Revised Interim Operations Plan for Nacimiento and San Antonio Reservoirs

Monterey County Water Resources Agency

Adopted by the Board of Directors

November 21, 2022

Recommended by the Reservoir Operations Advisory Committee
October 27, 2022

Contents

Introduction

The proposed Interim Operations Plan (IOP) described below would allow Monterey County Water Resources Agency (Agency) staff discretion to respond quickly to supplement naturally occurring streamflow events. Such actions would provide multiple benefits, including:

- Provide steelhead passage opportunities in the absence of currently existing operational flow enhancement triggers, while adhering to existing water rights, operational agreements and adopted release schedules.
- Support the ongoing development of the Salinas River Habitat Conservation Plan (HCP) through the gathering of pertinent supportive data and information.
- Provide enhanced recharge of Salinas Valley water supply aquifers through Salinas River percolation.

This Revised IOP is an update to the March 2022 IOP which was not adopted by the Agency Board of Directors.

Background

On June 21, 2007, the National Marine Fisheries Service (NMFS) issued a biological opinion to the U.S. Army Corps of Engineers (USACE) for their proposed permitting for the Agency's Salinas Valley Water Project (SVWP). As a result of that process, NMFS issued a biological opinion (BO) for the project in 2007. The BO was integrated into the Salinas Valley Water Project Flow Prescription for Steelhead Trout in the Salinas River (Flow Prescription), which stipulates situational requirements and operational guidelines to minimize impacts of SVWP operations on steelhead in the Salinas River and its tributaries. The Flow Prescription determines baseline spawning and rearing flows and relies on certain hydrologic conditions to trigger supplemental reservoir releases to enhance migration opportunities for steelhead.

In 2016, the USACE requested re-initiation of formal consultation with NMFS pursuant to section 7 of the Endangered Species Act (ESA) regarding construction activities associated with the USACE's permit for the Agency's SVWP. On February 19, 2019, NMFS informed the USACE that re-initiation of consultation was not necessary because the riparian area disturbed by construction of the Salinas River Diversion Facility had been naturally colonized by grasses and shrubs and that current conditions were sufficient to maintain stream temperature, cover, or other aspects of steelhead habitat. The USACE then confirmed that there is no further federal action or terms and conditions associated with the USACE's permit requiring re-initiation of consultation pursuant to section 7 of the ESA. NMFS also believed there was new information that revealed that the SVWP may affect threatened steelhead or its designated critical habitat in a manner or to an extent that was not considered in their 2007 biological opinion. For these reasons, on February 20, 2019, NMFS withdrew its biological opinion. With no biological opinion and no incidental take statement, the Agency has since lacked any exemptions from the take prohibitions of section 9 of the ESA (i.e., the Agency lost its incidental take coverage [ITC]).

The Flow Prescription had been incorporated into the Agency's water rights Licenses 7543 and 12624 and Permit 21089 in 2008, for the Nacimiento and San Antonio Rivers and the Agency continued and continues to operate according to its stipulations, despite NMFS's withdrawal of its BO. As documented by a review of historical reservoir operations and ongoing correspondence with NMFS staff, flow enhancement triggers first defined in the Flow Prescription and in effect since 2010 have so far fallen short of providing the anticipated passage opportunities during some hydrologic year types (See Attachment A).

This IOP is being proposed as a supplement to the existing Flow Prescription while the Salinas River Habitat Conservation Plan (HCP) and reoperation protocols are being developed to provide ITC under future operations. During this time, the Agency will continue to follow the existing Flow Prescription in addition to the supplemental actions defined in this IOP. Operational triggers and goals identified in this IOP are intended to address specific conditions where the Agency's adherence to the Flow Prescription over the first 13 years of operation indicates that further exploration and refinements to operations are needed to achieve the intended goals of the Flow Prescription. Data collected as a result of IOP implementation would provide key information needed to develop reoperation protocols and complete the HCP. As HCP development continues, this IOP may be updated to reflect the increasing understanding of species needs and the development of more effective operational strategies.

As written, this IOP adheres to the current Nacimiento Dam Operation Policy (Operation Policy), which was adopted by the Agency Board of Directors in February 2018. That document reflects reservoir operational policies incorporated since the SVWP began operating in 2010 and encompasses objectives of the Flow Prescription that were added to Agency water rights in 2008.

Current Efforts Related to Reservoir Operations

Flow Prescription and Recent Passage Opportunities

One of the Flow Prescription's central aims is to provide steelhead migration conditions to and from the lower Salinas River Basin, including the Arroyo Seco and lower Nacimiento Rivers, and the Monterey Bay, through the mainstem of the Salinas River. Spawning and rearing habitat in the Arroyo Seco is recognized to be the highest quality and most accessible in the lower Salinas River Basin. When triggered under the Flow Prescription, releases of water from Nacimiento and San Antonio Reservoirs are made to facilitate fish passage to the Arroyo Seco, lower Nacimiento River and other potential spawning and rearing habitat in the upper Salinas River watershed.

The Flow Prescription states that an adaptive management approach is essential to ensuring that proposed actions achieve their desired effects given the complexity and variability of the hydrology and hydraulics of the Salinas River and its tributaries. The Agency has the ability to influence only a portion of this system. During the development of the original Flow Prescription, it was acknowledged that fully understanding the system would take considerable time. A typical steelhead life-cycle is on the order of 4 to 5 years, with a high degree of variability. Understanding how operational changes can benefit one species of fish without severe harm being caused to other species and beneficial water uses within the system will require extensive analysis spanning multiple hydrologically variegated periods. The Agency recognizes that the long-term solution to addressing operational impacts to steelhead and other listed species is the completion and adoption of an HCP. While HCP development proceeds and the Agency lacks ITC, interim action, as presented in the proposed IOP, provides an adaptive management approach to reservoir operations that will simultaneously provide data allowing Agency staff to study different operational approaches to address environmental factors and ultimately will inform the HCP process.

As of the date of this report, the most recent substantial steelhead passage opportunities occurred during the wet winter and spring of 2018/19. The winters of 2019/20, 2020/21, and 2021/22 provided no adult steelhead passage opportunities as defined by the Flow Prescription. All three of these winters included short duration natural flow events that resulted in sandbar management at the Salinas

River Lagoon and provided connected flow from the Arroyo Seco to the ocean. None of these events met established thresholds to trigger supplemental releases under the Flow Prescription and therefore no supplemental reservoir releases were made during these events.

Need for an Interim Action

The ability to modify reservoir releases to capitalize on storm events in the absence of Flow Prescription triggers would provide critical information needed for possible re-operation scenarios that will then be used during the development of the HCP while beginning to address concerns regarding migration flows during dry periods. Limited migration opportunities for smolts to reach the ocean and anadromous adults to return to spawn have been linked to limited steelhead populations, possibly because a low rate of reproduction may not be sufficient to seed available rearing habitat (Dagit, et al 2017). The IOP will also inform our understanding of how the river system behaves outside of the analysis period in the Flow Prescription.

The Flow Prescription sets target 10-year average numbers of adult steelhead upstream passage days (defined as 260 cubic feet per second (cfs) at the Salinas River near Chualar gage [hereafter Chualar gage] when the Lagoon is open to the ocean), for each water year type. The target 10-year average for dry-normal year types is 14 to 18 passage days (16 passage days, plus or minus 10%). During the first thirteen years of SVWP and Flow Prescription operations (2010- 2022) no adult upstream passage days were recorded in any of the four dry-normal category years that occurred.

Most recently, in Water Year 2022, following a wet December, 2021, drought conditions quickly reemerged throughout the watershed. Limited adult steelhead passage opportunities had occurred during the past two water years and it became increasingly unlikely that any upstream migration passage days would occur in 2022, as extensive reaches of the Salinas and lower Arroyo Seco Rivers became dry and long-term forecasts indicated the likely persistence of drought conditions through the spring. To address concerns presented by NMFS, Agency staff developed an IOP proposal that would have authorized rapid operational action in February and March of 2022 to supplement a naturally occurring streamflow event to provide a window of steelhead passage opportunity in the absence of flow prescription triggers. On March 21, 2022, the Agency Board of Directors (BOD) declined to adopt a proposal that would expire in 10 days, citing a lack of opportunity within the abbreviated timeframe for stakeholder consideration and input and the unlikelihood of any action being necessary, based on the weather forecast. The BOD requested that staff keep working on the proposal and bring back a revised version for consideration before the next rainy season.

The Agency is working in cooperation with NMFS, the U.S. Fish and Wildlife Service (USFWS), and the California Department of Fish and Wildlife (CDFW) on a long-term solution to address operational impacts to steelhead and other listed species through the development and adoption of an HCP. For the years remaining until adoption of an HCP, authorization for Agency staff to act as defined in this IOP, in the absence of Flow Prescription triggers, affirms the Agency's good faith effort to address issues articulated by NMFS (Attachment B).

Agency staff is therefore recommending adoption of the IOP detailed in this document to enable interim modification to reservoir release operations allowing the augmentation of natural flow events to enhance steelhead migration opportunities between January 1st and March 31st in the absence of Flow Prescription triggers.

Habitat Conservation Plan Development

In 2016, with construction activities complete and no federal nexus related to operation of the SVWP, the Agency began investigating the development of an HCP as a means of acquiring required permits under the ESA. In 2018 the Agency began a phased approach to develop the Salinas River HCP. The first phase, creation of the Salinas River Long-term Management Plan (LTMP), was completed in 2019, the same year NMFS withdrew its 2007 BO and associated permits. Analysis of Flow Prescription performance by Agency staff indicates that although the Agency has followed the Flow Prescription correctly, the protocols have not met their intended goals under certain circumstances. The issue has been compounded by two periods of extended drought and what appear to be changing baseline hydrologic conditions.

The Agency is currently working on phase 2 development of the HCP. At a minimum, the HCP will result in a new flow prescription for SVWP operations, and a lagoon sandbar management plan that addresses the needs of steelhead in the Salinas River and tributaries as well as the needs of steelhead, tidewater goby, and western snowy plover at the Salinas River Lagoon.

Studies are currently being conducted to assess species presence, habitat, migration barriers, and streamflow needs that will help inform the HCP and the discussion of SVWP reoperation protocols. Some of these studies require specific hydrologic conditions or must be conducted during certain times of year that coincide with the lifecycle of the species being studied. A thorough investigation of these issues and development of meaningful long-term reoperation protocols will take multiple years to complete.

Interim Operations Plan Proposal

This IOP is being offered as supplemental adaptive management to the existing Flow Prescription, and is designed to acquire information fundamental to development of the Salinas River HCP and reoperation protocols. Operational triggers and goals identified in this IOP are intended to address specific conditions where the Flow Prescription has not fully met its intended goals over the first 13 years of operation. As HCP development continues, this IOP will be updated to reflect our increasing understanding of species needs and the development of more effective operational strategies.

The IOP will attempt to approximate features of a natural Salinas River hydrograph during storm events that have the potential to produce connected flow throughout the system, but may fall short of creating adequate steelhead passage conditions without supplemental releases. Recharge of Salinas River flows to groundwater supply aquifers is amplified when conditions are dry in the Salinas Valley. Supplemental releases will provide the added benefit of enhanced groundwater recharge. A substantial portion of water released under IOP operations, up to 85%, will recharge aquifers of the Salinas Valley Groundwater Basin.

During the interim operational period the Agency will make reservoir releases, at the discretion of the General Manager, if staff determines there is a reasonable probability of successfully augmenting a natural streamflow event for steelhead passage between January 1st and March 31st when the interim operations triggers enumerated below are in place.

During the interim operational period, all existing water rights and agreements will remain in effect and may override interim operations as determined by the General Manager. Any release schedule adopted by the Board of Directors will be focused on the Agency's Conservation Program and minimum flow requirements, and will not include Flow Prescription or IOP triggering events. Staff will continue to provide actual reservoir release and storage data updates to the Reservoir Operations Advisory Committee (ROAC) on a monthly basis. These updates will include a discussion of any IOP activity underway or under consideration. Upon adoption, the IOP will be reviewed each fall as to occurrence of triggers, implementation, operations, results, and knowledge obtained, in an annual report to the Agency Board of Directors. The report will act as a guide to assess any need for revisions to the plan in the succeeding year.

Interim Operations Triggers

Interim operations will be considered only when each of four triggers are met. Three of these triggers are indicative of the potential for watershed conditions and water availability favorable to the achievement of passage conditions (numbers 1-3 below, hereafter "watershed triggers"); the fourth trigger ensures consideration of release actions will not occur when a set cumulative passage day threshold has already been achieved (number 4 below, hereafter "passage day threshold trigger"). The triggers are as follows:

1. Inflow to Nacimiento and San Antonio Reservoirs is observed via reports from the USGS gage sites: USGS 11149900 SAN ANTONIO R NR LOCKWOOD CA and 11148900 NACIMIENTO R BL SAPAQUE C NR BRYSON CA at rates that exceed required minimum releases at each reservoir. This trigger ensures that water already stored under Agency water rights is not used for IOP releases under consideration herein. Water released under an IOP action will be strictly limited to bypass flows, defined as only those quantities of water that have entered the reservoirs within the most recent 30 day period.

2. Continuous flow is established from the Arroyo Seco River to its confluence with the Salinas River sufficient to provide fish passage. Based on the Flow Prescription, this occurs at a flow rate of 173 cfs (+/- 10%) or greater, as reported at USGS gage 11152050 ARROYO SECO BL RELIZ C NR SOLEDAD CA). Note: there remains potential for adult steelhead upstream migration to occur below 173 cfs. Completion of fish passage studies scheduled for 2022 and 2023 may refine our understanding of migration conditions and result in updated IOP passage threshold targets.
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3. The Salinas River Lagoon is open to the ocean or facilitated lagoon breaching has been initiated in conformance with the current Salinas River Lagoon Sandbar Management Plan. Specifically, the Agency manages the water levels in the lagoon to maintain fish and wildlife habitat, prevent saturation of adjacent agricultural fields' root zones, and to minimize flooding potential to residential and agricultural lands during high flows. The Agency may perform sandbar management activities as needed to prevent flooding in response to natural streamflow events that typically occur from late fall to late spring. Facilitated breaching is conducted during emergency situations to alleviate flooding by reducing the sandbar elevation between the Salinas River Lagoon and the Pacific Ocean.

4. Fewer than sixteen Passage Days, as defined in the Flow Prescription, have occurred during the current water year. Sixteen passage days is the Flow Prescription target for dry-normal year types. This target was not met in any of the four dry-normal years that occurred since 2010 when SVWP operation began, despite strict adherence to the Flow Prescription (Attachment A). This is the only upstream migration target that has not been met in the SVWP era. Therefore, an IOP release action will only be considered if this target has not been met.

An additional trigger included in previous drafts of this IOP would have required a minimum mean daily flow of 60 cfs as reported at the USGS gage: [USGS 11147500 SALINAS R A PASO ROBLES CA]. A review of historical streamflow data indicates that flow at Paso Robles is often decoupled from lower Salinas flows such that passage conditions in the lower Salinas can occur with a lack of flow at Paso Robles. Inclusion of this trigger would likely result in missed opportunities for successfully achieving passage opportunities downstream. For this reason, the trigger was removed.

Interim Reservoir Operations

Once all the triggers are met and Agency staff has determined that interim reservoir operations will meet the goals of the IOP, the General Manager will authorize interim reservoir operations, as follows:

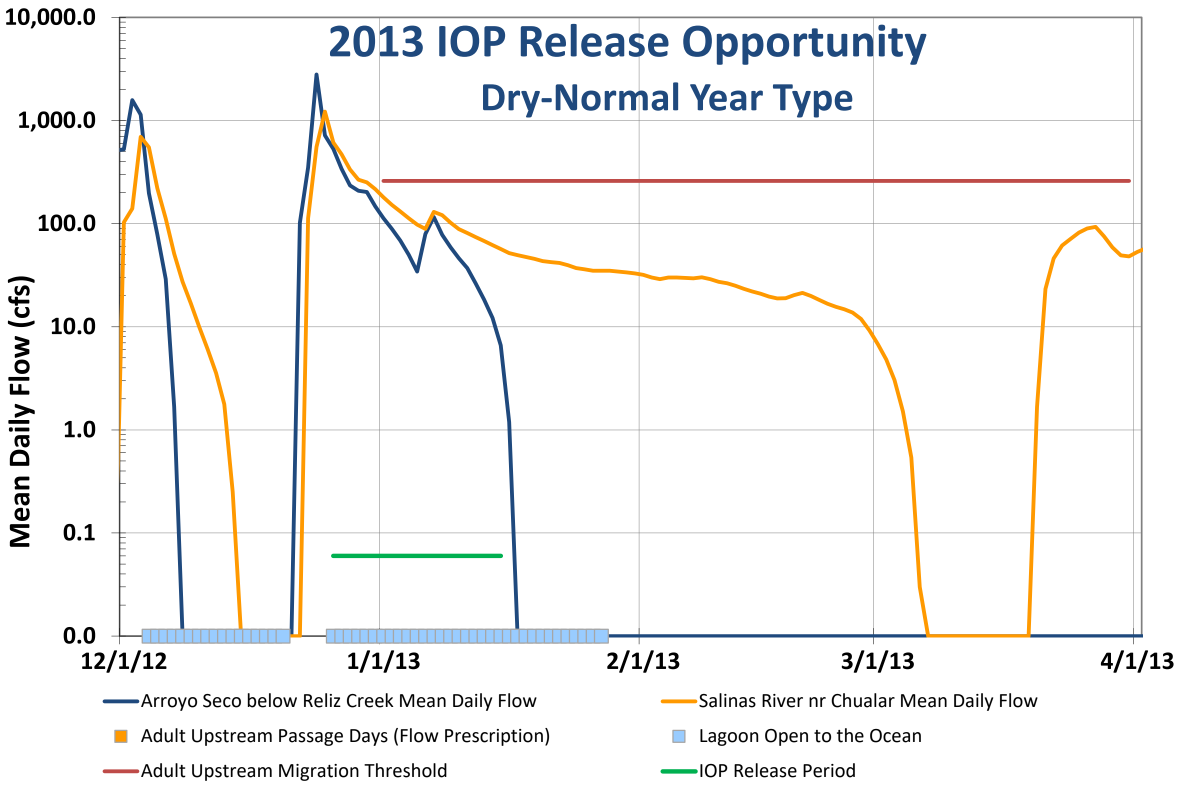
- The Agency will implement reservoir releases such that the total release volume will not exceed the volume of the inflow event triggering the release action. Release rates and durations will be based on safe operations of the outlet works and comply with all Agency operational policies, at both reservoirs.
- If, upon evaluation of factors including reservoir storage, weather forecasts, river forecasts, historical travel times, dam outlet capacity, storm inflow, and overall watershed conditions Agency staff determines that after seven days of interim releases, flows in the Salinas River will not reach the USGS gage site [11151700 SALINAS R A SOLEDAD CA], interim releases will cease and the Agency will resume normal operations.
- If Salinas River flows connect to Arroyo Seco flows, interim releases will be maintained to achieve a total of 16 passage days for the calendar year, as long as Arroyo Seco flows, as defined above, exceed 10 cfs.
- To ensure minimal instream impacts, interim releases will be ramped down gradually, over multiple days if needed.
- Pursuant to the Flow Prescription, the current adult steelhead upstream passage threshold of 260 cfs (+/- 10%) at the Chualar gage will be targeted, but the Agency recognizes that this target may not be achievable under all conditions and that there remains potential for steelhead migration to occur below the threshold. Completion of fish passage studies scheduled for 2022 and 2023 may refine our understanding of migration conditions and result in updated IOP passage threshold targets.
- Reservoir releases for this action will not occur below the minimum pool elevations of 687.8 ft at Nacimiento and 666.0 ft at San Antonio or cause elevations to decline to below the minimum pool elevations during the IOP operations.
- With the goal of achieving upstream passage opportunities between January 1st and March 31st, IOP release actions may be initiated prior to January 1st if all triggers are met and Agency staff has determined that such action will achieve IOP goals. Release actions may continue to conclusion after March 31st if triggers are met on or before that date.

Application of Interim Operations Plan

Agency staff has applied IOP protocols to recent historical data to assess their applicability and potential effectiveness in creating opportunities for upstream migration, as defined in the Flow Prescription. A review of historical data indicates that, in the 23 years since 2000 (2000-2022), IOP watershed triggers (numbers 1, 2, and 3) were met in fourteen different years. In six of these years, the IOP passage day threshold trigger (number 4) was not met because sixteen or more passage days had been achieved either without the aid of reservoir releases or with flood control releases playing a significant role in creating passage conditions. In the other eight years all four triggers were met. In two of those eight years (2017 and 2021) it is evident that IOP actions would have been precluded by storm forecasts and flooding concerns within the brief time windows when IOP triggers were met. In another year (2000) November and December 1999 releases maintained continuous flow from the reservoirs to downstream of the Chualar gage, prior to the occurrence January storm activity that resulted in IOP triggers being met. The remaining five years (2003, 2004, 2009, 2013, and 2019) likely would have warranted consideration for potential IOP implementation.

To illustrate the operational aim and scope of implementing an IOP release, historical data are used in Figure 1, a conceptual schematic showing relevant flow conditions and the timing of a potential IOP release to achieve sixteen passage days in 2013, one of the five potential implementation years.

Figure 1: 2013 IOP Release Opportunity, Dry-Normal Year Type



The orange curve indicates mean daily flow at the Chualar gage. The red line marks the threshold flow value for upstream migration of adult steelhead as defined in the Flow Prescription (260 cfs). The purpose of an IOP release action would be to extend the number of days where flow at the Chualar gage (orange curve) remains above 260 cfs, up to a total of sixteen days. The green bar near the bottom of the graph represents the time window during which an IOP release action could have been implemented to achieve a total of sixteen upstream passage days, following the attainment of all IOP triggers, including an open lagoon (light blue bar) and hydraulic connection between the Arroyo Seco and Salinas Rivers (dark blue line, indicating Arroyo Seco flow).
Figures 2 through 5 show similar IOP Release Opportunity hydrographs for 2003, 2004, 2009 and 2019. Year types are included to highlight the fact during the months of IOP implementation (January through March) year type is generally unknowable and although the IOP aims to improve passage day achievement in Dry-Normal year types, such as 2004, 2009 and 2013, all triggers may also be

met in other year types, including early in normal and wet years before passage days have been achieved by natural flows, as was the case in 2003 and 2019.

Figure 2: 2003 IOP Release Opportunity, Normal Year Type

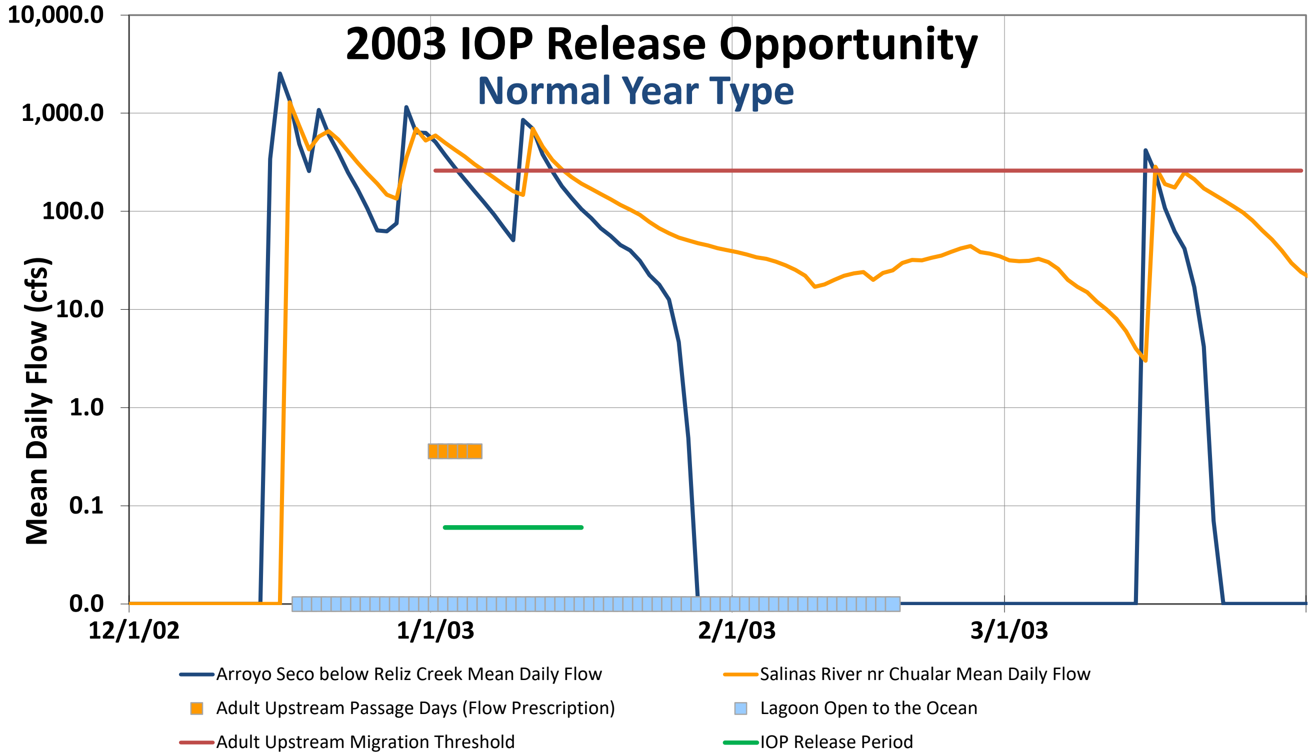


Figure 3: 2004 IOP Release Opportunity, Dry-Normal Year Type

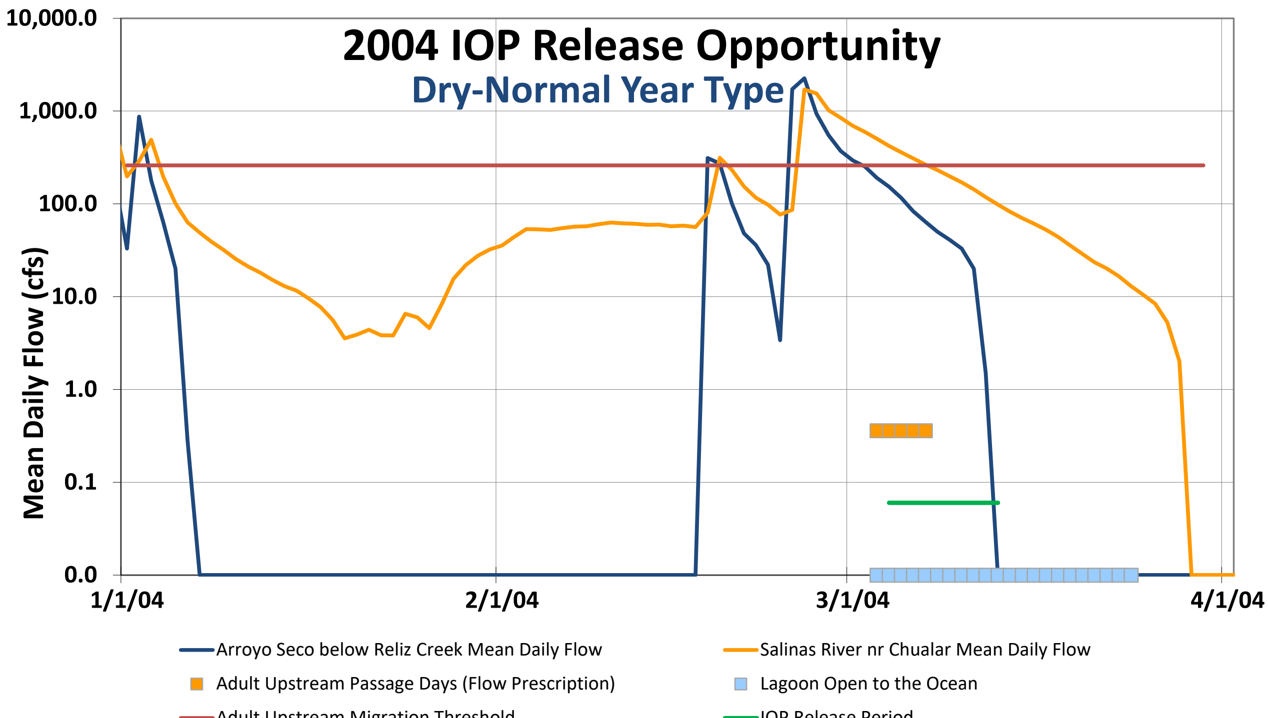


Figure 4: 2009 IOP Release Opportunity, Dry-Normal Year Type

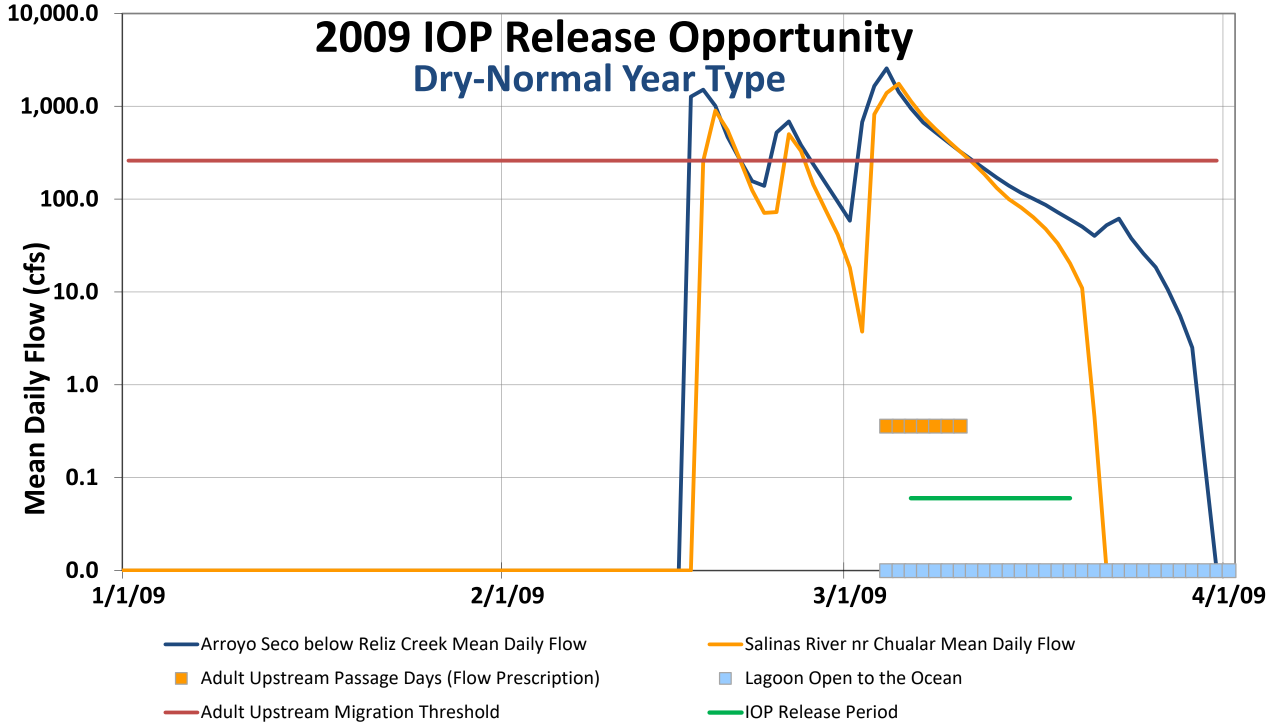
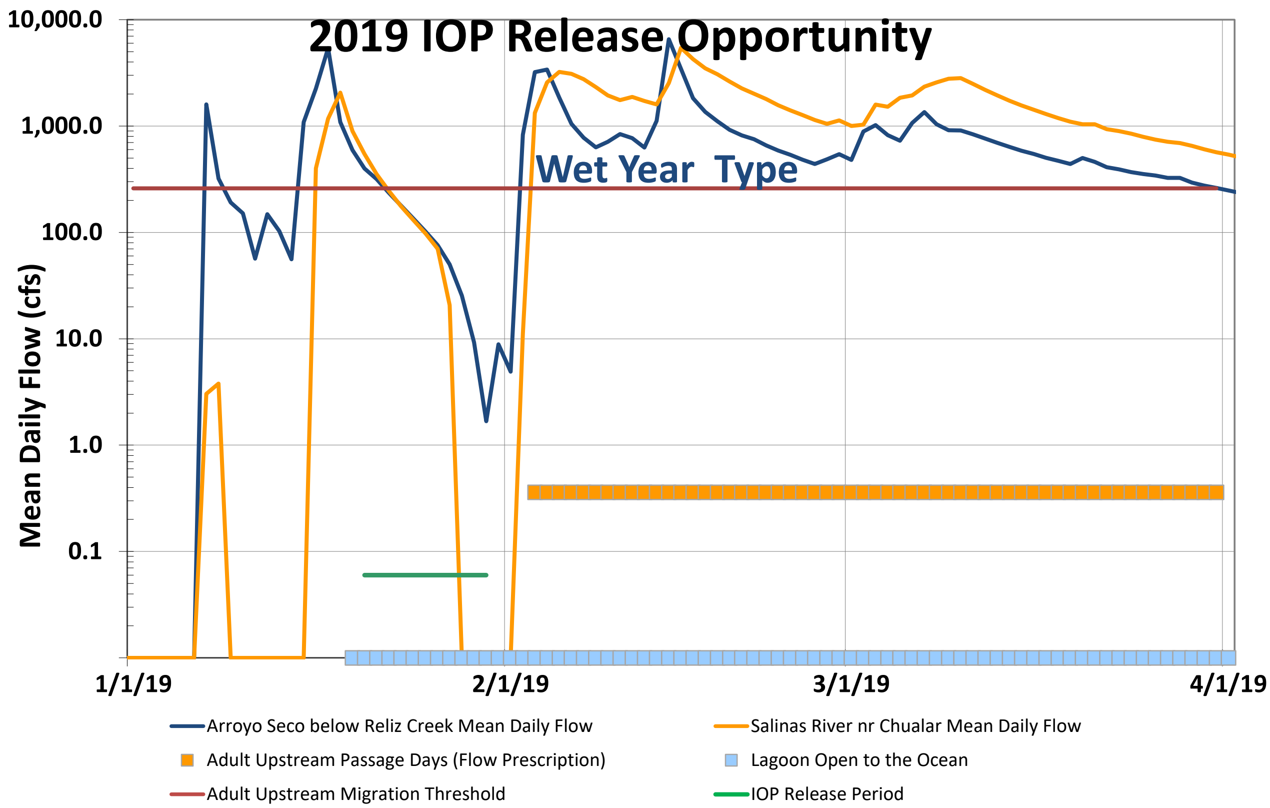


Figure 5: 2019 IOP Release Opportunity, Wet Year Type



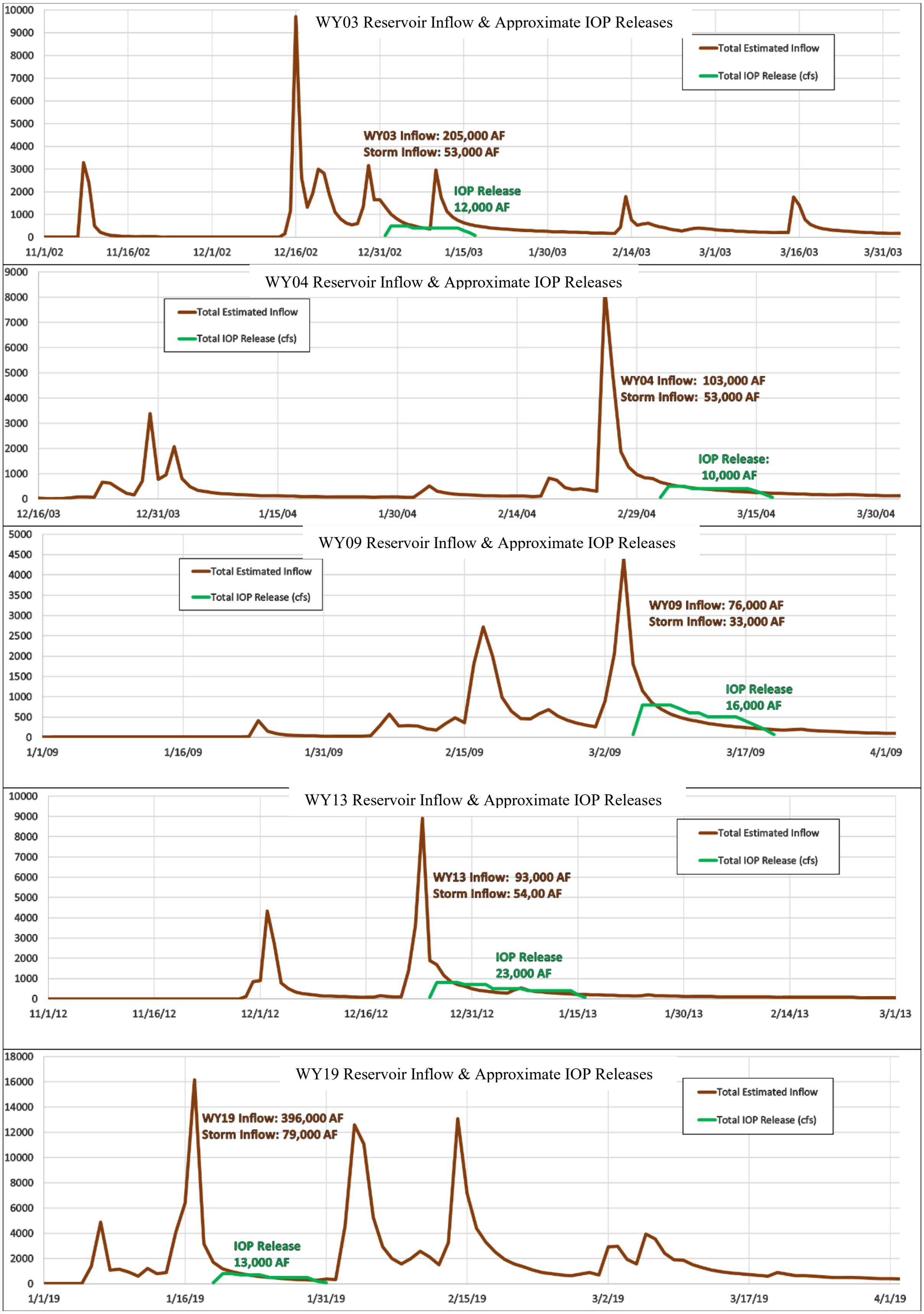
Owing to a complex interplay of watershed and operational factors, it is not possible, without modeling analysis, to determine the results of IOP actions applied to past events. It is possible, however, to conservatively estimate total water volume expenditures resulting from assumed IOP implementation (i.e, executing a release action). By applying realistic IOP release schedules to the five years during which an IOP action would have been considered, a useful comparison can be made between estimated IOP releases and actual reservoir inflow for the triggering storm and the water year. Table 1 summarizes these comparisons along with year type, release duration and a comparison of passage days achieved with and without a successful IOP release action.

Table 1: Summary of IOP Release Opportunities

Water Year	Year Type	Water Year Inflow (AF)	IOP Storm Inflow (AF)	Estimated IOP Release Volume (AF)	IOP Release Duration (days)	Passage Days without IOP	Potential Total Passage Days with IOP
2003	N	205,000	53,000	**12,000**	15	5	16
2004	DN	103,000	53,000	**9,000**	11	5	14
2009	DN	76,000	33,000	**16,000**	14	7	16
2013	DN	93,000	54,000	**23,000**	21	0	16
2019	W	396,000	79,000	**13,000**	11	61	71

Figure 6 below graphically depicts these comparisons of total combined reservoir inflow and plausible IOP release sequences for the same years. Brown lines represent actual combined inflow to the reservoirs while green lines show approximate IOP release amounts. Inflow and releases are in cfs with total estimated inflow and release volumes added in acre-feet.

Figure 6: Reservoir Inflow and Approximate IOP Release Graphs



Duration of Interim Operations Plan

Adoption of this IOP is intended to address Steelhead passage issues as observed in the Agency's 10-year review of the SVWP, as well as those expressed by NMFS in its 2021 Memo and its subsequent March 2022 letter (Attachment B). Adoption of this IOP will also provide necessary data and information integral to HCP development, beginning in the upcoming winter of 2023 and until completion and adoption of an HCP provides for long term incidental take coverage related to Agency operations. Revocation of this adopted IOP prior to adoption of an HCP shall require action of the Water Resources Agency Board of Directors.

If adopted, Agency staff will report on IOP actions as part of monthly Reservoir Release Updates to the ROAC. A summary of IOP actions taken or considered each year will also be incorporated into Salinas Valley Water Project Annual Flow Reports during the IOP implementation period. The IOP will also be reviewed each fall as to occurrence of triggers, implementation, operations, results, and knowledge obtained, in an annual report to the Agency Board of Directors. The report will act as a guide to assess any need for revisions to the plan in the succeeding year.

APPENDICES

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.

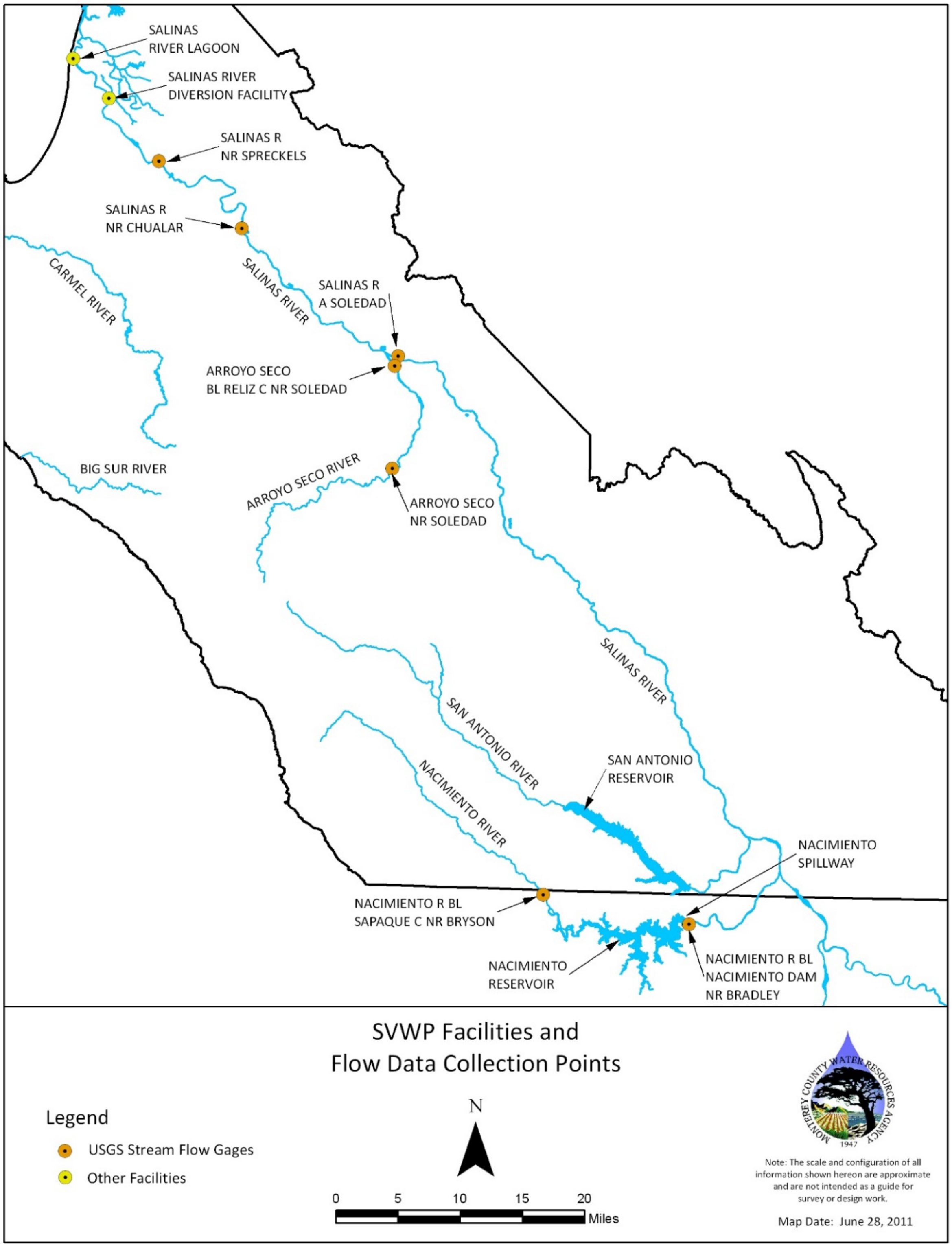

Figure 1. SVWP facilities and flow data collection points.

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).

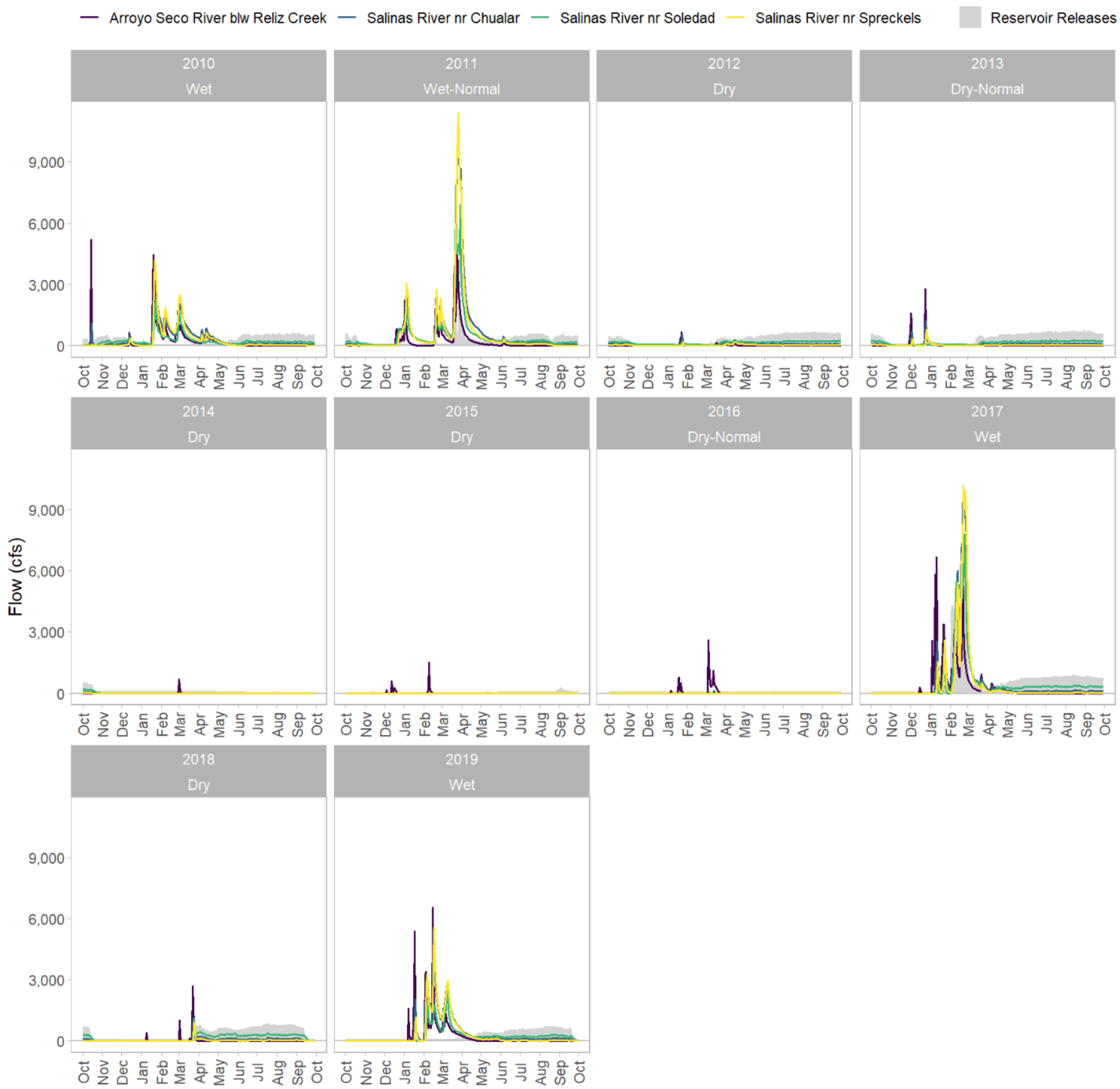

Figure 2. Stream flow summaries for selected flow monitoring locations in the Salinas River Basin. Reservoir releases are included as the grey shaded area. Water year type is indicated below the water year label in each panel.

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*)

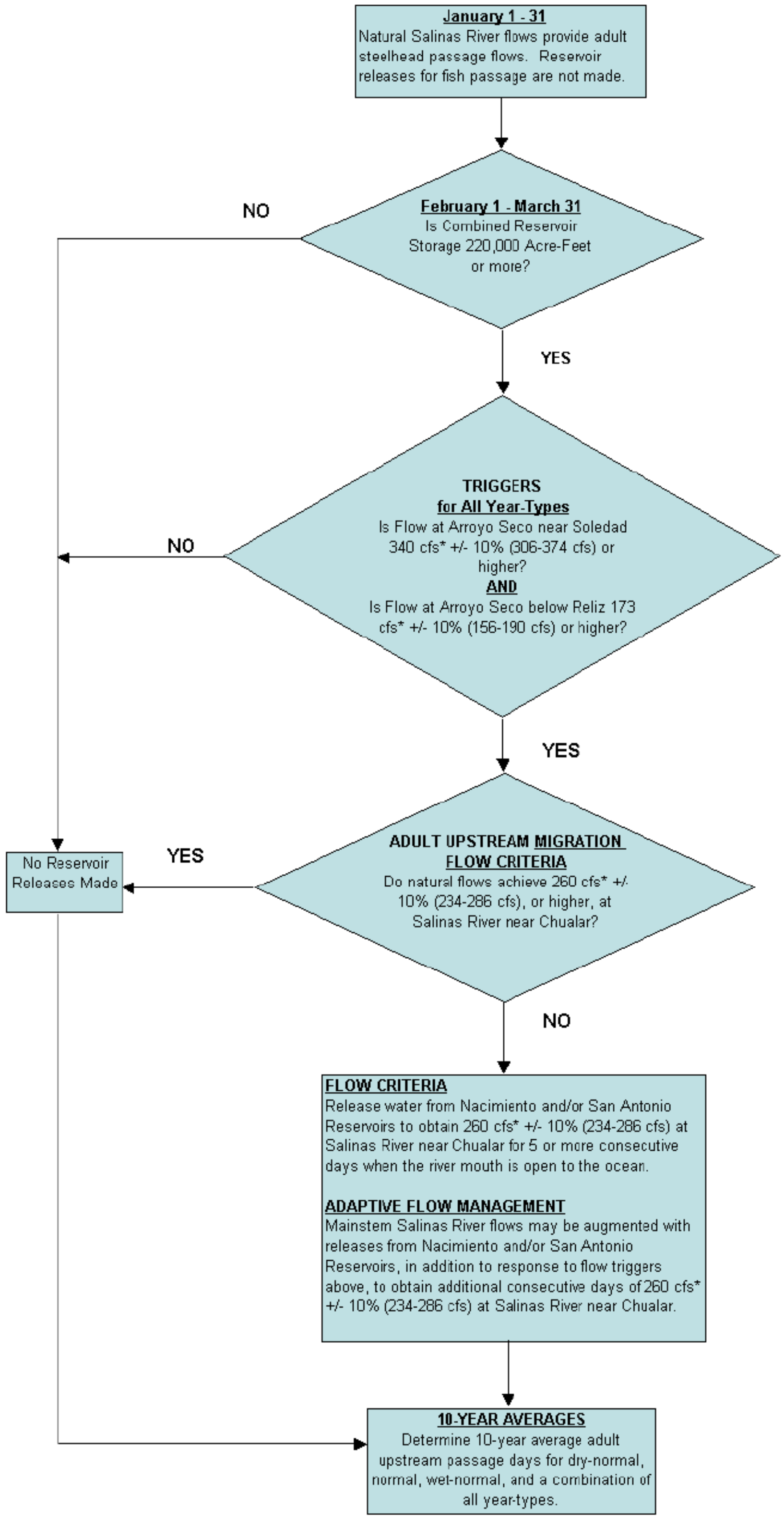

Figure 3. Adult upstream migration flow triggers. Figure from the 2005 Flow Prescription.

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.

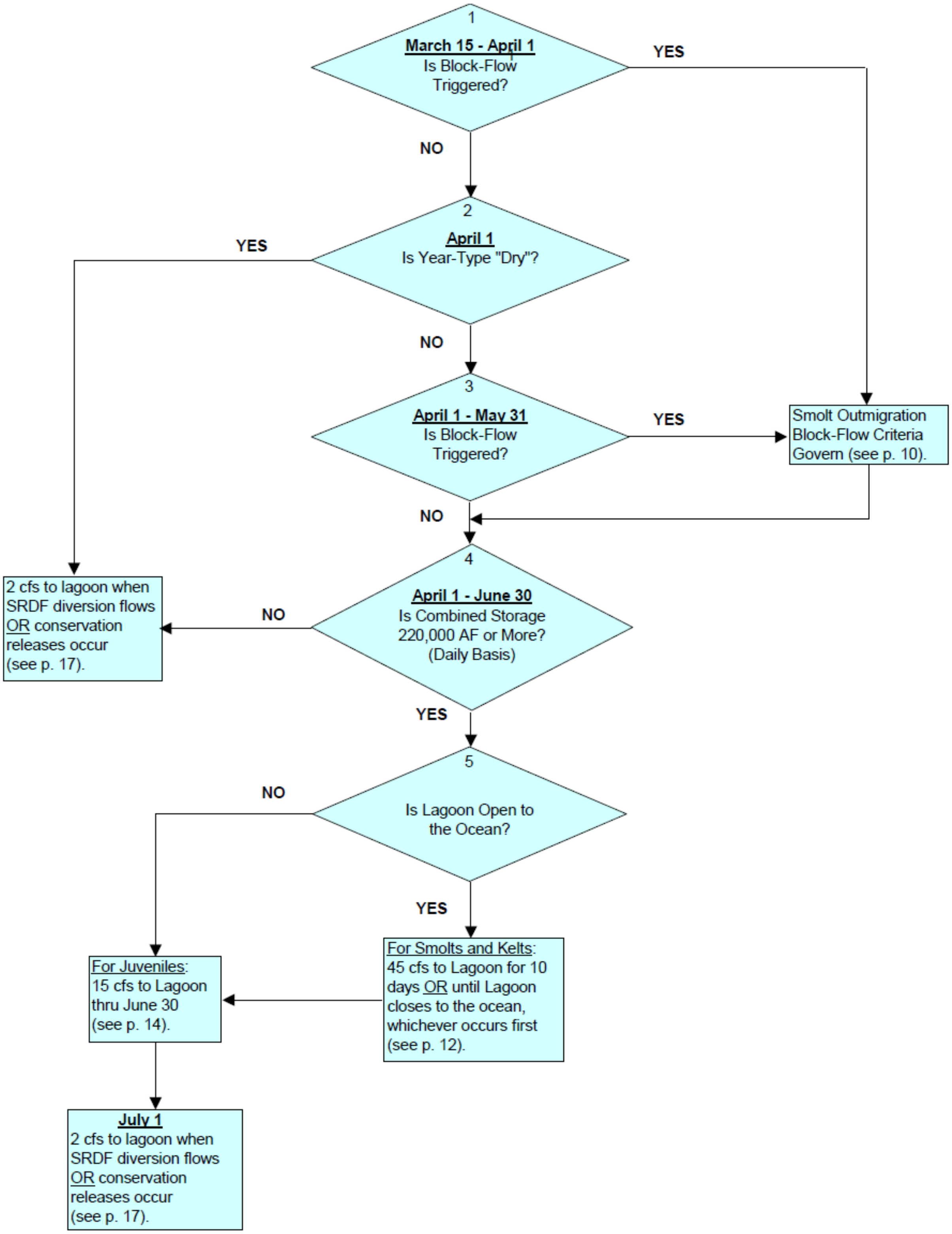

Figure 4. Smolt downstream migration flow triggers. Figure from the 2005 Flow Prescription.

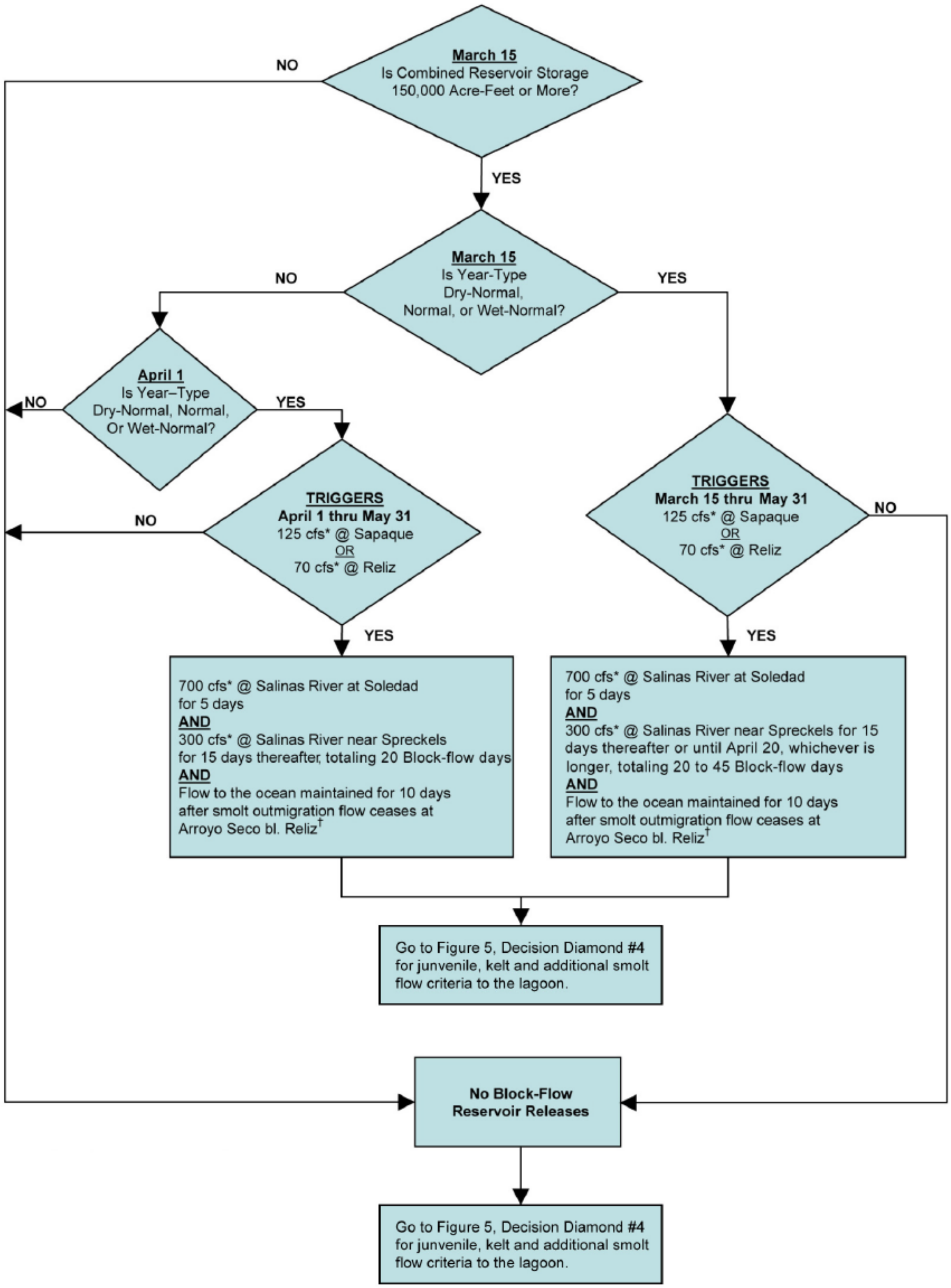

Figure 5. Smolt outmigration block flow triggers. Figure from the 2005 Flow Prescription.

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.

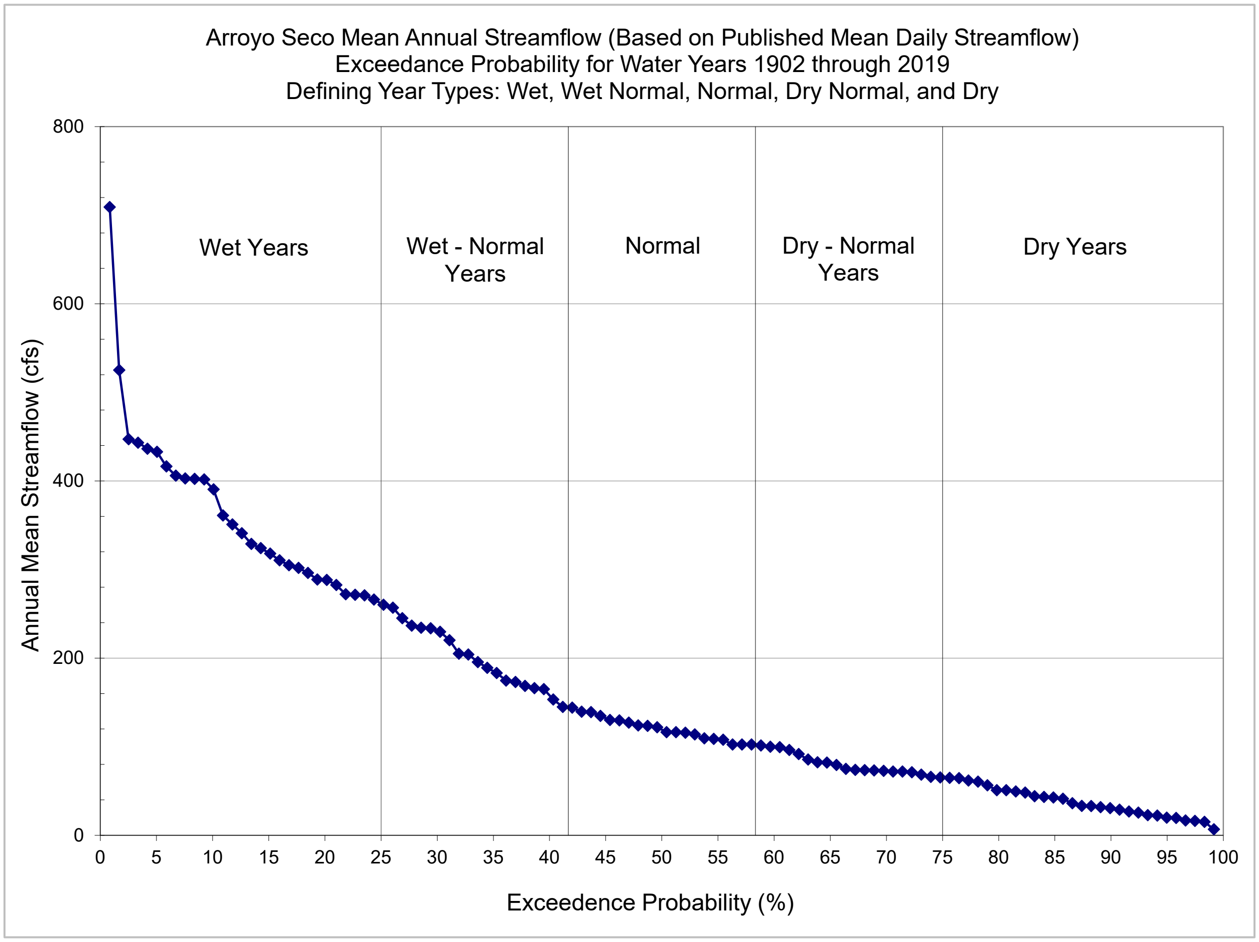

Figure 6. Exceedance probability of mean annual streamflow and year type boundaries.

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).

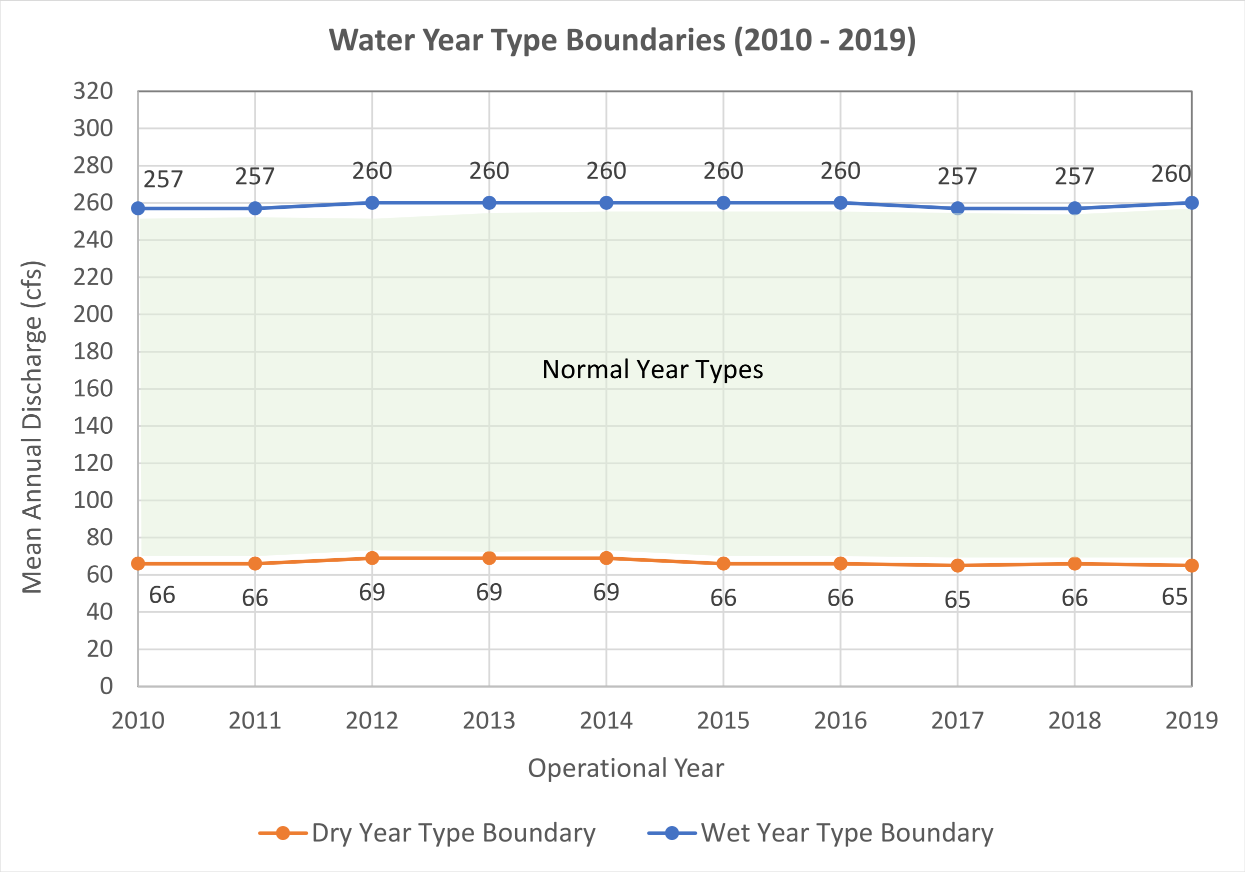

Figure 7. Water year type boundaries 2010-2019.

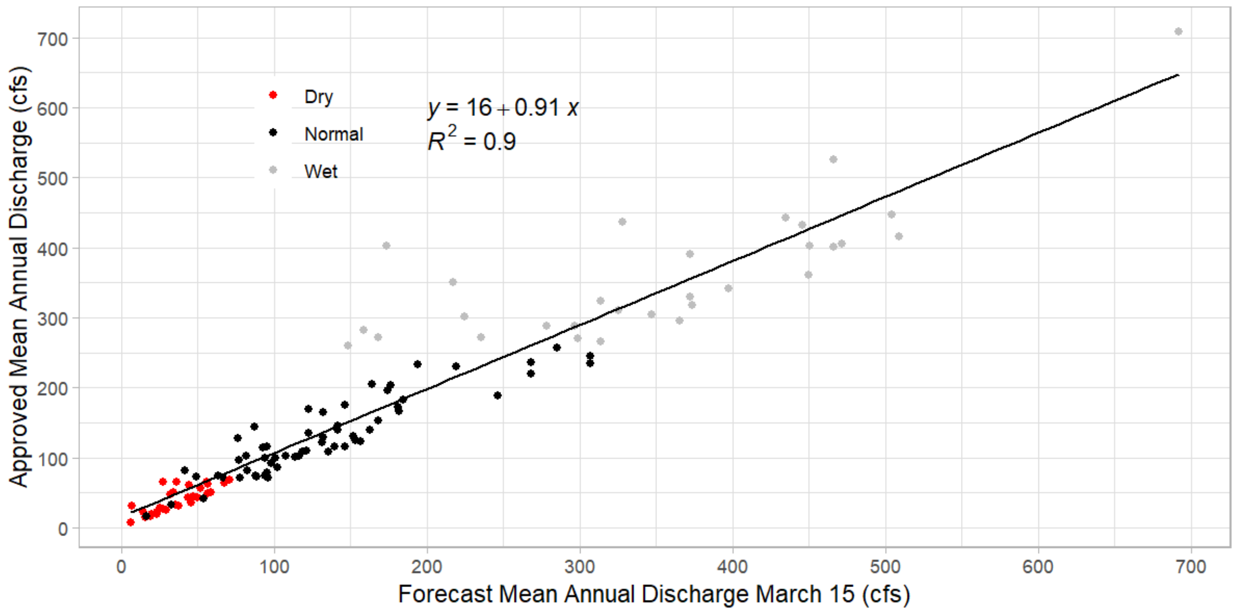

Figure 8. Relationship between forecasted mean annual discharge on March 15 and approved mean annual discharge from 1902 to 2019. Water year types are indicated by color and a linear trend line; fitted linear equation and R^2 value are also provided.

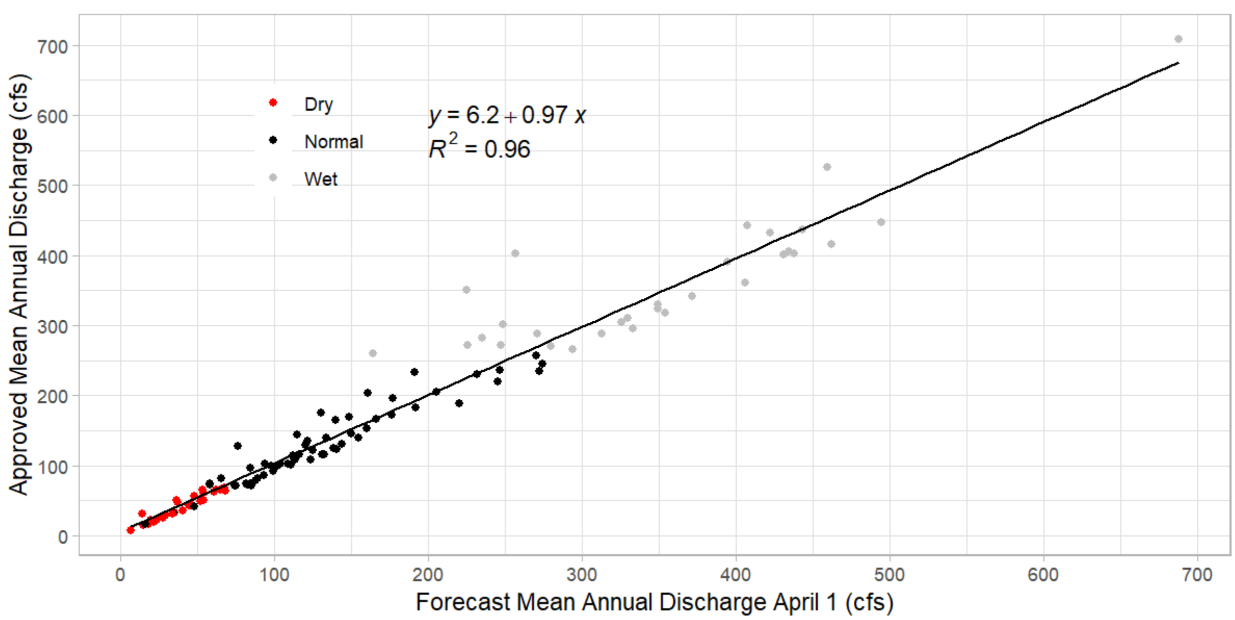

Figure 9. Relationship between forecasted mean annual discharge on April 1 and approved mean annual discharge from 1902 to 2019. Water year types are indicated by color and a linear trend line; fitted linear equation and R^2 value are also provided.

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.

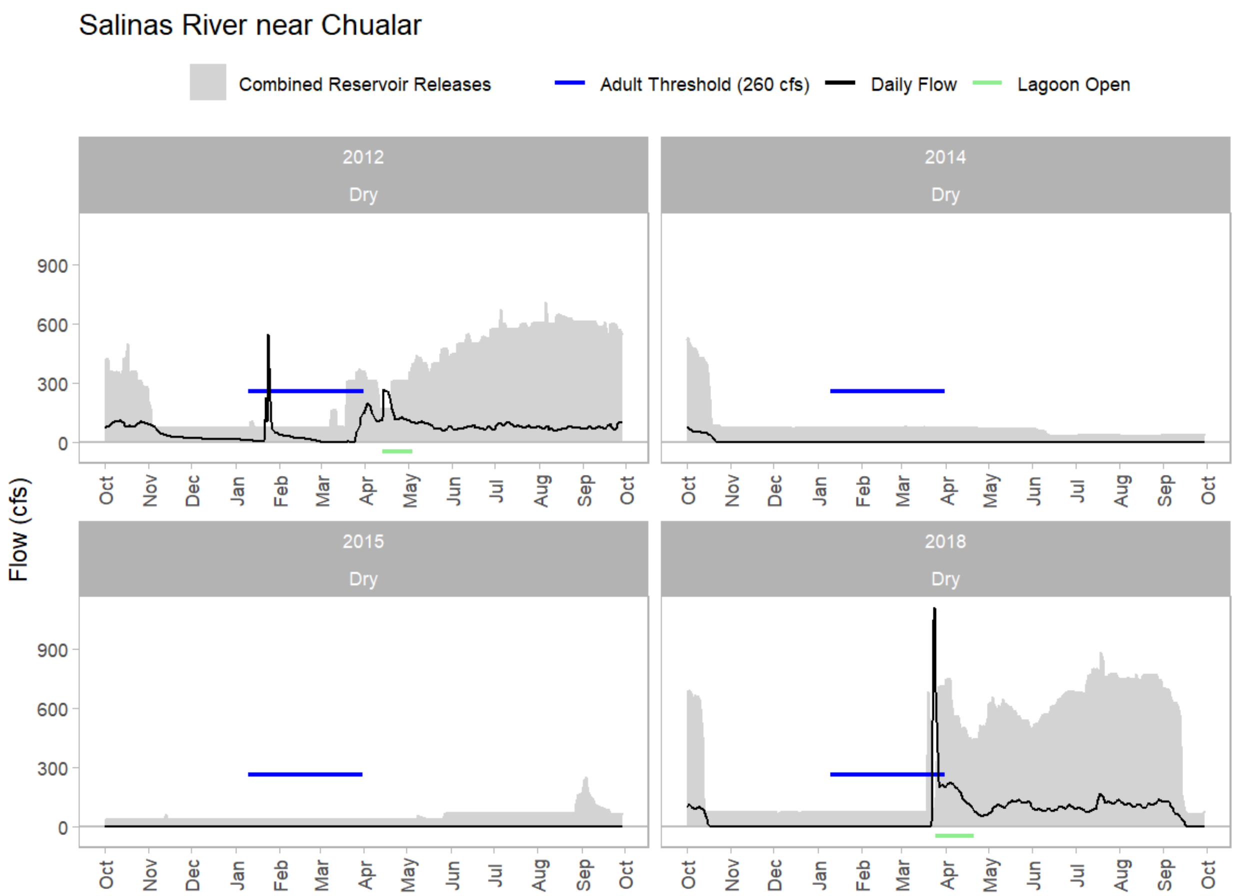

Figure 10. Mean daily flow (black line) conditions on the Salinas River near Chualar during dry water years. Combined reservoir releases are indicated in grey, the adult passage threshold is indicated by the blue horizontal line, and the green line below the x-axis indicates when the Salinas Lagoon was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

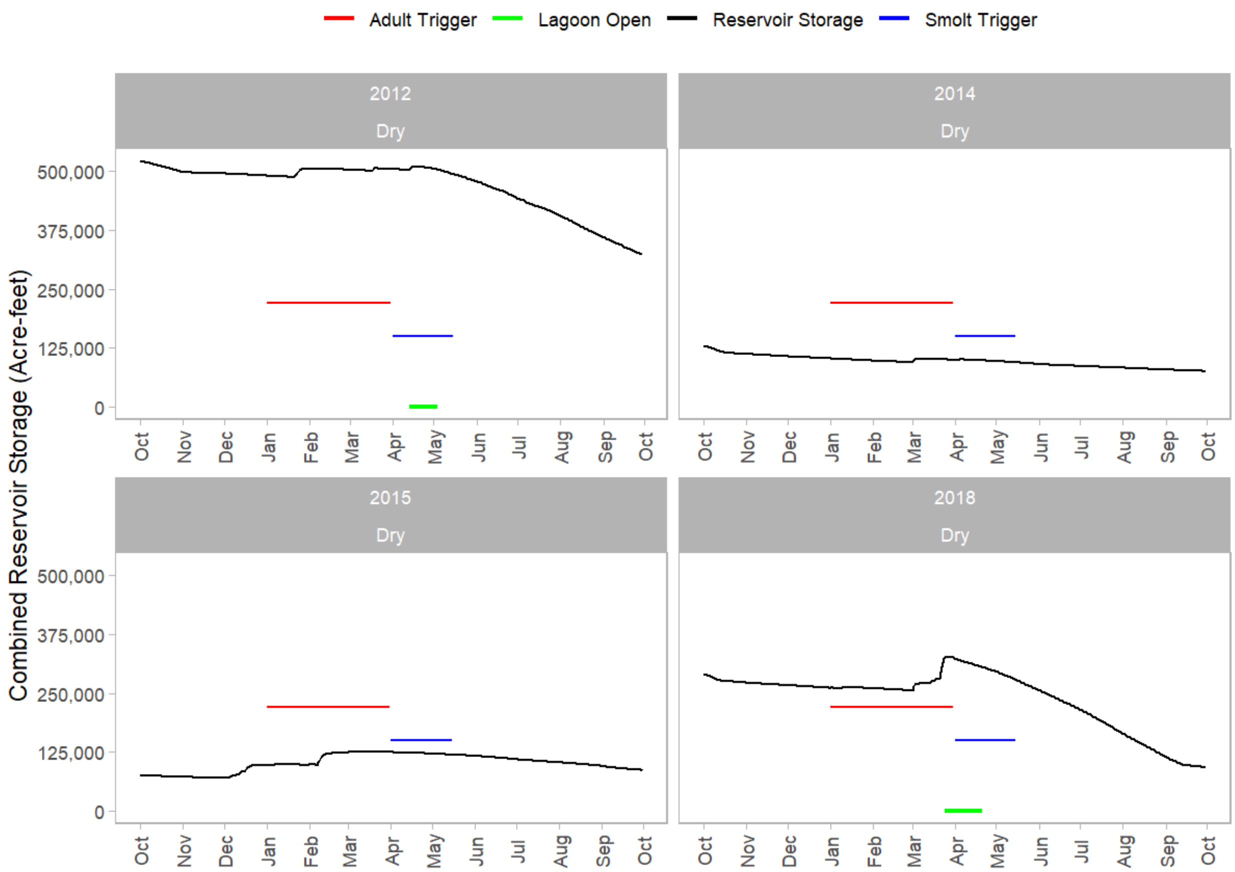

Figure 11. Combined Nacimiento and San Antonio reservoir storage during dry water years. The green line below the x-axis indicates when the lagoon was open. The horizontal red and blue lines indicate storage levels required to trigger adult and smolt flow augmentation, respectively. Minimum reservoir 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.

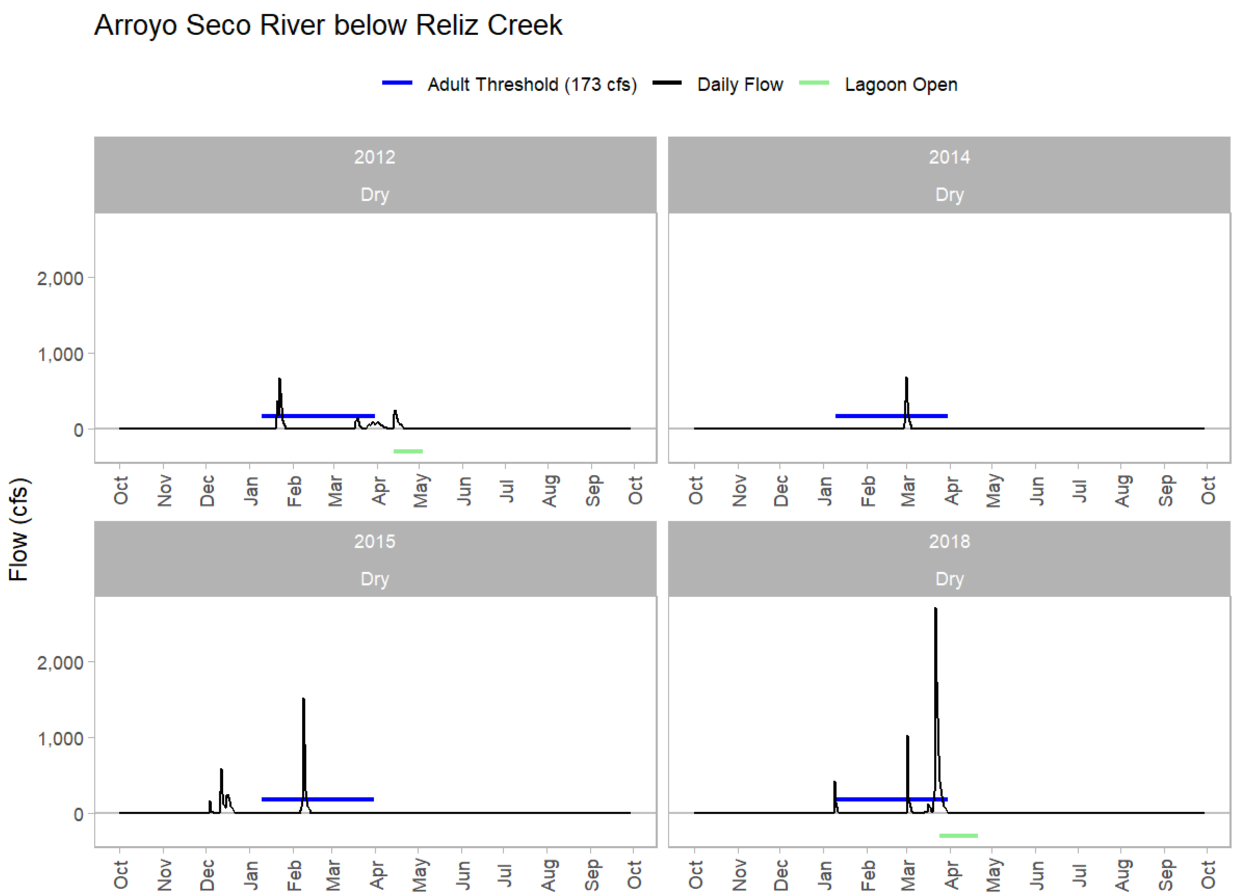

Figure 12. Mean daily flow (black line) conditions on the Arroyo Seco River below Reliz Creek during dry water years. The adult flow threshold is indicated by the blue horizontal line and the green line below the x-axis indicates when the Salinas Lagoon was open to the ocean.

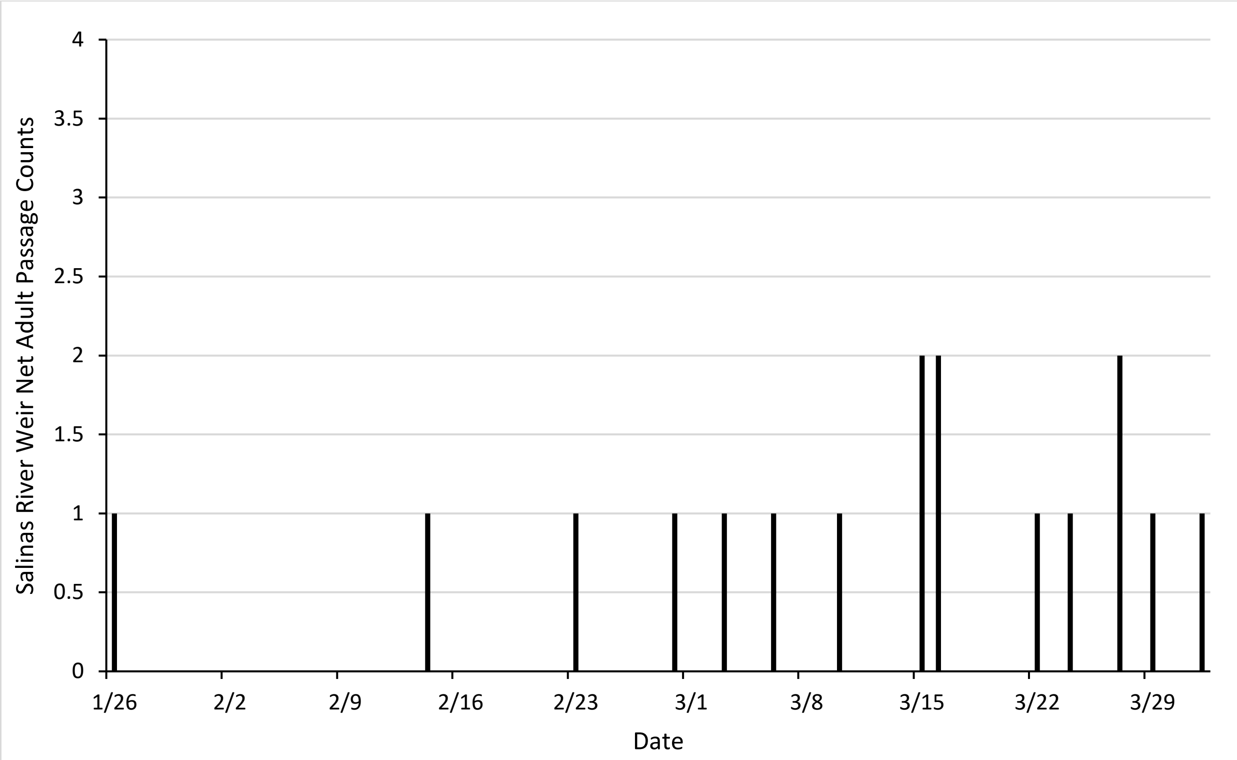

Figure 13. Daily net counts of adult steelhead sampled at the Salinas River weir near river mile 2.75 during the 2012 water year. Data are from Cuthbert and Hellmair (2012)

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.

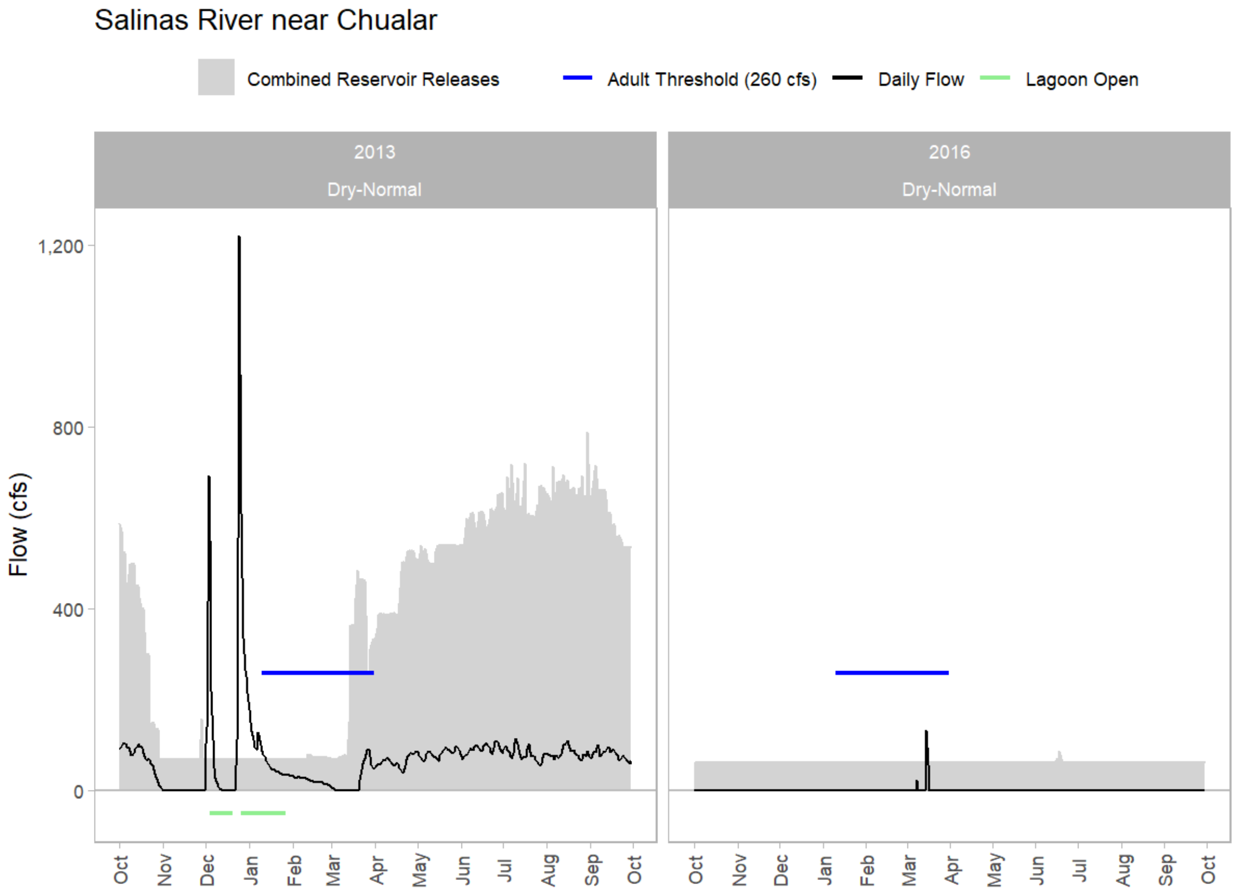

Figure 14. Mean daily flow (black line) conditions on the Salinas River near Chualar during dry-normal water years. Combined reservoir releases are indicated in grey, the adult passage flow threshold is indicated by the blue horizontal line, and the green line below the x-axis indicates when the Salinas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

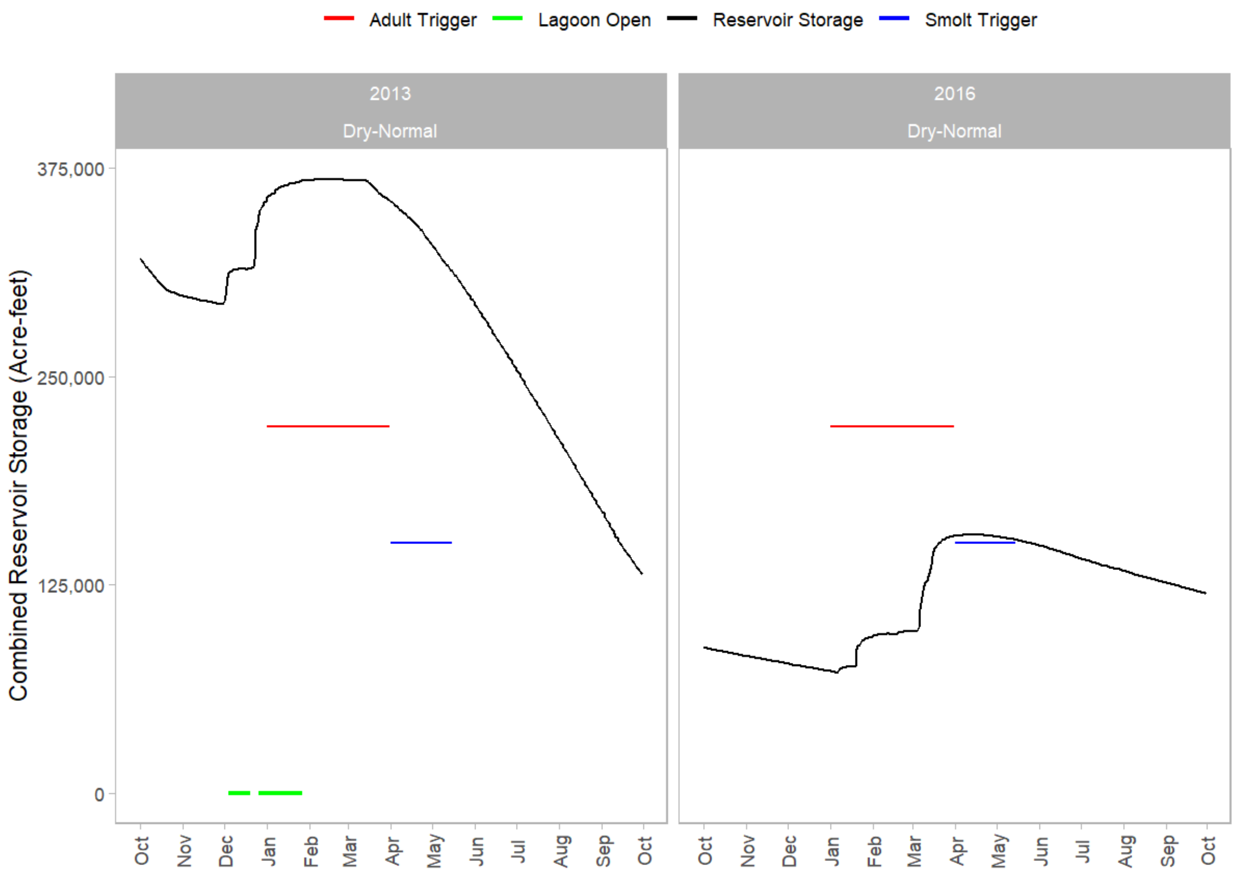

Figure 15. Combined Nacimiento and San Antonio reservoir storage during dry-normal water years. The green line near the x-axis indicates when the lagoon was open. The horizontal red and blue lines indicate storage levels required to trigger adult and smolt flow augmentation, respectively. Minimum reservoir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

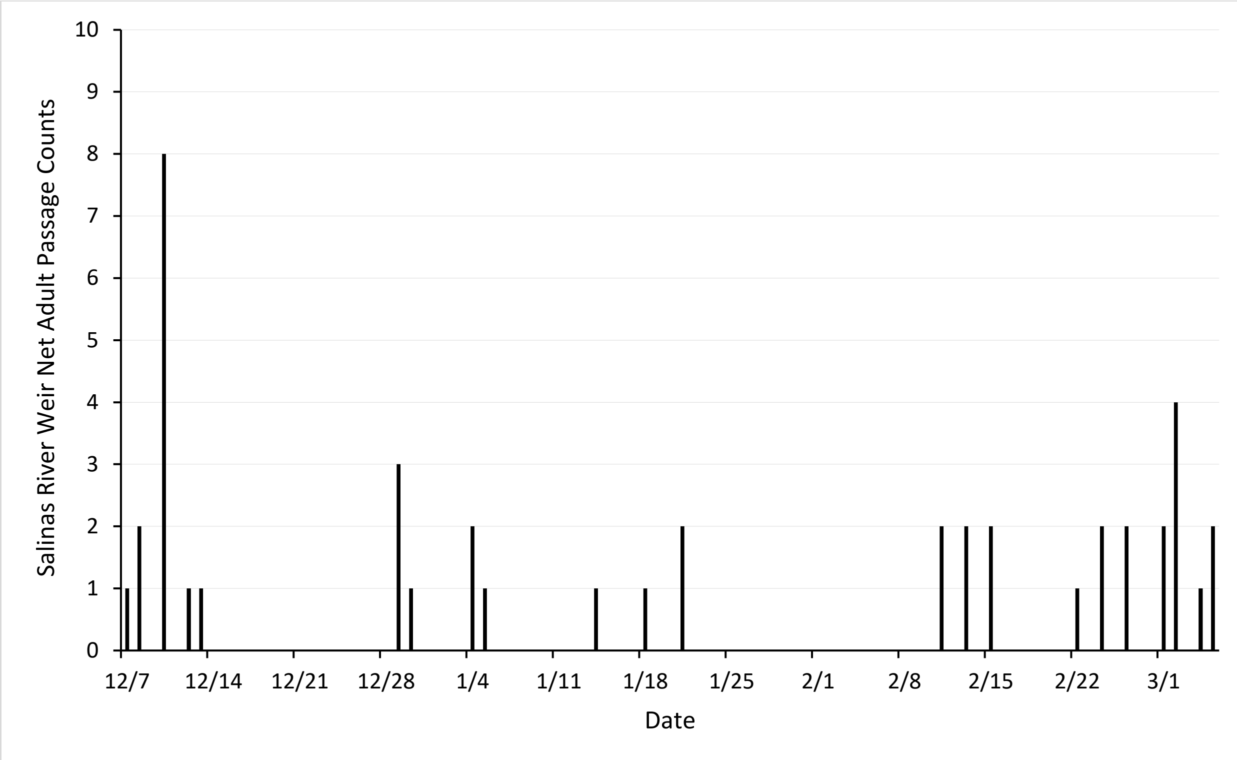

Figure 16. Daily net counts of adult steelhead sampled at the Salinas River weir near river mile 2.75 during the 2013 water year.

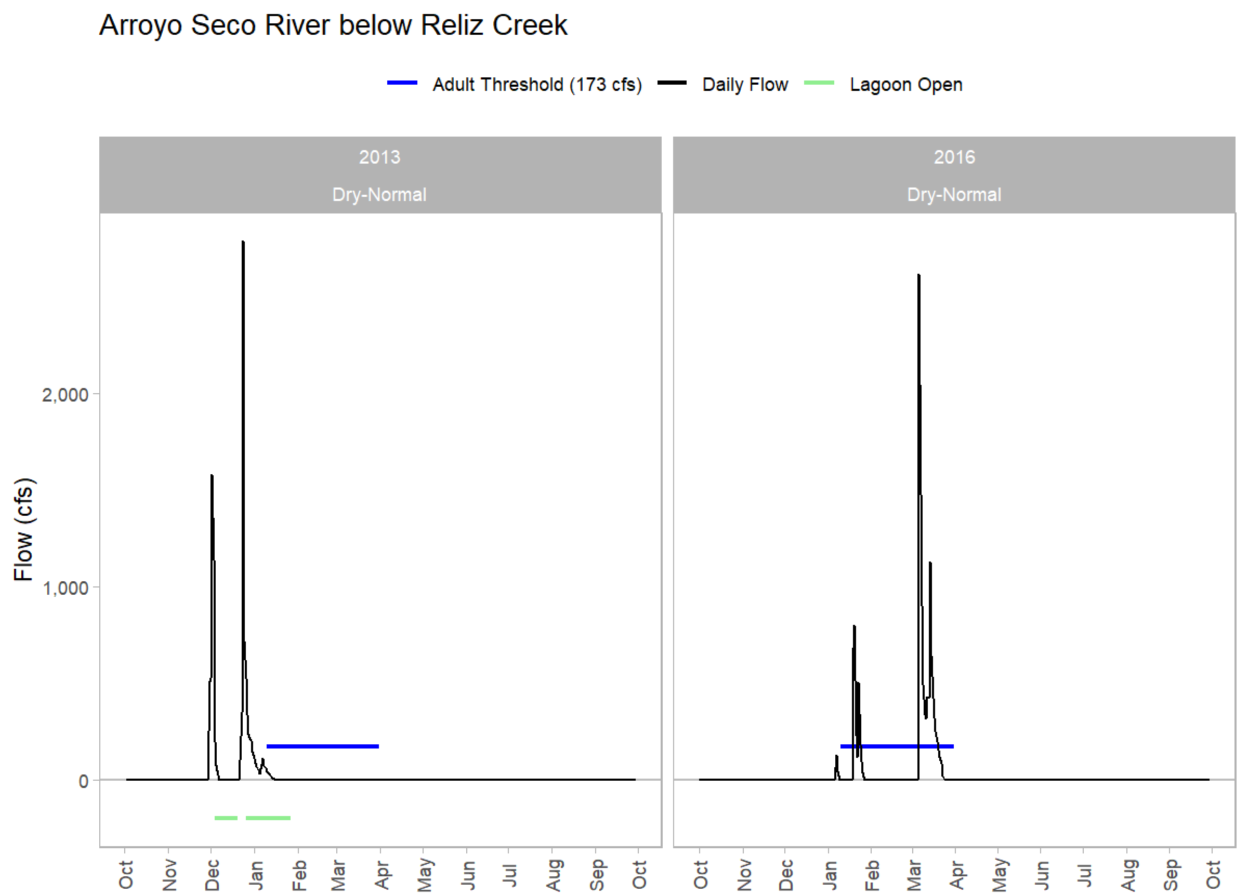

Figure 17. Mean daily flow (black line) conditions on the Arroyo Seco River below Reliz Creek during dry-normal water years. Combined reservoir releases are indicated in grey, adult flow triggers are indicated by the blue horizontal line, and the green line below the x-axis indicates when the Salinas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

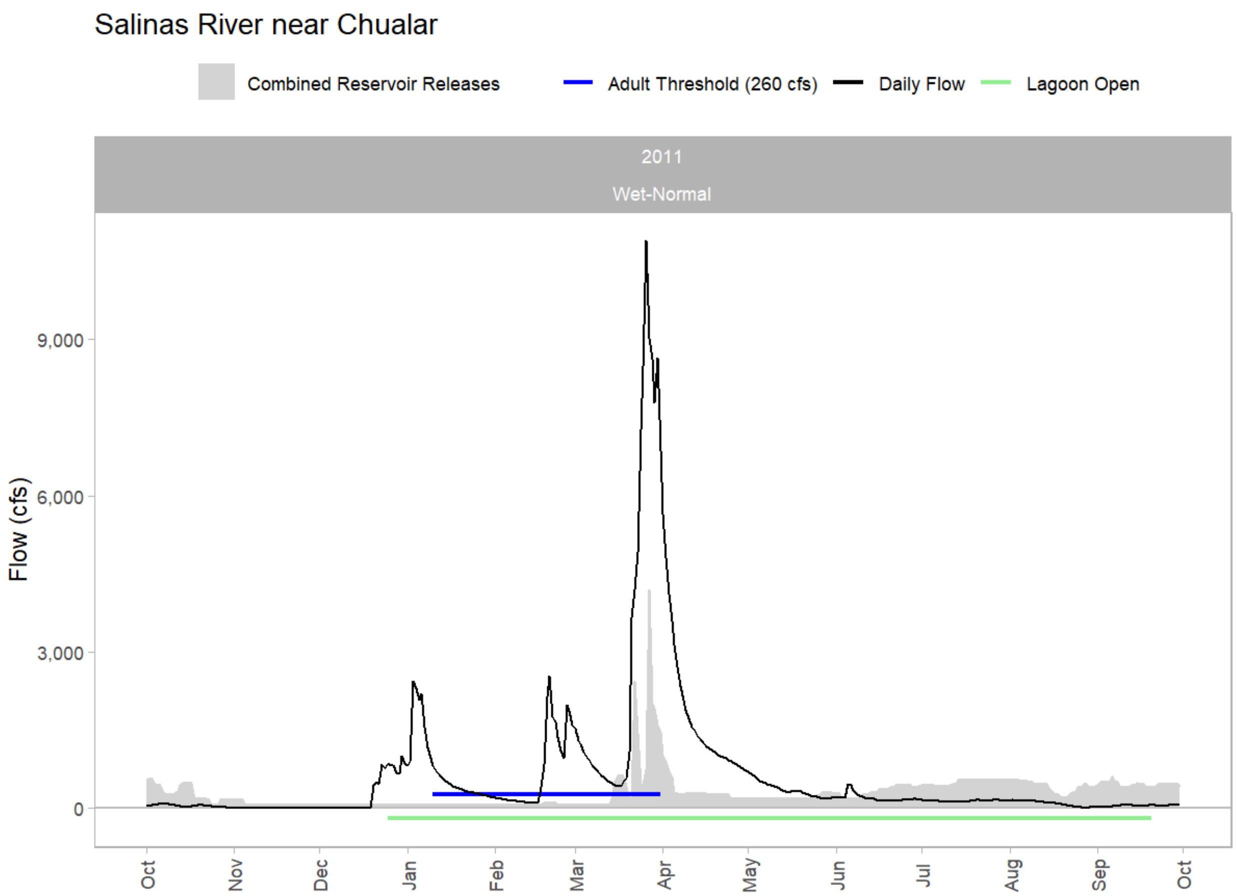

Figure 18. Mean daily flow (black line) conditions on the Salinas River near Chualar during wet-normal water years. Combined reservoir releases are indicated in grey, the adult steelhead passage threshold is indicated by the flow horizontal line, and the green line below the x-axis indicates when the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

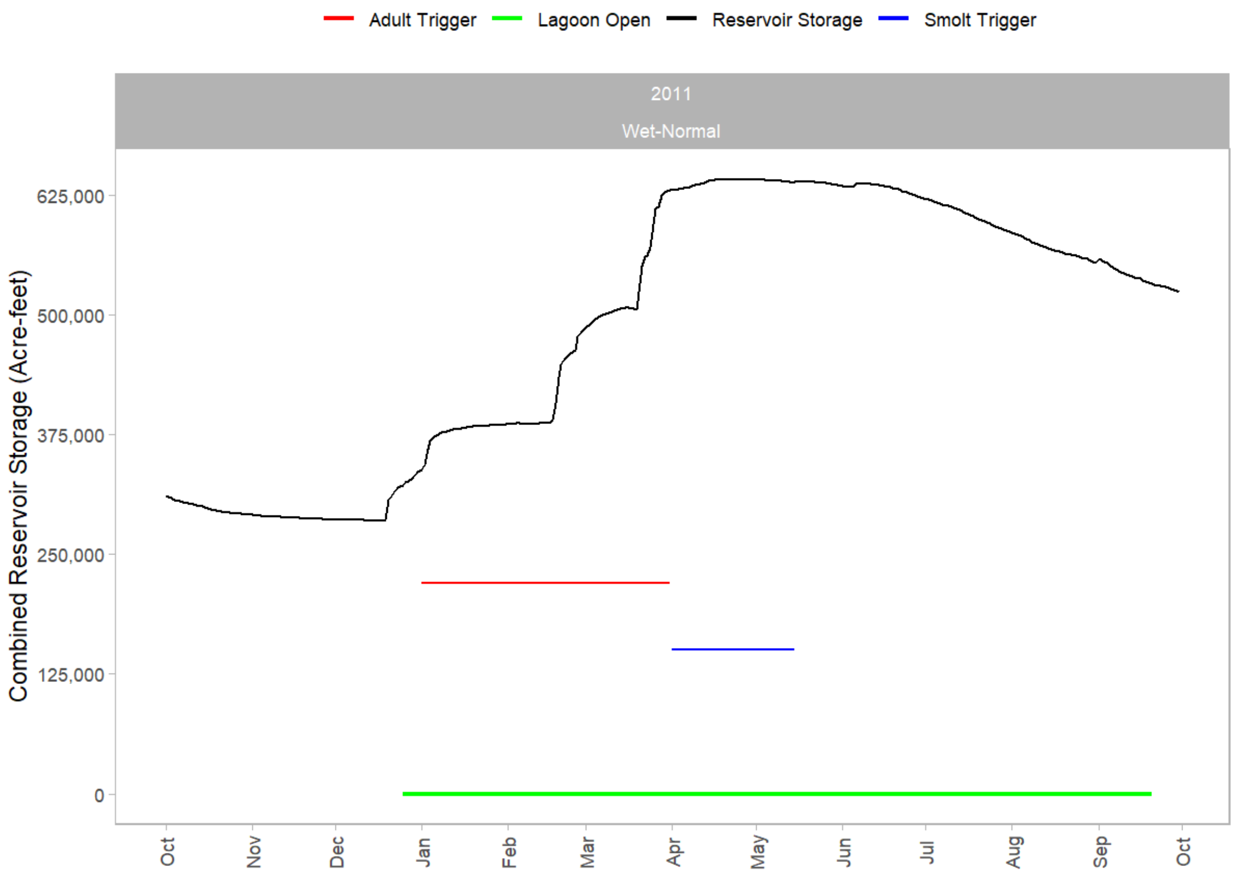

Figure 19. Combined Nacimiento and San Antonio reservoir storage during wet-normal water years. The green line near the x-axis indicates when the lagoon was open. The horizontal red and blue lines indicate storage levels required to trigger adult and smolt flow augmentation, respectively. Minimum reservoir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

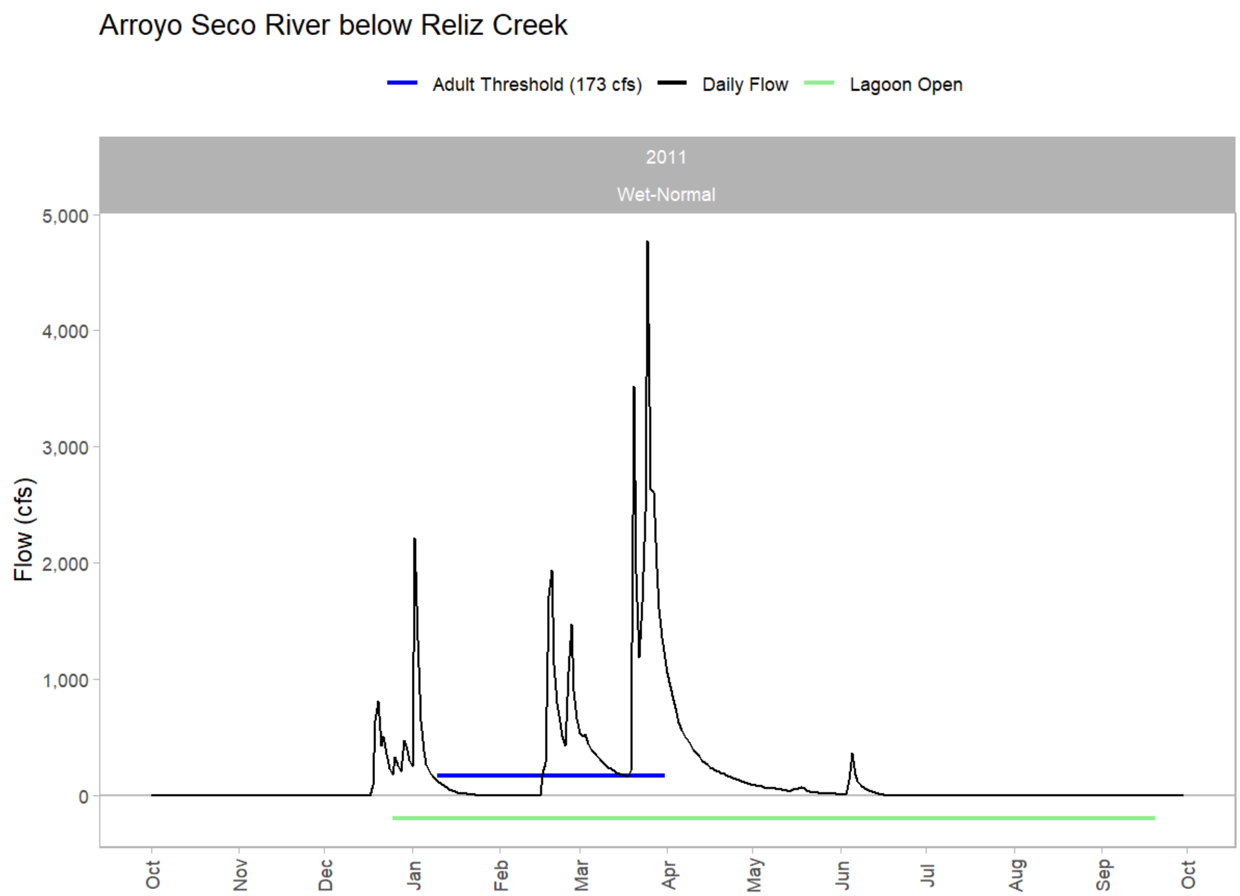

Figure 20. Mean daily flow (black line) conditions on the Arroyo Seco River below Reliz Creek during wet-normal water years. Combined reservoir releases are indicated in grey, the adult steelhead flow threshold is indicated by the blue horizontal line, and the green line along the x-axis indicates when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

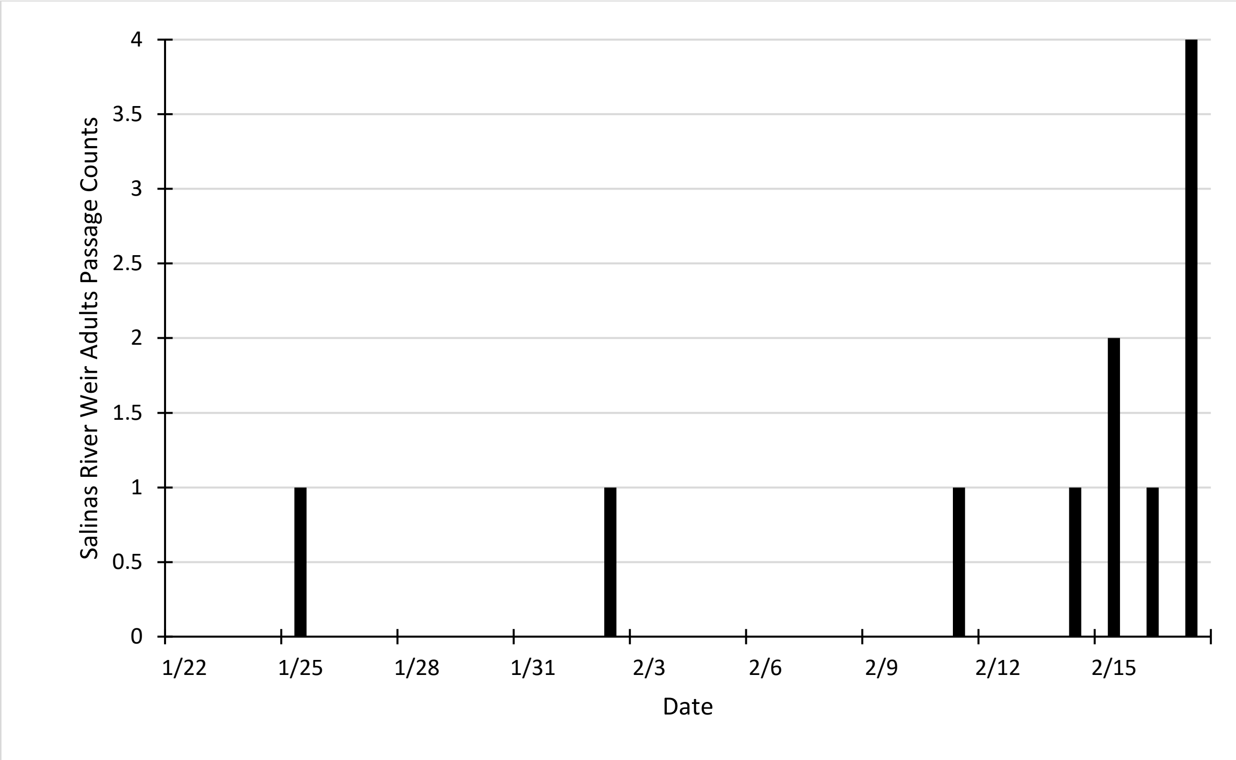

Figure 21. Daily counts of adult steelhead sampled at the Salinas River weir near river mile 2.75 during the 2011 water year.

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.

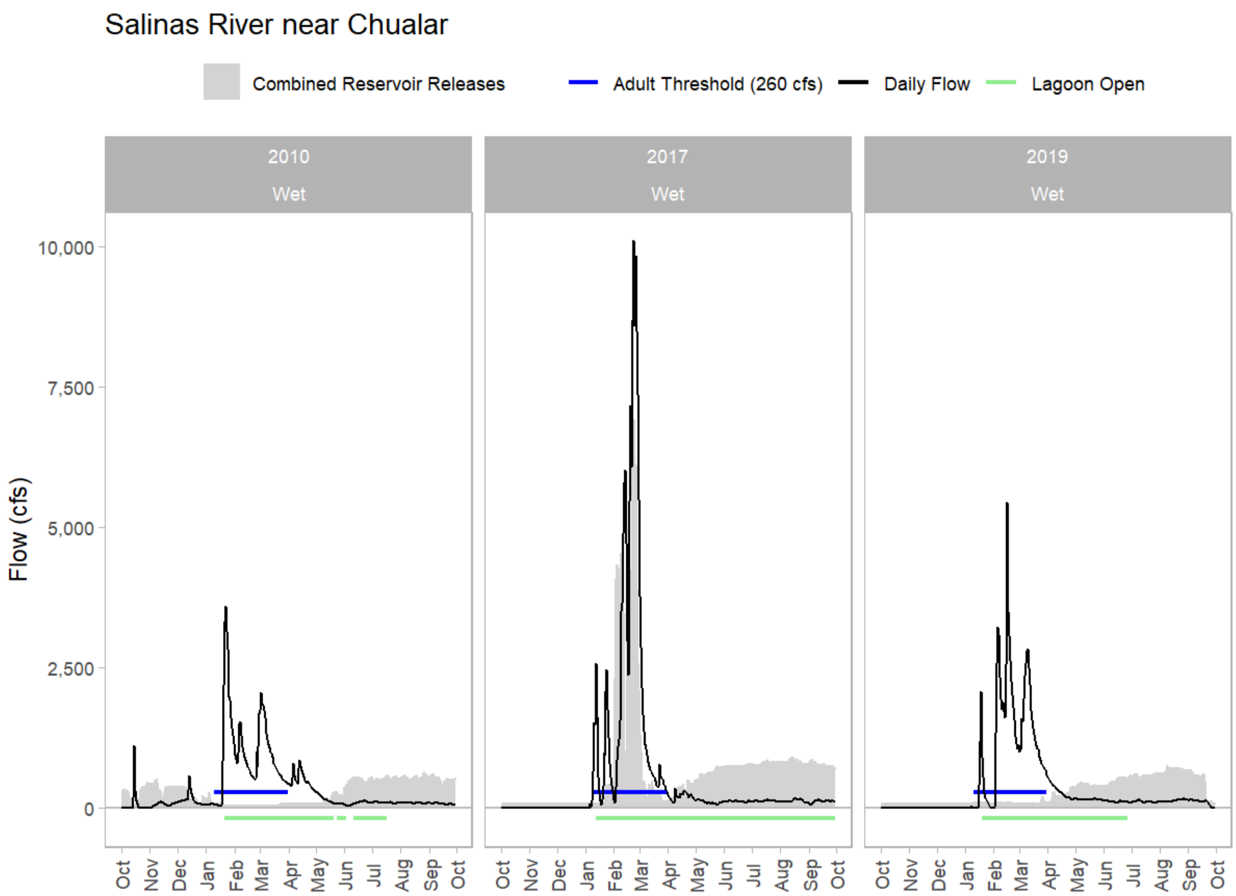

Figure 22. Mean daily flow (black line) conditions on the Salinas River near Chualar during wet water years. Combined reservoir releases are indicated in grey, adult steelhead passage flow thresholds are indicated by the blue horizontal line, and the green line below the x-axis indicates when the Salinas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

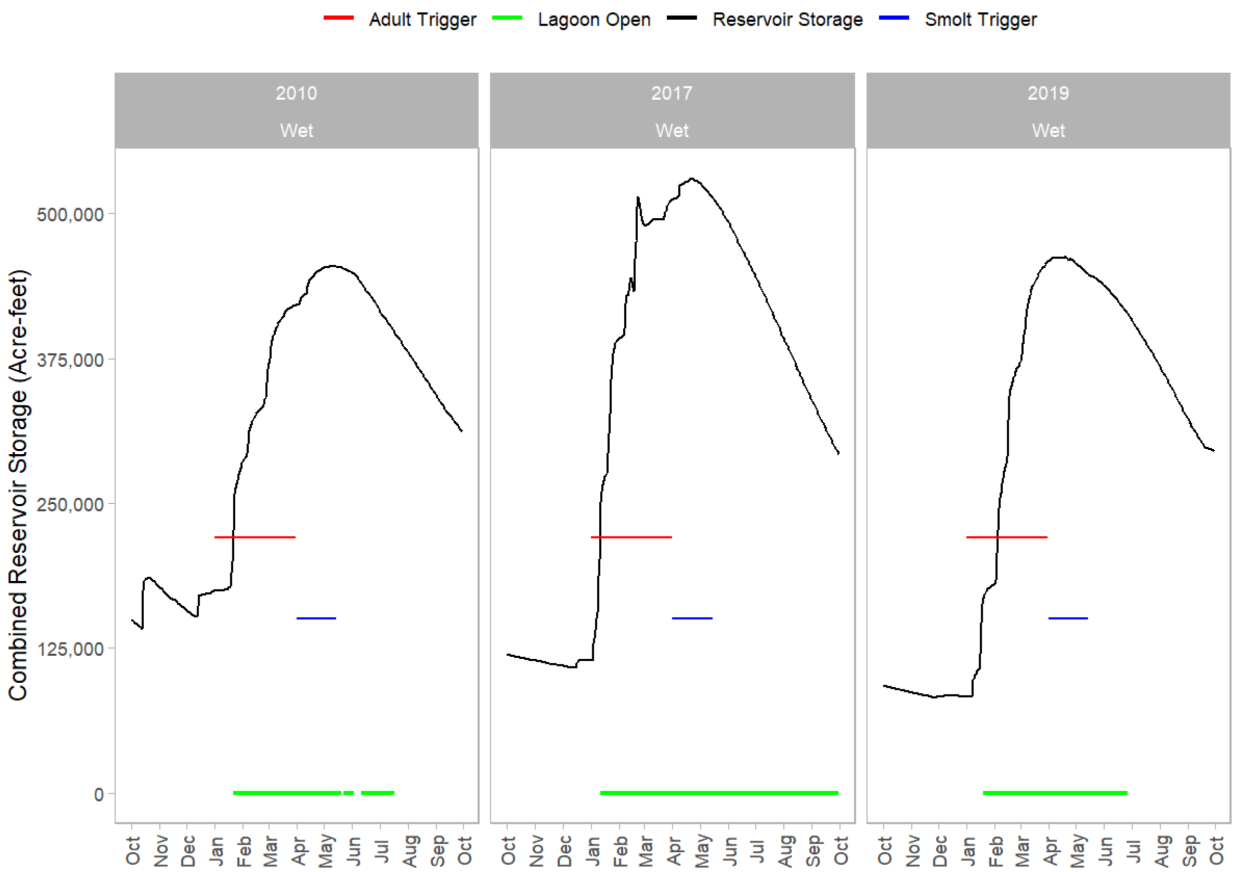

Figure 23. Combined Nacimiento and San Antonio reservoir storage during wet water years. The green line near the x-axis indicates when the lagoon was open. The horizontal red and blue lines indicate storage levels required to trigger adult and smolt flow augmentation, respectively. Minimum reservoir 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).

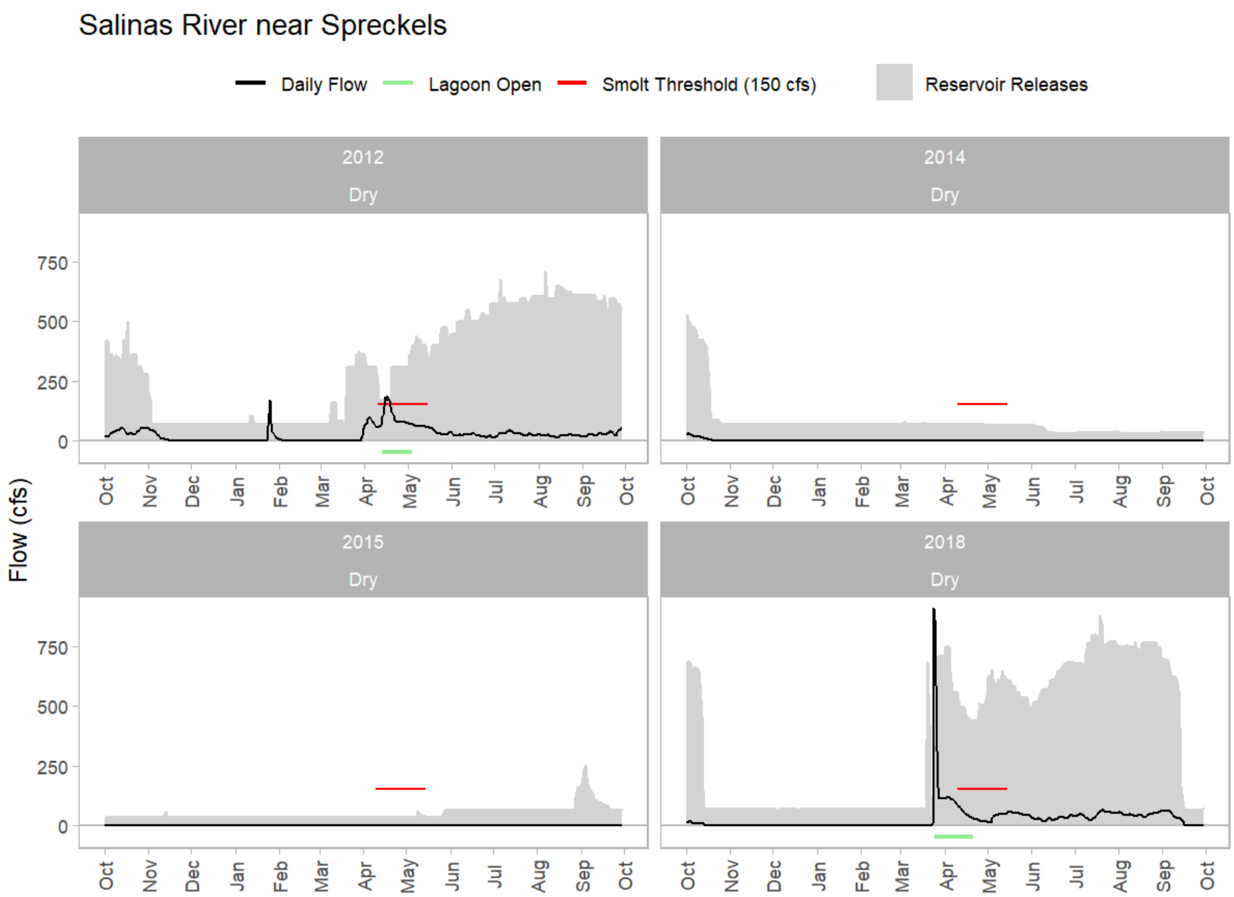

Figure 24. Mean daily flow (black line) conditions on the Salinas River near Spreckels during dry water years. Combined reservoir releases are indicated in grey; the red horizontal line indicates smolt flow threshold, and the green line below the x-axis indicates when the Salinas Lagoon was open to the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

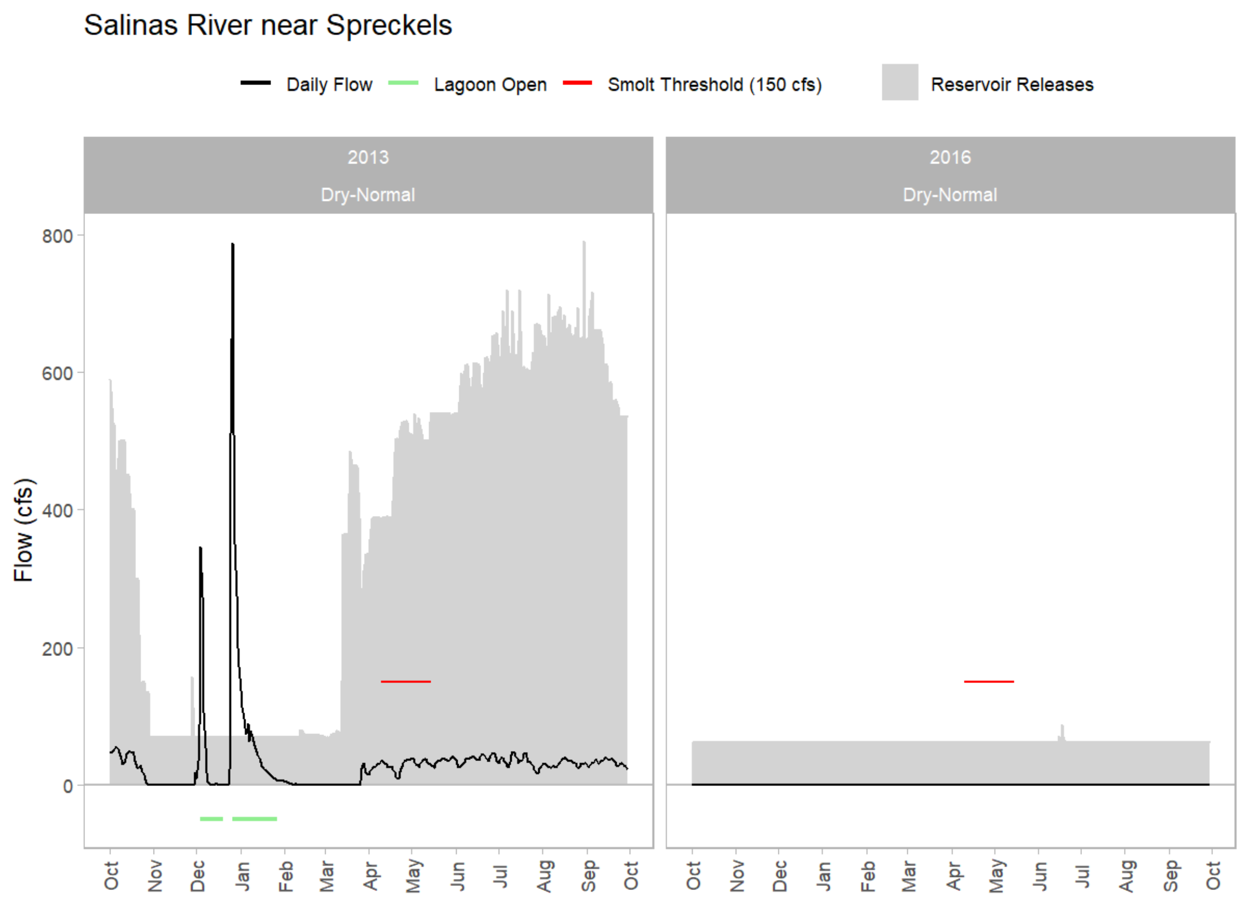

Figure 25. Mean daily flow (black line) conditions on the Salinas River near Spreckels during dry-normal water years. Combined reservoir releases are indicated in grey, the red horizontal line indicates smolt flow threshold, and the green line below the x-axis indicates when the Salinas Lagoon was open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

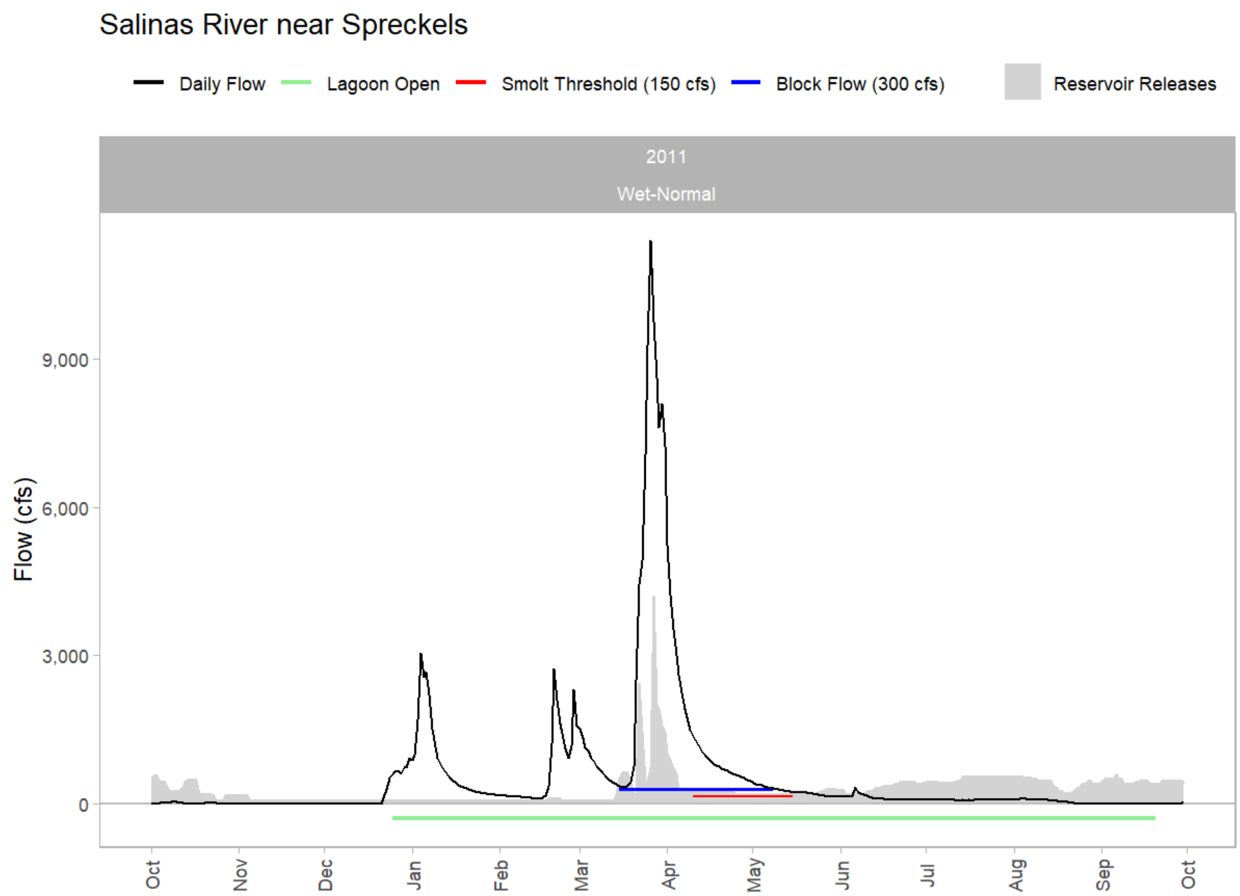

Figure 26. Mean daily flow (black line) conditions on the Salinas River near Spreckels during wet-normal water years. Combined reservoir releases are indicated in grey; the red horizontal line indicates smolt flow threshold, the green line below the x-axis indicates when the Salinas Lagoon was open to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

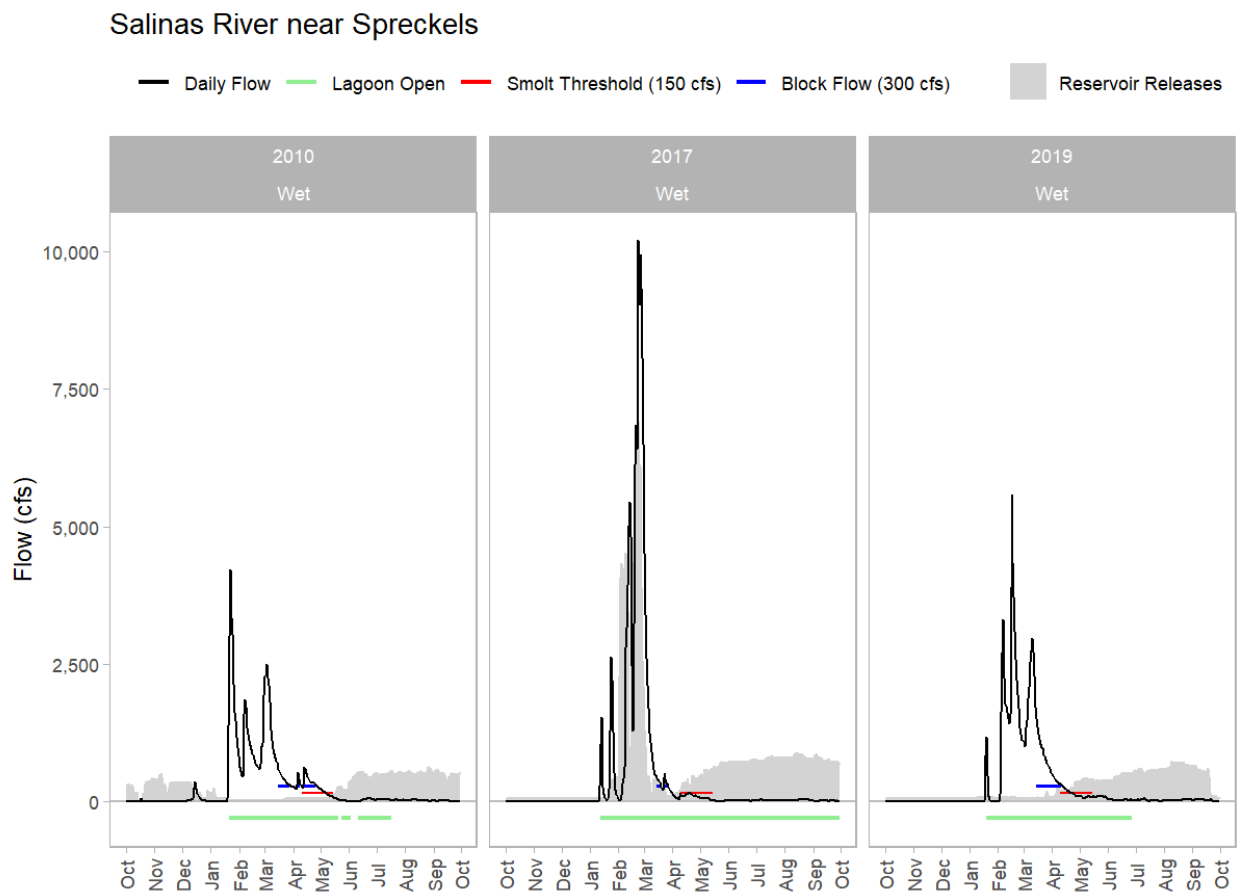

Figure 27. Mean daily flow (black line) conditions on the Salinas River near Spreckels during wet water years. Combined reservoir releases are indicated in grey; the red horizontal line indicates smolt flow threshold, the green line below the x-axis indicates when the Salinas Lagoon was open to the ocean, 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.

Literature Cited

Cuthbert, R. and Hellmair, M. 2012. Salinas River Basin Adult Steelhead Escapement Monitoring 2012 Annual Report. Submitted to Monterey County Water Resources Agency prepared by FISHBIO, Oakdale, CA.

Cuthbert, R., Cuthbert, P., and Fuller, A. 2013. Salinas River Basin Adult Steelhead Escapement Monitoring 2013 Annual Report. Submitted to Monterey County Water Resources Agency prepared by FISHBIO, Oakdale, CA.

Hagar Environmental Science. 2011. Salinas River Lagoon Monitoring Report 2011. Prepared for Monterey County Water Resources Agency by Hagar Environmental Science, Richmond, CA. Hagar Environmental Science. 2015. Salinas River Lagoon Monitoring Report 2014. Prepared for Monterey County Water Resources Agency by Hagar Environmental Science, Cobb, CA.

Stillwater Sciences. 2020. Steelhead in the Salinas - Conceptual Model Outline. Prepared for Central Coast Salmon Enhancement, Arroyo Grande, CA.

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*

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
West Coast Region
777 Sonoma Avenue, Room 325
Santa Rosa, California 95404-4731

March 25, 2022

Brent Buche
General Manager
Monterey County Water Resources Agency
1441 Schilling Place, North Building
Salinas, California 93901
bucheb@co.monterey.ca.us

Re: Potential Ongoing Take from Monterey County Water Resource Agency's Dams and Reservoir Operations

Dear Mr. Buche:

NOAA's National Marine Fisheries Service (NMFS) is the federal agency responsible for managing, conserving, and protecting living marine resources in inland, coastal, and offshore waters of the United States. We derive our mandates from numerous statutes, including the Federal Endangered Species Act (ESA). The purpose of the ESA is to conserve threatened and endangered species and their ecosystems. Threatened South-Central California Coast (S-CCC) steelhead[1] (*Oncorhynchus mykiss*) occur in the Nacimiento, San Antonio, and Salinas rivers, as well as the Salinas River lagoon. The mainstem Salinas River is a migration corridor for adult steelhead migrating upstream during the winter from the ocean to tributary spawning areas. Spawning and rearing habitats are located in tributary streams. Kelts (post-spawned adults), smolts, and rearing juveniles use the mainstem Salinas River in late winter and spring to migrate downstream to the ocean or lagoon.

We are issuing this letter to notify the Monterey County Water Resources Agency (MCWRA) that ongoing take[2] of S-CCC steelhead may be occurring at the Nacimiento and San Antonio dams, and downstream in the Salinas River, in San Luis Obispo and Monterey counties, California. MCWRA owns and operates the dams on the Nacimiento and San Antonio rivers for the combined goals of flood protection, water conservation, Salinas Valley Water Project (SVWP) operation, and recreation. MCWRA operates the reservoirs pursuant to the Salinas Valley Water Project Flow Prescription for Steelhead Trout in the Salinas River (hereafter referred to as the "Flow Prescription") (MCWRA 2005).

The Flow Prescription has provided limited benefits to steelhead in part due to the number of dry and dry-normal water years since 2010, and because the vast majority of natural runoff into the

[1] S-CCC steelhead Distinct Population Segment was listed as threatened in 2006 (71 FR 834), and critical habitat for S-CCC steelhead was designated on September 2, 2005 (70 FR 52488).
[2] The ESA defines "take" to mean "…harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct." 16 USC § 1532(19). The term "harm" has been defined by NMFS to mean the following: "… an act which actually kills or injures fish or wildlife. Such an act may include significant habitat modification or degradation which actually kills or injures fish or wildlife by significantly impairing essential behavioral patterns, including breeding, spawning, rearing, migrating, feeding or sheltering." 50 CFR 222.102

reservoirs is stored by MCWRA for spring and summer releases for agriculture instead of being released in the winter or bypassed at natural flow rates. The negative impacts to steelhead and steelhead habitat in the Nacimiento, San Antonio, and Salinas rivers from MCWRA's operation of Nacimiento and San Antonio dams are well established, and can be summarized as follows:

- Diminishes the value of physiological or biological features (e.g., migration, rearing, spawning, and estuarine areas) needed for steelhead life history through the alteration of natural stream flow dynamics; and
- Impedes access to 157 miles of high intrinsic potential over-summering rearing/refugia habitat in the Salinas River watershed upstream of the impassable dams.

In 2019, MCWRA initiated discussions with NMFS and U.S. Fish and Wildlife Service (FWS) about pursuing a section 10(a)(1)(B) incidental take permit to obtain ESA take coverage for the operation of the dams and reservoirs. NMFS is concerned that in the three years since MCWRA initiated habitat conservation plan (HCP) discussions, little progress has been made towards developing the HCP's steelhead conservation strategy or NMFS' recommended operations plan that would have lessened the impacts on S-CCC steelhead in the interim.

We offer the following recommendations on how to efficiently develop an interim operation plan that could reduce the potential for take of steelhead as a result of MCWRA's operations:

- Work cooperatively and transparently with NMFS and FWS to develop an interim operations plan by winter 2022/2023, which entails providing data and analyses to NMFS in a timely manner and meeting on a regular basis;
- Ensure sufficient funding is available to analyze, model, and evaluate interim operations proposals, as well as monitor and report the effectiveness of the interim operations;
- Refer to our May 14, 2021 memo, "Interim Streamflow Operations and Fish Passage Actions in the Salinas River Watershed" (enclosed) for guidance on establishing an interim flow operation plan;
- Finalize a draft interim operations plan for NMFS' review by October 15, 2022 so that it could be implemented during the 2022/2023 migration season and subsequent migration seasons pending issuance of an incidental take permit; and
- MCWRA and/or the Board of Directors streamline and/or delegate decision-making that will enable MCWRA staff to adaptively manage reservoir operations per the interim operation plan in coordination with NMFS and FWS, as needed.

Regarding fish passage at the dams, we urge the HCP development team (MCWRA and ICF) to initiate a fish passage feasibility study as soon as possible. We look forward to providing technical assistance on this study.

Please note that until a section 10(a)(1)(B) incidental take permit is issued by NMFS, any take of S-CCC steelhead resulting from MCWRA's dam/reservoir operations is unauthorized and, therefore, in violation of the ESA.

Please direct any questions regarding this matter to Mandy Ingham, Central Coast Branch Chief, at (707) 575-6083 or Mandy.Ingham@noaa.gov. We request the courtesy of your response by May 15, 2022, regarding your plans for interim flow operations. Thank you for your cooperation in this matter.

Sincerely,

Alecia Van Atta
Assistant Regional Administrator
California Coastal Office

Enclosure

cc: Paul Ortiz, NOAA Office of General Counsel, Enforcement Section, paul.ortiz@noaa.gov
Leilani Takano, Assistant Field Supervisor, FWS, Ventura, lelani_takano@fws.gov
John Baillie, Chair, MCWRA Board of Directors, c/o HenaultAG@co.monterey.ca.us
Mary Adams, Chair, Monterey County Board of Supervisors, Monterey, district5@co.monterey.ca.us
Julie Vance, Regional Manager, California Department of Fish and Wildlife, Fresno, julie.vance@wildlife.ca.gov
Copy to NMFS E-Folder FRN 151422WCR2019SR00271

References

Monterey County Water Resources Agency. 2005. Salinas Valley Water Project Flow Prescription for Steelhead Trout in the Salinas River. Prepared by: Monterey County Water Resources Agency and Hagar Environmental Science, with technical support from: RMC Water & Environment, Inc., WEIME, Inc., and ENTRIX, Inc. October 11, 2005. 140 pages.

National Marine Fisheries Service. 2013. South-Central California Steelhead Recovery Plan. NOAA Fisheries. West Coast Region, California Coastal Office, Long Beach, California.

<u>Interim Streamflow Operations and Fish Passage Actions in the Salinas River Watershed</u>

Prepared for: Salinas River HCP Coordination Team
Prepared by: Bill Stevens, National Marine Fisheries Service
Date: May 14, 2021

As discussed during the February 17, 2021, Salinas River Habitat Conservation Plan (HCP) Monthly Coordination Call, NOAA's National Marine Fisheries Service (NMFS) is interested in providing technical assistance to Monterey County Water Resources Agency (MCWRA) in the development of a water operation regime that MCWRA can implement during development of the HCP and potentially incorporate into the HCP's conservation strategy. This would primarily entail MCWRA providing interim streamflows that facilitate migration of both juvenile and adult South-Central California Coast (S-CCC) Distinct Population Segment (DPS) steelhead during all water-year types while developing the HCP. We believe such a collaborative approach is consistent with the intent of MCWRA's *Salinas Valley Water Project Flow Prescription for Steelhead Trout in the Salinas River (*dated October 11, 2005 with a November 8, 2005 errata), which stated, "This Flow Prescription is considered a stand-alone document, which may be modified upon mutual agreement of the (MCWRA) and NMFS outside formal (Endangered Species Act) Consultation."

Below we outline key principles to consider when developing an interim streamflow regime. We have also attached a memo (Attachment) that informs and supports the recovery strategy for the Salinas River (as outlined in NMFS' S-CCC Steelhead Recovery Plan) and provides a better understanding of the Salinas River and its role in the recovery of the S-CCC DPS.

First, MCWRA should develop interim (and long-term) flow prescriptions based on a scientifically sound environmental flow regime. Environmental flows consist of instream flow criteria that balance human and ecological needs for water. We suggest you evaluate the appropriateness of the California Environmental Flows Framework (ceff.ucdavis.edu), or a similar approach, for the Salinas River watershed. A good starting point may be to evaluate unimpaired streamflow patterns (e.g., see eflows.ucdavis.edu) to understand the ecological baseline condition in which S-CCC steelhead evolved. This would help frame developing desired future conditions that work towards the survival and recovery of S-CCC steelhead.

Second, the flow prescription should manage for conditions that accommodate the various life-history forms and migratory patterns of native steelhead within the Salinas River watershed. Specifically, we recommend, in collaboration with NMFS, MCWRA establish a flow prescription that provides the hydrologic and hydraulic conditions that supports steelhead migratory behavior and ecology. This would entail establishing a flow prescription that mimics the natural hydrograph from November through May, when steelhead migrations occur. It would also encompass wet periods in November that prime the Salinas River channel so that when winter flows increase, these releases reach the lagoon more efficiently. Mimicking the natural hydrograph would require releasing more water during the fall-winter and less during spring-summer, likely alleviating many of the current flow prescription's impacts on redds and/or juveniles (e.g. redd scour and juvenile displacement).

In addition to the flow-related actions described above, we recommend MCWRA begin investigating ways to facilitate the out-migration of juvenile steelhead (exhibiting smolting characteristics) trapped above the impassible Nacimiento and San Antonio dams. This would be an immediate step towards providing partial fish passage around the dams while MCWRA investigates upstream fish passage strategies. Providing downstream passage of juvenile steelhead (of which there are currently many more than adults) will likely meaningfully increase adult steelhead escapement in the watershed and in turn increase the momentum behind developing adult fish passage solutions at Nacimiento and San Antonio dams. MCWRA will need to initiate technical studies, such as steelhead habitat assessments and genetics analyses, soon to inform juvenile steelhead passage strategies. One possible funding source that MCWRA could explore for these technical studies is through ESA Section 6 grant monies. NMFS is available to help provide technical support in the design of the technical studies.

Attachment

February 24, 2021

To: William L. Stevens, NMFS West-Coast Region, California Coastal Office, Santa Rosa, CA

From Mark H. Capelli, NMFS South-Central/Southern California Steelhead Recovery Coordinator, California Coastal Office, Santa Barbara, CA

Re: Role of Salinas River in Meeting NMFS' South-Central California Coast Steelhead Viability/Recovery Criteria.

This is an updated response to the questions regarding the role of the tributaries to the Salinas River in meeting the viability/recovery criteria in the Salinas River watershed, and by extension the viability/recovery South-Central California Coast Steelhead Distinct Population Segment (DPS). The basic analysis conclusion remains the same but is supplemented by recently published research on the ecology and genetics of southern steelhead populations.

In summary, the tributaries to the Salinas River (including the Nacimiento and San Antonio) are essential to meeting the viability/recovery criteria (both the DPS-Wide and Population-Level viability criteria) set forth in NMFS' South Central Southern California Steelhead Recovery Plan (2013). Management of the surface and groundwater resources associated with these tributaries, as well as the mainstem Salinas River is critical to the recovery of this Core 1 population within the Interior Coast Range Biogeographic Population Group (BPG) of the threatened South-Central California Coast Steelhead DPS.

This role of the Salinas River tributaries in the recovery of the steelhead populations of the Salinas River raises a number of related issues and warrants a fuller response, which is provided below.

Introduction

NMFS' Technical Recovery Team (TRT) for the South-Central/Southern California Steelhead Recovery Planning Domain published a series of Technical Memoranda that provides the scientific framework for the recovery of the two listed species in this domain: the threatened South-Central California Coast DPS and the endangered Southern California Steelhead DPS. These Technical Memoranda provide information on:

- the historic distribution of native steelhead and the contraction of the southern range limit;
- a characterization of the ecology of southern steelhead populations;
- an assessment of the intrinsic habitat potential of individual watersheds;

- a suite of viability criteria (for the individual population and the DPS as a whole);

- a general strategy to achieve recovery; and

- a set of research questions to advance understanding of the species and further direct recovery activities.

See Boughton 2010a, 2010b, Boughton *et al*. 2007, 2006a, 2006b, and 2005.

Some of the TRT findings are directly pertinent to your question. These include:

- above artificial barrier *O. mykiss* populations are most closely related to below barrier populations;

- above artificial barrier populations (in a majority of the watersheds) are not descendent from planted hatchery rainbow trout;

- *O. mykiss* populations above artificial barriers have the potential to resume an anadromous life-history; and

- populations of *O. mykiss* above artificial barriers are an integral and important component of the anadromous populations.

See Boughton *et al.* 2006a, Girman and Garza 2006, Garza *et al.* 2004.

These findings have been further substantiated in more recent research: Arostegui *et al*. 2019, Adadia-Cardoza *et al.* 2016, Pearse 2016, Garza *et al.* 2014, Pearse *et al.* 2014, Clemento *et al*. 2009; see also Pearse 2016.

Pearse (2019) and others have further illuminated the genomic mechanisms by which both basic life-history forms of *O. mykiss* (anadromous and non-anadromous) mutually support the persistence of both forms. Pearse *et al.* (2019) and Kelson *et al*. (2019) looked at associations with migration behavior; and Leitwein *et al*. (2017) and Apgar *et al* (2017) examined environmental predictors for a high frequency of the "A" haplotype that is associated with the anadromous form of *O. mykiss*. These recent studies underscore the importance of the non-anadromous form of *O. mykiss* (including those currently land-locked above impassible barriers) and the importance of reestablishing connectivity between the various reaches of the watershed Salinas River watershed (including those reaches above the various dams within the watershed).

Some of their more pertinent findings are summarized below:

- Many of the genes in the inverted section of chromosome 5 of *O. mykiss* (Omy5) are associated with circadian rhythms, sensitivity to photosensory cues, the timing of age at maturity, and other traits associated with life-history variation. Genetic recombination among these different genes of the tightly linked Omy5 segment of the chromosome can occur during the generation of homozygous “RR” fish and “AA” fish, but not during the generation of heterozygous “AR” fish due to the inversion which prevents cross-over during meiosis. This feature allows the “A” and “R” haplotypes to adaptively diverge in response to selection for two distinct life-histories, while still being maintained together in the same population of *O. mykiss* within a watershed (Pearse 2016).

- The two Omy5 haplotypes appear to be associated with different expression of life-history forms (anadromous and resident). Pearse *et al*. (2019) found that in a small steelhead population, juvenile females with the homozygous “AA” and heterozygous “AR” genotypes were much more likely to migrate to the ocean than females with the homozygous “RR” genotype. Juvenile males with the homozygous “AA” and “RR” genotypes were similar to the females, but the male heterozygous “AR” genotype was much less likely to migrate than the female heterozygous “AR” genotype. This is consistent with adaptive evolution of contrasting life-history strategies in males and females: female fitness is more associated with large body size than is male fitness, because of the energetic demands of manufacturing eggs versus sperm. Thus, females should be more likely than males to pursue anadromy because *O. mykiss* can generally achieve larger size at maturity in the ocean than in freshwater, and this provides more of a fitness benefit to females than to males. Kelson *et al*. (2019) made similar observations, finding that the expression of the downstream-migrant phenotype was associated both with being female and with having the “A” haplotype. In their smaller sample, they did not detect a difference in the migration rate of heterozygous “AR” females versus “AR” males, but they did find that in general the migration frequency of the “heterozygous AR” genotype was intermediate between the “RR” and “AA” genotypes.

- This intermediate life-history expression of the heterozygous “AR” genotype provides a mechanism by which the steelhead life-history can disappear from an *O. mykiss* population when environmental conditions are adverse but rapidly reappear when conditions favor it. When conditions are adverse, the “A” haplotype may become rare enough that homozygous “AA” individuals are very unlikely and the haplotype is maintained by resident fish carrying the heterozygous “AR” genotype. Notably, some of the progeny of such fish are “AR” rainbow trout that perpetuate the “A” haplotype in the resident population, whereas other progeny would be heterozygous “AR” smolts that migrate to the ocean. These heterozygous “AR” smolts would likely be lost to mortality when conditions for anadromy are adverse (e.g., presence of anthropogenic barriers to fish passage, prolonged drought, debris flows degrading freshwater habitat, etc.), but could rapidly reconstitute steelhead runs when conditions for anadromy are favorable.

- When favorable conditions persist, adult steelhead would become common enough to start producing “A” individuals, and genetic recombination of the anadromous genome would resume and facilitate continuing adaptive evolution of the anadromous phenotype to changing conditions. A resident-only population may not sustain the A haplotype indefinitely because the “wasted” smolts produced by heterozygous “AR” parents represent a fitness cost, but the loss appears to be a slow process (Apgar *et al*. 2017). Significantly, a similar, reciprocal logic applies to the resident life-history, for example

> providing a mechanism by which heterozygous "AR steelhead could colonize vacant freshwater habitat that eventually transforms to a population of rainbow trout when conditions for anadromy are adverse; hence the emphasis placed on maintaining or restoring volitional access to coastal watersheds. Even when the "A" haplotype is rare in a population, so that homozygous "AA" individuals are unlikely to occur, anadromy is still subject to natural selection due to its partial expression in heterozygous "AR" individuals; and likewise for freshwater-residency and the "R" haplotype.

NMFS South-Central California Coast Steelhead Recovery Plan (2013) recognizes the interdependence of anadromous and non-anadromous life-history forms of native *O. mykiss*. As a result, the Recovery Plan concluded, "Recovery of the threatened SCCCS DPS will require a minimum number of viable populations within each of four Biogeographic Populations Groups (BPGs) within the SCCCS Recovery Planning Area. Recovery of these individual populations is necessary to conserve the natural diversity (genetic, phenotypic, and behavioral) spatial distribution, and abundance of the SCCCS DPS." (p. xiii) NMFS' Technical Review Team (Boughton *et al.* 2007) also identified "a need to maintain not just the fluvial-anadromous life-history form, but also lagoon-anadromous and freshwater-resident forms in each population" and noted, "Depending on the rate of transition, a group of resident and anadromous fish may function as a single population; two completely distinct populations; or something in between." (p. 8). Consequently, the resident form of *O. mykiss* is included in the viability criteria developed by the TRT and incorporated into NMFS South-Central California Coast Steelhead Recovery Plan. (p. 6-4).

Because of the close association of the two life-history forms (anadromous and nonanadromous), and the complex of factors controlling the expression of anadromous and resident life-histories, all native *O. mykiss* in anadromous waters (*i.e*., waters within the geographic boundary of the listed DPS and that are accessible to fish migrating from the ocean) are generally considered anadromous and afforded the protections of the ESA.

New research has also documented dispersal of anadromous *O. mykiss* from their natal watershed to non-natal watersheds (Donohoe, *et al*. 2021) which have implications for steelhead recovery and management within the South-Central/Southern California Steelhead Recovery Planning Domain. A study of small coastal stream in the central portion of the SCCCS DPS (Big Creek) revealed that of seven fish opportunistically sampled, all seven had dispersed from their natural watersheds. Three adults had originated from nearby streams (<72 km) on the Big Sur coast, while three had originated from more distant rivers, including the Klamath River (680 km to the north). Significantly, of the seven dispersed individuals, one was the progeny of a nonanadromous female. The rate of dispersal from natal watersheds to non-natal watersheds could not be estimated based on the small sample size, but the study did demonstrate that steelhead can disperse considerable distances and nonanadromous females can produce anadromous progeny that can disperse (thus providing genetic connectivity among widely dispersed watersheds). This phenomenon could be an important mechanism for naturally re-colonizing habitats that have been de-populated as a result of either (or both) anthropomorphic modifications (*e.g*., construction of artificial barriers such as dams or road crossings) or natural environmental perturbations (*e.g*., debris flows, droughts, or catastrophic floods).

NMFS' TRT specifically examined the role of artificial impassible barriers in the extirpation of populations of anadromous *O. mykiss* and the contraction of the southern range limit of the anadromous form. One of the major conclusions of this study was that the majority (68%) of the documented extirpations of the anadromous form of *O. mykiss* were associated with artificial barriers (*e.g.*, dams, culverts, flood-control channels). As a corollary, the probability of occurrence of anadromous *O. mykiss* in a watershed was correlated with the size of the watershed and the amount of accessible spawning and rearing/refugia habitat. Put simply, artificial barriers that affectively impede the migration of anadromous *O. mykiss,* or reduce the amount of spawning and rearing habitat available to the species, increases the likelihood of extirpation of a population. Conversely, restoring access (and therefore the amount of habitat available) increases the viability of the population.

See Boughton *et al.* 2005.

Aside from reducing the amount of spawning and rearing habitat available to steelhead, barriers, such as dams without effective fish passage provisions, have the effect of restricting anadromous *O. mykiss* to below-barrier, lower elevation habitats that are often both hydrologically and thermally less reliable than above-barrier habitats; these adverse conditions are often exacerbated by the artificial flow regimes associated with dams such as San Antonio and Nacimiento dams.

Above-barrier habitats in headwater, tributaries are often spring-fed, which provides suitable year-round rearing habitat (including important refugia habitat during periods of drought).[1] Additionally, above barrier habitats are often characterized boulder pools, with well-developed riparian habitat. These features provides both an important sources of invertebrate food for rearing juvenile *O. mykiss* as well as help to maintain suitable water temperatures, particularly during hot summer months.

Conversely, below-barrier habitats, particularly mainstem habitats are impacted by variety of anthropogenic activities; these include, diversions, floodplain encroachment for agricultural and various urban developments, and related flood control structures and activities that adversely affect the suitability of spawning and rearing habitats. While some studies have shown that below-barrier habitats (including mainstems) can provide high-growth rate opportunities, which lead to larger juvenile size at ocean entry (and thus greater ocean survival), this growth pattern is often associated with the ability of rearing individuals to access the estuary during periods of descending flows. Under unimpaired conditions, many of those juveniles rearing in the mainstem had moved downstream from upstream tributary habitats; but this instream movement is inhibited, or in many completely blocked, as a result of the construction of dams (and diversions) without the inclusion of effective fish passage provisions (including associated flows).

See for example, Quinones, *et al.* 2014, Boughton, *et al.* 2009, Olden and Naiman, 2009, Boughton *et al.* 2007, 2005, Nilsson and Berggren 2000.

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[1] The TRT specifically identified the important role of refugia habitat in headwater tributaries, and recommended that the recovery strategy "identify and maintain sustainable refugia against severe droughts and heat waves". Boughton *et al*. 2007, p. 24.

Given the different advantages of above- and below-barrier habitats, both are necessary to support a viable anadromous population. Where the up and downstream migration of adults and juveniles have been interrupted by impassible barriers, these habitats need to be reconnected. This can be accomplished through either the removal or modification of the barrier, to allow up and downstream migration of both juvenile and adult *O. mykiss*, and the provision of an appropriate flow regime that will promote and facilitate volitional migratory behavior.[2] Where spawning and rearing occurs below the dam (or diversion), a flow release regime must also support these essential fish behaviors.[3]

Consistent with NMFS's TRT recommendations, NMFS' South-Central California Coast Steelhead Recovery Plan identifies recovery actions that address the issue of reconnecting steelhead habitats that have been blocked by fish passage barriers. The DPS-Wide Recovery Actions include the following:

> "Physically modify passage barriers (including dams and diversion facilities identified in Table 7-2 and the BPG [Biogeographic Population Group] recovery action tables) to allow natural rates of migration to upstream spawning and rearing habitats."

See NMFS 2013, p. 8-2, 8.1 "DPS-Wide Recovery Actions".

NMFS' South-Central California Coast Steelhead Recovery Plan also includes watershed-specific recovery actions dealing with barrier removal or modification and related fish passage flows (these are dealt with in more detail in a separate section below on the Salinas River). Additionally, NMFS' Recovery Plan sets forth viability criteria for the DPS, which includes DPS-Wide and Population-Level viability criteria. These criteria describe the characteristics of both the DPS and individual populations that, if met, would indicate that the DPS is viable, and therefore at a low risk of extinction, rendering the DPS eligible for delisting.

The DPS-Wide viability criteria identify a suite of watersheds (steelhead populations) distributed across the landscape in four geographically distinct BPGs, with a minimum number of watersheds[4] in each BPG, and that are intended to address two important elements of the DPS-Wide viability criteria: "Biographic Diversity" and "Life-History Diversity". The Population-Level viability criteria include a number of separate metrics that address various aspects of individual populations ("Mean Annual Run Size", "Ocean Conditions", "Spawner Density", and "Anadromous Faction").

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[2] To address this issue, NMFS' TRT recommended that the recovery strategy secure the extant parts of the inland populations, including the Salinas River in the Interior Coast Range Biogeographic Population Group. The TRT also noted, "The original inland populations were relatively few in number, large in spatial extent, and inhabited challenging environments." Boughton *et al*. 2007, p. 24

[3] The mainstem of the Salinas River is characterized by long alluvial stretches. NMFS' TRT noted that the mainstem of the Salinas River currently does not provide suitable spawning or rearing habitat for steelhead; however, the mainstem prior to Spanish settlement may have been quite different ecologically, and these conditions would have been more conducive to steelhead spawning and rearing. See Boughton, *et al.* 2006, pp. 12, 24, 29, and 98-99.

[4] While the TRT did not have sufficient information to assert that these individual populations were functionally independent (*i.e*., individually viable in an unimpaired stated), it believed that these populations were distinct enough to be considered as separate populations for the purposes of developing the DPS-Wide and Population-Level viability criteria

See NMFS's South-Central California Steelhead Recovery Plan, Chapter 6, Steelhead Recovery Goals, Objectives & Criteria, and Appendix C. Composition of South-Central California Coast Steelhead Recovery Planning Area BPGs.

These are discussed in more detail as they relate to the Salinas River watershed in the separate section below.

Salinas River

The Salinas River is situated within the Interior Coast Range BPG (along with the Pajaro River)[5] and is classified as a Core 1 population within the South-Central California Coast Steelhead Recovery Plan. Core 1 populations are populations identified as having the highest priority for recovery planning based on the following factors:

- intrinsic potential of the population to support a viable population in an unimpaired condition (based on the amount of spawning and rearing habitat);
- the role of the population in meeting the DPS-Wide population viability criteria (minimum number of population per BPG, including spatial distribution, "Biogeographic Diversity", and "Life-History Diversity");
- severity of the threats facing the populations (or current condition of the population;
- potential ecological or genetic diversity of the watershed that contributes to the species overall diversity; and
- capacity of the watershed and population to respond to critical recovery actions needed to address identified threats.

Core 1 populations form the foundation of the recovery implementation strategy and must meet the Population-Level viability criteria identified in NMFS' South-Central California Coast Steelhead Recovery Plan.

See NMFS 2013, Chapter 6, "Steelhead Recovery Goals, Objectives & Criteria" and discussion below for details.

To meet these Population-Level viability criteria NMFS' TRT specifically identified "securing extant inland populations in the Interior Coast Range BPG (Pajaro and Salinas Rivers) and the Carmel Basin BPG (Carmel River)" as a critical component of the recovery strategy for the South-Central California Coast Steelhead DPS.[6] NMFS' TRT further noted, "The populations of the

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[5] See map of Biogeographic Population Groups in the South-Central California Coast Steelhead Recovery Planning Area in NMFS 2013, p. 2-10.

[6] NMF's TRT also recognized the importance of other inland populations within the South-Central/Southern California Steelhead Recovery Planning Domain: "The extant habitat of these populations— especially the anadromous waters of the Pajaro River, Arroyo Seco, the southern Salinas Valley, the Sisquoc River, the Santa Ynez River, the Ventura River and the Santa Clara River—merit high priority for immediate protection and recovery so

Interior Coast Range are particularly important because they appear to have produced the largest run sizes in the SCCCS DPS during years of high rainfall and runoff (Boughton *et al*, 2006, Good *et al*. 2005)."

The Salinas River watershed is unique in several respects that are relevant to the question you have posed.

First, it is the largest watershed within the South-Central California Coast Steelhead Recovery Planning Area (and within the South-Central/Southern California Coast Recovery Planning Domain). Its watershed encompasses approximately 4,391 square miles and extends over almost two degrees of latitude; it is also distinctive in that it runs south to north. The major tributaries of the Salinas (*e.g*., Arroyo Seco, Nacimiento, and San Antonio) are themselves considerably larger than the other individual watersheds within the South-Central California Coast Steelhead Recovery Planning Area.

See Figure 1, map of "Salinas River Major Subbasins".

Second, because of its geographic location and physical features, the Salinas River watershed exhibits the most diverse range of habitat types of all the watersheds within the South-Central/Southern California Coast Recovery Planning Domain: coastal dunes, estuarine marsh, oak woodland, coniferous forest, chaparral, grassland savannah, desert-like scrub, and riparian woodland. This diversity is reflected in the diversity of the native *O. mykiss* populations that occupy and utilize the Salinas River watershed (including anadromous, non-anadromous, and lagoon anadromous forms of *O. mykiss*).

Third, the Salinas River is also unique in that is the only watershed within the South-Central California Coast Steelhead Recovery Planning Area (and within the South-Central/Southern California Steelhead Recovery Planning Domain) for which the TRT has identified multiple populations of anadromous *O. mykiss* in a single watershed.

Multiple Recovery Populations of the Salinas River Watershed

For recovery planning NMFS' TRT for the South-Central/Southern California Coast Steelhead Recovery Planning Domain adopted the one-basin = one population rule. The only exception to this one-watershed/one population rule is the Salinas River watershed[7]. In this watershed, the TRT posited three separate recovery populations. The reason and significance for this characterization of the population structure of the Salinas River is described below.

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that fish passage does not decline further (and should be improved whenever possible, though this is a longer-term effort)." Boughton *et al.* 2007, p. 24.

[7] The TRT identified several other potential situations that could deviate from this rule, but did not have adequate information to propose an alternative population structure: 1) sets of small neighboring basins, such as in Big Sur, the southern Santa Barbara coast, and the Santa Monica Mountains; and 2) neighboring basins with unreliable flow, such as those in the "South of Los Angeles" section of the study area. In these situations, rather than a single watershed supporting multiple discrete populations, individual populations may function as a metapopulations, utilizing multiple watersheds.

As noted, the Salinas River watershed is unusually large, with several significant tributaries (including the Arroyo Seco, Nacimiento, and San Antonio rivers) that join the mainstem of the Salinas River from the west, which are characterized by perennial flow within some reaches, particularly upper reaches and sub-tributaries. These western tributaries are distinctively different from those tributaries that enter the Salinas River from the east (*e.g.*, Estrella River, San Juan Creek) which are more like desert washes. The exception to the eastern tributaries is Gabilan Creek that enters the Salinas System on the extreme northern end of the system. For an overview of the Salinas River watershed See Casagrande, *et al*. 2003; also Hager 2001, Franklin 1999.

Because of the size of the Salinas River watershed, NMFS' TRT examined the possibility that the watershed supported more than one population of anadromous *O. mykiss*. The TRT found that the Salinas River watershed contained five distinct steelhead habitat areas – Gabilan Creek, Arroyo Seco, San Antonio River, Nacimiento River, and the Upper Salinas River system (which includes a number of tributaries, including the Santa Margarita River).

Within these five distinct steelhead habitat areas, the TRT identified three distinguishable populations of anadromous *O. mykiss* within the Salinas River watershed:

1) Gabilan Creek

2) Arroyo Seco

3) Nacimiento River *et al.* (which includes Santa Antonio River and the upper Salinas tributaries)

See Figure 3, map of "Salinas Recovery Populations".

This three-population structure is based on a) the large size of the Salinas River watershed, b) the distance between the point of entry of anadromous *O. mykiss* into the estuary and the distances between the confluences of the various tributaries with the mainstem of the Salinas River, c) the ephemeral migratory flows within the mainstem, and d) the presumed migratory behavior of the steelhead within the watershed. While the direct evidence from documented fish movement is not sufficient to make a definitive determination regarding total number of distinguishable populations of in the Salinas River watershed, the preponderance of evidence indicates that the Salinas River is capable of supporting at least three discrete populations of anadromous *O. mykiss* within the five distinct steelhead habitat areas.

See Figure 1, map of "Salinas River Major Subbasins" for stream miles and Figure 2, map of "Salinas River Intrinsic Potential Steelhead Spawning and Rearing Habitat" for stream/river miles between confluences.

Gabilan Creek is considered a distinct population because of its unique connection with the ocean via the Temaldero Slough and the Old Salinas River channel with is connected to the Salinas River Estuary via the Elkhorn Slough. The principal steelhead spawning and rearing habitat is in the upper reaches of Gabilan and has the shortest access route to the Pacific Ocean.

Arroyo Seco is considered a distinct population for several reasons. First, it is separated from the three other upstream steelhead habitat areas by an extended reach of the Salinas River mainstem as a result of naturally ephemeral flow (further exacerbated by dams, diversions, and extensive groundwater pumping). This situation presents significant challenges to juvenile steelhead movement, acting as a mechanism isolating this population from others within the Salinas River watershed. Second, under natural hydrologic conditions *(i.e.*, unimpaired by groundwater extractions, surface water diversions, or dams), there is no evidence that natural low flows would have prevented returning adult steelhead from accessing Arroyo Seco (and thus *forcing* them to spawn in the other steelhead habitat areas of the Salinas River watershed). Third, from a recovery perspective, the adverse consequences of treating Arroyo Seco as indistinct and therefore lumping in it with the other steelhead habitat areas, are greater than splitting or distinguishing it from the other identified populations. (See additional comments below regarding lumping and splitting populations.)

Nacimiento, San Antonio, and Upper Salinas River together comprise a single, distinct population. The combination of the long distance between the point of entry of anadromous *O. mykiss* into the estuary and the confluences of the San Antonio, Nacimiento, and upper Salinas rivers (in conjunction with the ephemeral nature of migration flows, even under unimpaired conditions), frequently prevents adult steelhead from returning to these upper tributaries. As a result, anadromous *O. mykiss* entering the Salinas River are *forced* to spawn in one of the other four steelhead areas supporting the other two distinct recovery populations of the Salinas System (Gabilan Creek or Arroyo Seco), thus segregating the Nacimiento, *et al.* population from the other two recovery populations. Under natural flow conditions, the Nacimiento River exhibits the more reliable migration flows, and so fish natal to the San Antonio River (or Upper Salinas River) that would be forced by low flows in these waters to spawn in the Nacimiento River. NMFS' TRT noted that the Nacimiento and San Antonio rivers both have a high potential as steelhead spawning and rearing habitats, and that these habitats are concentrated in the upper reaches in each watershed above the Nacimiento Dam and San Antonio Dam, respectively.

Contributing to the habitat suitability of the upper reaches of both the Nacimiento and San Antonio rivers is the higher average annual rainfall in these two sub-watersheds. The Salinas River watershed has an overall average annual rainfall of 16.6 inches. By comparison, the Nacimiento River watershed has an average annual rainfall of 26.9 inches, and the San Antonio River watershed an average annual rainfall of 20.2 inches (a 38% and 18% higher average annual rainfall total than the Salinas River watershed, respectively).

See attached Figure 1, map of "Salinas River Major Subbasins" for average annual rainfall totals for the various subbasins of the Salinas River watershed.

In analyzing the population structure of the Salinas River watershed, NMFS' TRT discussed the relative risks, from a recovery perspective, of mistakenly lumping or splitting multiple populations in the Salinas River watershed. The TRT found that the more risky strategy would be to erroneously lump recovery populations. Applying the Population-Level viability criteria to a lumped pair, for example, would not necessarily be sufficient to protect either of the pair (*i.e.*, if neither of the lumped pair of populations met the Population-Viability-Level criteria). Conversely, the opposite strategy - of identifying (splitting) two populations when in reality there is only one functional population - only creates a margin of safety if both populations are recovered to the point that the they individually meet the Population-Level viability criteria. This approach is consistent with the general precautionary principle that the TRT adopted for the two listed species of steelhead at the southernmost end of their range. As the TRT noted, ". . . the bigger risk with respect to recovery appears to be erroneous lumping".

For a detailed analysis of this issue of multiple populations of *O. mykiss* in the Salinas River watershed see, Boughton *et al*. 2005, especially, Section 2.6. "Three Discrete Populations in the Salinas System", Part 4. "Distribution of Steelhead Habitat" and Part 10 Appendices, 10.1. "Evidence for Two or More Populations in the Salinas Basin".

To put this discussion of multiple steelhead populations in the Salinas River watershed in a broader context, it should be recognized that the Salinas River watershed contains approximately two-thirds of the total amount of stream mileage within the South-Central California Coast Steelhead Recovery Planning Area. See NFMS 2013, particularly Tables 9-1, 10-1, 11-1 and 12-1 for comparative stream mileages of the watersheds within the Interior Coast Range BPG and the three other BPGs comprising the South-Central California Coast Steelhead Recovery Planning Area.

Within the Salinas River watershed there are approximately 5,924 stream miles, with the major tributaries historically supporting *O. mykiss* containing 2,081 stream miles, distributed among the tributaries comprising the five steelhead areas, as follows:

Gabilan Creek: 175 miles

Arroyo Seco: 478 miles

San Antonio River: 578 miles

Nacimiento: 527 miles

Santa Margarita Creek: 153 miles

Upper Salinas and tributaries (above Salinas Dam): 170 miles

Of this 2,081 miles, approximately 694 stream miles have been identified has having high intrinsic potential over-summering rearing/refugia habitat (c. 33% of the total stream miles supporting *O. mykiss* within the Salinas River watershed). As noted above, a majority of this over-summering habitat is located in the upper reaches of the tributaries comprising the five steelhead habitat areas within the Salinas River watershed.

Of the three distinguishable recovery populations within the Salinas River, the Nacimiento *et al*. population (which includes the San Antonio River, Nacimiento River, Paso Robles Creek, Santa Margarita River, and Upper Salinas River and tributaries) contains 330 miles of identified high intrinsic potential over-summering rearing/refugia habitat; this represents approximately half (c. 48%) of the total amount of intrinsic potential over-summering habitat associated with the three distinct steelhead populations of the Salinas River watershed. Together, the San Antonio River and Nacimiento River watersheds contain approximately 157 miles of high intrinsic potential over-summering rearing/refugia habitat (74 and 83 miles respectively), and approximately half (c. 48%) of the over-summering habitat within the Nacimiento *et al*. population. Importantly, of the intrinsic potential habitat identified by the TRT in the San Antonio and Nacimiento watersheds, *all* of it is located above the San Antonio and Nacimiento dams.

For stream and intrinsic potential steelhead spawning and rearing habitat mileages, see Figure 1, maps of “Salinas River Major Subbasins”, and Figure 2, map of “Salinas River Intrinsic Potential Steelhead Spawning and Rearing Habitat”. Also, Boughton, *et al.* 2006 for a detailed discussion of the “envelope method” used to identify intrinsic potential steelhead over summering habitat, and the associated intrinsic potential maps.

NMFS’ TRT Viability Criteria

The DPS-Wide viability criteria for South-Central/Southern California Coast Steelhead Recovery Planning Domain provides that each BPG be comprised of a suite of restored core watersheds, each of which must meet the Population-Level viability criteria. As noted above, individual watersheds were generally presumed to support a single population that would meet the Population-Level viability criteria. However, in the case of the Salinas River, NMFS’ TRT recognized multiple populations, each of which must meet the Population-Level viability criteria to address the “Geographic Diversity and “Biological Diversity” elements of the viability criteria. Failure to reconnect the upper and lower watersheds of the San Antonio River and Nacimiento River by providing fish passage around the San Antonio and Nacimiento dams for both juvenile and adult *O. mykiss* would effectively preclude meeting the Population-Level viability criteria for the Nacimiento *et al*. population of the Salinas Watershed, where all of the high intrinsic potential over-summering rearing/refugia habitats exists in the headwater tributaries above the two dams.

Thus, not providing effective fish passage over the Nacimiento and San Antonio dams effectively precludes the recovery of the South-Central California Coast Steelhead DPS because it would prelude meeting the DPS-Wide viability criteria that requires a suite of restored core watersheds. NMFS’ South-Central California Coast Steelhead Recovery Plan, specifically requires recovery of the Pajaro River, Gabilan Creek, Arroyo Seco, and Upper Salinas Basin in the Interior Coast Range BPG.

See NMFS 2013, Appendix C. “Composition of South-Central California Coast Steelhead Recovery Planning Area BPGs”.

Salinas River Recovery Actions

To meet both the DPS-Wide and Population-Level viability criteria identified by NMFS’ TRT for the South-Central California Coast Steelhead Recovery Planning Area, NMFS’ South-Central California Coast Steelhead Recovery Plan identified a suite of recovery actions, including those dealing with flows and fish passage at impassible barriers on the suite of Core 1 populations identified in the Recovery Plan.

The DPS-Wide Recovery Actions include a general recovery action involving the physical modification of fish passage barriers identified in Table 7-2 and the BPG recovery action tables. Table 7-1 identifies the Core 1, 2 and 3 *O. mykiss* populations within the South-Central California

Coast Steelhead Recovery Planning Area. Core 1 populations are highlighted in bold face, and include the “Salinas River Watershed (all populations)”. See NMFS 2013, p. 7-7.

NMFS’ South-Central California Coast Steelhead Recovery Plan also identifies critical recovery actions for each Core 1 population for each BPG. Table 9-3, “Critical recovery actions for Core 1 populations within the Interior Coast Range BPG” identified critical recovery actions for the Salinas River, including the Arroyo Seco, San Antonio, and Nacimiento rivers. These critical recovery actions include physically modifying the dams “to allow steelhead natural rates of migration to upstream spawning and rearing habitats, and passage of smolts, kelts downstream to the estuary and the ocean” for the San Antonio Dam, Nacimiento Dam, and Salinas Dam, on the San Antonio, and Nacimiento, and Salinas rivers, respectively. See NMFS 2013 p. 9-18.

In addition, NMFS’ South-Central California Coast Steelhead Recovery Plan identifies watershed-specific recovery actions dealing with the provision of flows and fish passage at the San Antonio Dam, Nacimiento Dam, and Salinas Dam, as well as other fish passage barriers or impediments within the Salinas River watershed.

The most pertinent to the question of providing fish passage and related flows at the San Antonio and Nacimiento dams are:

- Recovery Actions: SAnt-SCCCS-4.1, SAnt-SCCCS-4.2, and SAnt-SCCCS-4.3 (San Antonio River Dams and Surface Water Diversions);

- Recovery Actions: Nac-SCCCS-4.1, Nac-SCCCS-4.2, and Nac-SCCCS-4.2 (Nacimiento Dams and Water Diversions).

There is also a comparable recovery action for the Salinas Dam.

- Recovery Actions: Sal-SCCCS-4.1, Sal-SCCCS-4.2, and Sal-SCCCS-3.3 (Salinas River Dams and Surface Water Diversions)

In addition, there are specific recovery actions dealing with other types of fish passage impediments within the Salinas River watershed; these include:

- Recovery Actions: Sal-SCCCS-3.1 and Sal-SCCCS-3.2 (Salinas River Culverts and Road Crossings);

- Recovery Actions: SAnt-SCCCS-3.1 and SAnt-SCCCS-3.2 (San Antonio River Culverts and Road Crossings);

- Recovery Actions: Nac-SCCCS-3.1 and Nac-SCCCs-3.2 (Nacimiento Culverts and Road Crossings).

See NMFS 2013, pp. 9-31 – 9-32; 9-45 – 9-46; and 9-50; also, NMFS 2016a.

These recovery actions are intended to provide appropriate flows below dams and diversions and related fish passage (for both adult and juvenile *O. mykiss*) around the and San Antonio, Nacimiento, and Salinas dams. The basic of goal of these recovery actions is to reconnect up and downstream migratory, spawning and rearing habitats to accommodate the various life-history forms and migratory patterns of native *O. mykiss* within the Salinas River watershed. They are also intended to enable the Salinas River to meet the Population-Level viability criteria identified by NMFS' TRT, and incorporated into NMFS' South-Central California Coast Steelhead Recovery Plan (including the "Biogeographic Diversity" and "Life-History Diversity" elements of the viability criteria).

There are also other recovery actions that are pertinent to the management of San Antonio, Nacimiento, and Salinas dams and the steelhead populations within the Salinas River watershed; these include recovery actions dealing with flood control, non-native species, recreational facilities, and variety of up-slope activities. See NMFS 2013, particularly Table 9-5. "South-Central California Coast Steelhead DPS Recovery Action Table for Lower Salinas River and Sub-Watersheds (Interior Coast Range BPG)", pp. 9-31 – 9-53.

Summary and Conclusion

Failure to provide passage at the San Antonio and Nacimiento dams would result is separating 157 miles of high intrinsic potential over-summering rearing/refugia habitat from the anadromous waters of the Salinas River watershed. This represents c. 48%c. of the total amount of high intrinsic potential over-summering spawning/refugia habitat within the Nacimiento *et al.* recovery population, and c. 23% of the total amount of high intrinsic potential over-summering rearing/refugia habitat within the Salinas River watershed. Importantly 100% of the total amount of high intrinsic potential over-summering rearing/refugia habitat (sustained by higher annual average rainfall) within the San Antonio River/Nacimiento River portion of the Nacimiento *et al*. recovery population is located above the San Antonio and Nacimiento dams.

In addition, failure to rectify the fish passage impediments (and related flows) at the San Antonio and Nacimiento dams would preclude meeting the "Geographic Diversity" and "Biological Diversity" elements of the Population-Level viability criteria within the Salinas River watershed, and within the South-Central California Coast Steelhead DPS as a whole.

As NMFS' South-Central California Coast Steelhead Recovery Plan noted:

> "Regarding the impacts of impassable anthropogenic barriers on threatened steelhead, the recovery objectives include restoring steelhead distribution to previously occupied areas and restoring genetic diversity and natural interchange within populations and metapopulations. One of the threats abatement criteria identified to meet these objectives is allowing sustainable effective access to historical spawning and rearing habitats."

NMFS South-Central California Coast Steelhead Recovery Plan includes the following critical recovery actions for the Salinas River:

> "Develop and implement operating criteria to ensure the pattern and magnitude of groundwater extractions and water releases from Salinas Dam[s] to provide the essential habitat functions to support the life history and habitat requirements of adult and juvenile steelhead. Physically modify all fish passage impediments, including the Salinas Dam[s],

to allow steelhead natural rates of migration to upstream spawning and rearing habitats, and passage of smolts and kelts downstream to the estuary and ocean. Management instream mining to minimize impacts to migration, spawning , and rearing habitat, and protect spawning and rearing habitat in major tributaries, including the Arroyo Seco. Identify, protect, and where necessary restore estuarine rearing habitats, including management of artificial breaching of the sandbar at the river's mouth."

Table 9-3. "Critical recovery actions for Core 1 populations within the Interior Coast Range BPG", p. 9-18.

The San Antonio and Nacimiento dams were specifically identified in NMFS' South-Central California Coast Steelhead Recovery Plan "Critical Recovery Actions":

> "Physically modify San Antonio Dam to allow steelhead natural rates of migration to upstream spawning and rearing habitats, and passage of smolts and kelts downstream to the estuary and the ocean."
>
> "Physically modify Nacimiento Dam to allow steelhead natural rates of migration to upstream spawning and rearing habitats, and passage of smolts and kelts downstream to the estuary and the ocean."

NMFS' 2013, Recovery Actions SAnt-SCCCS-4.1, SAnt-SCCCS-4.2, Sant-SCCCS-4.3 and Nac-SCCCS-4.1, Nac-SCCCS-4.2, Nac-SCCCS-4.3, pp 9-45 through 9-46, 9-50.

I hope that this analysis will provide a useful framework in which to consider NMFS' recovery actions for the Salinas River watershed identified in NMFS' South-Central California Coast Steelhead Recovery Plan.[8]

[8] For examples of the analyses of impacts and approaches to providing effective fish passage at other major dams within the South-Central/Southern California Steelhead Recovery Planning Domain, see, California State Water Resoruces Control Board 2019, and NMFS 2016b, 2008.

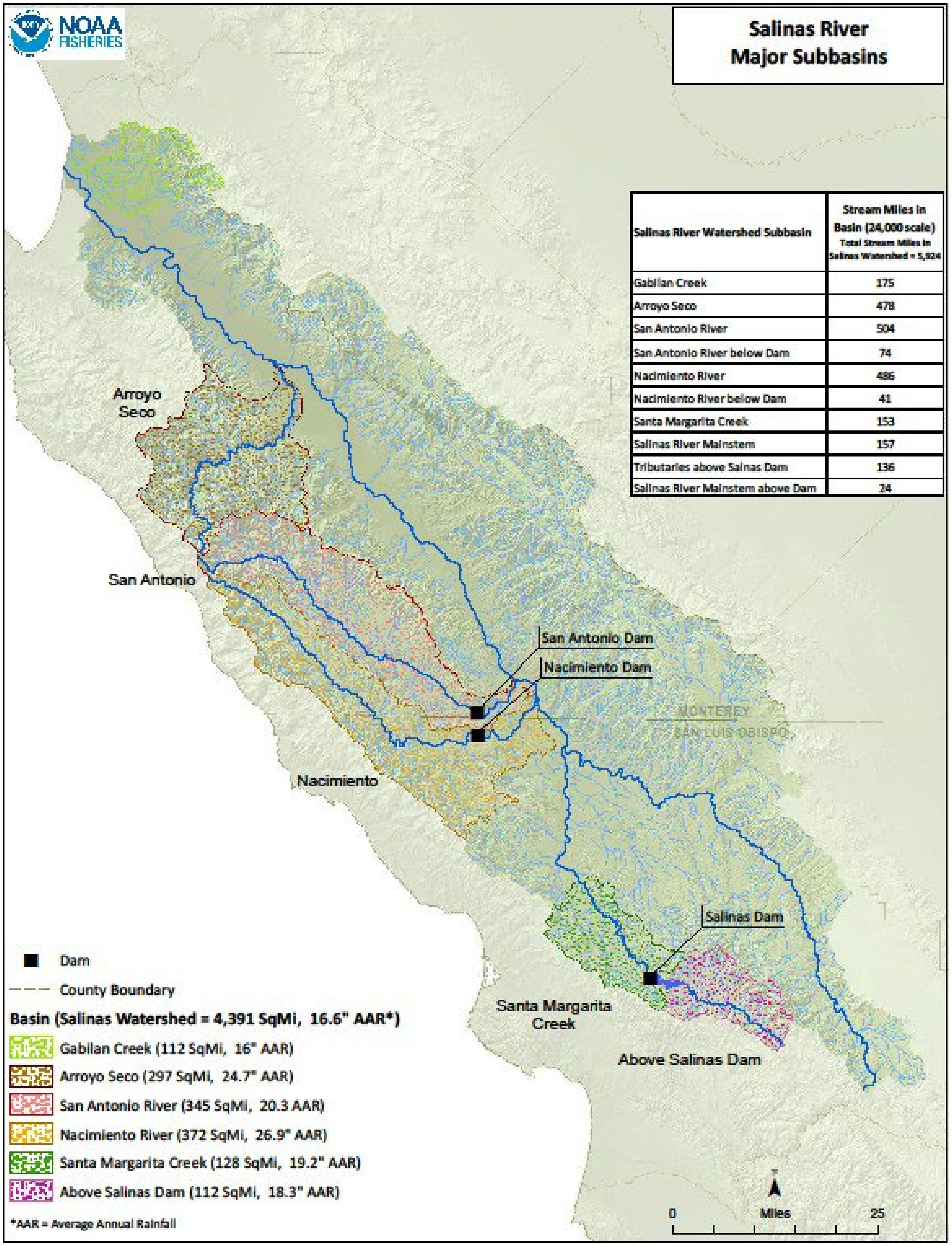
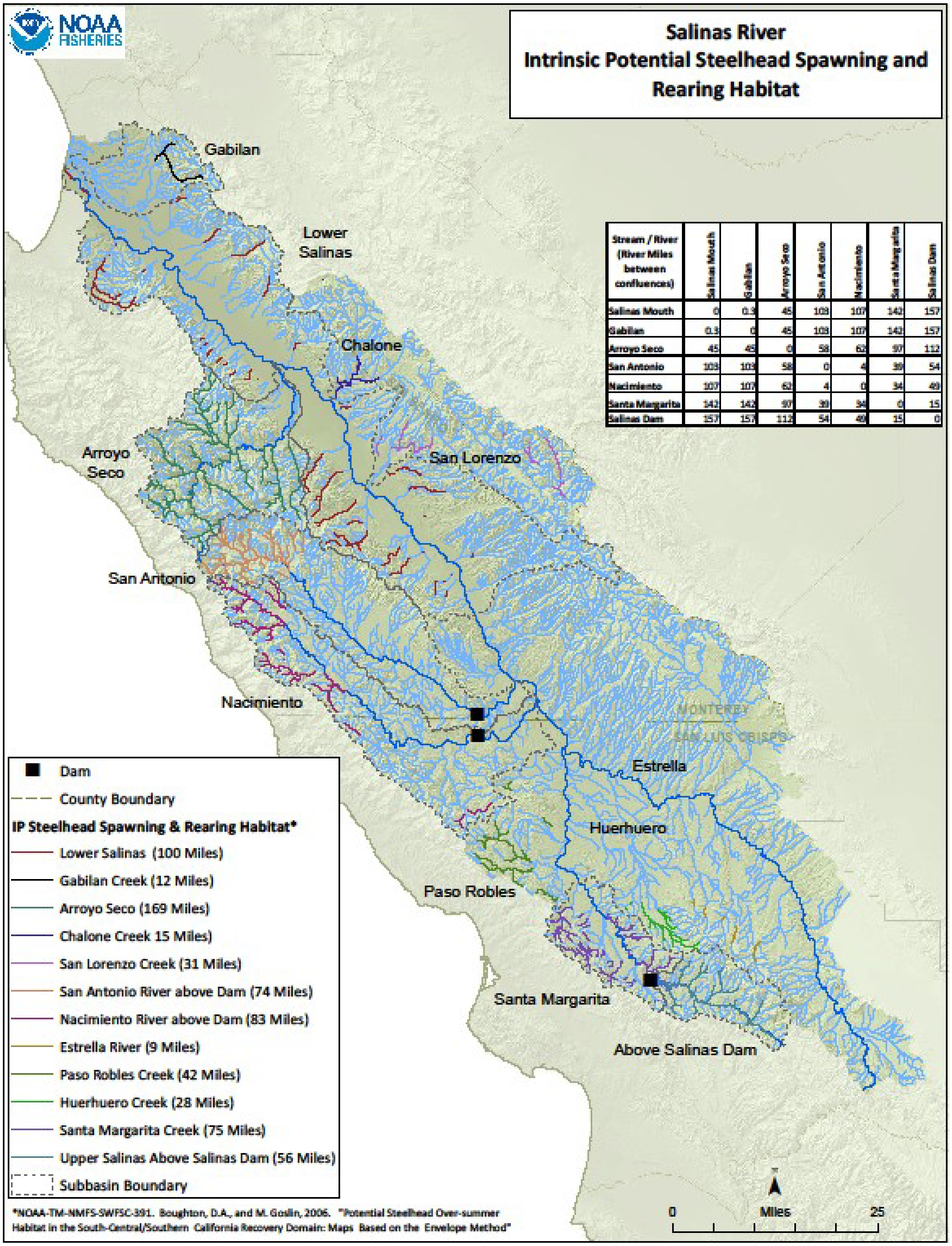


Figure 1. Salinas River Major Subbasins.



Stream / River (River Miles between confluences)	Salinas Mouth	Gabilan	Arroyo Seco	San Antonio	Nacimiento	Santa Margarita	Salinas Dam
Salinas Mouth	0	0.3	45	103	107	142	157
Gabilan	0.3	0	45	103	107	142	157
Arroyo Seco	45	45	0	58	62	97	112
San Antonio	103	103	58	0	4	39	54
Nacimiento	107	107	62	4	0	34	49
Santa Margarita	142	142	97	39	34	0	15
Salinas Dam	157	157	112	54	49	15	0

Figure 2. Salinas River Intrinsic Potential Steelhead Spawning and Rearing Habitat.

Figure 3. Salinas River Recovery Populations.

References

Adadia-Cardoso, A., D. E. Pearse, S. Jacobson, J. Marshall, D. Dalrymple, F. Kawasaki, G. Ruiz-Campos and J. C. Garza. 2016. Population genetic structure and ancestry of steelhead/rainbow trout (*Oncorhynchus mykiss*) at the extreme southern edge of their range in North America. *Conservation Genetics* DOI 10.1007/s10592-016-0814-9.

Apgar, T. M., D. E. Pearse, and E. P. Palkovacs. 2017. Evolutionary restoration potential evaluated through the use of train-linked genetic marker. *Evolutionary Applications* 10(5): 485-497.

Arostegui, M. C., T. P. Quinn, L. W. Seeb, and G. J. McKinney. 2019. Retention of a chromosomal inversion from an anadromous ancestor provides the genetic basis for alternative freshwater ecotypes in rainbow trout. *Molecular Ecology. Special Issue. The Role of Structural Variants in Adaptation and Diversification* 28(6): 1112-1247.

Boughton, D. H. 2010a. A Forward-Looking Scientific Frame of Reference for Steelhead Recovery on the South-Central and Southern California Coast. NOAA Technical Memorandum NMFS-SWFSC-466.

Boughton, D. H. 2010b. Some Research Questions on Recovery of Steelhead on the South-Central California Coast. NOAA Technical Memorandum NMFS-SWFSC-467.

Boughton, D., H. Fish, J. Pope and G. Holt. 2009. Spatial patterning of habitat for *Oncorhynchus mykiss* in a system of intermittent and perennial stream. *Ecology of Freshwater Fish* 18:92- 105.

Boughton, P. Adams, E. Anderson, C. Fusaro, E. Keller, E. Kelley, L. Lentsch, J. Nielsen, K. Perry, H. Regan, J. Smith, C. Swift, L. Thompson, F. Watson. 2007. Viability Criteria for Steelhead of the South-Central and Southern California Coast. NOAA-Technical Memorandum NMFS-SWFSC-407.

Boughton, D. A., P. Adams, E. Anderson, C. Fusaro, E. A. Keller, E. Kelley, L. Lentsch, J. Nielsen, K. Perry, H. M. Regan, J. J. Smith, C. Swift, L. Thompson, and F. Watson. 2006a. Steelhead of the South-Central/Southern California Coast: Population Characterization for Recovery Planning. NOAA Technical Memorandum NMFS-SWFSC-394.

Boughton, D. A. and Goslin, M. 2006b. Potential steelhead over-summering habitat in the South-Central/Southern California coast recovery domain: Maps based on the envelope method. *NOAA Technical Memorandum NMFS-SWFSC* 391.

Boughton, D.A., H. Fish, K. Pipal, J. Goin, F. Watson, J. Hager, J. Casagrande, and M. Stoecker. 2005. Contraction of the southern range limit for anadromous *Oncorhynchus mykiss*. *NOAA Fisheries Technical Memorandum SWFSC* 380.

California State Water Resources Control Board. 2019. State of California State Water Resources Control Board Order WR 2019-0148 In the Matter of Permits 11308 and 11310 (Applications

11331 and 11332) held by the United States Bureau of Reclamation for the Cachuma Project on the Santa Ynez River. Order Amending Permits 11308 and 11310.

Casagrande, J., J. Hager, and F. Watson. 2003. Fish species distribution and habitat quality for selected streams of the Salinas watershed. The Watershed Institute, California State University Monterey Bay.

Clemento, A. J., Anderson, E. C., Boughton, D., Girman, D., and Garza, J. C. 2009. Population genetic structure and ancestry of *Oncorhynchus mykiss* populations above and below dams in south-central California. *Conservation Genetics* 10:1321–1336.

Donohoe, C. J., D. E. Rundio, D. E. Pearse, T. H. Williams. 2021. Straying and life history of adult steelhead in a small California coastal stream revealed by otolith natural tags and genetic stock identification. *North American Journal of Fisheries Management* doi.1002/NAAFM.10577.

Franklin, H. A. 1999. Steelhead and salmon migration in the Salinas River. Unpublished report, H. Franklin, 1040 South River Road, Paso Robles, CA 93446.

Garza, J. C., L. Gilbert-Horvath, B. Spence, T. H. Williams, J. Anderson, and H. Fish. 2014. Population structure of steelhead in coastal California. *Transactions of the American Fisheries Society* 143:134-152.

Garza, J.C., L. Gilbert-Horvath, J. Anderson, T. Williams, B. Spence and H. Fish. 2004. Population structure and history of steelhead trout in California. *NPAFC Technical Report* No. 5.

Girman, D. and J.C. Garza. 2006. Population structure and ancestry of *O. mykiss* populations in South-Central California based on genetic analysis of microsatellite data. Final Report for California Department of Fish and Game Project No. P0350021 and Pacific States Marine Fisheries Contract No. AWIP-S-1, September 2006.

Good, T. P., R. S. Waples, and P. Adams (eds.) 2005. Updated Status of Federally Listed ESUs of West Coast Salmon and Steelhead. National Marine Fisheries Service. Northwest and Southwest Fisheries Science Centers. NOAA Technical Memorandum NMFS-NWFSC TM-66.

Hager, J. 2001. An Evaluation of Steelhead Habitat and Population in the Gabilan Creek Watershed. Capstone Project, Earth Systems and Policy, Center for Science, Technology, and Information Resources. California State University, Monterey Bay.

Kelson, S. J., M. R. Miller, T. Q. Thompson, S. M. O'Rourke, and S. M. Carlson. 2019. Do genomics and sex predict migration in a partially migratory salmonid fish, *Oncorhynchus mykiss*? *Canadian Journal of Fisheries and Aquatic Sciences* 76:2080-2088.

Leitwein, M., J. C. Garza, and D. E. Pearse. 2017. Ancestory and adaptive evolution of anadromous, resident, and adfluvial rainbow trout (*Oncorhynchus mykiss*) in the San Francisco bat area: application of adaptive genomic variation to conservation in highly impacted landscape. *Evolutionary Applications* 10(1):56-67.

National Marine Fisheries Service. 2016a. South-Central/Southern California Coast Steelhead Recovery Planning Domain. 5-Year Review: Summary and Evaluation. South-Central California Coast Steelhead Distinct Population Segment. National Marine Fisheries Service. West Coast Region. California Coastal Office, Santa Rosa, California.

National Marine Fisheries Service. 2016b. Endangered Species Act (ESA) Section 7(a)(2) Draft Biological Opinion. Operation and Maintenance of the Cachuma Project [Santa Ynez River]. NMFS Consultation Number: 2014-1014, Action Agency: U.S. Bureau of Reclamation.

National Marine Fisheries Service. 2013. South-Central California Coast Steelhead Recovery Plan. NOAA Fisheries. West Coast Region, California Coastal Office, Long Beach, California.

National Marine Fisheries Service. 2008. Final Biological Opinion. Operation of the Santa Felicia Hydroelectric Project (P-2153)-012). Action Agency: U. S. Federal Energy Regulatory Commission, Washington, D. C., license issued to United Water Conservation District. May 5, 2008. Tracking #: SWR/2002/02704.

Nilsson, C. and K. Berggren. 2000. Alteration of riparian ecosystem caused by river regulation. *BioScience* 50(9):783-792.

Olden, J.D. and R. J. Naiman. 2009. Incorporating thermal regimes into environmental flow assessments: modifying dam operations to restore freshwater ecosystem integrity. *Freshwater Biology* 85(1).

Pearse, D. E., N. J. Barson. T. Nome, G. T. Gao, M. A. Campbell, A. Abadia-Cardoso, E. C. Anderson, *et al.* 2019. Sex-dependent dominance maintains migration supergene in rainbow trout. *Nature Ecology & Evolution* 3(12):173-1742.

Pearse, D. E. 2016. Saving the Spandrels? Adaptive genomic variation in conservation and fisheries management. *Journal of Fish Biology*, doi: 10.1111/jfb.13168

Pearse, D. E., M. R. Miller, A. Abadia-Cardoso, and J. C. Garza. 2014. Rapid parallel evolution of standing variation in a single, complex, genomic region is associated with life-history in steelhead/rainbow trout. *Proceedings of the Royal Society* B-Biological Sciences [online serial] 281: article 2014.0012.

Pearse, D. and J. C. Garza. 2008. Historical Baseline for Genetic Monitoring of Coastal California Steelhead, *Oncorhynchus mykiss.* Final Report for California Department of Fish and Wildlife Fisheries Restoration Grant Program P0510530.

Quinones, R. M., T. E. Grantham, B. N. Harvey, J. D. Kiernan, M. Klasson, A. P. Wintzer, P. B. Moyle. 2014. Dam removal and anadromous salmonids (*Oncorhynchus* spp.) Conservation in California. *Review Fish Biology Fisheries*. DOI 10.1007/s1160-014-9359-5.