at the Salinas River Wier between January and March may have passed from the ocean into the lagoon from the Old Salinas River channel or may have been present in the lagoon since moving downstream as juveniles (i.e., lagoon anadromous).

A similar flow pattern occurred in 2018. Flows at Chualar were near zero between November and mid-March and the lagoon remained closed. However, between March 23 and March 26, flows averaged 805 cfs before declining below 260 cfs on March 27. Because of these pulse flows, the lagoon was open from March 25 to April 21, creating opportunities for adults to move up the system from the ocean. With the opening of the Salinas River Lagoon on March 25, the triggers for making adult steelhead upstream passage releases were met. Releases were made from Nacimiento Reservoir to augment natural flows in support of adult steelhead upstream migration between March 25, 2018, and March 31, 2018. The release action provided contiguous flow to the ocean but reservoir releases peaking as high as 750 cfs fell short of the adult steelhead upstream passage goal of 260 cfs at the Salinas River near Chualar for five or more consecutive days. No passage days (as defined by the Flow Prescription) were counted although passage opportunities existed through much of April.

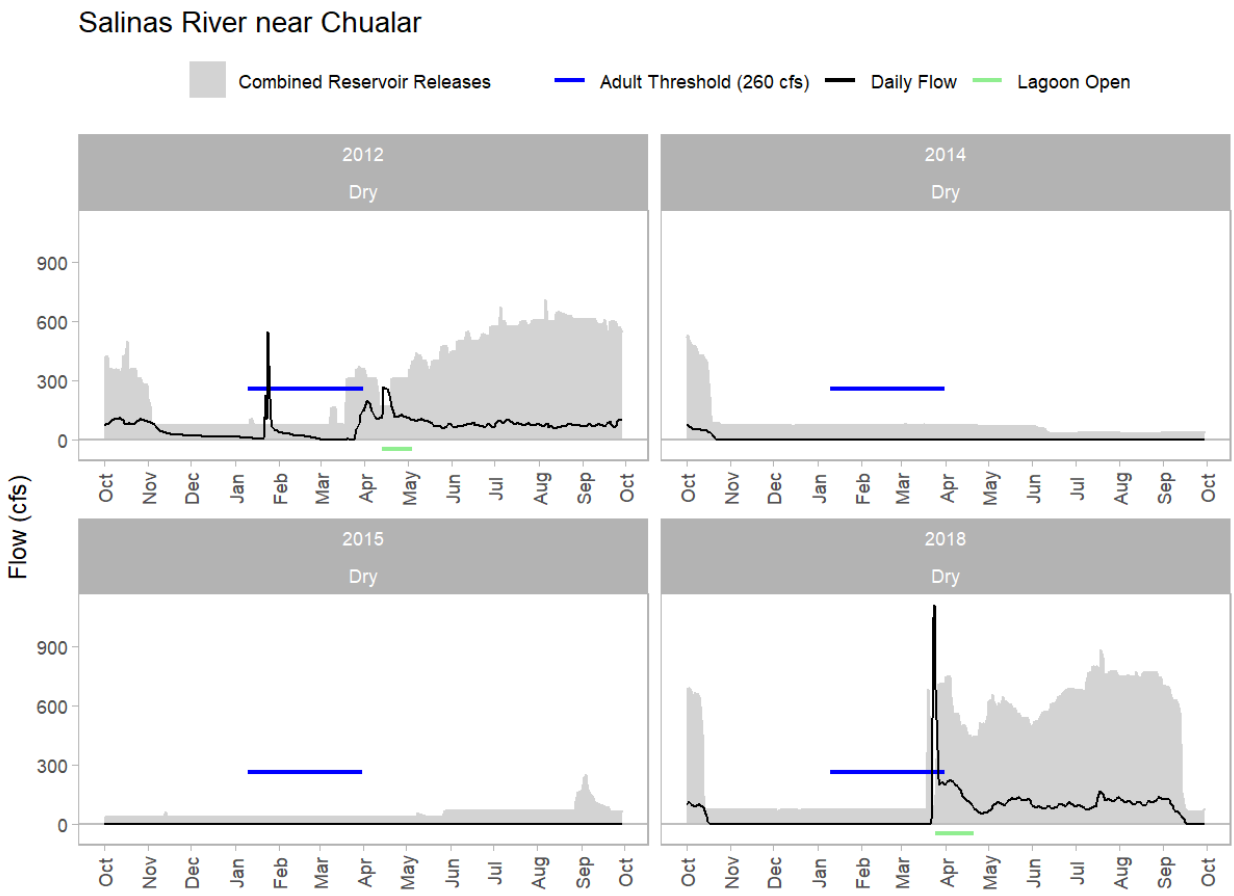

Figure 10. Mean daily flow (black line) conditions on the Salinas River near Chualar during dry water years. Combined reservoir releases are indicated in grey, the adult passage threshold is indicated by the blue horizontal line, and the green line below the x-axis indicates when the Salinas Lagoon was open to the ocean.

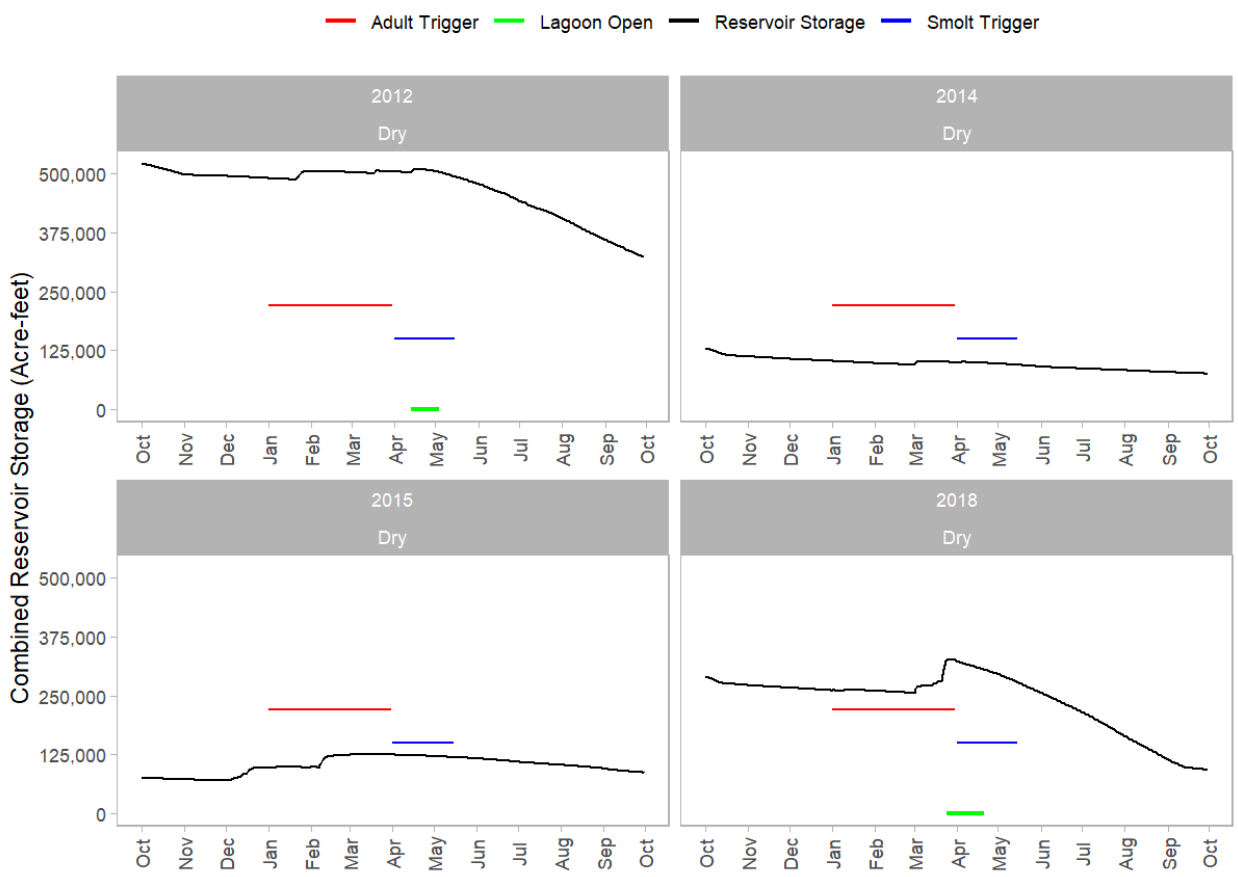

Figure 11. Combined Nacimiento and San Antonio reservoir storage during dry water years. The green line below the x-axis indicates when the lagoon was open. The horizontal red and blue lines indicate storage levels required to trigger adult and smolt flow augmentation, respectively. Minimum reservoir storage is one of three triggers required for flow augmentation (*see* Background Section and Figures 2, 3, and 4). Triggers to release water were met in 2018.

Figure 12. Mean daily flow (black line) conditions on the Arroyo Seco River below Reliz Creek during dry water years. The adult flow threshold is indicated by the blue horizontal line and the green line below the x-axis indicates when the Salinas Lagoon was open to the ocean.

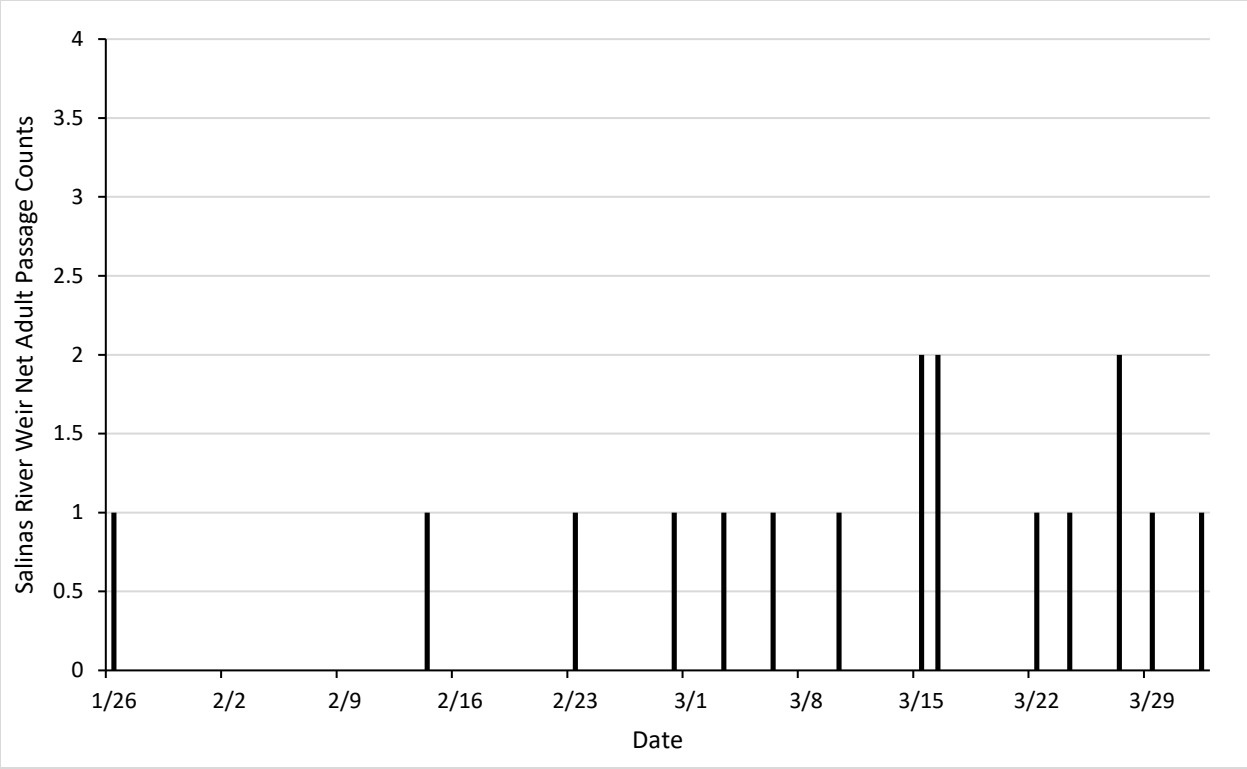

Figure 13. Daily net counts of adult steelhead sampled at the Salinas River weir near river mile 2.75 during the 2012 water year. Data are from Cuthbert and Hellmair (2012)

Table 4. Consecutive days the Arroyo Seco River and reservoir flow was hydraulically connected to the ocean during the adult steelhead migration period (January 1 – March 31).

Water Year	Water Type	Days Arroyo Seco was Connected to the Ocean During Adult Migration Period	Days Reservoir Flow was Connected to the Ocean During Adult Migration Period
2010	Wet	70	70
2011	Wet-Normal	69	90
2012	Dry	0	0
2013	Dry-Normal	16	27
2014	Dry	0	0
2015	Dry	0	0
2016	Dry-Normal	0	0
2017	Wet	79	66
2018	Dry	7	7
2019	Wet	64	60

Dry-Normal Water Years

Water years 2013 and 2016 were classified as dry-normal and did not provide any passage opportunities as defined in the Flow Prescription (Figure 14). Flow augmentation did not occur during these years because triggers were not met due to a combination of low flows (2013 and 2016), low reservoir storage (2016), and the lagoon only briefly opening (2013) (Figure 14 and Figure 15); reservoir storage in 2013 met adult triggers, but the other triggers for flow augmentation were not met (e.g., Arroyo Seco River flows). In 2013, however, passage was possible and likely in late December, preceding the adult migration period (January 1 – March 31), due to a winter storm event. On December 23, flows at Chualar increased from near zero to 113 cfs and peaked on December 25 at 1,220 cfs. The lagoon opened on December 26 following this flow event and remained open until January 27. Flows at Chualar dropped below 260 cfs on December 30, two days before the adult migration period. Flows exceeded 260 cfs while the lagoon was open for four days before dropping to 252 cfs on day five. These conditions did not count toward adult passage days as they occurred prior to the established migration period. Releases were not triggered, because the adult migration triggers were met before the migration period, as defined by the Flow Prescription, began.

A similar, but slightly smaller, storm event occurred earlier in December that opened the lagoon for 17 days from December 4 to 20. Flows were not nearly as high but provided conditions in which adults could access the lagoon and lower river for a brief period. Monitoring at the Salinas River weir confirmed that these conditions resulted in adult steelhead passage to the lower Salinas River (Figure 16). Data from the weir indicate that adults moved into the lagoon while it was open but waited to move upstream until later in the winter (Cuthbert et al. 2013). Moreover, 20 adults were sampled at the weir in February approximately two weeks after the lagoon was no longer accessible. During this period, flows near Spreckels averaged less than 4 cfs and at Chualar flows were about 30 cfs on average. These data suggest that adults migrate opportunistically after significant pulses of water open the lagoon. Furthermore, monitoring data at the Salinas River weir suggest that adults may hold in the lagoon for extended periods before moving up the lower Salinas River (Cuthbert et al. 2013). Some of these fish may also be lagoon anadromous meaning they grow and mature in the Salinas River lagoon without migrating to the ocean before migrating upstream to spawn.

Flow conditions observed on the Arroyo Seco River were nearly identical to those observed on the Salinas River at Chualar (Figure 17). During dry-normal years, the Arroyo Seco River was only connected to the ocean in 2013 when it was connected for 22 consecutive days (Table 4), which is only slightly higher relative to dry year conditions. This highlights the difficulty in providing adequate flow to sustain connectivity between the ocean and the Arroyo Seco River even during dry-normal years.

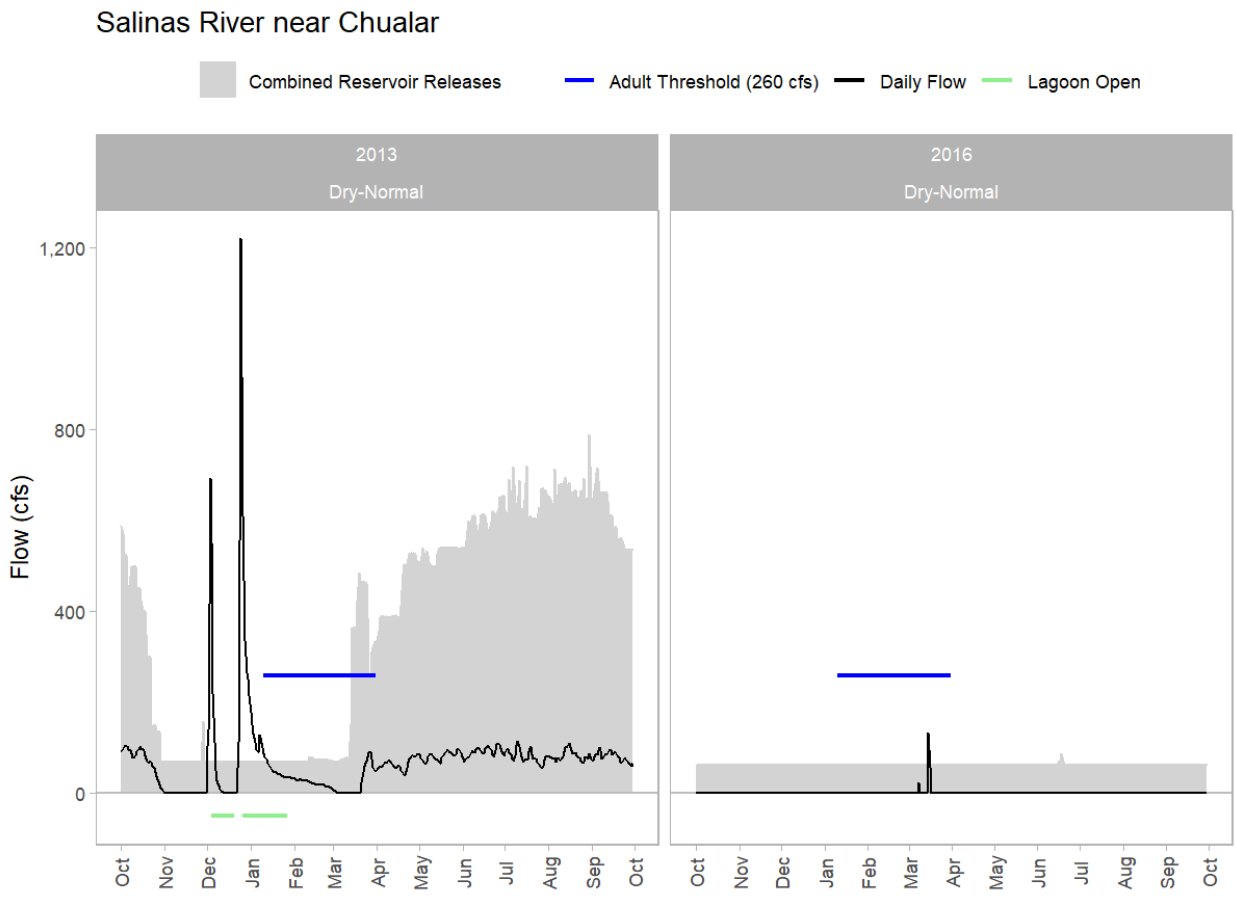

Figure 14. Mean daily flow (black line) conditions on the Salinas River near Chualar during dry-normal water years. Combined reservoir releases are indicated in grey, the adult passage flow threshold is indicated by the blue horizontal line, and the green line below the x-axis indicates when the Salinas Lagoon was open to the ocean.

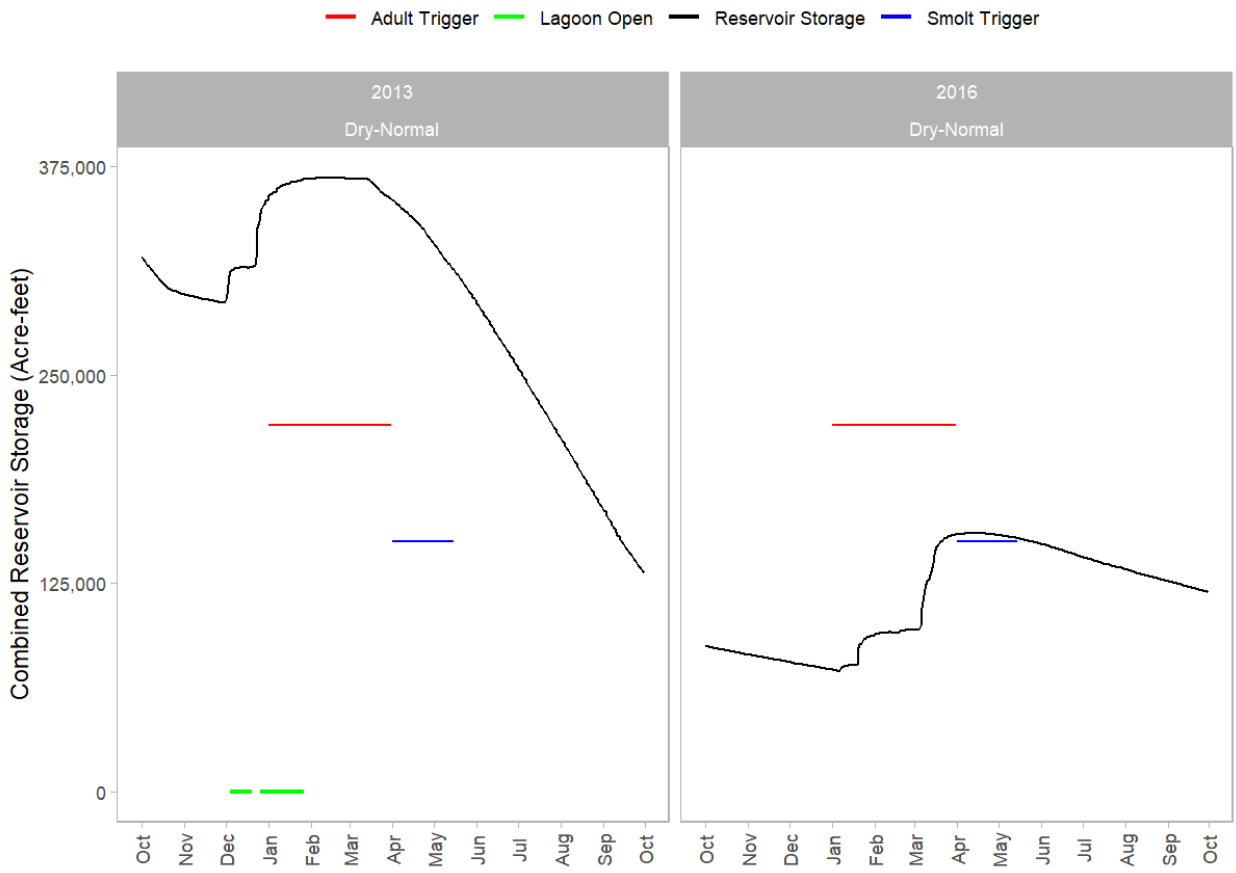

Figure 15. Combined Nacimiento and San Antonio reservoir storage during dry-normal water years. The green line near the x-axis indicates when the lagoon was open. The horizontal red and blue lines indicate storage levels required to trigger adult and smolt flow augmentation, respectively. Minimum reservoir storage is one of three triggers required for flow augmentation (*see* Background Section and Figures 2, 3, and 4).

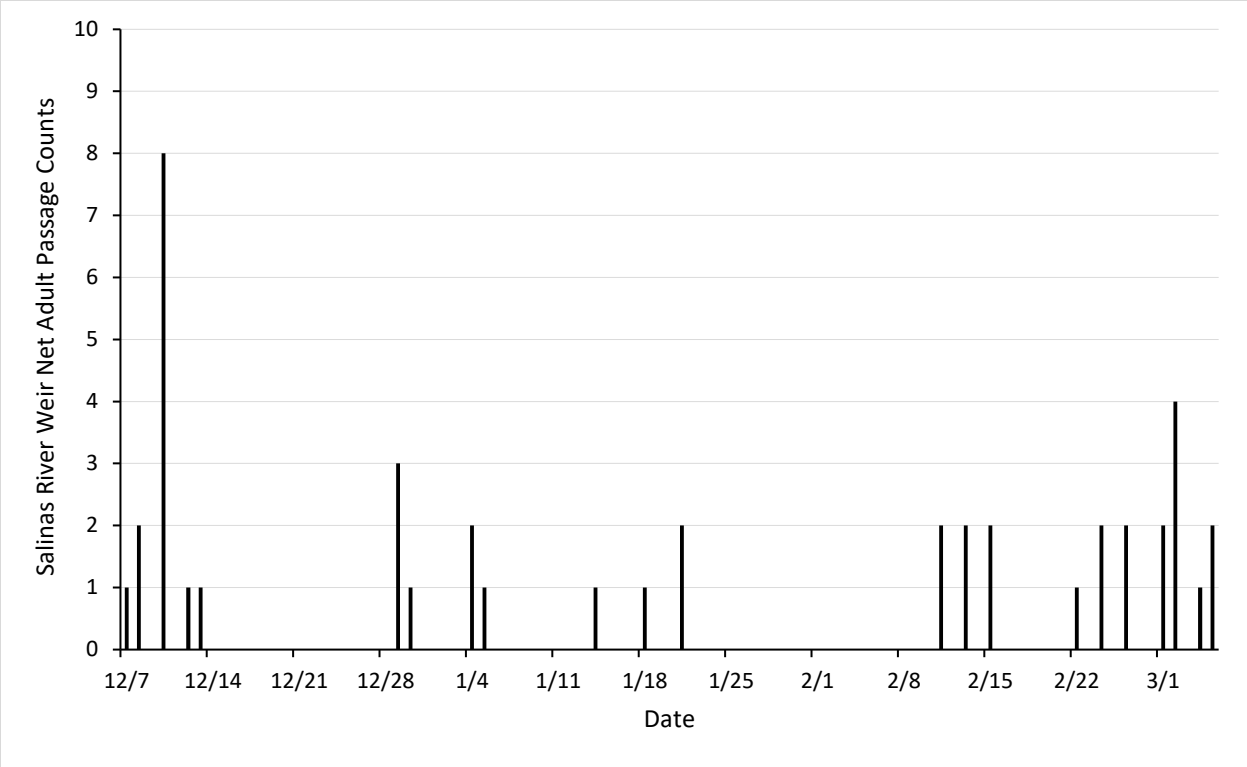

Figure 16. Daily net counts of adult steelhead sampled at the Salinas River weir near river mile 2.75 during the 2013 water year.

Figure 17. Mean daily flow (black line) conditions on the Arroyo Seco River below Reliz Creek during dry-normal water years. Combined reservoir releases are indicated in grey, adult flow triggers are indicated by the blue horizontal line, and the green line below the x-axis indicates when the Salinas Lagoon was open to the ocean.

Wet-Normal Water Years

Wet-normal water year conditions occurred in 2011 and resulted in 70 adult passage days, which falls within the 10 percent variance of the passage target (73) (Figure 18 and Table 3). Because natural flow conditions resulted in an abundance of water, additional reservoir releases were not necessary to create suitable adult passage conditions. Combined reservoir storage was high, increasing from 339,000 AF to 630,000 AF over the course of the adult migration period (Figure 19). The lagoon remained open from December 25, 2010, until September 20, 2011. Three periods of high flow conditions occurred during the 2011 water year on both the Salinas and Arroyo Seco Rivers (Figure 20). Beginning on January 1, 2011, the start of the upstream migration period as defined in the Flow Prescription, 27 continuous days of passage conditions were recorded. Flow Prescription passage criteria were met again between February 17 and March 31 for a total of 70 adult steelhead passage days as defined by the Flow Prescription.

In 2011, adult steelhead were counted passing the Salinas River weir between late January and the middle of February after the first high flow event in late December and early January (Figure 21). The Arroyo Seco River was connected to the ocean for nearly 80% of the adult migration period in 2011 (Table 5) providing access to spawning habitats located in the Arroyo Seco Basin. While 2011 was the only wet-normal water year during the study period, it appears that plenty of water was available to create numerous passage opportunities as defined in the Flow Prescription for adult steelhead upstream migration.

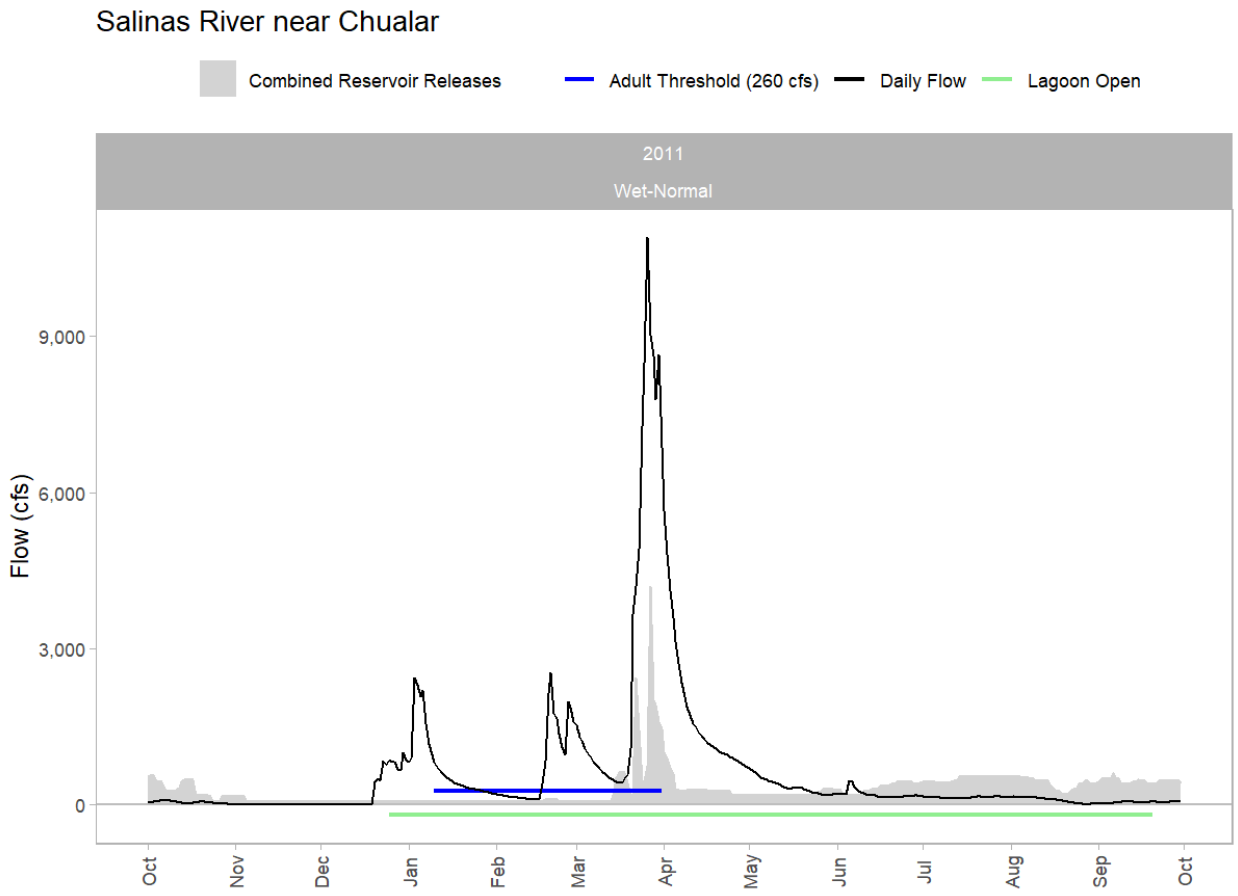

Figure 18. Mean daily flow (black line) conditions on the Salinas River near Chualar during wet-normal water years. Combined reservoir releases are indicated in grey, the adult steelhead passage threshold is indicated by the flow horizontal line, and the green line below the x-axis indicates when the Salinas Lagoon was open to the ocean.

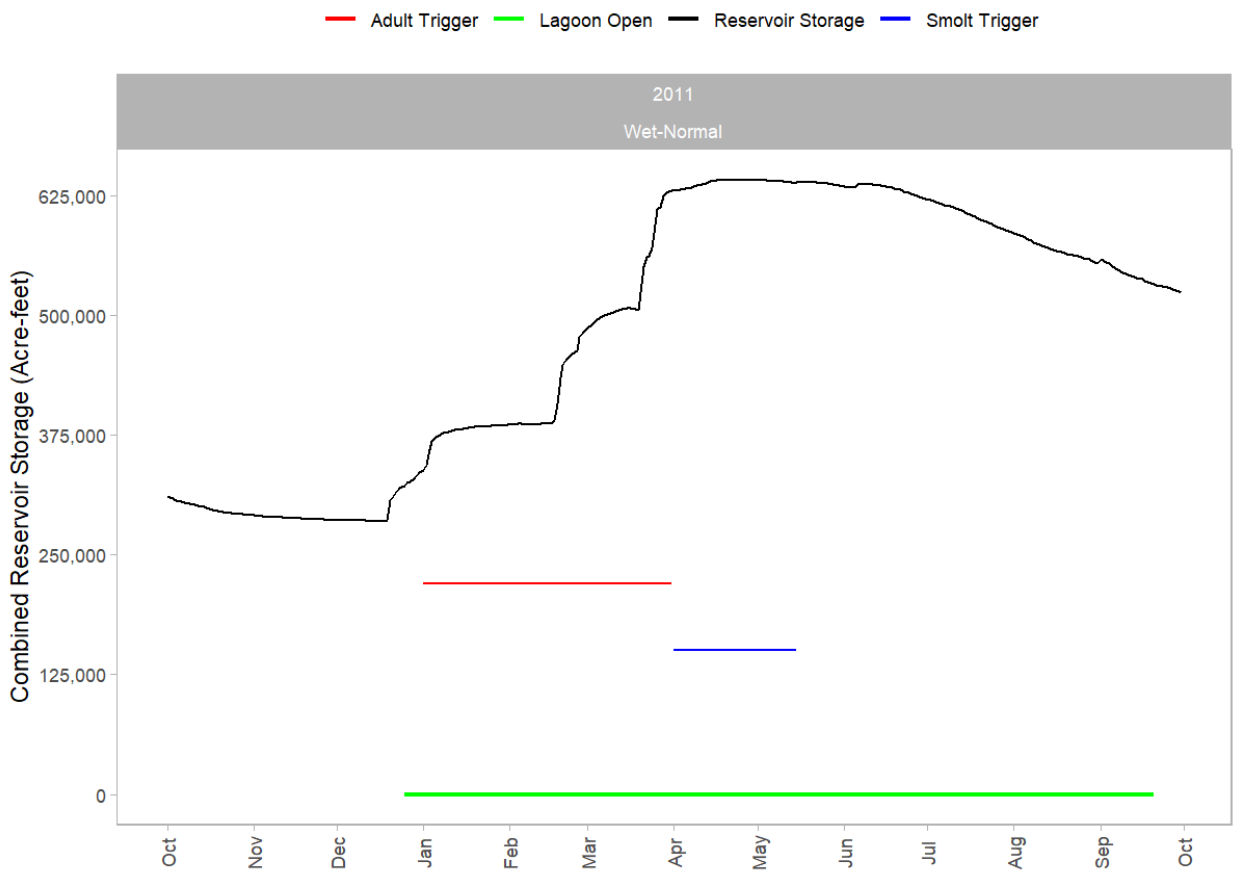

Figure 19. Combined Nacimiento and San Antonio reservoir storage during wet-normal water years. The green line near the x-axis indicates when the lagoon was open. The horizontal red and blue lines indicate storage levels required to trigger adult and smolt flow augmentation, respectively. Minimum reservoir storage is one of three triggers required for flow augmentation (*see* Background Section and Figures 2, 3, and 4).

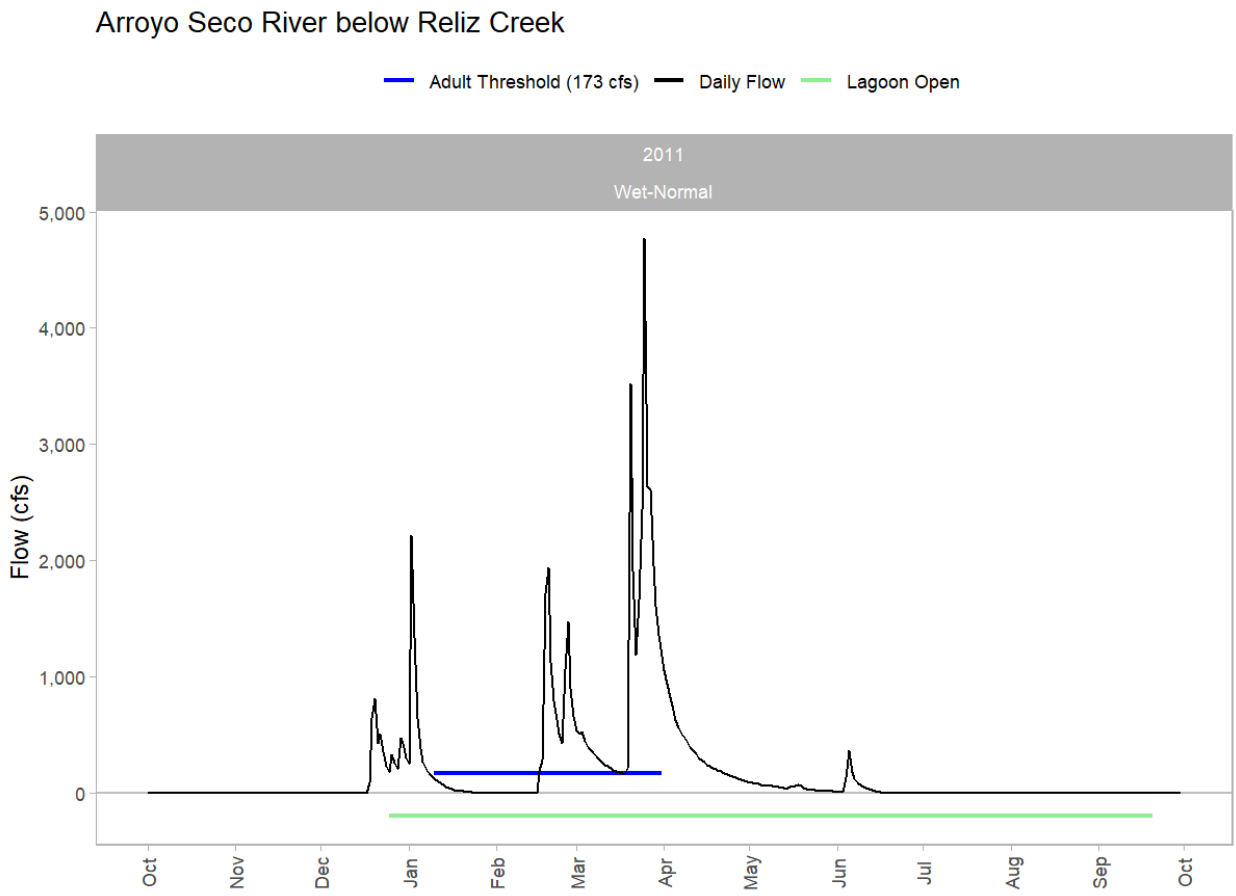

Figure 20. Mean daily flow (black line) conditions on the Arroyo Seco River below Reliz Creek during wet-normal water years. Combined reservoir releases are indicated in grey, the adult steelhead flow threshold is indicated by the blue horizontal line, and the green line along the x-axis indicates when the Salinas Lagoon was open to the ocean.

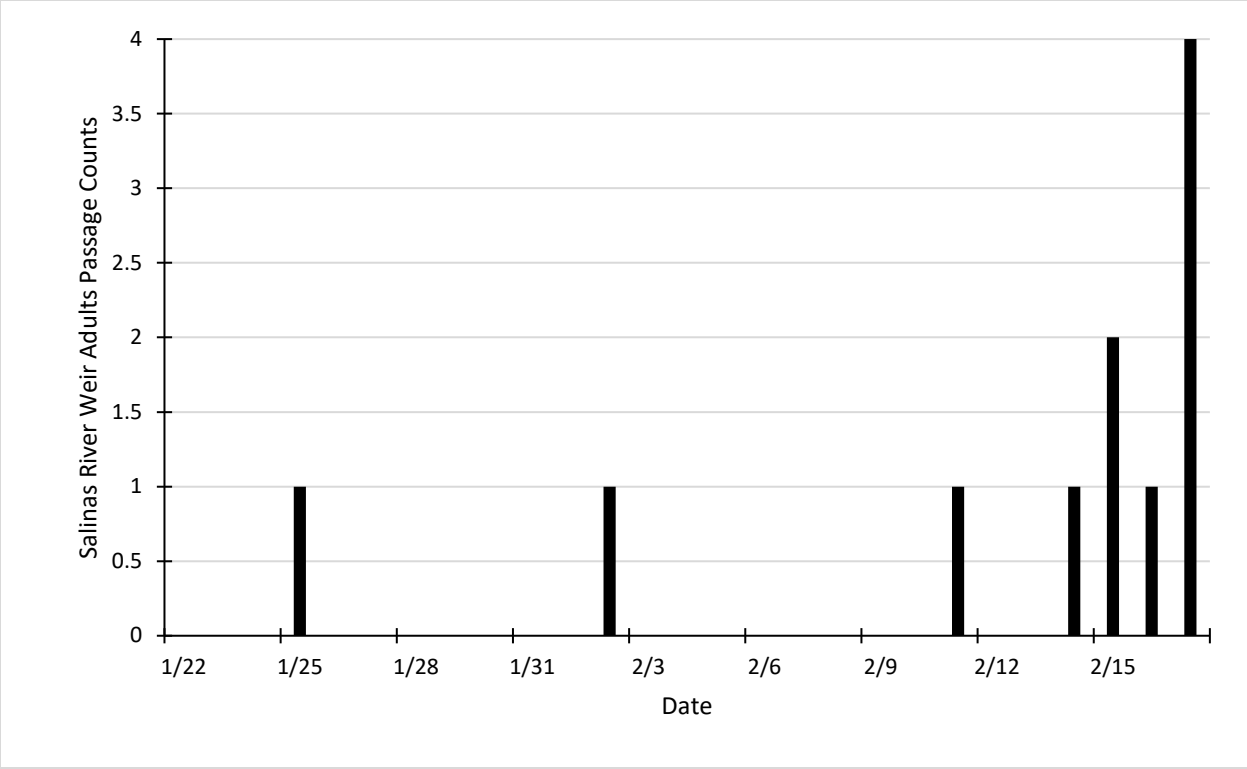

Figure 21. Daily counts of adult steelhead sampled at the Salinas River weir near river mile 2.75 during the 2011 water year.

Wet Water Years

As predicted in the Flow Prescription, wet years provided adequate adult steelhead upstream migration opportunities (Table 3) (Figure 22). Wet water years occurred in 2010, 2017, and 2019. Upstream passage days ranged from 61 in 2019 to 72 in 2017 with an average of 68 days in all wet years (Table 3). Aside from the wet-normal year in 2011, wet water years provided the most passage opportunities and did not require flow augmentation to provide passage. Reservoir storage was also high, exceeding 220,000 AF all three years within a few days of January 1 (Figure 23). In 2017, releases were made from Nacimiento Reservoir in response to rising reservoir levels and flood concerns. In this case, natural flows in combination with reservoir releases provided passage in the Salinas River. The Arroyo Seco River was connected to the ocean for much of the adult migration period during wet years, providing abundant passage opportunities to high quality spawning habitat.

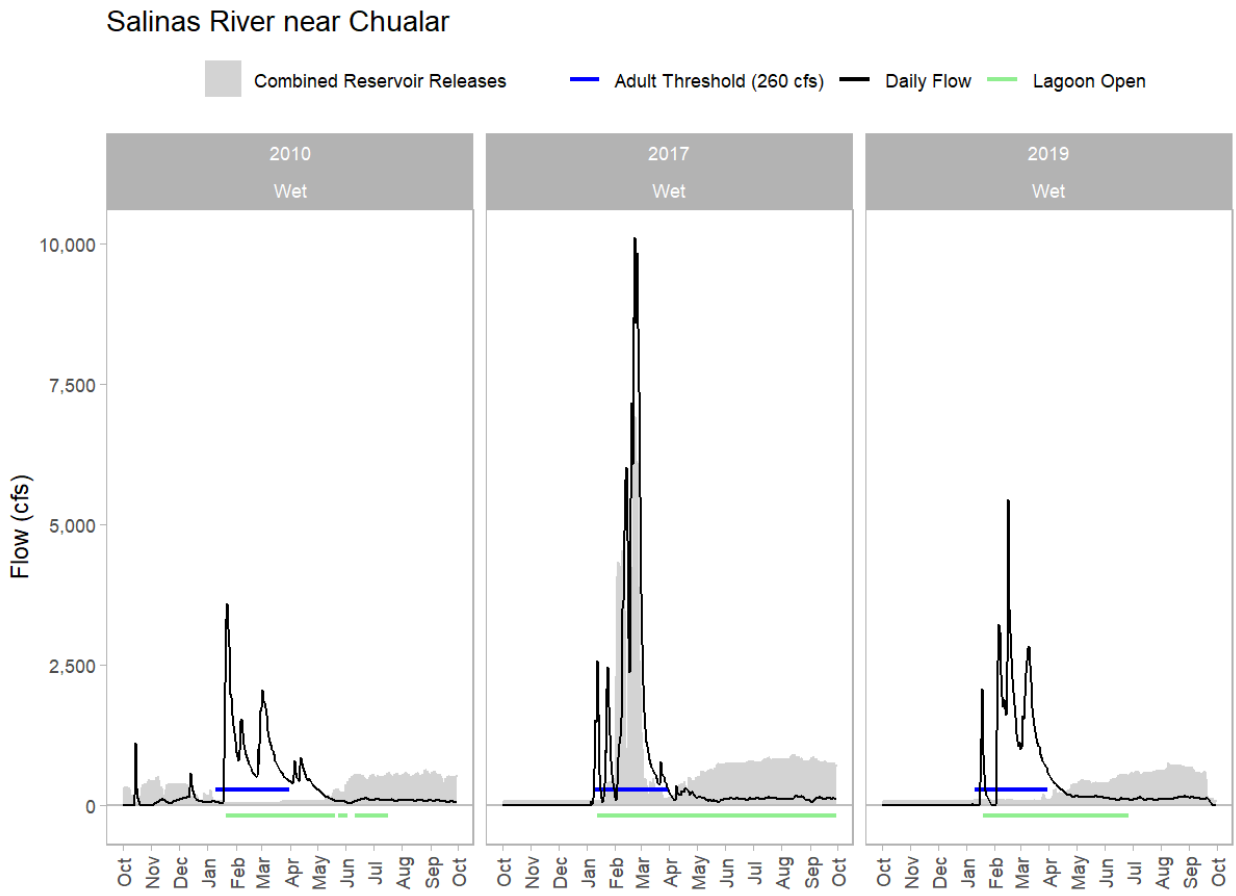

Figure 22. Mean daily flow (black line) conditions on the Salinas River near Chualar during wet water years. Combined reservoir releases are indicated in grey, adult steelhead passage flow thresholds are indicated by the blue horizontal line, and the green line below the x-axis indicates when the Salinas Lagoon was open to the ocean.

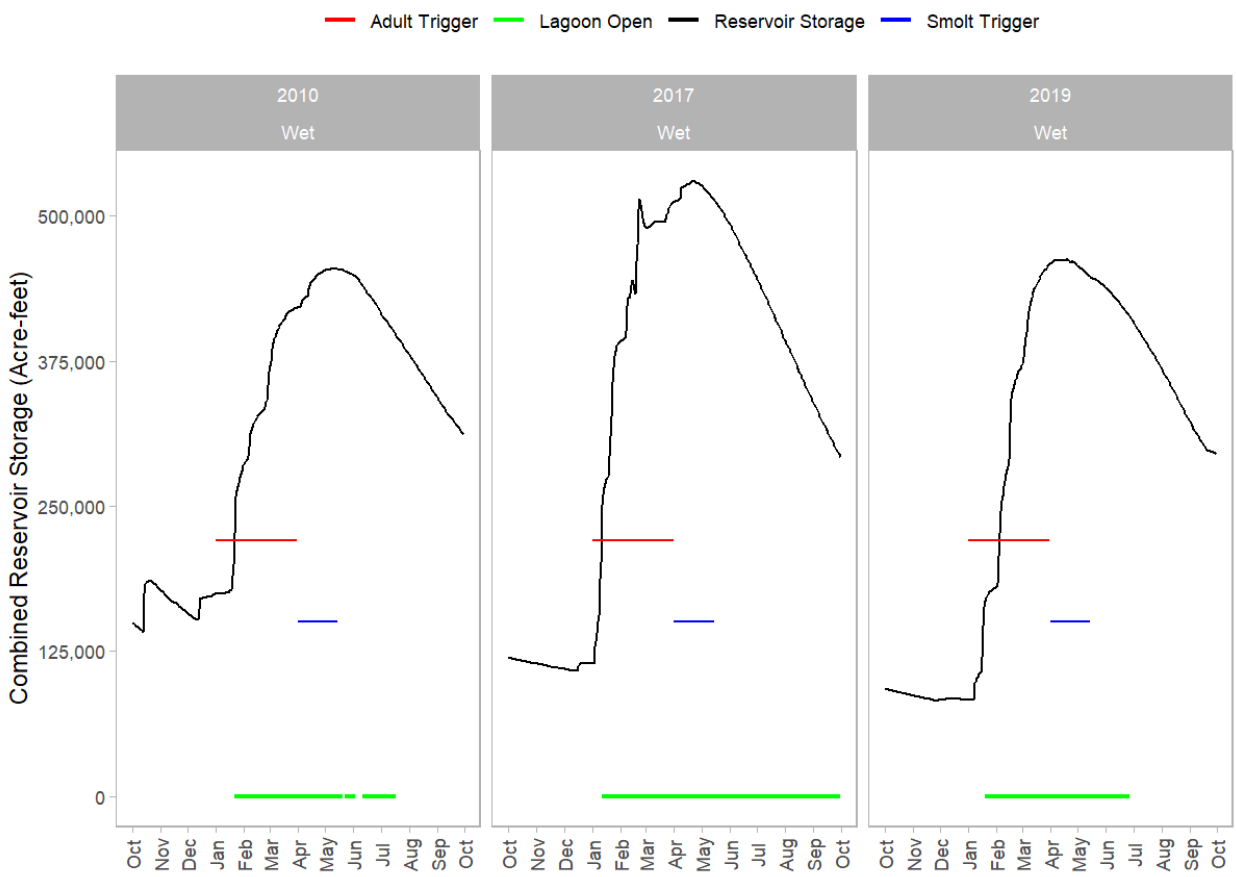

Figure 23. Combined Nacimiento and San Antonio reservoir storage during wet water years. The green line near the x-axis indicates when the lagoon was open. The horizontal red and blue lines indicate storage levels required to trigger adult and smolt flow augmentation, respectively. Minimum reservoir storage is one of three triggers required for flow augmentation (*see* Background Section and Figures 2, 3, and 4).

Adult Upstream Passage Achievement

The Agency achieved adult upstream passage in four of the 10 years in the evaluation period, the wet-normal year in 2011, and the wet years in 2010, 2017, and 2019. Adult upstream passage was not achieved in the two dry-normal years (2013 and 2016) (Table 5), according to the adult upstream passage achievement criteria described in the Flow Prescription. There were 27 passage days, on average across the 10-year period, achieving the historical median of 27 days (1949-1994) when all year types are included (i.e., dry, dry-normal, normal, and wet).

According to the National Integrated Drought Information System (NIDIS), Monterey County experienced moderate to exceptional drought from 2012 through 2016 with moderate drought conditions returning during 2018. Year types calculated as dry from unimpeded Arroyo Seco River flows aligned with reported drought conditions during 2012, 2014, 2015, and 2018. The Flow Prescription did not include passage day goals for dry year types as little or no passage has occurred historically. Actual passage opportunities may have been greater as this count only includes passage days as defined in the Flow Prescription.

Table 5. Adult steelhead upstream passage days by year type.

Year Type	Number of Years per Category	Number of Passage Days Required on a 10-year Average (*±10%*)	Average Number of Passage Days Achieved (2010-2019)
Wet	3	N/A	68
Wet-Normal	1	73 (*7*)	69
Normal	0	47 (*5*)	N/A
Dry-Normal	2	16 (*2*)	0
Dry	4	N/A	0
All Year Types	10	27 (*3*)	27

Steelhead Smolt Outmigration

Dry Water Years

Passage criteria for smolts were achieved in one of the four dry years (2012) between April 15 and April 18 (Table 6). Zero passage days (as defined by the Flow Prescription) occurred during the other dry years (2014, 2015, and 2018). The lagoon opened for 22 days during the smolt migration period in 2012. No block flows are required during dry years. Reservoir storage was below block flow triggers in 2014 and 2015 (Figure 24). Migration may have been possible in the Arroyo Seco River in 2018 prior to the established smolt migration window (Figure 24); a significant rain event on March 23 and 24 caused flows on the Arroyo Seco to climb to near 3,000 cfs before declining to zero cfs on April 1. Flows on the Arroyo Seco River during this period averaged 590 cfs and translated to flow on the Salinas River near Spreckels of 256 cfs on average for the same period (Figure 24). While this event occurred prior to the smolt migration window established in the Flow Prescription, it is likely that juveniles took advantage of this surge in flow to migrate downstream, possibly to the lagoon and the ocean. The lagoon was open during this period beginning on March 25, presenting an opportunity for smolts to reach the ocean.

The Arroyo Seco River was hydraulically connected to the ocean for nine days in 2012, but flows were never high enough during other dry years to connect the Arroyo Seco to the ocean. Conversely, reservoir releases from the Nacimiento and San Antonio dams connected the mainstem Salinas to the ocean for 22 days in 2012 and 21 days in 2018 (Table 7).

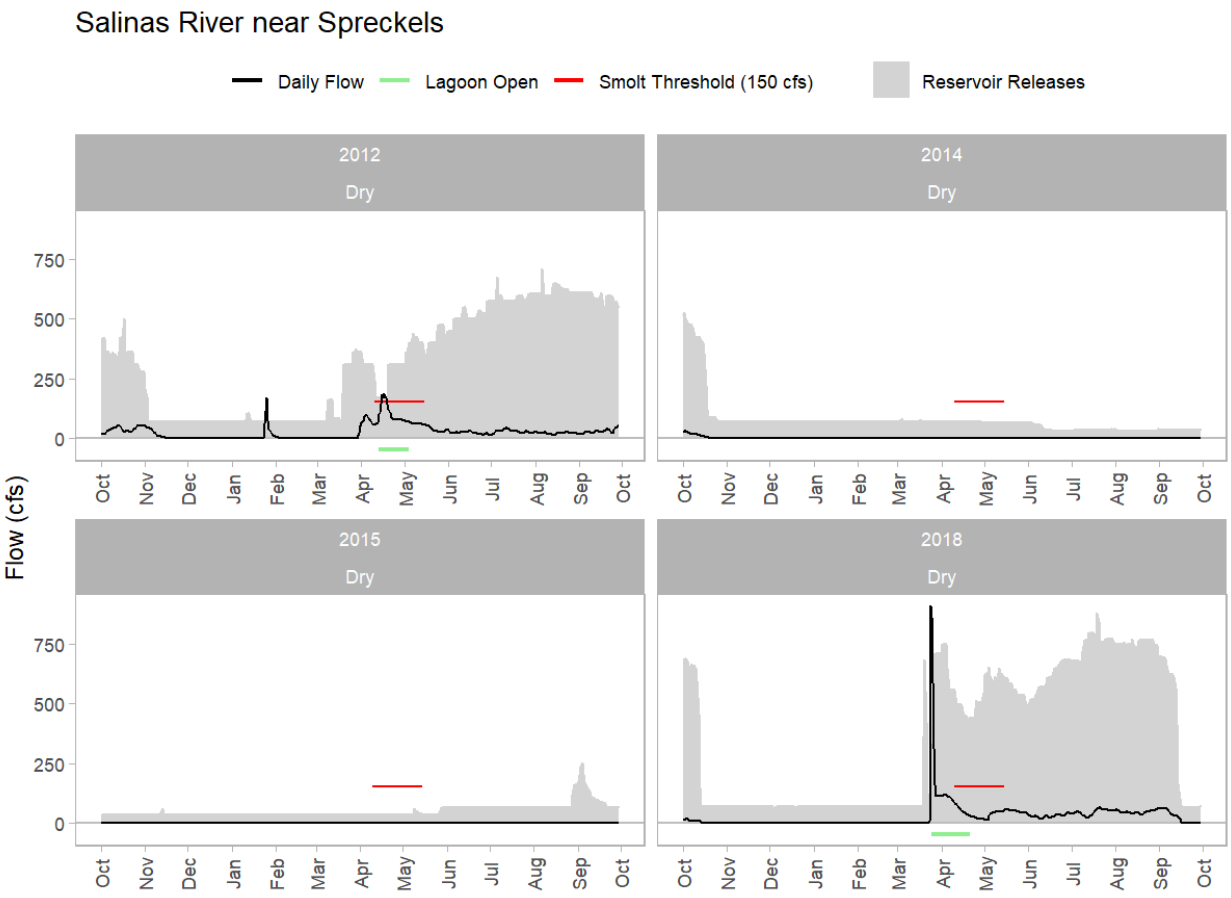

Figure 24. Mean daily flow (black line) conditions on the Salinas River near Spreckels during dry water years. Combined reservoir releases are indicated in grey; the red horizontal line indicates smolt flow threshold, and the green line below the x-axis indicates when the Salinas Lagoon was open to the ocean.

Table 6. Total steelhead smolt outmigration days by operational season.

Water Year	Type	Days Flow at Spreckels >= 150 cfs	Days Lagoon Opened	Days Outmigration Criteria Met	Block Flow
2010	Wet	36	45	36	No
2011	Wet-Normal	45	45	45	Yes
2012	Dry	4	22	4	No
2013	Dry-Normal	0	0	0	No
2014	Dry	0	0	0	No
2015	Dry	0	0	0	No
2016	Dry-Normal	0	0	0	No
2017	Wet	4	45	4	No
2018	Dry	0	21	0	No
2019	Wet	23	45	23	No

Table 7. Total days the Arroyo Seco River and reservoir releases were connected to the ocean during the smolt migration period for operational water years 2010 to 2019.

Water Year	Water Type	Days Arroyo Seco was Connected to the Ocean During Smolt Migration Period	Days Reservoir Flow was Connected to the Ocean During Smolt Migration Period
2010	Wet	45	45
2011	Wet-Normal	45	45
2012	Dry	9	22
2013	Dry-Normal	0	0
2014	Dry	0	0
2015	Dry	0	0
2016	Dry-Normal	0	0
2017	Wet	45	45
2018	Dry	0	21
2019	Wet	38	45

Dry-Normal Water Years

Dry-normal years forecasted on March 15 or April 1 would trigger block flow releases if reservoir storage and streamflow triggers were met. During 2013, reservoir storage was greater than or equal to the 150,000 AF block flow trigger (Figure 15). However, because flow triggers were not met during the migration period, block flows were not triggered in 2013 (Figure 25). Block flows were not initiated in 2016 because reservoir levels were below 150,000 AF (Figure 15).

Conservation releases were made in beginning in March 2013 to support operation of the Salinas River Diversion Facility (Figure 25). Reservoir flow and Arroyo Seco River flow was not hydraulically connected to the ocean in either dry-normal years (Table 7).

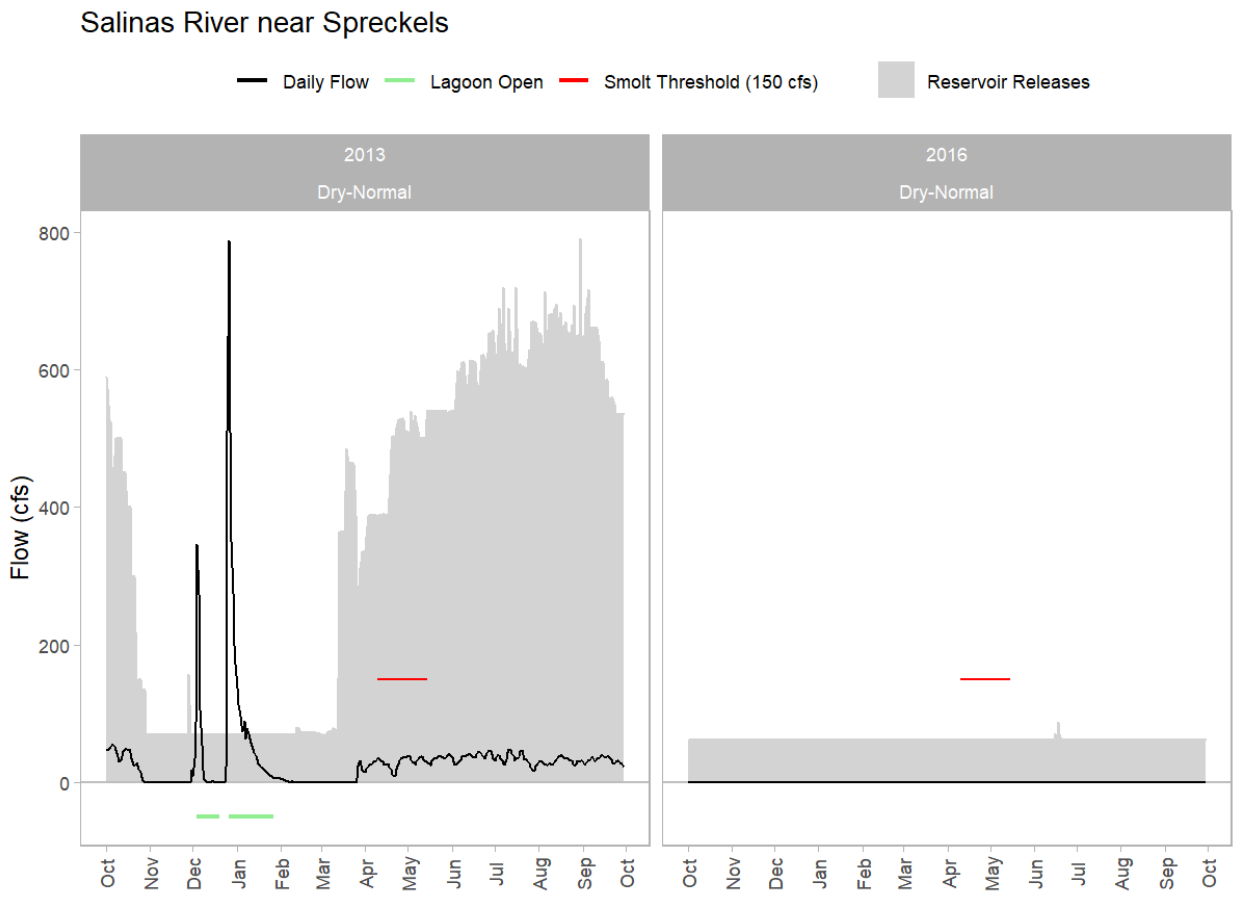

Figure 25. Mean daily flow (black line) conditions on the Salinas River near Spreckels during dry-normal water years. Combined reservoir releases are indicated in grey, the red horizontal line indicates smolt flow threshold, and the green line below the x-axis indicates when the Salinas Lagoon was open to the ocean.

Wet-Normal Water Years

There were suitable passage conditions for the entire smolt migration period in 2011, a wet-normal year (Figure 26). Additionally, the block-flow trigger at Arroyo Seco below Reliz Creek near Soledad was met on March 15, 2011, and releases from Nacimiento and San Antonio reservoirs were increased on the same day to engineer a block flow. Releases were reduced after four days when it was evident that natural flows were high enough to sustain block-flow requirements. The successful block-flow conditions started with Salinas River at Soledad flows of 700 cfs or more between March 20, 2011, and March 24, 2011, and continued with flows at Salinas River near Spreckels of 300 cfs or higher from March 25, 2011, through April 20, 2011. Connection between the ocean and the Arroyo Seco River during wet years ranged from 38 to 45 days; reservoir flows were connected to the ocean for the entire migration period in all wet years (Table 7).

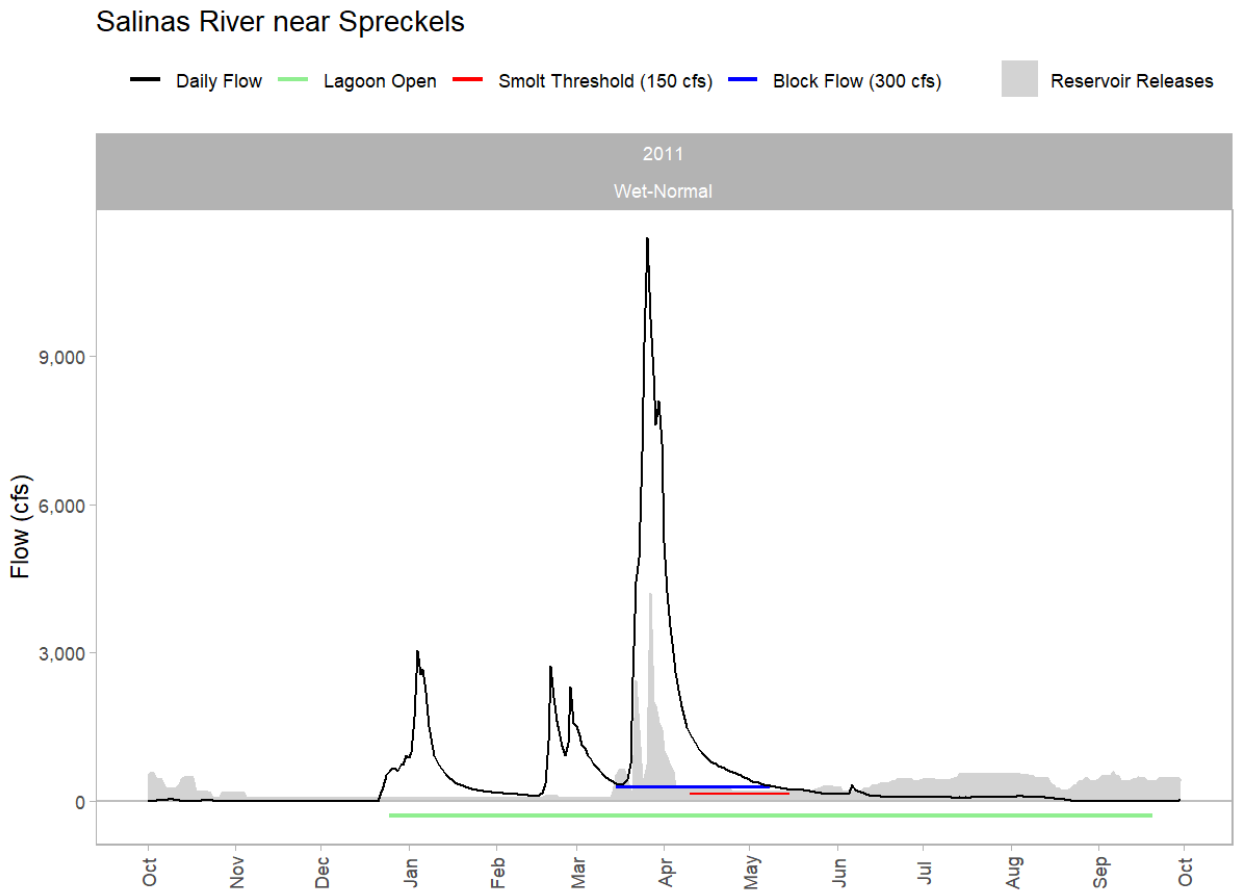

Figure 26. Mean daily flow (black line) conditions on the Salinas River near Spreckels during wet-normal water years. Combined reservoir releases are indicated in grey; the red horizontal line indicates smolt flow threshold, the green line below the x-axis indicates when the Salinas Lagoon was open to the ocean, and the blue indicates when block flow conditions were met at Spreckels.

Wet Water Years

There were suitable smolt passage days during each wet year. The most passage days achieved during a wet year occurred in 2010, when passage criteria were met for 36 days (Table 6). Despite having the highest peak flow out of all wet years, only four days met passage criteria in 2017 as defined by the Flow Prescription. This may be due, in part, to the persistent drought that occurred from 2012 through 2016. Flows near Spreckels were exceptionally high during the late winter through early spring but dropped considerably before the smolt migration window (Figure 27). Even with high reservoir releases and high combined reservoir storage, flow conditions at Spreckels averaged 92 cfs during the 2017 migration window. It is possible, however, that some smolts were able to move downstream during the latter half of March. Smolt passage criteria were met during 23 days in 2019 (Table 6). Rain events were distributed across a longer period and occurred later in the winter and spring compared to 2017, creating more passage opportunities.

Steelhead Smolt Outmigration Achievement

An analysis of streamflow conditions between April 1 and May 15 showed that smolt outmigration opportunities, as defined by the Flow Prescription, occurred during five years in the study period ranging from four during the dry year of 2012 to 45 during the wet-normal year of 2011 (Table 6.). Outmigration criteria were not met on any day during 2013, 2014, 2015, 2016, and 2018. Water year 2012 was the only dry year during which outmigration criteria were met. This may be due to a preceding water year effect, meaning that meeting passage criteria may be more likely if the preceding water years are wet, resulting in full reservoirs, recharged groundwater, and higher soil saturation. In 2012, the preceding two years were wet (2010) and wet-normal (2011) allowing for releases to be made from Nacimiento and San Antonio Dam to support SRDF operations and smolt outmigration.

During the 10-year review period, normal category years were forecast in three years or 30% of the time, with Block Flow triggers being met in one of the three years or 33% of normal category years. The March 15th forecast of a wet-normal year put block flow triggers in effect. Releases were made from Nacimiento and San Antonio reservoirs on March 15th in response to the triggers. Releases were reduced after four days when it became evident that natural flows would meet block flow goals without supplemental releases.

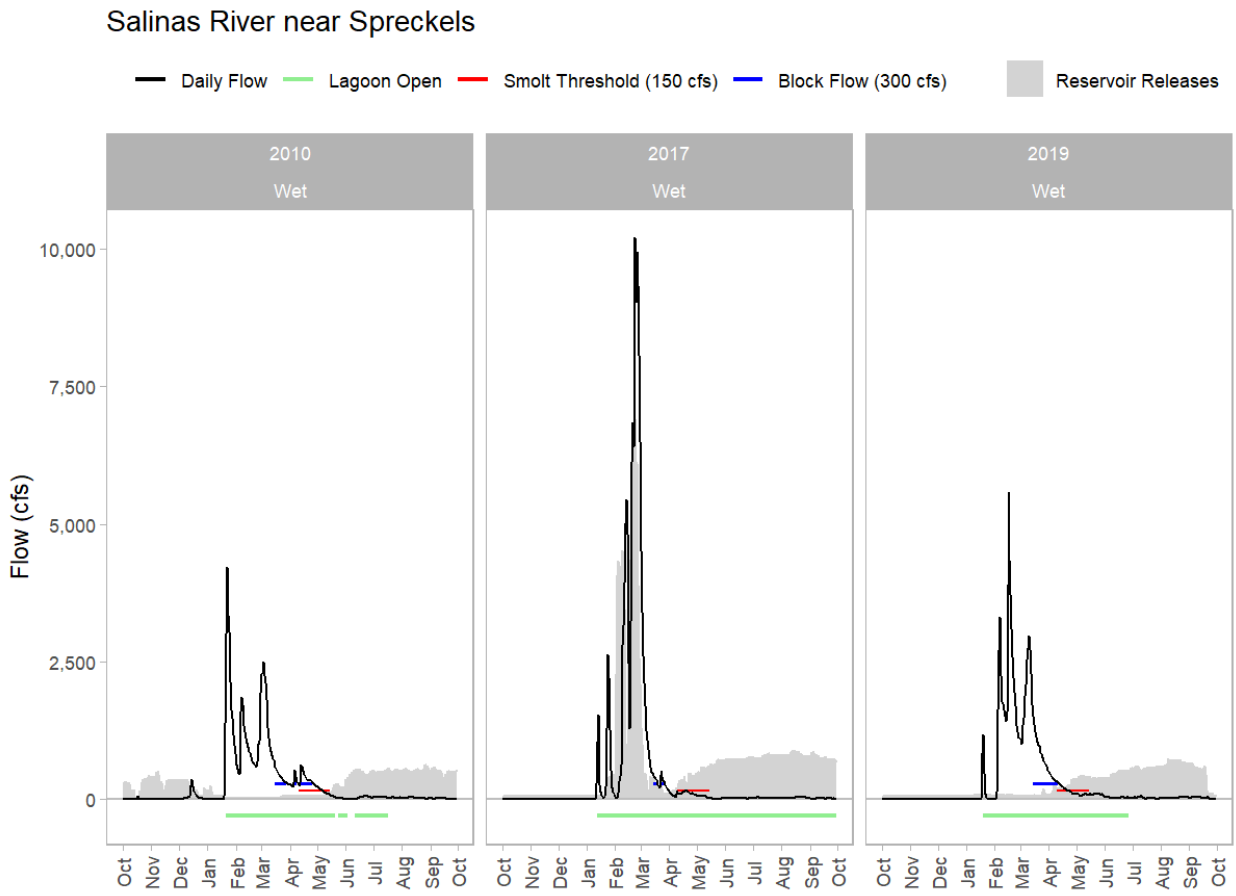

Figure 27. Mean daily flow (black line) conditions on the Salinas River near Spreckels during wet water years. Combined reservoir releases are indicated in grey; the red horizontal line indicates smolt flow threshold, the green line below the x-axis indicates when the Salinas Lagoon was open to the ocean, and the blue indicates when block flow conditions were met at Spreckels. Block flows are not required in wet water years.

Discussion

The Agency complied with the terms of the Flow Prescription throughout the 10-year evaluation period. Over the first 10 years of operation, the Flow Prescription largely performed as intended. One of the goals of the Flow Prescription was to provide the average number of historic annual passage days in the lower Salinas River for each water year type, and all water year types combined, across a 10-year period, with a 10 percent variance. The Agency achieved adult upstream passage, on average across all water year types for the 10-year evaluation period, and for the wet-normal year (2011). It did not achieve adult upstream passage in the two dry-normal years. Adult passage in wet years and dry years were as expected in the Flow Prescription: precipitation during wet years provided enough water to enable substantial passage opportunities, whereas there were few or no passage opportunities during dry years. Smolt outmigration, as defined by the Flow Prescription, was achieved in five of the 10 years evaluated in this report.

The 10-year evaluation period was dominated by drought, with three dry years and two dry-normal years from 2012 through 2016. During this period, there were few natural migration opportunities and there was a limited amount of stored water to augment natural events. Adult passage, as defined by the Flow Prescription, was not achieved during the five consecutive years of drought.

Due to the extended drought, the dry-normal years of 2013 and 2016 shed light on the challenges of natural and augmented passage opportunities during dry conditions. The Flow Prescription missed the best opportunity to augment flows to provide passage during the 2012-2016 drought, which occurred during the 2013 dry-normal year. The Agency complied with the Flow Prescription, which did not trigger release of water after substantial, late December rain. During and after this storm, flows exceeded the adult threshold, the lagoon was open (Figure 17), and there was adequate storage in the reservoirs (Figure 15); however, releases were not triggered because the pulse occurred prior to the action period in February. There were no substantial pulses after late December during the winter of 2012-2013 (operational season 2013). It was impossible to know at the time that these events would be the only passage opportunities of the season and the beginning of a multi-year drought. A more flexible Flow Prescription that enables the Agency to take advantage of early (e.g., December) or late (e.g., April) season storms would likely improve adult steelhead passage opportunities.

The drought of 2012-2016 was the defining weather event of the decade. Both statewide and local drought impacts were seen beginning in water year 2012. Low natural streamflow during the winter of 2011-12 resulted in limited opportunities for steelhead migration, and Flow Prescription triggers for reservoir releases were not met. Reservoir storage captured during the wet years of 2010 and 2011 allowed for SRDF operations during the 2012 and 2013 operational seasons even though both winters were relatively dry. The full effects of the drought were

realized locally in operational seasons 2014-2016. Conditions during this period were dry and reservoir storage remained low. Combined reservoir storage remained below 150,000 AF for the entirety of water years 2014 and 2015, only exceeding 150,000 AF for a short period in 2016 (Figure 11 and Figure 15). No reservoir releases were made for conservation or fish passage during these years. The main stem Salinas River and its tributaries were very dry during this period and Agency surveys performed on the Arroyo Seco River in September 2014 identified multiple areas of dry channel conditions and only isolated pooling remained in the Arroyo Seco Gorge. Multiple years of drought left the entire watershed dry, preventing both natural and supplemental fish passage flows.

The dry years of 2012, 2014, 2015, and 2018 provided limited opportunities for steelhead migration. The drought years of 2014 and 2015 were exceptionally dry due to the preceding dry and dry-normal years of 2012 and 2013. Operational season 2018 followed the wet year of 2017 which provided some recovery of reservoir storage. Reservoir releases were made when adult steelhead upstream migration triggers were met in late March 2018. The effort fell just short of meeting Flow Prescription passage flow criteria of 260 cfs at the Salinas River near Chualar (Chualar flow was approximately 200 cfs) due to dry channel conditions, but connectivity was established from the Nacimiento, San Antonio, and Arroyo Seco watersheds to the ocean.

By operational season 2016, consecutive years of drought conditions had taken their toll on the watershed and were widespread and severe, reducing groundwater elevations and drying out the landscape. Rain events produced enough streamflow to warrant a year type calculation of dry-normal but antecedent conditions were dry and natural flow events were rare and short lived. Even if supplemental releases had been triggered, the dry conditions and low reservoir storage would have made it very difficult, if not impossible, to extend the natural hydrograph with the limited reservoir storage at the time.

Each year addressed in this report was unique with different antecedent conditions and different natural rain and runoff events. Aside from five years of historic drought conditions, no single operational parameter stood out as the limiting factor to fish passage opportunities across all year types.

Limitations and Constraints

The Agency's ability to provide passage opportunities to adult and juvenile steelhead is limited or constrained by multiple factors including include lagoon accessibility, water year and condition forecasting, preceding water year effects, and flow augmentation windows (established migration periods).

When the Salinas Lagoon remains closed to the ocean, migration opportunities are almost entirely prevented. The lagoon not only dictates passage opportunities, but the Flow Prescription

also requires the lagoon to be open for releases to be triggered. If the lagoon does not open because of natural flows, then mechanical breaching is necessary to connect the Salinas River to the ocean[1]. The Lagoon did not open to the ocean during the drought years of 2014 – 2016 (Table 8). Despite remaining closed during drought years of 2014 – 2016, the Lagoon opened to the ocean during 7 of 10 years in the study period. During the seven years that the lagoon opened to the-ocean, it remained open for a minimum of 22 days with four years exceeding 160 days. Managing accessibility to the Salinas River via the lagoon could be evaluated outside of the current context of flood control to provide additional passage opportunities for adult or juvenile steelhead.

Table 8. Periods when the lagoon opened and closed during operational years 2010 to 2019.

Water Year	Date Lagoon Opened	Date Lagoon Closed	Number of Days Open per Event	Total Days Open per Water Year
2010	1/21 5/23 6/11	5/21 6/4 7/18	120 12 37	169
2011	12/25/10	9/21	270	270
2012	4/13	5/5	22	22
2013	12/4/12 12/26/12	12/21 1/28	17 33	50
2014	N/A	N/A	0	0
2015	N/A	N/A	0	0
2016	N/A	N/A	0	0
2017	1/12	9/30	262	262
2018	10/1/17 3/25	10/2/17 4/22	1 28	29
2019	1/19	6/28	160	160

[1] Lagoon breaching is not currently permitted for steelhead passage.

Ultimately, it appears conditions during the dry-normal years, primarily those that occur within an extended drought, limited the Agency's ability to improve passage across the 10-year span addressed in this report. The number of passage days for wet and wet-normal years were within or close to historical range. The only normal-normal or dry-normal type years were the two dry dry-normal years, and the lagoon was open during the adult migration period during only one (2013).

Short duration natural flow events can occur with little forecast lead time. This is especially true of flow from the Arroyo Seco watershed. The lack of reliable long and medium-term rain and streamflow forecasts can make a supplemental release response too slow to connect to a natural event before it ends. Reservoir releases to a dry river channel can take days or even weeks to reach the confluence with the Arroyo Seco.

Another limiting factor is the February 1st start of the supplemental release period. The original intent of the February 1st start of the action period was to allow early winter events to wet the channel naturally and reduce the burden of trying to make migration releases to short duration events in a dry channel. Given the unpredictable nature of the watershed it may be beneficial to explore alternative strategies such as prioritizing actions to enhance early winter (January-February) passage opportunities and allowing natural events to provide for unassisted outmigration flows in March when they have a higher probability of occurring.

Given the short period of ten years (plus two additional years of data) and the severe drought conditions that occurred between 2012 and 2016, it was difficult to assess the efficacy of the Flow Prescription during normal years (i.e., providing fish passage opportunities during normal water year types that are consistent with historical conditions) because only four normal year types occurred during the review period. Dry water years and prolonged droughts are likely to occur more frequently as precipitation frequency, duration, quantity, and temperatures change because of climate change.

The Flow Prescription relies on flow thresholds that were derived based on data from watersheds outside of the Salinas River basin and may not represent the actual conditions needed to provide passage opportunities. Work is underway to determine minimum passage depths through critical riffles throughout the Salinas River. Data from these surveys will help inform flow prescriptions moving forward and ensure that passage criteria are based on data from the Salinas River.

Next Steps

The Agency is planning to re-evaluate the current Flow Prescription during the ongoing Habitat Conservation Plan development. The Agency believes the existing Flow Prescription framework is a solid starting place but should be re-evaluated in the context of improved analysis tools,

additional years of data, changing hydrologic conditions, and lessons learned from the historic drought conditions that occurred after the implementation of the current Flow Prescription. Some specific items that should be evaluated include but are not limited to:

- Stream depth and flow requirements for adult steelhead upstream passage
- Stream depth and flow requirements for juvenile steelhead outmigration
- Methodology for determining steelhead passage day targets
- Stream depth and flow requirements for spawning and rearing habitat
- Alternative migration pathways in and out of the Salinas River system

The evaluation of the first 10 years of SVWP operations under the Flow Prescription as defined by this report provides a starting point and guidance for further investigations into operational strategies for Agency projects and the analysis of any impacts to SCCC steelhead in the Salinas River watershed.

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Appendix A: SRDF Operations

2010

The first Operational Season of the SRDF began with the installation of the fish screens and raising of the main impoundment gates on April 5, 2010. At the time the gates were raised, approximately 300 cfs was flowing past the Salinas River near Spreckels USGS gage. Water diversions from the Salinas River at the SRDF began on May 3, 2010. Diversions ended on October 18, 2010. The impoundment was gradually drained, and the gates were lowered on November 17, 2010.

2011

The 2011 Operational Season began on April 29, 2011, when the gates were raised at the SRDF, and the impoundment of water began. Water diversions from the Salinas River at the SRDF began on May 3, 2011. SRDF diversions from the Salinas River ended on August 23, 2011. Fish screens were removed from the SRDF intake structure on November 1, 2011, with a recorded SRDF bypass flow of approximately 7 cfs. The SRDF gates were lowered on November 28, 2011. In June 2011 a scour hole was identified on the southerly side of the SRDF fish ladder. SRDF operations ceased on August 23rd so that the impoundment could be drained, and repair work conducted. Flow was restored to the impoundment in October for testing, but SRDF operation was not required due to lack of demand.

2012

During the 2012 SRDF Operational Season water diversions from the Salinas River at the SRDF began on May 2, 2012. Diversions ended on October 19, 2012. The impoundment was gradually drained over 27 days and the gates were lowered beginning November 15, 2012.

2013

The 2013 SRDF Operational Season began on April 8, 2013, when the gates were raised at the SRDF, and the impoundment of water began. Water diversions from the Salinas River at the SRDF began on April 10, 2013. Diversions ended on October 11, 2013. The impoundment was gradually drained over 28 days and the gates were lowered beginning November 8, 2013.

In September 2012, the hydroelectric plant at Nacimiento Dam sustained significant damage when a piece of the intake structure passed through the penstock and into the primary hydroelectric turbine (Unit 1). Unit 1 was shut down and an initial inspection identified the cause of the damage. A thorough evaluation of the damage and repair of Unit 1 began February 11, 2013. For increased safety during the evaluation and repair, releases from the Low-Level Outlet

Works (LLOW) were halted and double-block-and-bleed containment was maintained while work was performed in the hydroelectric facility.

Double-block-and-bleed containment requires closing the reservoir intake valve, draining the penstock (the pipeline from the reservoir intake to the hydroelectric plant), and closing the valve to the hydroelectric generator. This configuration offers two layers of containment for the protection of workers in the hydroelectric facility but prevents any release of water from the LLOW. When reservoir elevation allowed (water surface elevation greater than 755 feet), releases were made from the High-Level Outlet Works (HLOW) in the Nacimiento Dam spillway. NMFS was consulted and mitigation measures were recommended to reduce the likelihood of take of steelhead in the Nacimiento River while the repair work was completed. For much of the months of June, July, and August water was pumped over the spillway from the reservoir at a rate of 10 to 15 cfs during work hours when double containment was required. Releases of 30 cfs or greater were made from the LLOW when double containment was not required. All repair work, including start-up testing and commissioning of Unit 1 was completed on August 29, 2013. Testing of the secondary power generating unit, Unit 2, was completed September 5, 2013. Due to emergency repair activities, minimum Nacimiento River spawning and rearing habitat flows of 60 cfs were not met on 42 days between October 1, 2012, and November 30, 2013.

2014

The SRDF was not operated during the 2014 operational season due to low reservoir storage. The Nacimiento watershed generates approximately three times the annual runoff of the San Antonio watershed. Because of this, reservoir releases are typically made with a goal of creating approximately three times the volume of empty space in the conservation pool of Nacimiento reservoir as in the conservation pool at San Antonio Reservoir at the end of each season. Nacimiento reservoir is typically used as the primary source of reservoir releases during the conservation season but due to the limitations of the LLOW at Nacimiento Dam, supplemental releases are frequently required from San Antonio to meet downstream demands. The emergency repair work that occurred at Nacimiento Dam during the 2013 operational season resulted in low water storage in San Antonio and a departure from the desired three to one operational ratio that was further exacerbated by ongoing drought conditions.

2015 & 2016

The SRDF was not operated during the 2015 or 2016 operational seasons due to low reservoir levels resulting from ongoing drought conditions. 2016 was the third consecutive season without SRDF operations.

2017

The 2017 SRDF Operational Season began with the installation of the fish screens and raising of the main impoundment gates on April 28, 2017. At the time the gates were raised, approximately 92 cfs was flowing past the Salinas River near Spreckels USGS gage. Diversions ended on October 13, 2017. The impoundment was gradually drained, and the regulating weir gate was fully lowered by November 9, 2017. The main gate remained in the raised position for maintenance until November 21, 2017.

2018

The SRDF impoundment main gates were raised for the 2018 operational season on April 16, 2018, with a mean daily flow at the Salinas River near Spreckels of 48 cfs. Bypass flows were made through the fish ladder while the impoundment was being raised. SRDF pumping operations began on April 23, 2018. SRDF diversions ceased for the 2018 operational season on September 14, 2018. The SRDF impoundment was gradually drained using the regulating weir over a period of 28 days. The main impoundment gates were lowered on October 11, 2018, with a mean daily stream flow of 0 cfs recorded at the Salinas River near Spreckels on that date.

2019

The 2019 Operational Season began on April 1, 2019, when the gates were raised at the SRDF and the impoundment of water began. Water diversions from the Salinas River at the SRDF also began on April 1, 2019. SRDF diversions from the Salinas River ended on September 21, 2019. The impoundment was gradually drained using the regulating weir and the main impoundment gates were lowered on October 23, 2019.

Appendix B: Table of Year Type Forecasts

Table B - 1. Forecast and observed year types as a test of Agency forecast methodology.

Water Year	Forecast Mean Annual Discharge (March 15)	Forecast Mean Annual Discharge (April 1)	Approved Mean Annual Discharge
1902	122.8	121.9	134.8
1903	87.4	115.1	144.1
1904	41.4	65.7	82.3
1905	122.7	148.5	168.6
1906	158.2	235.0	282.5
1907	327.7	443.0	436.5
1908	116.1	109.0	102.5
1909	372.1	349.4	329.0
1910	95.2	116.1	116.5
1911	450.3	437.9	402.8
1912	34.0	36.3	50.9
1913	19.5	19.8	19.6
1914	449.7	406.4	361.1
1915	278.6	271.2	288.8
1916	397.1	371.4	341.0
1917	268.3	245.4	220.3
1918	93.9	101.7	100.0
1919	97.8	99.3	91.7
1920	48.7	57.9	72.7
1921	139.3	131.3	115.7
1922	313.8	294.2	266.2
1923	146.1	130.2	174.7
1924	14.5	19.6	22.7
1925	63.4	57.8	73.8
1926	175.9	161.1	204.1
1927	268.2	246.5	236.6
1928	81.5	94.2	102.4
1929	77.4	74.3	71.1
1930	67.3	67.9	64.5
1931	19.3	18.5	16.7
1932	246.0	220.3	189.1
1933	27.3	27.1	26.8
1934	135.7	123.9	108.8
1935	76.4	76.6	127.2
1936	181.8	166.1	166.0
1937	164.3	205.6	205.0

Water Year	Forecast Mean Annual Discharge (March 15)	Forecast Mean Annual Discharge (April 1)	Approved Mean Annual Discharge
1938	504.3	494.5	447.1
1939	35.1	35.0	33.2
1940	285.1	270.3	257.0
1941	466.0	459.5	525.1
1942	194.2	191.1	233.8
1943	184.4	192.2	183.2
1944	131.6	125.2	122.0
1945	141.2	149.8	144.9
1946	121.2	112.5	109.4
1947	47.1	44.9	44.1
1948	7.1	13.9	30.7
1949	66.8	75.0	71.9
1950	70.7	67.5	68.5
1951	156.4	140.2	123.6
1952	296.6	312.9	288.3
1953	100.4	97.7	99.5
1954	44.5	54.2	60.5
1955	51.8	48.2	56.4
1956	307.1	274.2	245.0
1957	56.0	53.2	65.4
1958	173.4	256.9	402.3
1959	95.5	87.5	79.4
1960	58.3	53.7	50.9
1961	23.3	23.7	22.2
1962	162.5	154.4	139.1
1963	235.6	225.4	272.2
1964	56.7	52.1	49.4
1965	132.2	120.3	129.8
1966	94.2	84.6	73.5
1967	224.8	248.6	302.0
1968	32.6	34.5	33.0
1969	508.8	462.4	416.4
1970	151.9	143.9	130.1
1971	102.0	93.4	85.5
1972	45.5	40.7	36.1
1973	373.7	354.1	318.0
1974	174.4	176.7	195.6
1975	218.9	231.5	229.8
1976	15.7	15.0	15.2
1977	6.3	6.9	6.7

Water Year	Forecast Mean Annual Discharge (March 15)	Forecast Mean Annual Discharge (April 1)	Approved Mean Annual Discharge
1978	445.6	422.6	432.9
1979	131.7	139.9	164.9
1980	471.7	434.3	406.0
1981	92.7	112.0	113.9
1982	217.1	224.7	350.9
1983	691.8	687.7	709.2
1984	153.2	138.2	124.1
1985	56.4	60.8	61.8
1986	313.6	349.5	324.2
1987	43.3	44.6	43.3
1988	37.5	33.9	31.8
1989	25.0	29.1	28.9
1990	23.1	21.7	19.9
1991	26.9	62.3	65.9
1992	113.7	110.7	101.4
1993	365.3	333.2	296.2
1994	49.7	46.0	42.7
1995	372.1	394.6	390.4
1996	181.3	176.4	173.0
1997	306.7	272.0	234.3
1998	434.6	407.7	443.2
1999	77.0	84.3	96.3
2000	168.2	160.3	153.2
2001	118.2	113.2	107.8
2002	88.1	81.9	74.9
2003	141.7	134.1	139.5
2004	88.5	82.3	73.2
2005	325.4	329.5	310.4
2006	148.6	163.9	260.2
2007	29.3	27.6	25.6
2008	146.0	132.3	116.5
2009	107.7	104.1	102.5
2010	299.0	280.0	270.8
2011	168.0	247.0	271.5
2012	31.7	37.3	48.2
2013	96.1	85.2	72.0
2014	16.4	15.9	16.2
2015	54.0	48.0	41.2
2016	82.0	89.0	82.0
2017	466.0	431.0	401.7

Water Year	Forecast Mean Annual Discharge (March 15)	Forecast Mean Annual Discharge (April 1)	Approved Mean Annual Discharge
2018	36.0	65.0	64.8
2019	347.0	326.0	304.9
Legend:	*Dry Year Type*	*Normal Year Type*	*Wet Year Type*