SALINAS VALLEY OPERATIONAL MODEL REPORT

Interlake Tunnel and Spillway Modification Project
Monterey County, California

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ACRONYMS AND ABBREVIATIONS

af	acre-feet
afy	acre-feet per year
Amec Foster Wheeler	Amec Foster Wheeler Environment & Infrastructure, Inc.
cfs	cubic feet per second
DWR	California Department of Water Resources
FMP	Farm Process
GHB	General Head Boundary
HLOW	High Level Outlet Works
HSPF	Hydrological Simulation Program – FORTRAN
ILT	Interlake Tunnel and Spillway Modification Project
LLOW	Low Level Outlet Works
MCWRA	Monterey County Water Resources Agency
msl	mean sea level
OWHM	One-Water Hydrologic Flow Model
SFR	Streamflow Routing
SRDF	Salinas River Diversion Facility
SVIHM	Salinas Valley Integrated Hydrologic Model
SVGB	Salinas Valley Groundwater Basin
SVWM	Salinas Valley Watershed Model
SWO	Surface Water Operations
SWRCB	State Water Resources Control Board
TM	Technical Memorandum
USGS	U.S. Geological Survey
Wood	Wood Environment & Infrastructure Solutions, Inc. ("Wood", formerly known as Amec Foster Wheeler Environment & Infrastructure, Inc.)
WY	Water Year

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EXECUTIVE SUMMARY

This Technical Memorandum (TM) describes the results of a modeling investigation into the effects of various proposed infrastructure changes to the Nacimiento and San Antonio Dams and Reservoirs in Monterey and San Luis Obispo Counties, California. This investigation was undertaken using the Salinas Valley Operational Model (SVOM), a complex three-dimensional groundwater-surface water interaction model built using the USGS MODFLOW-OWHM code. It relies upon an iterative relationship with a reservoir operations code (SWO) that dictates when the reservoirs will release water and how much, based on conditions both at the reservoirs and within the groundwater-surface water model domain.

This investigation focused on three proposed infrastructure changes: the Nacimiento-San Antonio Interlake Tunnel, the San Antonio Dam Spillway Raise, and the Nacimiento Dam Low-Level Outlet Works Modification. The model was used to estimate the effect of each of these changes separately, focusing on how they modify conditions and operations at the two reservoirs and operation of the Salinas River Diversion Facility (SRDF).

ES.1 STUDY AREA

The study area for this investigation comprises the Salinas Valley Groundwater Basin (SVGB) from near the Monterey-San Luis Obispo County line in the south to Elkhorn Slough in the north, bounded on the west and east by the foothills of the Santa Lucia and Gabilan Ranges. The Salinas River runs from south to north through the valley floor and is its dominant surface water feature. Two reservoirs (Nacimiento and San Antonio Reservoirs) store substantial amounts of water above the valley, releasing it according to a complex set of rules that attempt to fulfill all of the various purposes of the reservoirs.

ES.2 MODELING SYSTEM

The modeling performed for this investigation used the USGS-built SVOM, which is based on a historical model of the same area (the Salinas Valley Integrated Hydrologic Model, SVIHM) and informed by a rainfall-runoff model of the Salinas Valley watershed (the Salinas Valley Watershed Model, SVWM), which provides streamflow inputs to the boundaries of the SVOM. The SVOM is a 3d groundwater-surface water interaction model of the entire groundwater basin with a horizontal spatial discretization of 529 feet, 9 model layers, and 567 monthly stress periods, each with either 5 or 6 computational timesteps.

ES.3 BASELINE SCENARIO

To serve as a point of comparison, a Baseline scenario was constructed that attempts to reflect the current approach to basin management simulated over an extended period forced by a realistic hydrologic cycle. The Baseline scenario uses the current reservoir operational approach, current infrastructure and projects, 2014 land use conditions, and the historical hydrology (climate and streamflow conditions) from October 1967 to December 2014. This serves as an indication of long-term conditions in the basin should no changes be made to the current operational approach. The Baseline scenario was compared to the other scenarios simulating conditions with the various infrastructure changes in place to provide an indication of the impact of just the change being investigated with each scenario.

Table ES-1 provides a general overview of the results of the Baseline scenario. Average combined storage is about 281,000 af, and average releases total about 248,000 afy, split between Flood Control Release (about 58,000 afy) and non-Flood Control Release (about 191 afy). Table ES-2 gives details of the operation of the SRDF. On average, SRDF diverts about 10,000 afy and operates for about 136 diversion days per year. During dry years, SRDF diverts about 3,000 afy and operates for about 47 days per year.

ES.4 TUNNEL-ONLY SCENARIO

The Nacimiento-San Antonio Interlake Tunnel (Interlake Tunnel) is a proposed hard-rock tunnel that would directly connect Nacimiento and San Antonio Reservoirs, allowing for gravity-driven transfer of water from Nacimiento Reservoir to San Antonio Reservoir when conditions permit. The Interlake Tunnel was included in the Tunnel-Only scenario; differences between this scenario and the Baseline scenario provide an indication of the effect of the Interlake Tunnel on conditions in the system.

The Interlake Tunnel results in an increase of about 39,000 af in average storage, with a decrease (of about 52,000 af) at Nacimiento Reservoir and an increase (of about 90,000 af) at San Antonio Reservoir (Table ES-1). This results from an average annual transfer of about 30,000 afy through the Interlake Tunnel. Moving this water from Nacimiento Reservoir to San Antonio Reservoir takes advantage of available storage capacity in San Antonio Reservoir that generally is not filled by inflow from its watershed. The Interlake Tunnel results in a decrease (by about 12,000 afy) in Flood Control Release for the combined reservoir system and an increase (by about 10,000 afy) of non-Flood Control Release. This indicates that the Interlake Tunnel keeps more water in storage in the reservoirs, preventing it from being lost as Flood Control Release and making it available at later times for other uses. The Interlake Tunnel results in a slight increase (by about 1,000 afy) in the amount of water diverted at SRDF and a slight lengthening (by about 13 days per year) of the diversion season (Table ES-2). During dry years, SRDF diverts about 6,000 afy and operates for about 89 days per year.

ES.5 TUNNEL PLUS 7' SPILLWAY RAISE SCENARIO

The San Antonio Dam Spillway Raise would increase the elevation of the spillway crest at San Antonio Dam by seven feet, from its current elevation of 780 feet above mean sea level to 787 feet above mean sea level. This would increase the maximum storage capacity of San Antonio Reservoir from about 335,000 af to about 376,200 af. The Spillway Raise was included in the Tunnel Plus 7’ Spillway Raise scenario; differences between it and the Tunnel-Only scenario provide an indication of the effect of the Spillway Raise.

The Spillway Raise causes an increase (by about 15,000 af) in the overall average storage in the reservoirs, with increases in both Nacimiento Reservoir (by about 3,000 af) and San Antonio Reservoir (by about 12,000 af) (Table ES-1). Transfer through the Interlake Tunnel is about the same as under the Tunnel-Only scenario. The Spillway Raise decreases (by about 5,000 afy) combined Flood Control Release and increases (by about 4,000 afy) combined non-Flood Control Release. The volume of water diverted at the SRDF is approximately the same with or without the Spillway Raise, and the average SRDF season is very slightly longer (by 1 day per year) (Table ES-2). Some SRDF seasons that had nearly reached completion without the

Spillway Raise are full with the Spillway Raise. During dry years, SRDF diverts about 7,000 afy and operates for about 92 days per year.

ES.6 MODIFIED NACIMIENTO DAM LLOW SCENARIO

The Nacimiento Dam Low-Level Outlet Works (LLOW) Modification would increase the release capacity of the LLOW beyond its current limit of 460 cfs, which hampers the ability of Nacimiento Reservoir to supply Conservation Releases during drier periods. The Modified Nacimiento Dam LLOW scenario includes the LLOW modification; differences between it and the Baseline scenario provide an indication of the effect of the LLOW modification.

The LLOW modification causes a decrease (by about 14,000 af) in the overall average storage in the reservoirs, with decreased storage in Nacimiento Reservoir (by about 17,000 af) and increased storage in San Antonio Reservoir (by about 3,000 af; Table ES-1). Flood Control Release decreases (by about 7,000 afy), while non-Flood Control Release increases (by about 9,000 afy). This is due to the fact that the increased release capacity in Nacimiento Reservoir generally leaves it somewhat emptier, leaving more available storage capacity to absorb large winter storms, reducing the amount of Flood Control Release they generate. SRDF diverts slightly more water (about 1,000 afy more than under the Baseline scenario) and diversion lasts for longer in the season (by about 8 days per year; Table ES-2). During dry years, SRDF diverts about 4,000 afy and operates for about 60 days per year.

ES.7 2070 CLIMATE CHANGE SCENARIOS

The effect of future climate change on operations of the Interlake Tunnel and Spillway Raise was investigated by applying projected 2070 climate, streamflow, and land use conditions to the SVOM. The Tunnel-Only scenario with 2070 Climate Change and the Tunnel Plus 7′ Spillway Raise scenario with 2070 Climate Change modify the non-climate change scenarios in various ways to show how the benefits realized may change over time.

In general, the predictive models that DWR used to prepare the inputs used for this analysis predict that the Salinas River watershed will be substantially wetter by 2070, with inflow to the Nacimiento and San Antonio Reservoirs increasing by about 20% compared to the historical period used to force the non-climate change scenarios. This large increase results in substantially more water moving into and through the reservoirs.

Average reservoir storage is much higher with climate change (about 55,000 af higher for the Tunnel-Only scenario and about 70,000 af higher for the Tunnel Plus 7’ Spillway Raise scenario; Table ES-1). This increase is split fairly evenly between the two reservoirs. Releases are about 50,000 afy higher for both scenarios, reflecting the 20% increase in inflow. Almost all of the increased release occurs as Flood Control Release, with only a minor increase (about 2,000 afy for both scenarios) in non-Flood Control Release. Tunnel transfers increase slightly (by about 2,000 afy for both scenarios). SRDF diverts about 12,000 afy for both scenarios, and operates in the neighborhood of 170 days per year, about 20 days longer than without climate change. Under both scenarios, SRDF diverts about 9,000 afy during dry years and operates for around 130 days per year.

TABLE ES-1

SUMMARY RESULTS FOR ALL MODEL SCENARIOS

Scenario	Average Storage (af)			Avg. Stage (ft above msl)		Average Annual Releases (afy)					Tunnel Transfer (afy)	Tunnel Transfer Days Per Year
	Nacimiento Reservoir	San Antonio Reservoir	Combined	Nacimiento Reservoir	San Antonio Reservoir	Total	Flood Control	Environ-mental	Conserva-tion	Over-Release		
Baseline	183,000	98,000	281,000	754	704	248,000	58,000	43,000	135,000	13,000	--	--
Tunnel-Only	132,000	188,000	320,000	735	734	247,000	46,000	39,000	150,000	11,000	30,000	40
Difference from Baseline Scenario	*-52,000*	*+90,000*	*+39,000*	*-18*	*+29*	*-2,000*	*-12,000*	*-4,000*	*+15,000*	*-2,000*	--	--
Tunnel Plus 7' Spillway Raise	135,000	200,000	335,000	736	736	246,000	40,000	40,000	154,000	11,000	30,000	37
Difference from Baseline Scenario	*-49,000*	*+102,000*	*+54,000*	*-17*	*+32*	*-3,000*	*-17,000*	*-3,000*	*+19,000*	*-2,000*	--	--
Difference from Tunnel-Only Scenario	*+3,000*	*+12,000*	*+15,000*	*+1*	*+3*	*-1,000*	*-5,000*	*0*	*+4,000*	*0*	*0*	*-3*
Modified Nacimiento Dam LLOW	167,000	101,000	267,000	746	706	250,000	50,000	39,000	146,000	14,000	--	--
Difference from Baseline Scenario	*-17,000*	*+3,000*	*-14,000*	*-8*	*+1*	*+1,000*	*-7,000*	*-4,000*	*+12,000*	*+1,000*	--	--
Tunnel-Only with 2070 Climate Change	161,00	213,000	375,000	743	742	298,000	96,000	62,000	130,000	10,000	32,000	53
Difference from Tunnel-Only Scenario	*+29,000*	*+25,000*	*+55,000*	*+8*	*+8*	*+51,000*	*+50,000*	*+23,000*	*-20,000*	*-1,000*	*+2,000*	*+13*
Tunnel Plus 7' Spillway Raise with 2070 Climate Change	170,000	234,000	404,000	746	747	296,000	88,000	67,000	131,000	10,000	32,000	53
Difference from Tunnel Plus 7' Spillway Raise Scenario	*+35,000*	*+35,000*	*+70,000*	*+10*	*+11*	*+50,000*	*+48,000*	*+27,000*	*-23,000*	*-1,000*	*+2,000*	*+16*

Notes:
- Abbreviations: af = acre-feet; afy = acre-feet per year; avg = average; ft above msl = feet above mean sea level.
- Average storage values are rounded to the nearest 1,000 af; average releases/transfers are rounded to the nearest 1,000 afy; transfer days are rounded to the nearest whole day. Differences between scenarios are calculated from unrounded numbers, and sums may not total due to rounding.
- *Provisional data subject to revision.*

TABLE ES-2

SRDF OPERATIONS FOR ALL MODEL SCENARIOS

Scenario	All Water Year Types						Wet Water Years		Normal Water Years		Dry Water Years	
	Avg. Annual Diversion (afy)	Avg. Annual Diversion Days	Percentage of Full Seasons	Percentage of Partial Seasons	Percentage of Failed Seasons	Avg. Length of Partial Season (Days)	Avg. Annual Diversion (afy)	Avg. Annual Diversion Days	Avg. Annual Diversion (afy)	Avg. Annual Diversion Days	Avg. Annual Diversion (afy)	Avg. Annual Diversion Days
Baseline	10,000	136	53%	17%	30%	128	15,000	214	10,000	138	3,000	47
Tunnel-Only	11,000	149	55%	19%	26%	160	15,000	214	10,000	143	6,000	89
Difference from Baseline Scenario	*+1,000*	*+13*	*+2%*	*+2%*	*-4%*	*+31*	*0*	*0*	*0*	*+5*	*+3,000*	*+43*
Tunnel Plus 7' Spillway Raise	11,000	150	60%	15%	26%	152	15,000	214	10,000	144	7,000	92
Difference from Baseline Scenario	*+1,000*	*+15*	*+6%*	*-2%*	*-4%*	*+24*	*0*	*0*	*+1,000*	*+6*	*+3,000*	*+45*
Difference from Tunnel-Only Scenario	*0*	*+1*	*+4%*	*-4%*	*0%*	*-7*	*0*	*0*	*0*	*+1*	*0*	*+3*
Modified Nacimiento Dam LLOW	10,000	143	49%	32%	19%	121	15,000	214	10,000	147	4,000	60
Difference from Baseline Scenario	*+1,000*	*+8*	*-4%*	*+15%*	*-11%*	*-8*	*0*	*0*	*+1,000*	*+9*	*+1,000*	*+14*
Tunnel-Only with 2070 Climate Change	12,000	168	66%	21%	13%	125	15,000	214	11,000	159	9,000	126
Difference from Tunnel-Only Scenario	*+1,000*	*+19*	*+11%*	*+2%*	*-13%*	*-35*	*0*	*0*	*+1,000*	*+16*	*+3,000*	*+37*
Tunnel Plus 7' Spillway Raise with 2070 Climate Change	12,000	173	70%	17%	13%	131	15,000	214	12,000	167	9,000	133
Difference from Tunnel Plus 7' Spillway Raise Scenario	*+2,000*	*+22*	*+11%*	*+2%*	*-13%*	*-21*	*0*	*0*	*+2,000*	*+23*	*+3,000*	*+41*

Notes:
- Abbreviations: afy = acre-feet per year; avg = average.
- Average annual diversion volumes are rounded to the nearest 1,000 afy, percentages to the nearest whole percentage, and days to the nearest whole day. Differences between scenarios are calculated from unrounded numbers, and sums may not total due to rounding.
- See Section 4.2.4 for more information on full, partial, and failed seasons.
- Determination of water year types is described in Appendix A.

Provisional data subject to revision.

SVOM MODELING REPORT

Interlake Tunnel and Spillway Modification Project

1.0 INTRODUCTION

This Technical Memorandum (TM) presents the results of modeling that Wood Environment and Infrastructure Solutions, Inc. (Wood) has performed to support investigations by the Monterey County Water Resources Agency (MCWRA) into the benefit of 1) constructing an Interlake Tunnel (ILT) between the Nacimiento and San Antonio Reservoirs in Monterey and San Luis Obispo Counties, California, and 2) increasing the spillway height at San Antonio Dam to increase the storage capacity of San Antonio Reservoir. The purpose of the ILT is to move water from Nacimiento Reservoir to San Antonio Reservoir in times when the former has excess inflow, while the latter has excess storage capacity.

This TM provides the results of several different modeling scenarios, including Baseline, Tunnel-Only, and Tunnel Plus Spillway Raise scenarios. This set of scenarios represents an incremental approach to quantifying the effect of construction of the ILT and raising the San Antonio Dam spillway. The purpose and configuration of each scenario are described in individual sections below.

This TM is organized as follows:

1. Introduction
2. Description of Project Components
3. Model Assumptions and Limitations
4. Baseline Scenario
5. Tunnel-Only Scenario
6. Tunnel Plus 7’ Spillway Raise Scenario
7. Interlake Tunnel Scenario Inundation Modeling
8. Modified Nacimiento Dam Low-Level Outlet Works Scenario
9. Climate Change Analysis
10. Summary
11. References

1.1 STUDY AREA

The study area for this investigation comprises the Salinas Valley Groundwater Basin (SVGB) and the entire watershed of the Salinas River (Figure 1). This section provides a brief summary of the hydrology and hydrogeology of the study area; these have been investigated in great detail in numerous previous reports, including:

- The Salinas Basin Investigation, California Department of Water Resources (DWR) Bulletin 52 (DWR, 1946)
- Salinas River Basin Investigation, State Water Resources Board (SWRB) Bulletin 19 (SWRB, 1956)
- Hydrostratigraphic Analysis of the Northern Salinas Valley (Kennedy/Jenks, 2004)
- State of the Salinas River Groundwater Basin (Brown and Caldwell, 2015)

The Salinas River watershed represents the land area that contributes to streamflow in the Salinas River and its tributaries; it stretches from the Salinas River headwaters in the La Panza Hills in the south to Monterey Bay in the north. The Salinas River has numerous important tributaries within its watershed, including the San Antonio, Nacimiento, and Estrella Rivers and Arroyo Seco. The watershed contains several small to large dams, with the most significant being Nacimiento Dam (along the Nacimiento River, completed in 1957) and San Antonio Dam (along the San Antonio River, completed in 1967). These two dams form the Nacimiento and San Antonio Reservoirs, respectively, which provide aquifer replenishment, surface water storage, flood control, and recreational services, with a combined storage capacity of more than 700,000 acre-feet (af).

The SVGB is the volume of permeable sediments that forms a coherent, connected set of aquifers surrounding the Salinas River, from approximately the Monterey-San Luis Obispo County Line in the south to Monterey Bay in the north. The SVGB is flanked on the west by the Santa Lucia Mountains and the Sierra de Salinas and on the east by the Gabilan and Diablo Ranges. Sediments in the SVGB can be as much as 15,000 feet thick (DWR, 2016). The SVGB contains all or part of 6 DWR-defined groundwater basins (DWR, 2016):

- 180/400-Foot Aquifer (DWR Groundwater Basin 3-004.01)
- East Side Aquifer (3-004.02)
- Forebay Aquifer (3-004.04)
- Upper Valley Aquifer (3-004.05)
- Seaside (3-004.08)
- Langley Area (3-004.09)
- Monterey (3-004.10)

These DWR-defined basins are referred to here as subbasins, and are considered parts of the SVGB. These subbasins are similar to, but not identical to, the subareas of Zone 2C, which has a slightly different extent from the groundwater basin. The study area also includes parts of the Paso Robles Area (DWR basin 3-004.06) to the south of the SVGB.

The Salinas River runs down the length of the SVGB, and interacts strongly with the sediments of the basin. The Salinas River loses water to the basin aquifers along much of its length, representing the main source of recharge to the basin (e.g., Brown and Caldwell, 2015). The majority of these streamflow losses occur in the southern subbasins (particularly the Upper Valley Aquifer, and Forebay Aquifer subbasins). In the 180/400-Foot Aquifer subbasin, the Salinas River is largely separated from the underlying aquifers by the presence of the low-permeability Salinas Valley Aquitard in the shallow subsurface, which inhibits the percolation of streamflow into the main aquifers of this subbasin. The Salinas River does not run through the remaining subbasins.

1.2 MODELING SYSTEM

To simulate groundwater and surface water conditions in the SVGB, the U.S. Geological Survey (USGS) has developed a system of inter-connected models. The modeling system comprises two main models: the Salinas Valley Watershed Model (SVWM) and the Salinas Valley Operational Model (SVOM).

The SVWM is a rainfall-runoff model, built using Hydrological Simulation Program – FORTRAN (HSPF), that converts precipitation into runoff based on climate inputs (e.g., temperature and precipitation) and land surface parameters (e.g., soil permeability, aspect, and slope), and routes that runoff through the stream system as one-dimensional flow. The SVWM simulates the entire Salinas River watershed, from its headwaters in the south to Monterey Bay in the north. The SVWM outputs streamflow at pour points along the edges of the SVOM.

The SVOM is a groundwater flow model built using the USGS MODFLOW code, specifically the One-Water Hydrologic Model (OWHM; Boyce et al., 2020). The SVOM simulates three-dimensional groundwater flow in the SVGB, as well as surface water flow in the defined stream network, exchange between the surface water and groundwater systems, and operations of the San Antonio and Nacimiento Reservoirs. This model represents the first tool capable of simulating the groundwater, surface water, and water storage systems of the SVGB in an integrated manner, such that releases from the reservoirs are directly informed by groundwater and surface water conditions within the model domain. For example, the SVOM is capable of determining how much water must be released from the reservoirs to supply a set amount of water to the Salinas River Diversion Facility (SRDF), which is located approximately 5 miles upriver from Monterey Bay; almost 100 miles of the Salinas River lie between the reservoirs and the SRDF, and a great deal of streamflow is lost to the aquifer along the river, which the model must take into account when calculating reservoir release. The SVOM is built from the Salinas Valley Integrated Hydrologic Model (SVIHM), which the USGS created to simulate historical conditions in the SVGB; the SVIHM is discussed in Section 1.3.

The SVIHM and SVOM are still under development by the USGS, so documentation of these models is not yet available. Until such time as it is published, the reader is directed to several presentations given by the USGS to the model Technical Advisory Committee (TAC) that acted as an expert advisory panel during development of the SVWM and SVIHM. These presentations, which include depictions of the model domains, can be found on the MCWRA website (http://www.co.monterey.ca.us/government/government-links/water-resources-agency/documents/model-development-technical-advisory-committee-resources#wra). The following advisory, provided by the USGS, is included with this TM because of the preliminary nature of the model [sic]:

> "SVOM Model: Unofficial Collaborator Development Version of Preliminary Model. Access to this repository and use of its data is limited to those who are collaborating on the model development. Once the model is published and received full USGS approval it will be archived and released to the public. This preliminary data (model and/or model results) are preliminary or provisional

and are subject to revision. This model and model results are being provided specifically to collaborate with agencies who are contributing to the model development and meet the need for timely best science. The model has not received final approval by the U.S. Geological Survey (USGS). No warranty, expressed or implied, is made by the USGS or the U.S. Government as to the functionality of the model and related material nor shall the fact of release constitute any such warranty. The model is provided on the condition that neither the USGS nor the U.S. Government shall be held liable for any damages resulting from the authorized or unauthorized use of the model."

1.3 SVIHM (Historical Model)

The USGS constructed the SVWM and SVIHM to simulate a historical period that started with October 1967 (corresponding to the start of Water Year 1968, when San Antonio Reservoir started operating) and ended with December 2014. The SVWM was calibrated to historical streamflow at USGS stream gauges throughout the Salinas River watershed. The SVIHM was calibrated to groundwater head, streamflow, and groundwater pumping observations in the Salinas Valley Groundwater Basin. The SVIHM uses historical reservoir releases (reported by MCWRA) as the streamflow boundary conditions at the Nacimiento and San Antonio Rivers. The USGS ran the historical simulation and post-processed its results. No documentation for the historical model has yet been published; until such time as the documentation is available, the user is directed toward the TAC materials on the MCWRA website (see Section 1.2).

1.4 SVOM (Operational Model)

The SVOM was used to simulate the various scenarios designed to support analysis of the Interlake Tunnel and associated projects. This model was built by the USGS based on the SVIHM; it has the same extent, three-dimensional grid, parameter distribution, and boundary conditions as the SVIHM. The intent of the SVOM is to simulate the effect of infrastructure projects, operational changes, and management approaches on conditions within the deeply interconnected groundwater-surface water-reservoir system of the Salinas Valley. To that end, the SVOM uses the Surface Water Operations Process (SWO; Ferguson et al., 2015) to operate Nacimiento and San Antonio Reservoirs based on a pre-defined suite of logic-based rules that dictate when the reservoirs release water, and how much. SWO has a wide range of features and capabilities that allow it to represent any aspects of reservoir operations that can be expressed as an if-then statement (or a series of such statements) that queries conditions within the reservoirs, the surface water system, or the connected groundwater system either contemporary with or prior to the time the decision is being made (i.e., decisions are not made based on future conditions). SWO also cannot make the type of ad-hoc decisions that reservoir managers may make based on decades of experience with their reservoirs.

2.0 DESCRIPTION OF PROJECT COMPONENTS

This section describes the individual project components investigated in the modeling scenarios. These components represent alterations to existing physical structures, new physical structures, and changes to management approaches. Their effects were simulated either individually or in combination to analyze their impact on conditions in the basin. Additional detail on various aspects of the dams and reservoirs and their operations, as well as some of the terminology used in this section, are described in Appendix A.

2.1 INTERLAKE TUNNEL

The Interlake Tunnel would physically connect Nacimiento and San Antonio Reservoirs, allowing for the transfer of water from Nacimiento Reservoir to San Antonio Reservoir when sufficient water is held in Nacimiento Reservoir and space is available in San Antonio Reservoir. Flow through the Tunnel would be uni-directional (from Nacimiento Reservoir to San Antonio Reservoir); no reverse flow is allowed.

According to an initial feasibility analysis (ECORP, 2016), the Interlake Tunnel would have a length of approximately 11,000 feet and a diameter of 10 feet. The inlet at Nacimiento Reservoir would have an elevation of 745 feet above mean sea level (msl), and the outlet at San Antonio Reservoir would have an elevation of 699.25 feet above msl. The Tunnel would only operate when stage in Nacimiento Reservoir is above 760 feet above msl (this is referred to in this TM as the Tunnel Threshold). There is no minimum stage in San Antonio for tunnel transfer; the Tunnel is designed to flow even if the San Antonio end of it is above the reservoir stage.

The flowrate through the Tunnel is a function of stage in the two reservoirs, and reaches a maximum of 1,665 cubic feet per second (cfs) when Nacimiento Reservoir is at a stage of 800 feet above msl and San Antonio Reservoir stage is below 700 feet above msl. Figure 2 shows the rating curve for the Tunnel.

There are several limits on flow through the Tunnel, both operational and physical. The Tunnel Threshold requires that stage in Nacimiento Reservoir be above 760 feet above msl. The Tunnel will not operate when stage in San Antonio Reservoir is at or above the stage in Nacimiento Reservoir because there will be no head difference driving water through the tunnel. The Tunnel will not be operated if stage in San Antonio Reservoir is at or near its maximum allowable elevation, as this would result in spilling of the transferred water. Finally, the Tunnel will not be operated if stage in Nacimiento Reservoir is above the crest elevation of the inflated Obermeyer gate, 800 feet above msl. Other than these situations, the Tunnel has the capability to operate at all times.

2.2 San Antonio Dam Spillway Modification

The Spillway Raise would increase the elevation of the spillway crest on San Antonio Dam from 780 feet above msl to 787 feet above msl. This would increase the maximum capacity of the reservoir from 335,000 acre-feet (af) to 376,200 af.

The maximum storage allowed at any given time is dictated by the Flood Rule Curve (see Section 3.3), which maintains available capacity in the reservoir during the winter wet season. With a raised spillway, the modified Flood Rule Curve maintains the same available capacity as the original Flood Rule Curve. This is not the same as just shifting the Flood Rule Curve upward by seven feet (the height of the Spillway Raise) because the relationship between stage and storage is non-linear. Figure 3 shows the existing and modified Flood Rule Curves.

2.3 Nacimiento Dam Low Level Outlet Works Modification

Releases from Nacimiento Reservoir are constrained at certain stage elevations (i.e., below a stage of 755 feet above msl) by the capacity of the existing Low Level Outlet Works (LLOW), which is 460 cfs. A new, higher-capacity LLOW would allow for greater release capacity from Nacimiento Reservoir, which naturally receives more inflow than San Antonio Reservoir.

Although no engineering design document yet exists for the new Nacimiento LLOW, a conceptual rating curve has been produced that estimates the LLOW capacity at various values of Nacimiento Reservoir stage (Figure 4). This rating curve indicates that the LLOW capacity varies from 0 cfs at a stage of 670 feet above msl to about 2,000 cfs at a stage of 800 feet above msl (i.e., the Nacimiento Dam spillway crest elevation with the Obermeyer gate raised).

3.0 MODEL ASSUMPTIONS AND LIMITATIONS

As with any modeling tool, the SVOM relies on numerous simplifications that allow for the numerical simulation of a complex real-world system. The MODFLOW code itself relies on a number of assumptions that are adequately described in MODFLOW documentation (e.g., Boyce et al., 2020 and references therein) and therefore are not restated here. Instead, this section elucidates assumptions and limitations that are particular to the SVOM.

3.1 TIMESTEP LENGTH

The SVOM system simulates conditions in both the groundwater and surface water domains. In reality, the movement of water through the groundwater domain is generally orders of magnitude slower than its movement through the surface water domain. Processes in the groundwater domain occur at a longer temporal scale and a larger spatial scale, while those in the surface water system tend to occur at a more restricted spatial scale (restricted to the land surface and surface water system) and a shorter temporal scale. In order to include both systems (and interaction between them) in the same modeling system, a compromise has to be made between a coarse temporal discretization (suited to the spatial and temporal scale of groundwater processes) and a fine temporal discretization (suited to surface water processes).

The SVOM uses a timestep length[1] of 5 to 6 days[2]. This length was determined to be an appropriate compromise between the ideal time scales for the groundwater and surface water systems, while being well-suited to some of the critical time scales of the reservoir and river operations and certain limitations of the MODFLOW code, described below.

- Although a model timestep has a defined length (5 to 6 days for this model), the timestep is effectively simulated as a point in time, with all calculated fluxes (between model cells and across boundaries) uniform within the timestep. One

[1] The stress period is the basic unit of temporal discretization in MODFLOW, and the timestep is a sub-division of the stress period. A stress period is a unit of model time over which the model stresses (i.e., boundary conditions), such as recharge and pumping, are uniform. The model computes a solution for each timestep, so groundwater and surface water conditions can change each timestep, although the stresses are the same for all timesteps within a single stress period. For the SVOM, each stress period represents one calendar month.

[2] The timestep length varies depending on the length of the calendar month. February is divided into 5 timesteps of equal length (5.5, or 5.75 days for leap years) followed by a six-day timestep. 30-day months are divided into 6 five-day timesteps. 31-day months are divided into 6 timesteps of which the first 5 are five days each, and the last six days.

important effect of this is that streamflow does not move down the system in a natural fashion, where it might take a streamflow pulse several days to move from the upstream to the downstream end of the system. Instead, MODFLOW instantaneously routes streamflow through the stream system assuming that mass balance is preserved[3]. The timestep length was chosen to approximately match the time it takes streamflow to move from the reservoirs to Monterey Bay.

- Many of the block flow procedures set by the Flow Prescription (MCWRA, 2005) are counted in multiples of 5 days. For example, smolt outmigration block flows typically last for 30 days. Setting most timesteps to a length of 5 days minimizes the over-prediction of block flow releases that could be caused by a substantial mismatch between timestep length and block flow requirements.
- The time required to run the model is also a consideration. As it is currently configured, the model takes approximately 20 hours to run. A shorter timestep length would result in a longer model runtime, while a longer timestep length would result in a shorter model runtime.

3.2 LAND USE

In the SVOM, land surface processes, including agricultural supply and demand, are simulated using the Farm Process (FMP; Schmid et al., 2006, Schmid and Hanson, 2009). FMP takes input including monthly gridded climate data (precipitation and potential evapotranspiration), soil parameters, crop distribution, and crop data (rooting depth, crop coefficients, etc.) and uses it to calculate the crop demand. FMP then meets that demand using direct precipitation, groundwater within the crop root zone, available surface water, and groundwater pumped via wells (in that order of priority).

Land use in the Salinas Valley has varied over time as agricultural economics have changed. The crop distribution changes several times through the duration of the historical model based on various land use maps published by the California Department of Water Resources (DWR) and others. These maps have been produced at sporadic intervals, so there is no regular update of land use information.

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[3] Streamflow is routed stepwise down the stream system from the upstream end to the downstream end. Inflow is pre-defined at the model boundaries. Each successive model cell in a given stream segment receives inflow from the segment above, and also from overland runoff. Interaction with groundwater can result in either an inflow to the stream, or an outflow to the aquifer. Outflow to the next model cell in the stream is a combination of these inflows and outflows.

In addition to long-term trends in cropping, seasonal rotation is critical in the Salinas Valley, where the mild environment allows for multiple crops per year. Although the historical model has the capability of changing the crop distribution every stress period, a six-month crop rotation was chosen (i.e., one crop distribution is in effect from October to March of each water year, then a second distribution is in effect from April to September). Crop rotation and recent land use coverages are based on data from the California Pesticide Use Reporting Database (CalPUR) in a method developed by the USGS as part of the SVIHM development.

In the SVOM, land use is assumed to be static throughout the model duration, with only the 6-month crop rotation used. The SVOM uses the 2014 land use information, which is the version of land use in use at the end of the historical model. The 2014 land use is used throughout the SVOM so that the model results are not impacted by changes unrelated to the project(s) of interest (see Section 4.0).

3.3 RESERVOIR AND RIVER OPERATIONS

MCWRA owns and operates the Nacimiento and San Antonio Reservoirs within the Salinas River watershed, which are critical to hydrology of the basin. MCWRA operates these two reservoirs for several purposes:

- Flood control: The reservoirs capture and store streamflow during the winter wet season, so that it can be released through the rest of the year. This reduces the occurrence of flooding during the winter. The dams are designed to pass the probable maximum flood over the spillways when the reservoirs are full, protecting the dams themselves from damage during a flood event.
- Supporting fish and wildlife habitat: The reservoirs release a small amount of water year-round as necessary to support fish and wildlife habitat below the Nacimiento and San Antonio Dams. These are referred to in this document as minimum releases.
- Supporting Steelhead migration: Steelhead spawning habitats exist in Arroyo Seco and possibly other areas of the Salinas River and its tributaries. The reservoirs make releases to support the migration of Steelhead between these spawning habitats and Monterey Bay at specific periods of their life cycle. Releases made for this purpose are referred to in this document as fish passage releases.
- Water conservation: The reservoirs, by capturing and storing flow during the winter wet season, retain water within the system that may otherwise flow out to Monterey Bay. As it is released through the dry season, much of this water recharges through

the bed of the Salinas River into the groundwater system. This keeps the captured streamflow within the system, making it available for agricultural users.

- Salinas Valley Water Project (SVWP) operation: The purpose of the SVWP is to provide for the long-term management of groundwater resources in the basin by halting seawater intrusion and increasing the amount of surface water supplied for conservation and fish passage releases. The Salinas River Diversion Facility (SRDF) is an important component of the SVWP, consisting of a pneumatic dam along the Salinas River near Marina and facilities for taking and treating water from the Salinas River and delivering it to agricultural users in the Castroville Seawater Intrusion Project (CSIP) area. Delivery of this water allows for users in the CSIP area to reduce their groundwater pumping during the peak agricultural demand period, which in turn allows for natural recharge to occur in the coastal part of the basin.
- Recreation: Both reservoirs are used for recreation, including boating, fishing, and hiking.

Reservoir and river operations are complex, subject to limitations of the reservoirs themselves (storage and release capacities), downstream demands (for fish passage and SRDF diversion), and dynamic groundwater-surface water exchange along the Salinas River (which is mostly losing between the Reservoirs and the SRDF). Reservoir releases have to satisfy the downstream demands while accounting for the amount of stream loss along the way. The current configuration of reservoir and river operations (as implemented in the SVOM) is explained in detail in Appendix A. Modifications to the reservoir and river operations implemented in the various Project scenarios are described in Appendix B.

In order to operate the reservoirs to meet their various demands and limitations, the SVOM uses a new MODFLOW module, the Surface Water Operations Process (SWO), currently under development by the U.S. Bureau of Reclamation (USBR) and the USGS. SWO utilizes a system of user-specified logical rules that define properties of the reservoirs, locations and amounts of demands, release triggers, and other aspects of the operations. SWO iteratively calculates releases from the reservoirs to satisfy downstream demands, subject to the limitations of the reservoirs. SWO simulates the reservoirs themselves as buckets; all inflow and outflow occurs in the reservoirs instantaneously, and there is no interaction between the reservoirs and the subsurface below them.

When the reservoirs release water, it is categorized into three release types (see Appendix A for additional details):

- Flood Control Releases – occur when the reservoirs have to release water to stay below the flood rule curve elevation, which changes through the year.
- Conservation Releases – occur during the Conservation Release Season (April 1 to October 31) to supply downstream demands at SRDF and to recharge the groundwater basin; this also includes any channel wetting releases prior to the Conservation Release Season. Conservation Releases are subdivided based on the fate of the released water: water diverted at the SRDF is considered SRDF Diversion, while the remaining amount of the Conservation Release is considered Conveyance Loss[4] (i.e., water lost from the stream system between the reservoirs and the SRDF).
- Environmental Releases – support fish passage along the Salinas River and fish and wildlife habitat below the reservoirs. Environmental Releases are subdivided based on whether they are made to meet downstream streamflow requirements at various locations along the Salinas River (Fish Passage Releases, including bypass flows at SRDF), as dictated by the Flow Prescription, or to meet the minimum release targets for the two reservoirs (Minimum Releases), 60 cfs from Nacimiento Reservoir and 10 cfs from San Antonio Reservoir (see Appendix A).

When estimating reservoir releases, SVOM does not perfectly achieve the desired downstream flows, generally over-delivering by some amount. The magnitude of this over-delivery can occasionally reach hundreds of cubic feet per second. It is unclear why SWO does this, but these releases do not seem to be called for by any downstream demand or conditions at the reservoirs (e.g., being above the Flood Rule Curve). Releases made in excess of necessity are tracked separately and referred to as a fourth release type, Over-Release, in this TM. Reservoir releases are discussed in terms of these four release types throughout this TM.

MCWRA holds water rights for both reservoirs that restrict the amount of water that can be stored and released each year; details of how these limitations are incorporated into the operational approach are given in Appendix A.

By re-creating the current reservoir operations, the model assumes a different set of operational rules than applied during the historical period. For example, the SRDF operates

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[4] The SVOM does not simulate evaporation from the stream, so all Conservation Release that does not reach SRDF is assumed to be lost to infiltration from the Salinas River into connected aquifers; some of this infiltration may be rapidly lost to riparian zone evapotranspiration (ET), but the complexity of the system precludes a simple accounting of riparian ET supplied by Conservation Releases.

whenever it can and takes as much water out of the Salinas River as it can (up to its diversion limit), regardless of the simulated demand in the CSIP area; this results in annual diversions that are larger than have historically occurred at SRDF. However, this allows for an estimation of the potential amount of water that SRDF could divert from the Salinas River if improvements were made to the way water is delivered and used in the CSIP area. While the diversions at SRDF could be limited in the SVOM to better reflect historical diversions, the SVOM would still have to deliver 36 cfs to the SRDF because 1) MCWRA experience shows that targeting lower streamflows at the SRDF runs the risk of streamflow interruptions below Chualar (leading to no streamflow reaching SRDF); 2) there may be periods when the users in the CSIP area demand 36 cfs because crop demands are higher; and 3) diversions at the SRDF have historically been below 36 cfs on average because diversions tend to happen during daylight hours, when irrigation is active, and the timescale of streamflow from the reservoirs to the SRDF (on the order of 7 days) prevents MCWRA from attempting to deliver water on a diurnal cycle (i.e., delivering more water during daylight hours and less during nighttime hours). For these reasons, the SVOM assumes that 36 cfs must be delivered to SRDF, whether or not the users demand or can use that much water.

Additional limitations of the implementation of current river and reservoir operations in the model are discussed in Appendix A.

3.4 INPUT HYDROLOGY

The SVOM is driven by hydrologic conditions at its boundaries, namely gridded climate data (precipitation and reference evapotranspiration) at the land surface and streamflow time series along the lateral edges of the model. These climate and streamflow data represent the input hydrology.

To ensure that a realistic and consistent input hydrology is used to drive the model, the SVOM repeats the historical hydrology from October 1967 to December 2014[5] (i.e., the gridded climate data and streamflow inputs are the same as were used for the Historical SVIHM). Gridded climate data are derived from the USGS Basin Characterization Model (BCM; Flint and Flint, 2014). Streamflow time series are derived from the Salinas Valley Watershed Model

[5] Although the SVIHM has been updated to cover the period through 2018, this change has not yet been implemented in the SVOM.

(SVWM; see Section 1.2). The input hydrology does not account for the potential effects of climate change, which are addressed in parallel investigations like the USBR Salinas and Carmel River Basins Study. However, it does contain very wet years (e.g., Model Year 16, equivalent to Water Year 1983) and extended drought periods (e.g., Model Years 20 to 23, equivalent to Water Years 1987 to 1990) that allow for an analysis of how the system performs under both wet and dry extremes. Figure 5 shows a time series of annual total streamflow in the Salinas River at the upstream end of the model (not influence by releases from Nacimiento and San Antonio Reservoirs). This figure also shows the year type (i.e., dry, normal, or wet; see Appendix A for details).

It is important to note that the historical hydrology is used for convenience, since it is already configured as an input to the Historical Model. This is not meant to imply that future conditions are expected to be identical to the historical hydrology; indeed, future conditions are expected to be different due to both climate change and natural variability. However, the historical hydrology does represent a realistic time series of climate for the basin, absent the overall changes resulting from a changing climate (as stated above, climate change is being considered under parallel projects). The goal of the Operational Model is not to predict future conditions under any likely climate regime, but to simulate basin conditions under current management (with scenario-specific modifications described in the following sections), with a reasonable set of climate conditions.

Section 9 of this TM describes the implementation of modifications to the model to represent the effects of climate change and sea level rise, including development of a modified input hydrology.

4.0 BASELINE SCENARIO

In order to quantify the effects of potential changes to infrastructure and management approach, the results of various scenarios are compared against the results of a Baseline scenario, which simulates conditions assuming no change from the current operations (described in Section 3.3). The Baseline scenario is not designed to provide an indication of what is likely to occur in the future; instead, it is a point of comparison that can be used to isolate the effects of individual changes to the model; if the only change from the Baseline scenario to a Project scenario is the inclusion of a particular component, then the difference in the results between the Baseline and Project scenario is due to that project component. The model inputs (such as the input hydrology, see Section 3.4) are designed to be realistic so that useful results can be achieved, but are not meant to be a prediction of future conditions.

4.1 Scenario Design

Many aspects of the design of the Baseline scenario are described above, but they are summarized briefly here:

- a 47.25-year model duration, discretized into 567 one-month stress periods and 3,355 five- to six-day timesteps;
- static land use (i.e., crop distribution) representative of 2014 conditions, with seasonal crop rotation represented using two alternating land use patterns, each in effect for six months of the year (October to March and April to September);
- input hydrology repeated from the historical period (October 1967 to December 2014); and
- reservoir operations representative of current operations, with SRDF diverting its maximum (36 cfs, or as much water as is available if flow at SRDF is below 36 cfs) whenever possible, whether or not the CSIP area demands 36 cfs (unused diversion is returned to the Salinas River below the location of the SRDF).

As noted above, this scenario does not predict the future, but rather provides a realistic time series of conditions within the groundwater-surface water-reservoir system under the current basin management approach. As such, the Baseline scenario serves as a point of comparison for the other scenarios described in this TM. Because the Baseline scenario is not meant to represent any particular future, it should not be compared to the results of the SVIHM to indicate any changes in the basin over time.

4.2 Scenario Results

For this and other scenarios, results are presented mostly in terms of annual averages and percentages, rather than totals (e.g., total amount of release or total number of days). This is done because totals are highly dependent on the duration of the model (i.e., they increase as the model duration increases).

Table 1 includes a summary of results from the Baseline scenario and other scenarios; Table 2 provides a more extensive set of results for just the Baseline scenario.

4.2.1 Storage and Stage

Reservoir storage and stage are directly related to each other, with storage increasing with stage[6]. As such, they are discussed together for this and the other scenarios. Storage and stage vary substantially through the duration of the Baseline scenario, as the reservoirs perform their duties to store excess flow during wet periods and release it when natural flow is not enough to supply downstream demands (Figure 6).

The reservoirs attain a combined maximum storage of about 682,000 acre-feet (af). Nacimiento Reservoir reaches a maximum stage of 802 feet above mean sea level (msl; storage of about 388,000 af), above the spillway elevation (800 feet above msl). San Antonio Reservoir reaches a maximum stage of 775 feet above msl (storage of about 308,000 af), about 5 feet below the elevation of the spillway crest (780 feet above msl).

Figure 7 shows the entire range of storage and stage values for the two reservoirs (and storage for the combined reservoirs), colored by quartile[7]. The charts in this figure show that storage and stage in Nacimiento Reservoir tend to be fairly evenly distributed (average storage = 183,000 af, median storage = 172,000 af; average stage = 754 feet above msl, median stage = 756 feet above msl). In San Antonio Reservoir, storage tends to cluster on the low end of the range (average storage = 98,000 af, median storage = 67,000 af; average stage = 704 feet above msl, median stage = 702 feet above msl), indicating that storage is frequently near the minimum. Combined storage is slightly weighted toward low values (average storage = 281,000 af, median storage = 255,000 af).

Monthly storage and stage patterns reflect the seasonality of rainfall and reservoir usage in the basin, with the highest average storage and stage occurring in April, after the winter wet season, and the lowest average storage and stage occurring in October, at the end of the

[6] This relationship is not linear because the area of each reservoir increases as it fills; a one-foot rise in reservoir stage results in a larger storage increase when the reservoir is relatively full compared to when it is relatively empty.

[7] 25% of the simulated values are contained in each segment of the columns. The darker colors are given to the middle two quartiles (the middle 50% of all values), while the lighter colors are given to the outer two quartiles (the lowest 25% and highest 25% of all values). A short quartile segment (such as the lowest 25% of San Antonio storage values) indicates that many datapoints fall within a very narrow range, whereas a long quartile segment (such as the highest 25% of San Antonio storage values) indicates a dispersal of values across a wider range.

Conservation Release Season, as shown on Figure 8[8]. In addition to the general annual pattern of storage and stage, this figure demonstrates that, following the winter wet season, storage and stage are typically much higher during wet years (when, on average, combined reservoir storage increases by almost 400,000 af from October to May) compared to normal and dry years. Dry years show effectively no increase in combined reservoir storage during the winter wet season before dropping throughout the Conservation Release Season.

Figure 8 shows that, under the current operational approach, there is typically a great deal of available storage capacity in the two reservoirs by the end of the winter wet season. The upper left pane of Figure 8e, for example, shows an average combined storage of about 368,000 af in April, compared to a combined reservoir capacity of about 713,000 af. Despite the fact that the current operational approach calls for release from Nacimiento Reservoir to be prioritized, it is, on average, much closer to its maximum capacity of about 377,900 af throughout the year compared to San Antonio Reservoir (compare Figure 8a to Figure 8c). Nacimiento Reservoir effectively fills up during wet years, without the capacity to accept all of the natural flow generated within the Nacimiento River watershed, leading to Flood Control Releases (see Section 4.2.2). San Antonio Reservoir, on the other hand, is substantially below its capacity on average, even during wet years. These results indicate that, under current operations, the reservoir system frequently has a great deal of un-utilized storage available, particularly in San Antonio Reservoir, and is not ideally configured to capture and store the highest winter flows.

4.2.2 Reservoir Releases

As noted in Section 3.3, reservoir releases are categorized into four different types, depending on their purpose: Flood Control Release, Environmental Release, Conservation Releases, and Over-Release. Figure 9 shows the average annual release volume (in af) by release type for all

[8] This figure is separated into five sections, depicting Nacimiento Reservoir storage and stage, San Antonio Reservoir storage and stage, and the combined reservoir storage. Each section of this figure includes four panes, showing monthly storage and stage for all year types, wet years, normal years, and dry years. The year type is determined in March to April each year, and generally reflects the wetness of the previous few months. For this analysis, the year type determined in the spring is applied throughout the extent of the water year, which starts on October 1. This explains why the storage and stage values depicted in October through December may be incongruous with their year type (for example, average storage and stage in October is higher during dry water years than wet water years because these October values are determined by the wetness of the previous winter, and only one wet water year follows immediately after another wet water year).

water year types as well as for wet, normal, and dry water years, with subcategorized releases shown on Figure 10. These average annual volumes are also presented in Table 2.

Releases averaged about 248,000 acre-feet per year (afy) from the two reservoirs combined (about 179,000 afy from Nacimiento Reservoir and about 69,000 afy from San Antonio Reservoir). During wet water years, this increased to about 370,000 afy (about 312,000 afy from Nacimiento Reservoir and about 58,000 afy from San Antonio Reservoir). Normal water years saw about 242,000 afy of release (about 156,000 afy from Nacimiento Reservoir and about 86,000 afy from San Antonio Reservoir). Dry water years had about 128,000 afy of release on average (about 78,000 afy from Nacimiento Reservoir, about 49,000 afy from San Antonio Reservoir).

On average, the reservoirs release about 58,000 acre-feet per year (afy) as Flood Control Releases under the Baseline scenario, with about 96% (about 55,000 afy) coming from Nacimiento Reservoir and 4% (about 2,000 afy) coming from San Antonio Reservoir. Flood Control Releases occur most prominently during wet water years (averaging about 178,000 afy) and are effectively absent from dry water years (Figure 9). Some Flood Control Release occurs in 92% of wet water years, 32% of normal water years, and 8% of dry water years.

On average, the reservoirs release about 43,000 afy of Environmental Releases to support fish and wildlife habitat and fish passage flows under the Baseline scenario. About 84% (about 36,000 afy) comes from Nacimiento Reservoir, with the remaining 16% (about 7,000 afy) coming from San Antonio Reservoir. Environmental Releases are fairly uniform across water year types (Figure 9). Fish and wildlife habitat releases make up about 80% of the Environmental Releases, and are very uniform across year types. Fish passage releases (made to meet streamflow requirements within the Salinas River to support steelhead migration) make up the remaining 20% of Environmental Releases, and are heavily weighted toward normal year types, when most of the rules of the Flow Prescription are applicable.

On average, the reservoirs release about 135,000 afy of Conservation Releases under the Baseline scenario. About 60% (about 80,000 afy) comes from Nacimiento Reservoir, with the remaining 40% (about 54,000 afy) coming from San Antonio Reservoir. Conservation Releases average about 147,000 afy in wet years, 156,000 afy in normal years, and 82,000 afy in dry years (Figure 9). Section 4.2.3 provides a more detailed analysis of the Conservation Releases.

Over-Release averages about 13,000 afy, with about 59% (about 8,000 afy) coming from Nacimiento Reservoir and about 41% (about 5,000 afy) coming from San Antonio Reservoir. Over-Release averages about 13,000 afy during wet water years, 17,000 afy during normal water years, and 6,000 afy during dry water years. The average annual Over-Release represents about 5% of the total release

Overall, about 54% of the total release is Conservation Release, about 23% is Flood Control Release, about 17% is Environmental Release, and the remaining 5% is Over-Release. This varies with year type, with Flood Control Releases much more prominent during wet water years and nearly absent during dry years.

4.2.3 Conservation Releases

This section provides further detail on Conservation Releases under the Baseline scenario. Conservation Releases are subdivided based on the destination of the water. This section discusses Conservation Releases in terms of two subcategories:

- SRDF Diversion: this is water that is diverted by the SRDF; some of it may be returned to the Salinas River, but it is still counted as SRDF Diversion.
- Conveyance Losses: this is water that does not reach the SRDF, instead being lost along the way through infiltration into the groundwater system.

The SVOM is very complex, particularly within the riparian corridor, so there is some degree of simplification involved in this subcategorization of Conservation Releases. For example, groundwater, overland runoff, or tributary streamflow may be entering the Salinas River along certain stretches and at certain times, and this water may end up reaching the SRDF and contributing to SRDF Diversion. These potential sources of increased flow are assumed to be fairly minor during the Conservation Release Season (April 1 to October 31), so no attempt was made to try to account for this water during the process of subcategorization.

Figure 10 shows the average annual releases, with Conservation Releases broken up into subcategories; averages are included in Table 3. Of the 135,000 afy of average annual Conservation Release, 6% (about 8,000 afy) is diverted at SRDF[9], and 94% (about 127,000 afy)

[9] The 8,000 afy of Conservation Releases diverted at SRDF is smaller than the average annual SRDF diversion of about 10,000 afy because the SRDF is able to divert natural streamflow when it is sufficient to meet the SRDF demand.

leaves the Salinas River along the riparian corridor as Conveyance Losses. This demonstrates the importance of Conservation Releases to maintaining groundwater storage. During wet years, SRDF Diversion makes up about 6% of Conservation Releases (about 9,000 afy), and Conveyance Losses 94% (about 138,000 afy). During normal years, SRDF Diversion makes up about 5% of Conservation Releases (about 9,000 afy), and Conveyance Losses 95% (about 148,000 afy). During dry years, SRDF Diversion makes up 5% of Conservation Releases (about 4,000 afy) and Conveyance Losses 95% (about 78,000 afy). The proportion of releases diverted at SRDF (5-6%) is quite uniform across year types.

4.2.4 SRDF Operations

The SRDF, located on the Salinas River near the Monterey One Water Treatment Plant (see Figure 1), diverts water from the Salinas River and delivers it to agricultural users in the CSIP area. SRDF operations are described in more detail in Appendix A, but in general the facility diverts water for the duration of the Conservation Release Season (April 1 to October 31) at a specified rate (36 cubic feet per second, cfs,); if the flowrate in the River cannot be maintained at the specified rate at SRDF, the Conservation Release Season ends. From the standpoint of SRDF, a Conservation Release Season can be classified as full (i.e., lasting for 214 days), partial (i.e., lasting between 1 and 214 days), or failed (i.e., lasting for zero days). Note that the Conservation Release Season extends past the end of the Water Year; when averaging, individual Conservation Release Seasons are always maintained whole.

Table 4 provides details on the SRDF operations for the Baseline scenario. Across all year types, an average Conservation Release Season sees 136 days of diversion, with about 10,000 afy diverted. Wet years average 214 days of diversion (i.e., all simulated wet years are full Conservation Release Seasons), with about 15,000 afy diverted; normal years average 138 days of diversion, with about 10,000 afy diverted; and dry years average 47 days of diversion, with about 3,000 afy diverted. All told, 53% of Conservation Release Seasons are full (214 days long), 17% are partial, and 30% are failed. For the partial seasons, the average length was about 128 days.

4.2.5 Water Rights

As noted in Section 3.3 (and discussed in more detail in Appendix A), MCWRA holds water rights on both reservoirs that limit the amount of water that can be stored in and released from them. These water rights limitations were in place for the Baseline scenario, and they can limit reservoir operations (to prevent exceeding storage and withdrawal limits to the extent possible).

As described in Appendix A, normal operations can be curtailed in order to ensure that minimum fish and wildlife habitat releases can continue to be made for the rest of the year without exceeding the water right withdrawal limits. This can cause Nacimiento Reservoir to stop making releases to meet downstream requirements before the end of the release season; if San Antonio Reservoir cannot make up the shortfall in release, this can result in shortened SRDF seasons in some cases.

4.2.6 Groundwater Budget

A groundwater budget is a standard tool for understanding conditions within a groundwater basin. The groundwater budget simplifies the groundwater system into a number of components based on how water moves in or out of the aquifers. In the case of the Salinas Valley Groundwater Basin, one way to write the groundwater budget is:

$$\Delta S = Q_{swi} + Q_{ghb} + Q_{drain} + Q_{sw} + Q_{well} + Q_{rz}$$

where:

- ΔS is the change in storage,
- Q_{swi} is the flux through the aquifer-ocean boundary (i.e., seawater intrusion),
- Q_{ghb} is the flux through the northern and southern onshore boundaries of the model (represented in the model as general head boundaries, GHBs),
- Q_{drain} is the flux of water into or out of the agricultural drains (note that this only represents interaction between the aquifer and the drains, and not agricultural runoff flowing into the drains),
- Q_{sw} is the net exchange between the aquifer and the surface water system,
- Q_{well} is the net extraction of groundwater from wells, and
- Q_{rz} is the net flux of water across the base of the root zone (this combines percolation of rainfall and irrigation water, as well as runoff of groundwater intersecting the land surface and direct evapotranspiration of groundwater within the root zone).

Any of the components of the groundwater budget could be either positive or negative, depending on the direction of the movement of the water. Typically, groundwater budget components are positive if water is being added to the aquifers, and negative if water is being removed; using this approach, groundwater extraction via wells would be negative, whereas recharge would be positive. The groundwater budget components used here are based on the Farm Process (FMP) approach to understanding the combined groundwater-surface water-land surface system (e.g., Schmid and Hanson, 2009).

The list below explains the meaning of the sign (positive or negative) for each of the water budget components:

- ΔS: a negative value means that water is leaving storage (i.e., a decrease in storage), while a positive value means that water is going into storage (i.e., an increase in storage).
- Q_{swi}: a positive value means that water is entering the freshwater aquifer from the ocean (i.e., seawater intrusion), while a negative value means that water is discharging into the ocean.
- Q_{ghb} : a positive value means that water is entering the basin from adjacent areas, while a negative value means that water is leaving the basin to move into adjacent areas; the northern boundary separates the basin from the Pajaro Basin, while the southern boundary separates the basin from the Paso Robles Basin.
- Q_{drain}: a positive value means that water is moving from the agricultural drain system into the aquifer, while a negative value means that groundwater is discharging into the drains.
- Q_{sw}: a positive value means that water is leaving the streams to enter the groundwater (i.e., streams are losing), while a negative value means that groundwater is discharging into the stream system (i.e., streams are gaining).
- Q_{well}: a positive value means that water is entering the groundwater system via wells (this can happen if the wells are being used for injection), while a negative value means that groundwater is being extracted from the aquifers.
- Q_{rz}: a positive value means that water is moving downward below the root zone, recharging the aquifer, while a negative value means that plants on the land surface are extracting groundwater for evapotranspiration.

Note that at any given time both positive and negative aspects of each of the water budget components can be occurring simultaneously (e.g., there may be deep percolation, Q_{rz} positive, at the same time as evapotranspiration of groundwater, Q_{rz} negative). The groundwater budget numbers given in this TM represent *net* budget components (e.g., a positive net Q_{rz} indicates that recharge is larger than groundwater evapotranspiration).

Figure 11 and Table 5 provide details on the groundwater budget for the Baseline scenario for the entire model domain (note that the arrows are bi-directional to clearly indicate that water can move in either direction for each water budget component). The largest groundwater budget components are groundwater pumping (Q_{well} = -109,000 afy) and groundwater-surface water exchange (Q_{sw} = +98,000 afy). Net exchange through the root zone indicates that evapotranspiration of groundwater is greater than percolation (Q_{rz} = -10,000 afy). Net seawater intrusion at the aquifer-ocean interface is about 4,000 afy (Q_{swi} = +4,000 afy). Net exchange with the drains (Q_{drain}) and exchange with adjacent basins (Q_{land}) are very minor (<1,000 afy). The sum of all these water budget components is a net loss of storage averaging about 17,000 afy (ΔS = -17,000 afy).

Water budget components for wet, normal, and dry water years are also shown on Figure 11 and Table 5. In general, most of the individual water budget components do not change substantially in different year types. The biggest differences are in net groundwater/surface water exchange (Q_{sw} is about +145,000 afy in wet years, +91,000 afy in normal years, and +58,000 afy in dry years) and change in storage (ΔS is about +28,000 afy in wet years, -23,000 afy in normal years, and -53,000 afy in dry years).

The groundwater budget results presented here indicate that, under the Baseline scenario, the groundwater basin is out of balance by about 17,000 afy (the average annual storage loss). This is largely controlled by the ability of the River to recharge the aquifers (highly dependent on water year type), since groundwater pumping changes very little from wet to dry conditions.

4.3 SCENARIO SUMMARY

The Baseline scenario simulates basin conditions under the current operational approach, with no changes to the reservoirs; the scenario is forced by a 47.25-year natural hydrologic cycle. The results of the scenario illustrate the current issues in the system:

- Storage in Nacimiento Reservoir tends to be fairly high on average (average storage of 183,000 af, median storage of 172,000 af, out of a capacity of 377,900 af), while storage in San Antonio Reservoir tends to be fairly low (average storage of 98,000 af, median storage of 67,000 af, out of a capacity of 335,000 af).
- Flood Control Releases average about 58,000 afy, almost all of it coming from Nacimiento Reservoir. Flood Control Releases chiefly occur during wet conditions (averaging about 178,000 afy during wet water years).
- Conservation Releases average about 135,000 afy, with Nacimiento Reservoir contributing about two thirds of the releases. More than 90% of the Conservation Releases are lost during conveyance between the reservoirs and Monterey Bay, with the remainder diverted at SRDF. The average SRDF season lasts for 136 days (out of 214 possible) and results in about 10,000 afy of diversion (out of a maximum of about 15,000 afy).

- The basin as a whole is out of balance, with an average annual loss of storage of about 17,000 afy. Groundwater storage is heavily dependent on water year type , because wet years experience substantially more streamflow, recharging the groundwater system much more than during dry years.

These results show that San Antonio Reservoir regularly has unfilled storage capacity. Nacimiento Reservoir, on the other hand, regularly has to release Flood Control Releases, losing the opportunity to use that water for later release. SVOM simulates an average annual loss in storage of about 17,000 afy and seawater intrusion of about 4,000 afy.

5.0 TUNNEL-ONLY SCENARIO

This scenario is identical to the Baseline scenario, except that the Interlake Tunnel (see Section 2.1) is enabled, allowing it to transfer water from Nacimiento Reservoir into San Antonio Reservoir. As noted above, the Interlake Tunnel would transfer water as long as the following four conditions are met:

1. stage in Nacimiento Reservoir is above the trigger elevation ("Tunnel Threshold") of 760 feet above msl;
2. stage in San Antonio Reservoir is lower than stage in Nacimiento Reservoir;
3. stage in San Antonio Reservoir is not at or near the Flood Rule Curve; and
4. stage in Nacimiento Reservoir is below the elevation of the crest of the Obermeyer gate (800 feet above msl).

The purpose of the Interlake Tunnel is to move water from Nacimiento Reservoir, which receives relatively high annual inflow but is limited in its ability to release at high rates by the capacity of its outlet works, to San Antonio Reservoir, which receives relatively low annual inflow and has higher outlet capacity.

Under existing reservoir operations, releases may end prematurely during a given Conservation Season because Nacimiento Reservoir release capacity is limited and San Antonio Reservoir does not have enough water in storage to supplement releases from Nacimiento Reservoir. As seen under the Baseline scenario (see Section 4), there is frequently a large amount of available storage in San Antonio Reservoir that goes unfilled each year; the Interlake Tunnel would take advantage of some of that unfilled storage and provide more operational flexibility.

5.1 SCENARIO DESIGN

The aspects of the scenario design for the Tunnel-Only scenario are identical to those of the Baseline scenario (listed in Section 4.1), except for the following:

- an Interlake Tunnel transfers water from Nacimiento Reservoir to San Antonio Reservoir, subject to stage and tunnel capacity limitations
- water right limitations are not in place (although the amount of water collected to and withdrawn from storage in each reservoir are tracked)

The Interlake Tunnel is described in more detail (including design and operations) in Section 2.1 and Appendix B. There is no change to reservoir operations for the Tunnel-Only scenario; Nacimiento is still prioritized for release.

5.2 SCENARIO RESULTS

This section presents the results of the Tunnel-Only scenario. Table 1 includes a summary of results from this and other scenarios; Table 6 provides a more extensive set of results for just the Tunnel-Only scenario.

5.2.1 Storage and Stage

Figure 12 shows time series of storage and stage in Nacimiento and San Antonio Reservoirs under the Tunnel-Only scenario. The reservoirs attain a maximum combined storage of about 728,000 acre-feet (af), about 46,000 af higher than the maximum storage under the Baseline scenario. Nacimiento Reservoir reaches a maximum stage of 801 feet above mean sea level (msl; storage of about 382,000 af), above the spillway elevation. San Antonio Reservoir reaches a maximum stage of 783 feet above msl (storage of about 353,000 af), above the elevation of the spillway crest (780 feet above msl).

Figure 7 shows the entire range of storage and stage values for the two reservoirs (and storage for the combined reservoirs), colored by quartile. The charts in this figure show that storage in Nacimiento Reservoir under the Tunnel-Only scenario tends to be slightly lower than under the Baseline scenario (the average storage of about 132,000 af is about 52,000 af lower than the Baseline scenario average storage, while the median storage of about 99,000 af is about 51,000 af lower than the Baseline scenario median storage). In San Antonio Reservoir, storage under the Tunnel-Only scenario is generally much higher than under the Baseline scenario (the average storage of about 188,000 af is about 90,000 af higher than the Baseline scenario average storage, while the median storage of about 238,000 af is about 83,000 af higher than the Baseline scenario median storage). Combined storage is generally higher than under the Baseline scenario (the average storage of about 320,000 af is about 39,000 af higher than the Baseline scenario average storage, while the median storage of about 346,000 af is about 29,000 af higher than the Baseline scenario median storage). These results indicate that, with the Interlake Tunnel operating, combined reservoir storage would be substantially higher, with that increase driven by much higher storage in San Antonio Reservoir.

Monthly average and median storage and stage values for Nacimiento and San Antonio Reservoirs (and combined reservoir storage) are presented in Figure 13. Average and median storage and stage values are uniformly lower in Nacimiento Reservoir compared to the Baseline scenario, showing that the Interlake Tunnel decreases storage in Nacimiento Reservoir substantially (Figures 13a and 13b). Monthly average storage in Nacimiento Reservoir is 44,000 to 59,000 af lower than under the Baseline scenario, and monthly average stage is 14 to 25 feet lower.

Conversely, monthly average storage and stage are substantially higher in San Antonio Reservoir (Figures 13c and 13d). Monthly average storage in San Antonio Reservoir is 82,000 to 96,000 af higher than under the Baseline scenario, and monthly average stage is 26 to 34 feet higher. Median monthly storage and stage in San Antonio Reservoir is noticeably higher than average monthly stage (especially during normal water years), indicating that storage in San Antonio Reservoir is skewed toward high values, with the average affected by fewer very low storage periods.

Overall, the combined storage in the two reservoirs is higher. Monthly average storage is between 34,000 and 46,000 af higher than under the Baseline scenario (Figure 13e). The individual reservoir storage and stage values described in the previous two paragraphs indicate that this increase in storage is a result of the increase in storage in San Antonio Reservoir, which is greater in magnitude than the decrease in storage at Nacimiento Reservoir. This indicates that the Interlake Tunnel is, as intended, keeping more water in the combined reservoir system by moving it from Nacimiento Reservoir to San Antonio Reservoir. San Antonio Reservoir is typically much closer to its capacity of 335,000 af, although it still has unfilled capacity, especially during dry periods. With the Interlake Tunnel, most of the available capacity is in Nacimiento Reservoir rather than San Antonio Reservoir.

5.2.2 Reservoir Releases

As noted in Section 3.3, reservoir releases are categorized into four different types, depending on their purpose: Flood Control Release, Environmental Release, Conservation Release, and Over-Release. Figure 9 shows the average annual release volume (in af) for all water year types as well as for wet, normal, and dry water years, with subcategorized releases shown on Figure 10. These average volumes are also presented in Table 6.

Releases under the Tunnel-Only scenario averaged about 247,000 acre-feet per year (afy) from the two reservoirs combined, almost identical to the Baseline scenario, since the amount of inflow to the reservoirs is unchanged. About 152,000 afy of the total release comes from Nacimiento Reservoir (about 27,000 afy less than under the Baseline scenario) and about 94,000 afy comes from San Antonio Reservoir (about 25,000 afy more than under the Baseline scenario). During wet water years, releases averaged about 321,000 afy (about 49,000 afy less than under the Baseline scenario), with about 230,000 afy coming from Nacimiento Reservoir and about 91,000 afy from San Antonio Reservoir. Normal water years saw about 233,000 afy of release (about 10,000 afy less than under the Baseline scenario), with about 155,000 afy from Nacimiento Reservoir and about 78,000 afy from San Antonio Reservoir. Dry water years had about 192,000 afy of release on average (about 64,000 afy more than under the Baseline scenario), with about 63,000 afy coming from Nacimiento Reservoir and about 129,000 afy from San Antonio Reservoir.

On average, the reservoirs release about 46,000 acre-feet per year (afy) as Flood Control Releases under the Tunnel-Only scenario (about 12,000 afy less than under the Baseline scenario), with about 59% (about 27,000 afy) coming from Nacimiento Reservoir and 41% (about 19,000 afy) coming from San Antonio Reservoir. As under the Baseline scenario, Flood Control Releases occur most prominently during wet water years (averaging 139,000 afy). Flood Control Releases are completely absent from dry water years (Figure 9). Some Flood Control Release occurs in 54% of wet water years, 45% of normal water years, and none in dry water years.

On average, the reservoirs release about 39,000 afy of Environmental Releases (29,000 afy of fish and wildlife habitat releases and 10,000 afy of fish passage releases) under the Tunnel-Only scenario, about 4,000 afy less than under the Baseline scenario. The decrease in Environmental Releases is due almost entirely to decreased fish and wildlife habitat releases, which is largely driven by Nacimiento Reservoir. Fish and wildlife habitat releases can decrease either because of storage or water right limitations, or because other releases are being made, removing the necessity of the fish and wildlife habitat releases. At Nacimiento Reservoir, about 60% of the decrease in fish and wildlife habitat releases is driven by storage and water rights limitations, with the remaining 40% being no longer needed because other types of releases are occurring and achieving the goals of the fish and wildlife habitat releases. At San Antonio Reservoir, the decrease in fish and wildlife habitat releases is entirely driven by storage limitations.

Of the average annual Environmental Release volume, 79% (about 31,000 afy) comes from Nacimiento Reservoir, with the remaining 21% (about 8,000 afy) coming from San Antonio Reservoir. Fish and wildlife habitat releases make up about 74% of the Environmental Releases, and are very uniform across year types (Figure 10). Fish passage releases (made to meet streamflow requirements within the Salinas River to support steelhead migration) make up the remaining 26% of Environmental Releases, and are heavily weighted toward normal year types, when most of the Flow Prescription requirements are active.

On average, the reservoirs release about 150,000 afy of Conservation Releases under the Tunnel-Only scenario, about 15,000 afy more than under the Baseline scenario. Of the average annual release volume, 59% (about 88,000 afy) comes from Nacimiento Reservoir, with the remaining 41% (about 62,000 afy) coming from San Antonio Reservoir. Conservation Releases average about 143,000 afy in wet years, 155,000 afy in normal years, and 147,000 afy in dry years (Figure 9). Section 5.2.3 provides a more detailed analysis of the Conservation Releases.

The average reservoir release numbers for the Tunnel-Only scenario indicate that there is a general shift in total release from Nacimiento Reservoir to San Antonio Reservoir, and from wet water years to dry water years. This results from a decrease in Flood Control Release (especially during wet years) and an increase in Conservation Release (especially during dry years). This indicates that the Interlake Tunnel successfully keeps additional water in storage (by decreasing Flood Control Release), allowing it to be stored for later use (as Conservation Release during dry years).

5.2.3 Conservation Releases

This section provides further detail on Conservation Releases under the Tunnel-Only scenario. See Section 4.2.3 for information on how the categorization presented here was performed.

Figure 10 shows the average annual releases, with Conservation Releases broken up into subcategories; averages are included in Table 3. Of the 158,000 afy of average annual Conservation Release, 6% (about 9,000 afy) is diverted at SRDF, and 94% (about 141,000 afy) leaves the Salinas River along the riparian corridor. During wet years, SRDF Diversion makes up 7% of Conservation Releases (about 10,000 afy) and Conveyance Losses 93% (about 134,000 afy). During normal years, SRDF Diversion makes up 6% of Conservation Releases (about 9,000 afy) and Conveyance Losses 94% (about 146,000 afy). During dry years, SRDF Diversion makes up 5% of Conservation Releases (about 7,000 afy) and Conveyance Losses 95% (about 140,000 afy). All of the percentages presented here are nearly identical to those simulated under the Baseline scenario, indicating that more than 90% of Conservation Releases are lost during conveyance, largely irrespective of the year type or magnitude of release.

5.2.4 SRDF Operations

Table 4 provides details on the SRDF operations for the Tunnel-Only scenario, as well as a comparison to the SRDF Operations simulated under the Baseline scenario (see Section 4.2.4 for more description of the SRDF and its operations). Across all year types, an average Conservation Release Season sees 149 days of diversion (13 days longer than under the Baseline scenario), with about 11,000 afy diverted (about 1,000 af more than under the Baseline scenario). Wet years average 214 days of diversion, with about 15,000 afy diverted; normal years average 143 days of diversion, with about 10,000 afy diverted; and dry years average 89 days of diversion, with about 6,000 afy diverted. All told, 55% of Conservation Release Seasons are full (214 days long), 19% are partial, and 26% are failed. For the partial seasons, the average length was about 160 days.

These results indicate that the Interlake Tunnel allows the SRDF to operate more often and for a longer duration. The average SRDF season is longer (by 13 days) with additional diversion. SRDF seasons are slightly more successful (55% full seasons versus 53% under the Baseline scenario and 19% partial seasons versus 17% under the Baseline scenario), and partial seasons last substantially longer (160 days on average versus 128 days under the Baseline scenario).

5.2.5 Water Rights

As noted in Section 5.1, water rights limitations are not in place for scenarios including the Interlake Tunnel, because of uncertainty about how the limitations would be implemented for an interconnected reservoir system and how water passed from Nacimiento Reservoir to San Antonio Reservoir through the Interlake Tunnel would be accounted. However, the water rights accounting still takes place using the same approach as for the Baseline scenario (see Section 3.3 and Appendix A).

5.2.6 Tunnel Operations

The purpose of the Interlake Tunnel is to transfer water from Nacimiento Reservoir to San Antonio Reservoir; operations of the Interlake Tunnel are summarized in Table 1, with more detail provided in Table 7. On average, about 30,000 afy is transferred through the Interlake Tunnel under the Tunnel-Only scenario. The Interlake Tunnel is used in 51% of the Model Years, and on average operates for 40 days per year. Usage of the Interlake Tunnel is highly dependent on water year type. During wet water years, the Interlake Tunnel transfers about 92,000 afy under the Tunnel-Only scenario, transferring at least some water every year and on average operating for 104 days per year. During normal water years, the Interlake Tunnel transfers about 6,000 afy, transferring at least some water in 45% of years and on average operating for 21 days per year. During dry years, the Interlake Tunnel transfers about 6,000 afy, transferring at least some water in 8% of years and on average operating for 7 days per year.

As noted in Section 2.1, the Interlake Tunnel only transfers water if four conditions are met (stage in Nacimiento Reservoir is at least 760 feet above msl, stage in Nacimiento Reservoir is higher than stage in San Antonio Reservoir, San Antonio Reservoir has capacity available to receive the transferred water, and Nacimiento Reservoir stage is below 800 feet above msl). As noted above, the Interlake Tunnel on average transfers water 40 days per year under the Tunnel-Only scenario. Of the remaining days, the majority (264 days per year) had stage in Nacimiento Reservoir that was too low (i.e., below 760 feet above msl). An additional 35 days per year had stage in San Antonio Reservoir that was too close to the Flood Rule Curve, and 26 days per year had no tunnel transfer because stage in San Antonio Reservoir was at or above stage in Nacimiento Reservoir. Nacimiento Reservoir stage rising above 800 feet above msl was very rare, averaging less than one day per year. Figure 14 shows the distribution of Interlake Tunnel operations averaged across all water year types, and for wet, normal, and dry years.

5.2.7 Groundwater Budget

Details on the groundwater budget approach for this TM are provided in Section 4.2.5. Figure 15 and Table 5 provide details on the groundwater budget for the Tunnel-Only scenario for the entire model domain. The largest groundwater budget components are groundwater pumping (Q_{well} = -109,000 afy) and groundwater-surface water exchange (Q_{sw} = +99,000 afy). Net exchange through the root zone indicates that evapotranspiration of groundwater is greater than percolation (Q_{rz} = -10,000 afy). Net seawater intrusion at the aquifer-ocean interface is about 4,000 afy (Q_{swi} = +4,000 afy). Net exchange with the drains (Q_{drain}) and exchange with adjacent basins (Q_{land}) are very minor (<1,000 afy). The sum of all these water budget components is a net loss of storage averaging about 16,000 afy (ΔS = -16,000 afy). These water budget numbers are nearly identical to those of the Baseline scenario.

Water budget components for wet, normal, and dry water years are also shown on Figure 15 and Table 5. As under the Baseline scenario, most of the individual water budget components do not change substantially in different year types. The biggest differences are in net groundwater/surface water exchange (Q_{sw} is about +141,000 afy in wet years, +91,000 afy in normal years, and +69,000 afy in dry years) and change in storage (ΔS is about +25,000 afy in wet years, -25,000 afy in normal years, and -44,000 afy in dry years).

The groundwater budget results presented here indicate that, under the Tunnel-Only scenario, the groundwater basin remains out of balance by about 16,000 afy (the average annual storage loss) with the Interlake Tunnel in operation, about 1,000 afy less than under the Baseline scenario. The largest difference from the Baseline scenario is an increase in the amount of groundwater/surface water exchange during dry years (+69,000 afy versus +58,000 afy under the Baseline scenario), and an associated decrease in the loss of storage (44,000 afy versus 53,000 afy under the Baseline scenario).

5.3 Scenario Summary

The Tunnel-Only scenario simulates conditions in the basin with the Interlake Tunnel transferring water from Nacimiento Reservoir to San Antonio Reservoir. Otherwise, this scenario is identical to the Baseline scenario. Therefore, comparing this scenario to the Baseline scenario demonstrates the impact of the Interlake Tunnel on the system.

- The Interlake Tunnel results in less water in storage in Nacimiento Reservoir (average of about 132,000 af, about 52,000 af less than under the Baseline scenario) and more water in storage in San Antonio Reservoir (average of about 188,000 af, about 90,000 af more than under the Baseline scenario), with the combined storage in the two reservoirs generally higher (average of about 320,000 af, about 39,000 af more than under the Baseline scenario).
- Flood Control Releases decrease by 20% (about 46,000 afy under the Tunnel-Only scenario, about 12,000 afy lower than under the Baseline scenario), with 59% of releases coming from Nacimiento Reservoir (versus 96% under the Baseline scenario) and 41% coming from San Antonio Reservoir (versus 4% under the Baseline scenario).
- Conservation Releases increase by 11% (about 150,000 afy under the Tunnel-Only scenario, about 15,000 afy higher than under the Baseline scenario), with 59% of releases coming from Nacimiento Reservoir (versus 60% under the Baseline scenario) and 41% coming from San Antonio Reservoir (versus 40% under the Baseline scenario); Conservation Releases are slightly smaller in wet and normal water years, but increased by about 65,000 afy during dry water years.
- Operation of the SRDF is increased in terms of length of the season (149 days on average, 13 days longer than the average season under the Baseline scenario) with slightly more water diverted, lengthened partial SRDF seasons, and fewer seasons where there is no diversion at SRDF.
- The Interlake Tunnel transfers about 30,000 afy under the Tunnel-Only scenario, operating during 45% of years and for 40 days per year on average.
- Impact on the groundwater budget is fairly small, except for a general increase in streamflow losses to the groundwater system during dry years that results in less storage loss during those same years and slightly less storage loss overall (16,000 afy, about 1,000 afy less than under the Baseline scenario).

These results demonstrate the impact that the Interlake Tunnel would have on the system, in terms of increasing the amount of water held in storage, decreasing the volume of Flood Control Releases, and increasing the volume of water that the reservoirs are able to make available as Conservation Releases. This has positive impacts on the operation of the SRDF, while also increasing the amount of water recharged to the Basin along the riparian corridor, especially during dry years.

6.0 TUNNEL PLUS 7' SPILLWAY RAISE SCENARIO

This scenario is identical to the Tunnel-Only scenario, except that the San Antonio Dam spillway is raised by seven feet (see Section 2.2). This would increase the maximum capacity of San Antonio Reservoir, allowing it to store more water when available.

6.1 SCENARIO DESIGN

The scenario design for the Tunnel Plus 7′ Spillway Raise scenario is identical to that of the Tunnel-Only scenario, except for the raised spillway at San Antonio Dam (spillway crest elevation changes from 780 to 787 feet above msl). As described in Section 2.2, the raised spillway increases the storage in San Antonio Reservoir with stage at the spillway crest from 335,000 af to 376,200 af. As described in Section 3.3, the Flood Rule Curve for San Antonio Reservoir maintains some amount of empty storage capacity during the wet season, meaning that the maximum stage is some distance below the spillway crest over the winter. The Flood Rule Curves for San Antonio Reservoir with and without the raised spillway are shown on Figure 3.

This scenario assumes that the rating curve for releases from San Antonio Reservoir is unchanged. The rating curve was already defined to the crest of San Antonio Dam, the elevation of which would not change. Operational modifications are described in more detail in Appendix B.

6.2 SCENARIO RESULTS

This section presents the results of the Tunnel Plus 7' Spillway Raise scenario. Table 1 includes a summary of results from the this and other scenarios; Table 8 provides a more extensive set of results for just the Tunnel Plus 7' Spillway Raise scenario.

6.2.1 Storage and Stage

Figure 16 shows time series of storage and stage in Nacimiento and San Antonio Reservoirs under the Tunnel Plus 7' Spillway Raise scenario. The reservoirs attain a maximum combined storage of about 768,000 af, about 89,000 af higher than the maximum storage under the Baseline scenario and 41,000 af higher than the maximum storage under the Tunnel-Only scenario. Nacimiento Reservoir reaches a maximum stage of 801 feet above msl (storage of about 382,000 af), above the spillway elevation (800 feet above msl). San Antonio Reservoir reaches a maximum stage of 789 feet above msl (storage of about 386,000 af); this is about two feet above the raised spillway crest elevation.

Figure 7 shows the entire range of storage and stage values for the two reservoirs (and storage for the combined reservoirs), colored by quartile. The charts in this figure show that storage in Nacimiento Reservoir under the Tunnel Plus 7' Spillway Raise scenario tends to be distributed similarly to the Tunnel-Only scenario (the average storage of about 135,000 af is about 3,000 af higher than the Tunnel-Only scenario average storage, while the median storage of about 105,000 af is about the same as the Tunnel-Only scenario median storage). In San Antonio Reservoir, storage under the Tunnel Plus 7' Spillway Raise scenario is somewhat higher than under the Tunnel-Only scenario (the average storage of about 200,000 af is about 12,000 af higher than the Tunnel-Only scenario average storage, while the median storage of about 255,000 af is about 2,000 af higher than the Tunnel-Only scenario median storage). Combined storage is somewhat higher than under the Tunnel-Only scenario (the average storage of about 335,000 af is about 15,000 af higher than the Tunnel-Only scenario average storage, while the median storage of about 361,000 af is about 3,000 af higher than the Tunnel-Only scenario median storage). These results indicate that, with the San Antonio Dam spillway elevation raised, combined reservoir storage would be somewhat higher, with most of that increase occurring in San Antonio Reservoir.

Figure 17 shows the monthly average and median storage and stage for the Tunnel Plus 7' Spillway Raise scenario. At Nacimiento Reservoir, monthly average and median storage and stage are generally slightly higher than or about the same as under the Tunnel-Only scenario. At San Antonio Reservoir, monthly average storage is uniformly higher (by 9,000 to 15,000 af) than under the Tunnel-Only scenario, with the largest differences seen during normal years (11,000 to 20,000 af) and the smallest differences seen during dry years (3,000 to 5,000 af). Changes to median monthly storage and stage are less uniform in direction, with some months (especially during dry years) experiencing lower monthly median storage and stage; this indicates that there are more months with very low storage in San Antonio Reservoir compared to the Tunnel-Only scenario.

The quartile ranges for Nacimiento Reservoir indicate very little difference between the Tunnel-Only and Tunnel Plus 7' Spillway Raise scenarios (Figure 7). There is slightly more water in storage in Nacimiento Reservoir with the raised spillway in place, but the difference is minor. For San Antonio Reservoir, the bottom-most quartile is largely unchanged, indicating that there has been little change to the frequency of very low storage conditions. However, the median and maximum storage in San Antonio Reservoir are clearly increased, indicating that the highest storage conditions are shifted to slightly higher values with the spillway raise. This indicates that the reservoirs are able to store more water during the wet conditions that allow for the reservoirs to fill completely.

In addition to the overall average storage and stage conditions discussed above, another indication of the benefit provided by the spillway raise at San Antonio Dam is the frequency and magnitude of storage above the existing spillway elevation. Maximum storage in San Antonio Reservoir rises above the existing spillway elevation in 38% of model years, with an average of about 11,000 af taken across all years (or 29,000 af considering only those years where storage rises above the existing spillway elevation). This condition occurs in 46% of wet years (averaging 17,000 af for those years where storage rises above the existing spillway elevation) and 55% of normal years (averaging 14,000 af for those year where storage rises above the existing spillway elevation); it never occurs during a dry year through the model duration. It may seem counterintuitive that the raised spillway is used less frequently in wet years than in normal years, but this results from the large part that the wetness of previous years plays on reservoir storage. On average, years preceding wet water years are drier than years preceding normal water years. Of the wet years in the model duration, 31% are preceded by dry years, 54% are preceded by normal years, and 15% are preceded by wet years. Of the normal years, 14% are preceded by dry years, 50% are preceded by normal years, and 36% are preceded by wet years. Because conditions are typically wetter leading into normal water years, storage tends to be higher prior to the winter wet season, leaving less unfilled storage capacity and an easier time getting storage up to the raised spillway elevation.

6.2.2 Reservoir Releases

As noted in Section 3.3, reservoir releases are categorized into four different types, depending on their purpose: Flood Control Release, Environmental Release, Conservation Release, and Over-Release. Figure 9 shows the average annual release volume (in af) for all water year types as well as for wet, normal, and dry water years. These average volumes are also presented in Table 8.

Releases under the Tunnel Plus 7' Spillway Raise scenario averaged about 246,000 acre-feet per year (afy) from the two reservoirs combined, almost identical to the Baseline scenario, since the amount of inflow to the reservoirs is unchanged. About 152,000 afy of the total release comes from Nacimiento Reservoir (the same as under the Tunnel-Only scenario) and about 93,000 afy comes from San Antonio Reservoir (about 1,000 afy less than under the Tunnel-Only scenario). During wet water years, releases averaged about 317,000 afy (about 3,000 afy less than under the Tunnel-Only scenario), with about 228,000 afy coming from Nacimiento Reservoir and about 90,000 afy from San Antonio Reservoir. Normal water years saw about 231,000 afy of release (about 2,000 afy less than under the Tunnel-Only scenario), with about 156,000 afy from Nacimiento Reservoir and about 75,000 afy from San Antonio Reservoir. Dry water years had about 195,000 afy of release on average (about 3,000 afy more than under the Tunnel- Only scenario), with about 64,000 afy coming from Nacimiento Reservoir and about 131,000 afy from San Antonio Reservoir.

On average, the reservoirs release about 40,000 acre-feet per year (afy) as Flood Control Releases under the Tunnel Plus 7' Spillway Raise scenario (about 5,000 afy less than under the Tunnel-Only scenario), with about 69% (about 28,000 afy) coming from Nacimiento Reservoir and 31% (about 13,000 afy) coming from San Antonio Reservoir. As under the Baseline and

Tunnel-Only scenarios, Flood Control Releases occur most prominently during wet water years (averaging 133,000 afy) and are absent from dry water years (Figure 9). Some Flood Control Release occurs in 54% of wet water years, 9% of normal water years, and 0% of dry water years.

On average, the reservoirs release about 40,000 afy of Environmental Releases under the Tunnel Plus 7' Spillway Raise scenario, about the same as under the Tunnel-Only scenario. Of this, 79% (about 32,000 afy) comes from Nacimiento Reservoir, with the remaining 21% (about 8,000 afy) coming from San Antonio Reservoir. Fish and wildlife habitat releases make up 74% of the Environmental Releases, and are very uniform across year types (Figure 10). Fish passage releases (made to meet streamflow requirements within the Salinas River to support steelhead migration) make up the remaining 26% of Environmental Releases, and are heavily weighted toward normal year types, when most of the Flow Prescription requirements are active.

On average, the reservoirs release about 154,000 afy of Conservation Releases under the Tunnel Plus 7' Spillway Raise scenario, a slight increase (of about 4,000 afy) over the Tunnel-Only scenario. Of the average annual volume, 56% (about 87,000 afy) comes from Nacimiento Reservoir, with the remaining 44% (about 67,000 afy) coming from San Antonio Reservoir. Conservation Releases average about 145,000 afy in wet years (about 2,000 afy more than under the Tunnel-Only scenario), 162,000 afy in normal years (about 6,000 afy more than under the Tunnel-Only scenario), and 150,000 afy in dry years (about 3,000 afy more than under the Tunnel-Only scenario; Figure 9). Section 6.2.3 provides a more detailed analysis of the Conservation Releases.

The average reservoir release numbers for the Tunnel Plus 7' Spillway Raise scenario indicate that increasing the height of the spillway at San Antonio Dam would result in a modest decrease in Flood Control Release (by about 5,000 afy compared to the Tunnel-Only scenario), with most of that water later being used for Conservation Release (about 4,000 afy more than under the Tunnel-Only scenario). The reduction in Flood Control Release occurs during wet (5,000 afy less than the Tunnel-Only scenario) and normal (8,000 afy less than under the Tunnel-Only scenario). The increase in Conservation Release is largest in normal years (6,000 afy more than under the Tunnel-Only scenario) and dry years (3,000 afy more than under the Tunnel-Only scenario). This indicates that the raised spillway allows the combined reservoir system to store additional water that would otherwise be lost as Flood Control Release, allowing for its later use as Conservation Release.

6.2.3 Conservation Releases

This section provides further detail on Conservation Releases under the Tunnel Plus 7' Spillway Raise scenario. See Section 4.2.3 for information on how the categorization presented here was performed.

Figure 10 shows the average annual releases, with Conservation Releases broken up into subcategories; averages are included in Table 3. Of the 154,000 afy of average annual Conservation Release, 6% (about 9,000 afy) is diverted at SRDF, with the remaining 94% (about 145,000 afy) leaves the Salinas River along the riparian corridor. During wet years, SRDF Diversion makes up 7% of Conservation Releases (about 10,000 afy) and Conveyance Losses 93% (about 135,000 afy). During normal years, SRDF Diversion makes up 6% of Conservation Releases (about 9,000 afy) and Conveyance Losses 94% (about 152,000 afy). During dry years, SRDF Diversion makes up 5% of Conservation Releases (about 7,000 afy), and Conveyance Losses 95% (about 143,000 afy). All of the percentages presented here are nearly identical to those simulated under the Baseline and Tunnel-Only scenarios, indicating that more than 90% of Conservation Releases are lost along the riparian corridor, largely irrespective of the year type or magnitude of release.

6.2.4 SRDF Operations

Table 4 provides details on the SRDF operations for the Tunnel Plus 7' Spillway Raise scenario, as well as a comparison to the SRDF Operations simulated under the Baseline and Tunnel-Only scenarios (see Section 4.2.4 for more description of the SRDF and its operations). Across all year types, an average Conservation Release Season sees 150 days of diversion (15 days longer than under the Baseline scenario and 1 day longer than under the Tunnel-Only scenario), with about 11,000 afy diverted (about 1,000 afy more than under the Baseline scenario and about the same as under the Tunnel-Only scenario). Wet years average 214 days of diversion, with about 15,000 afy diverted; normal years average 144 days of diversion, with about 10,000 afy diverted; and dry years average 92 days of diversion, with about 7,000 afy diverted. All told, 60% of Conservation Release Seasons are full (214 days long), 15% are partial, and 26% are failed; compared to the Tunnel-Only scenario, some partial seasons become full seasons. For the partial seasons, the average length was about 152 days, about 7 days shorter than under the Tunnel-Only scenario.

These results indicate that the San Antonio Dam spillway modification has a small impact on the operations of SRDF, slightly increasing the average length of the Conservation Release Season, especially during dry years, and leads to a change from partial to full for a small number of Conservation Release Seasons.

6.2.5 Water Rights

As discussed in Section 5.2.5 for the Tunnel-Only scenario, water rights limitations were not in place for the Tunnel Plus 7' Spillway Raise scenario.

6.2.6 Tunnel Operations

The purpose of the Interlake Tunnel is to transfer water from Nacimiento Reservoir to San Antonio Reservoir; operations of the Interlake Tunnel are summarized in Table 1, with more detail provided in Table 7. On average, about 30,000 afy is transferred through the Interlake Tunnel under the Tunnel Plus 7’ Spillway Raise scenario. This is the same as under the Tunnel-Only scenario, despite the generally higher storage values in San Antonio Reservoir.

The Interlake Tunnel is used in 47% of the Model Years (slightly less than under the Tunnel-Only scenario), and on average operates for 37 days per year (three fewer than under the Tunnel-Only scenario). Usage of the Interlake Tunnel is highly dependent on water year type. During wet water years, the Interlake Tunnel transfers about 93,000 afy, transferring at least some water every year and on average operating for 97 days per year. During normal water years, the Interlake Tunnel transfers about 6,000 afy, transferring at least some water in 36% of years and on average operating for 18 days per year. During dry years, the Interlake Tunnel transfers about 6,000 afy, transferring at least some water in 8% of years and on average operating for 7 days per year.

As noted in Section 2.1, the Interlake Tunnel only transfers water if four conditions are met (stage in Nacimiento Reservoir is at least 760 feet above msl, stage in Nacimiento Reservoir is higher than stage in San Antonio Reservoir, San Antonio Reservoir has capacity available to receive the transferred water, and stage in Nacimiento Reservoir is below 800 feet above msl). As noted above, the Interlake Tunnel on average transfers water 37 days per year under the Tunnel Plus 7’ Spillway Raise scenario. Of the remaining days, the majority (258 days per year) had stage in Nacimiento Reservoir that was too low (i.e., below 760 feet above msl).

An additional 55 days per year had stage in San Antonio Reservoir that was too close to the Flood Rule Curve, and 15 days per year had no tunnel transfer because stage in San Antonio Reservoir was at or above stage in Nacimiento Reservoir. Less than one day per year there was no Tunnel transfer because stage at Nacimiento Reservoir was above 800 feet above msl. Figure 14 shows the distribution of Interlake Tunnel operations averaged across all water year types, and for wet, normal, and dry years.

6.2.7 Groundwater Budget

Details on the groundwater budget approach for this TM are provided in Section 4.2.5. Figure 18 and Table 5 provide details on the groundwater budget for the Tunnel Plus 7' Spillway Raise scenario for the entire model domain. The largest groundwater budget components are groundwater pumping (Q_{well} = -109,000 afy) and groundwater-surface water exchange (Q_{sw} = +99,000 afy). Net exchange through the root zone indicates that evapotranspiration of groundwater is greater than percolation (Q_{rz} = -10,000 afy). Net seawater intrusion at the aquifer-ocean interface is about 4,000 afy (Q_{swi} = +4,000 afy). Net exchange with the drains (Q_{drain}) and exchange with adjacent basins (Q_{land}) are very minor (<1,000 afy). The sum of all these water budget components is a net loss of storage averaging about 16,000 afy (ΔS = -16,000 afy). These water budget numbers are identical to those of the Tunnel-Only scenario.

Water budget components for wet, normal, and dry water years are also shown on Figure 18 and Table 5. As under the Baseline and Tunnel-Only scenarios, most of the individual water budget components do not change substantially in different year types. The biggest differences are in net groundwater/surface water exchange (Q_{sw} is about +141,000 afy in wet years, +91,000 afy in normal years, and +69,000 afy in dry years) and change in storage (ΔS is about +24,000 afy in wet years, -25,000 afy in normal years, and -44,000 afy in dry years). These numbers are largely identical to those simulated under the Tunnel-Only scenario.

The groundwater budget results presented here indicate that, under the Tunnel Plus 7' Spillway Raise scenario, there is little difference in the groundwater system compared to the Tunnel-Only scenario.

6.3 SCENARIO SUMMARY

The Tunnel Plus 7′ Spillway Raise scenario simulates conditions in the basin with the Interlake Tunnel transferring water from Nacimiento Reservoir to San Antonio Reservoir and the spillway crest elevation at San Antonio Dam raised by seven feet to 787 feet above msl. Other than the spillway raise, this scenario is identical to the Tunnel-Only scenario. Therefore, comparing this scenario to the Tunnel-Only scenario demonstrates the impact of the spillway raise on the system.

- The spillway raise results in more water in storage in both Nacimiento Reservoir (average of about 135,000 af, about 3,000 af more than under the Tunnel-Only scenario) and San Antonio Reservoir (average of about 200,000 af, about 12,000 af more than under the Tunnel-Only scenario), as well as combined between the two (average of about 335,000 af, about 15,000 af more than under the Tunnel-Only scenario).
- Flood Control Releases decrease by 12% (about 40,000 afy under the Tunnel Plus 7′ Spillway Raise scenario, about 5,000 afy lower than under the Tunnel-Only scenario), with 69% of releases coming from Nacimiento Reservoir (versus 59% under the Tunnel-Only scenario) and 31% coming from San Antonio Reservoir (versus 41% under the Tunnel-Only scenario).
- Conservation Releases increase by 3% (about 154,000 afy under the Tunnel Plus 7′ Spillway Raise scenario, about 4,000 afy higher than under the Tunnel-Only scenario), with 56% of releases coming from Nacimiento Reservoir (versus 59% under the Tunnel-Only scenario) and 44% coming from San Antonio Reservoir (versus 31% under the Tunnel-Only scenario).
- Little difference is simulated in operation of the SRDF under the Tunnel Plus 7′ Spillway Raise scenario, with the length of the season increasing to 150 days (an increase of 1 day per year over the Tunnel-Only scenario) and the amount of water diverted also slightly increasing (to 11,000 afy, about 1,000 afy more than under the Tunnel-Only scenario).
- The Interlake Tunnel transfers about 30,000 afy under the Tunnel Plus 7′ Spillway Raise scenario, about the same as under the Tunnel-Only scenario, operating during 47% of years and for 37 days per year on average.
- Impact on the groundwater budget is negligible, changes are very small.

These results demonstrate that the San Antonio Dam Spillway Modification would have an overall positive impact on storage in both Nacimiento and San Antonio Reservoirs, and would result in slightly decreased Flood Control Releases and increased Conservation Releases.

7.0 INTERLAKE TUNNEL SCENARIO INUNDATION MODELING

As part of the analysis of the effect of the Interlake Tunnel and Spillway Raise, Wood used an existing HEC-RAS 2D model of the Salinas River to investigate the project's impact on flood inundation. A full writeup of this analysis is included as Appendix C.

The inundation modeling focused on the highest flow event that occurred during the duration of the SVOM; in the SVOM input hydrology, this event is equivalent to the high flow event that occurred in February 1998 (i.e., during Model Year 31). The same event was used as an input to the HEC-RAS 2D model for the Baseline, Tunnel-Only, and Tunnel Plus 7′ Spillway Raise Scenario. Simulated streamflow from the SVOM in the Salinas River at Bradley was used as the upstream boundary condition to the HEC-RAS 2D model. Various modifications were made to the simulated SVOM streamflow time series to create an appropriate input time series to act as input to the HEC-RAS 2D model, which runs on a much finer time discretization. These modifications are described in Appendix C.

The result of the HEC-RAS 2D model indicates that, for the particular event selected, the Interlake Tunnel results in a higher streamflow at Bradley, and therefore more inundation along the Salinas River; the Spillway Raise mitigates this streamflow increase to a certain degree, but does not fully. The event peak streamflow used for the HEC-RAS 2D model is about 27,000 cfs under the Baseline scenario, 36,000 cfs under the Tunnel-Only scenario, and 33,000 cfs under the Tunnel Plus 7′ Spillway Raise scenario. This increase in peak streamflow reflects the fact that storage in the reservoirs prior to the event is substantially higher with the Interlake Tunnel in place, because, under the Tunnel-Only scenario the Tunnel moves approximately 171,000 af from Nacimiento Reservoir to San Antonio Reservoir over the previous 3 years, with a similar reduction (by about 178,000 af) of Flood Control Release during the same period (under the Tunnel Plus 7′ Spillway Raise scenario, about 161,000 af is moved through the Tunnel during the same period, and Flood Control Release is reduced by about 226,000 af). At the start of the stress period preceding the high flow event (January of Model Year 31), storage in Nacimiento Reservoir is lower than under the Baseline scenario (by about 57,000 af under the Tunnel-Only scenario and 38,000 af under the Tunnel Plus 7′ Spillway Raise scenario), while storage in San Antonio Reservoir is substantially higher (by about 234,000 af under the Tunnel-Only scenario and 250,000 af under the Tunnel Plus 7′ Spillway Raise scenario).

Combined storage is therefore much higher than under the Baseline scenario (by about 178,000 af under the Tunnel-Only scenario and 212,000 af under the Tunnel Plus 7’ Spillway Raise scenario). This leaves the reservoirs with much less available storage space with the Interlake Tunnel operating, increasing the amount of Flood Control Release that occurs during the event, leading to the increase in event peak flow if the current operational strategy were in place under these conditions.

As has been shown in Sections 5 and 6, both the Interlake Tunnel and the Spillway Raise result in a reduction in average annual Flood Control Release, so the increase in inundation simulated for this particular event should not be considered typical of the system behavior. It is likely that the extent of inundation for many smaller events would be decreased compared to the Baseline scenario. In addition, if the simulated event had followed multiple very dry years, leaving the reservoirs relative empty under all scenarios (such as occurs after the four consecutive dry years in Model Years 20 to 23), the Interlake Tunnel and Spillway Raise would have resulted in an overall reduction in inundation, as the reservoirs would have had more capacity to absorb the very large inflow event.

8.0 MODIFIED NACIMIENTO DAM LLOW SCENARIO

As an alternative to the Interlake Tunnel and Spillway Raise, MCWRA is investigating modification of the Low-Level Outlet Works (LLOW) at Nacimiento Dam to increase its release capacity. This would allow Nacimiento Reservoir to release more water when reservoir stage is below the inlet to the High-Level Outlet Works (HLOW) at 755 ft above msl, potentially allowing the reservoirs to continue to meet downstream requirements in cases where San Antonio Reservoir is storage-limited and demand is higher than the capacity of the existing LLOW.

8.1 SCENARIO DESIGN

The LLOW release capacity is currently limited to 460 cfs. Modifications to the LLOW would increase its capacity to more than 2,000 cfs at a reservoir stage of 800 ft above msl and around 1,700 cfs at the elevation of the HLOW inlet (755 ft above msl). Figure 4 shows the rating curve for the Nacimiento Dam LLOW used for this scenario.

The Baseline scenario has a storage requirement in place for various different aspects of reservoir operations, including portions of the Flow Prescription and the SRDF. In the case of the SRDF, the reservoirs must have a combined storage of at least 145,000 af at some point between March 15 and April 30 for releases to be made, and San Antonio Reservoir must hold at least 55,000 af. This storage requirement for San Antonio Reservoir is in place because the release capacity limitation at Nacimiento Reservoir generally prevents it from being able to supply SRDF on its own at low reservoir stage elevations. San Antonio Reservoir, on the other hand, can release at a high enough capacity to supply SRDF on its own, even at low stage, so there is not similar specific storage requirement for Nacimiento Reservoir. Because the modified Nacimiento Dam LLOW would allow for much higher release capacity, the San Antonio Reservoir storage requirement was removed for this scenario; the reservoirs must still have a combined storage of 145,000 af at some point between March 15 and April 30, but it does not matter how that storage is distributed between the two reservoirs.

Other than the modified rating curve for the LLOW and the removal of the storage requirement at San Antonio Reservoir, there were no other changes for this scenario. Operations were identical to the Baseline scenario, including the prioritization of release from Nacimiento Reservoir.

8.2 SCENARIO RESULTS

This section presents the results of the Modified Nacimiento Dam LLOW scenario. Table 1 includes a summary of results from the this and other scenarios; Table 9 provides a more extensive set of results for just the Modified Nacimiento Dam LLOW scenario.

8.2.1 Storage and Stage

Figure 19 shows time series of storage and stage in Nacimiento and San Antonio Reservoirs under the Modified Nacimiento Dam LLOW scenario. The reservoirs attain a maximum storage of about 687,000 acre-feet (af), about 5,000 af higher than the maximum storage under the Baseline scenario. Nacimiento Reservoir reaches a maximum stage of 800 feet above mean sea level (msl; storage of about 378,000 af), equal to the spillway elevation. San Antonio Reservoir reaches a maximum stage of 775 feet above msl (storage of about 310,000 af), about 5 feet below the elevation of the spillway crest.

Figure 7 shows the entire range of storage and stage values for the two reservoirs (and storage for the combined reservoirs), colored by quartile. The charts in this figure show that storage in Nacimiento Reservoir under the Modified Nacimiento Dam LLOW scenario is somewhat lower than under the Baseline scenario (the average storage of about 167,000 af is about 17,000 af lower than the Baseline scenario average storage, while the median storage of about 165,000 af is about 6,000 af lower than the Baseline scenario median storage). In San Antonio Reservoir, storage under the Modified Nacimiento Dam LLOW scenario is also slightly higher than under the Baseline scenario (the average storage of about 101,000 af is about 3,000 af higher than the Baseline scenario average storage, while the median storage of about 79,000 af is about 12,000 af higher than the Baseline scenario median storage). On average, combined storage is slightly lower than under the Baseline scenario (the average storage of about 267,000 af is about 14,000 af lower than the Baseline scenario average storage, while the median storage of about 255,000 af is identical to the Baseline scenario median storage). These results indicate that, with the increased release capacity through the Nacimiento Dam LLOW, combined storage in the reservoirs would be somewhat lower as the reservoirs release additional water to meet demands, with higher storage in San Antonio Reservoir and lower storage in Nacimiento Reservoir.

Monthly average and median storage and stage values for Nacimiento and San Antonio Reservoirs (and combined reservoir storage) under the Modified Nacimiento Dam LLOW scenario are presented in Figure 20. Monthly average storage and stage values are uniformly lower in Nacimiento Reservoir compared to the Baseline scenario, showing that the increased release capacity decreases storage in Nacimiento Reservoir (Figures 20a and 20b). Monthly median storage values are typically lower compared to the Baseline scenario, although median storages are higher early in the Conservation Release Season. Monthly average storage in Nacimiento Reservoir is 11,000 to 21,000 af lower than under the Baseline scenario, and monthly average stage is 4 to 10 feet lower.

Conversely, monthly average storage and stage are slightly higher in San Antonio Reservoir (Figures 20c and 20d) compared to the Baseline scenario. Monthly average storage in San Antonio Reservoir is 3,000 to 6,000 af higher than under the Baseline scenario, and monthly average stage is 0 to 2 feet higher. Differences between median monthly storage and stage in San Antonio Reservoir under the Modified Nacimiento Dam LLOW and Baseline scenarios is more variable, with some months showing a positive difference and others a negative difference; this indicates that, overall, storage changes in San Antonio Reservoir are fairly minor.

Overall, the combined storage in the two reservoirs is slightly lower than under the Baseline scenario. Monthly average storage is between 8,000 and 16,000 af lower than under the Baseline scenario (Figure 20e). The individual reservoir storage and stage values described in the previous two paragraphs indicate that this decrease in storage is a result of the decrease in storage in Nacimiento Reservoir, which is greater in magnitude than the small increase in storage at San Antonio Reservoir. This indicates that the increased outlet works capacity at Nacimiento Dam allows for more release from Nacimiento Reservoir (hence a lower storage), without substantially affecting conditions in San Antonio Reservoir.

8.2.2 Reservoir Releases

As noted in Section 3.3, reservoir releases are categorized into four different types, depending on their purpose: Flood Control Release, Environmental Release, Conservation Release, and Over-Release. Figure 9 shows the average annual release volume (in af) for all water year types as well as for wet, normal and dry water years, with subcategorized releases shown on Figure 10. These average volumes are also presented in Table 9.

Releases under the Modified Nacimiento Dam LLOW scenario averaged about 250,000 afy from the two reservoirs combined, about 2,000 afy more than under the Baseline scenario, since the amount of inflow to the reservoirs is unchanged. About 181,000 afy of the total release comes from Nacimiento Reservoir (about 29,000 afy more than under the Baseline scenario) and about 69,000 afy comes from San Antonio Reservoir (about 26,000 afy less than under the Baseline scenario). During wet water years, releases averaged about 339,000 afy (about 19,000 more than under the Baseline scenario), with about 289,000 afy coming from Nacimiento Reservoir and about 50,000 afy from San Antonio Reservoir. Normal water years saw about 252,000 afy of release (about 19,000 afy more than under the Baseline scenario), with about 163,000 afy from Nacimiento Reservoir and about 89,000 afy from San Antonio Reservoir. Dry water years had about 149,000 afy of release on average (about 43,000 afy less than under the Baseline scenario), with about 96,000 afy coming from Nacimiento Reservoir and about 53,000 afy from San Antonio Reservoir.

On average, the reservoirs release about 50,000 afy as Flood Control Releases under the Modified Nacimiento Dam LLOW scenario (about 7,000 afy less than under the Baseline scenario), with about 95% (about 48,000 afy) coming from Nacimiento Reservoir and 5% (about 2,000 afy) coming from San Antonio Reservoir. As under the Baseline scenario, Flood Control Releases occur most prominently during wet years (averaging 154,000 afy). Flood Control Releases are completely absent from dry water years (Figure 9). Some Flood Control Release occurs in 85% of wet water years, 32% of normal water years, and none in dry water years.

On average, the reservoirs release about 39,000 afy of Environmental Releases (32,000 afy of fish and wildlife habitat releases and 6,000 afy of fish passage releases) under the Modified Nacimiento Dam LLOW scenario, about 4,000 afy less than under the Baseline scenario. The decrease in Environmental Releases is due to decreases in both fish and wildelife habitat releases and fish passage releases. Of the average annual Environmental Release volume, 87% (about 34,000 afy) comes from Nacimiento Reservoir, with the remaining 13% (about 5,000 afy) coming from San Antonio Reservoir. Fish and wildlife habitat releases make up about 84% of the Environmental Releases, and are very uniform across year types (Figure 10). Fish passage releases make up the remaining 16% of Environmental Releases, and are heavily weighted toward normal year types, when most of the Flow Prescription requirements are active.

On average, the reservoirs release about 146,000 afy of Conservation Releases under the Modified Nacimiento Dam LLOW scenario, about 12,000 afy more than under the Baseline scenario. Of the average annual release volume, 62% (about 91,000 afy) comes from Nacimiento Reservoir, with the remaining 38% (about 55,000 afy) coming from San Antonio Reservoir. Conservation Releases average about 145,000 afy in wet years; 171,000 afy in normal years; and 103,000 afy in dry years (Figure 9). Section 8.2.3 provides a more detailed analysis of the Conservation Releases.

The average reservoir release numbers for the Modified Nacimiento Dam LLOW scenario indicate that there is a decline in the amount of Flood Control Release at Nacimiento Reservoir, with this water instead being used for Conservation Release, especially during dry years (Nacimiento Reservoir makes about 60,000 afy of Conservation Release during dry years, about 19,000 afy more than under the Baseline Scenario). Since the increased release capacity at Nacimiento Reservoir does not result in any modifications to the ability of the reservoirs to store water, the reduction in Flood Control Release must result from lower storage going into the wet winters. Indeed, monthly average storage in Nacimiento Reservoir is between 19,000 and 21,000 af lower than under the Baseline Scenario. This lower storage leaves more available storage capacity leading into wet winter months.

8.2.3 Conservation Releases

This section provides further detail on Conservation Releases under the Modified Nacimiento Dam LLOW scenario. See Section 4.2.3 for information on how the categorization presented here was performed.

Figure 10 shows the average annual releases, with Conservation Releases broken up into subcategories; averages are included in Table 3. Of the 130,000 afy of average annual Conservation Release, 6% (about 8,000 afy) is diverted at SRDF, and 94% (about 122,000 afy) leaves the Salinas River along the riparian corridor. During wet years, SRDF Diversion makes up 8% of Conservation Releases (about 9,000 afy) and Conveyance Losses 92% (about 109,000 afy). During normal years, SRDF Diversion makes up 7% of Conservation Releases (about 9,000 afy) and Conveyance Losses 93% (about 123,000 afy). During dry years, SRDF Diversion makes up 3% of Conservation Releases (about 5,000 afy) and Conveyance Losses 97% (about 137,000 afy). All of the percentages presented here are similar to those simulated under the Baseline scenario, indicating that more than 90% of Conservation Releases are lost along the riparian corridor, largely irrespective of the year type or magnitude of release.

8.2.4 SRDF Operations

Table 4 provides details on the SRDF operations for the Modified Nacimiento Dam LLOW scenario, as well as a comparison to the SRDF Operations simulated under the Baseline scenario (see Section 4.2.4 for more description of the SRDF and its operations). Across all year types, an average Conservation Release Season sees 143 days of diversion (8 days longer than under the Baseline scenario), with about 10,000 afy diverted (about 1,000 af more than under the Baseline scenario). Wet years average 214 days of diversion, with about 15,000 afy diverted; normal years average 147 days of diversion, with about 10,000 afy diverted; and dry years average 60 days of diversion, with about 4,000 afy diverted. All told, 49% of Conservation Release Seasons are full (214 days long), 32% are partial, and 19% are failed. For the partial seasons, the average length was about 121 days.

8.2.5 Groundwater Budget

Details on the groundwater budget approach for this TM are provided in Section 4.2.5. Figure 21 and Table 5 provide details on the groundwater budget for the Modified Nacimiento Dam LLOW scenario for the entire model domain. The largest groundwater budget components are groundwater pumping (Q_{well} = -109,000 afy) and groundwater-surface water exchange (Q_{sw} = +99,000 afy). Net exchange through the root zone indicates that evapotranspiration of groundwater is greater than percolation (Q_{rz} = -10,000 afy). Net seawater intrusion at the aquifer-ocean interface is about 4,000 afy (Q_{swi} = +4,000 afy). Net exchange with the drains (Q_{drain}) and exchange with adjacent basins (Q_{land}) are very minor (<1,000 afy). The sum of all these water budget components is a net loss of storage averaging about 17,000 afy (ΔS = -17,000 afy). These water budget numbers are nearly identical to those of the Baseline scenario.

Water budget components for wet, normal, and dry water years are also shown on Figure 21 and Table 5. As under the Baseline scenario, most of the individual water budget components do not change substantially in different year types. The biggest differences are in net groundwater/surface water exchange (Q_{sw} is about +143,000 afy in wet years, +93,000 afy in normal years, and +62,000 afy in dry years) and change in storage (ΔS is about +26,000 afy in wet years, -23,000 afy in normal years, and -51,000 afy in dry years).

The groundwater budget results presented here indicate that, under the Modified Nacimiento Dam LLOW scenario, the groundwater basin remains out of balance by about 17,000 afy (the average annual storage loss) with the increased release capacity from Nacimiento Reservoir, about 1,000 afy more than under the Baseline scenario. The largest difference from the Baseline scenario is an increase in the amount of groundwater/surface water exchange during dry years (+62,000 afy versus +58,000 afy under the Baseline scenario), and an associated decrease in the loss of storage (51,000 afy versus 53,000 afy under the Baseline scenario). These differences are smaller in magnitude than those simulated under the Tunnel-Only scenario (see Section 5.2.7).

8.3 SCENARIO SUMMARY

The Modified Nacimiento Dam LLOW scenario simulates conditions in the basin with increased release capacity through the outlet works at Nacimiento Dam. Otherwise, this scenario is identical to the Baseline scenario. Therefore, comparing this scenario to the Baseline scenario demonstrates the impact of the increased release capacity.

- The LLOW modification results in less water in storage in Nacimiento Reservoir (average of about 167,000 af, about 17,000 af less than under the Baseline scenario) and more water in storage in San Antonio Reservoir (average of about 101,000 af, about 3,000 af more than under the Baseline scenario), with the combined storage in the two reservoirs generally lower (average of about 267,000 af, about 14,000 af less than under the Baseline scenario).
- Flood Control Releases decrease by 13% (about 50,000 afy under the Modified Nacimiento Dam LLOW scenario, about 7,000 afy lower than under the Baseline scenario), with 95% of releases coming from Nacimiento Reservoir (versus 96% under the Baseline scenario) and 5% coming from San Antonio Reservoir (versus 4% under the Baseline scenario).
- Conservation Releases increase by 9% (about 146,000 afy under the Modified Nacimiento Dam LLOW scenario, about 12,000 afy higher than under the Baseline scenario), with 62% of releases coming from Nacimiento Reservoir (versus 60% under the Baseline scenario) and 38% coming from San Antonio Reservoir (versus 40% under the Baseline scenario); Conservation Releases are slightly smaller in wet water years, but increased by about 14,000 afy in normal water years and 21,000 afy during dry water years.
- Operation of the SRDF is increased in terms of length of the season (143 days on average, 8 days longer than the average season under the Baseline scenario) with slightly more water diverted and fewer seasons where there is no diversion at SRDF.
- Impact on the groundwater budget is fairly small, except for a general increase in streamflow losses to the groundwater system during dry years that results in less storage loss during those same years. Storage loss overall was about the same (17,000 afy, about 1,000 afy more than under the Baseline scenario).

These results demonstrate the impact that the modification to the Nacimiento Dam outlet works would have on the system, in terms of slightly decreasing the amount of water held in storage, decreasing the volume of Flood Control Releases, and increasing the volume of water used Conservation Releases. This has positive impacts on the operation of the SRDF, while also increasing the amount of water recharged to the Basin along the riparian corridor, especially during dry years.

9.0 CLIMATE CHANGE ANALYSIS

This section describes the simulated impact of climate change on the Project scenarios described in Sections 5 and 6. The intent of this analysis is to provide an initial indication of the magnitude of change that might be expected to the system with the Interlake Tunnel and Spillway Raise in place under a modified climate.

The climate change impacts analyzed here are meant to be representative of estimated 2070 climate conditions throughout the model duration, rather than climate change over some period (e.g., 47 years starting in 2015). This is consistent with approaches taken by the California Department of Water Resources (DWR) for analyzing groundwater impacts of climate change for Groundwater Sustainability Planning purposes, for example.

In general, the climate conditions used here are warmer and wetter compared to the historical hydrology (both climate change scenarios use a central tendency climate future, meaning that it represents fairly average climate change for 2070). The increased wetness has a substantial effect on conditions in the reservoirs, as described in Section 9.2. The data products made available by DWR assume a particular climate future, but this is not the only possibility, and there is a wide envelope of potential climate futures that may lead to very different conditions from those shown here by 2070. The reader should keep in mind that the results of these climate change scenarios are in no way meant to be a specific prediction of the future, and instead give an indication of the simulated effect of one of a range of possible climate futures on conditions in the basin.

9.1 MODIFICATIONS FOR CLIMATE CHANGE ANALYSIS

In general, there are four places where climate change directly impacts the groundwater model system: climate inputs (precipitation and potential evapotranspiration; streamflow inputs; sea level along the ocean boundaries; and, land use. Data sources and approaches for each of the categories are described in the subsections below. Different approaches were taken within the active model grid and for the reservoirs. Modifications are described in more detail in Appendix B.

9.1.1 Climate Inputs Within Active Model Grid

Gridded climate data (precipitation and potential evapotranspiration) for the climate change scenarios were developed based on products provided by DWR, as described in Appendix B. These gridded data were developed by the Salinas Valley Basin Groundwater Sustainability Agency (SVBGSA) for development of the basin Groundwater Sustainability Plans (GSPs), and were provided to MCWRA by SVBGSA.

9.1.2 Climate Inputs for Reservoirs

Precipitation and evaporation time series for the reservoirs were developed using the same approach as the gridded climate data used as inputs to the numerical model grid (see Appendix B). These time series were also developed by SVBGSA and provided to MCWRA. Precipitation and evaporation rates were multiplied by the reservoir area to determine a monthly volume of precipitation entering or evaporation leaving each reservoir.

9.1.3 Streamflow Inputs to Active Model Grid

As with the gridded climate data, DWR provides products that were used to develop time series of streamflow entering the numerical model grid along its lateral boundaries, as detailed in Appendix B. These time series were developed by the SVBGSA and provided to MCWRA.

9.1.4 Streamflow Inputs to SWO

Additional streamflow time series were developed for the climate change scenarios as input to SWO, including:

- daily inflow to Nacimiento Reservoir,
- daily inflow to San Antonio Reservoir,
- mean daily streamflow at the USGS Arroyo Seco near Soledad stream gauge, and
- mean daily streamflow at the USGS Nacimiento River below Sapaque Creek near Bryson gauge.

The first two are inputs to the reservoir balance calculated by SWO. The last two are used to determine the timing and duration of block flows and the year type. The process of development of these modified streamflow values was similar to that of the streamflow boundary conditions to the active model grid, and more details are provided in Appendix B. The modified streamflow time series were developed by SVBGSA and provided to MCWRA. Overall, reservoir inflow is about 20% higher for the climate change scenarios compared to the Baseline scenario, indicating that the modeling tools used to prepare the DWR climate and hydrology products envision a wetter climate in the Salinas River watershed by 2070.

Because streamflow in Arroyo Seco is used to determine the year type, there are changes to the distribution of year types under the climate change scenarios. For the Baseline and Project scenarios (without climate change), 28% of model years are wet, 47% are normal, and 26% are dry. For the climate change scenarios, 32% of model years are wet, 40% are normal, and 28% are dry.

9.1.5 Sea Level Rise

A uniform elevation increase of 45 cm was applied to the boundary condition representing the interface between the freshwater aquifers and the ocean, as described in Appendix B. The modified boundary condition was developed by SVBGSA and provided to MCWRA.

9.1.6 Land Use

Land use, representing vegetation on the land surface, is defined throughout uppermost layer of the model grid. Land use data for the climate change scenarios were developed by the USGS and provided to MCWRA. More information is provided in Appendix B.

9.2 Climate Change Scenario Results

The modifications described in Section 9.1 were applied to the Tunnel-Only and Tunnel Plus 7′ Spillway Raise scenarios to examine the impact of changing climate conditions on the Project. This section describes the effect of a changing climate on conditions within the Basin, comparing results from the climate change scenarios to the scenario results described in Sections 5.2 and 6.2.

9.2.1 Tunnel-Only Scenario with 2070 Climate Change

This section describes the results of the Tunnel-Only scenario under 2070 climate change conditions. This scenario is compared only to the Tunnel-Only scenario because a comparison to the Baseline scenario would not be informative, since differences between this scenario and the Baseline scenario would be due to both the Interlake Tunnel and climate change, and it would be impossible to tease out which is driving each difference.

9.2.1.1 Storage and Stage

Figure 22 shows time series of storage and stage in Nacimiento and San Antonio Reservoirs under the Tunnel-Only scenario with 2070 climate change. The reservoirs attain a maximum combined storage of about 760,000 af, about 32,000 af higher than the maximum storage under the Tunnel-Only scenario. Nacimiento Reservoir reaches a maximum stage of 804 feet above msl (storage of about 404,000 af), about four feet above the spillway elevation. San Antonio Reservoir reaches a maximum stage of 786 feet above msl (storage of about 371,000 af); this is about six feet above the spillway crest elevation. These maximum storage and stage values are all higher than those attained under the Tunnel-Only scenario.

Figure 23 shows the entire range of storage and stage values for the two reservoirs (and storage for the combined reservoirs), colored by quartile. The charts in this figure show that storage in Nacimiento Reservoir under the Tunnel-Only scenario with 2070 Climate Change tends to be substantially higher than under the Tunnel-Only scenario (the average storage of about 161,000 af is about 29,000 af higher than the Tunnel-Only scenario average storage, while the median storage of about 149,000 af is about 50,000 af higher than the Tunnel-Only scenario median storage). In San Antonio Reservoir, storage under the Tunnel-Only scenario with 2070 Climate Change is also substantially higher than under the Tunnel-Only scenario (the average storage of about 213,000 af is about 25,000 af higher than the Tunnel-Only scenario average storage, while the median storage of about 288,000 af is about 50,000 af higher than the Tunnel-Only scenario median storage). Combined storage is similarly much higher than under the Tunnel-Only scenario (the average storage of about 375,000 af is about 55,000 af higher than the Tunnel-Only scenario average storage, while the median storage of about 425,000 af is about 79,000 af higher than the Tunnel-Only scenario median storage). These results indicate that the effect of the climate change used for this analysis is to greatly increase the amount of water typically in storage in the reservoirs.

Figure 24 shows the monthly average and median storage and stage for the Tunnel-Only scenario with 2070 Climate Change. At Nacimiento Reservoir, monthly average storage is noticeably higher (by 24,000 to 35,000 af) than under the Tunnel-Only scenario, as is stage (by 7 to 10 feet). Both average and median storage and stage are higher for every month under every year type. At San Antonio Reservoir, monthly average storage is higher (by 20,000 to 31,000 af) than under the Tunnel-Only scenario, as is stage (by 5 to 10 feet). The largest changes at San Antonio Reservoir occur during dry years (average monthly storage increased by 35,000 to 55,000 af and average monthly stage increased by 8 to 21 feet), particularly near the end of the Conservation Release Season. Changes to median monthly storage and stage are almost entirely positive in direction, except for Septembers of dry years, which see a slight decrease in median storage (by 7,000 af) and stage (by 8 feet) compared to the Tunnel-Only scenario; this indicates that there are more occurrences of very low storage in San Antonio Reservoir at the end of the Conservation Release Season, a consequence of the reservoirs being able to operate for longer periods of time under climate change conditions.

The simulated storage and stage values for the Tunnel-Only scenario with 2070 Climate Change demonstrate that the system is substantially wetter under the particular set of climate change conditions provided by DWR. This results in increased storage in both reservoirs across a variety of conditions.

9.2.1.2 Reservoir Releases

As noted in Section 3.3, reservoir releases are categorized into four different types, depending on their purpose: Flood Control Release, Environmental Release, Conservation Release, and Over-Release. Figure 25 shows the average annual release volume (in af) for all water year types as well as for wet, normal, and dry water years. These average volumes are also presented in Table 10.

Releases under the Tunnel-Only scenario with 2070 Climate Change averaged about 298,000 acre-feet per year (afy) from the two reservoirs combined, about 51,000 afy more than under the Tunnel-Only scenario, since inflow to the reservoirs is increased. About 190,000 afy of the total release comes from Nacimiento Reservoir (about 38,000 afy more than under the Tunnel-Only scenario) and about 108,000 afy comes from San Antonio Reservoir (about 13,000 afy more than under the Tunnel-Only scenario). During wet water years, releases averaged about 393,000 afy (about 72,000 afy more than under the Tunnel-Only scenario), with about 290,000 afy coming from Nacimiento Reservoir and about 103,000 afy from San Antonio Reservoir. Normal water years saw about 274,000 afy of release (about 41,000 afy more than under the Tunnel-Only scenario), with about 176,000 afy from Nacimiento Reservoir and about 98,000 afy from San Antonio Reservoir. Dry water years had about 223,000 afy of release on average (about 31,000 afy more than under the Tunnel-Only scenario), with about 96,000 afy coming from Nacimiento Reservoir and about 127,000 afy from San Antonio Reservoir.

On average, the reservoirs release about 96,000 acre-feet per year (afy) as Flood Control Releases under the Tunnel-Only scenario with 2070 Climate Change (about 50,000 afy more than under the Tunnel-Only scenario), with about 65% (about 62,000 afy) coming from Nacimiento Reservoir and 35% (about 34,000 afy) coming from San Antonio Reservoir. As under the Tunnel-Only scenario, Flood Control Releases occur most prominently during wet water years (averaging 234,000 afy). Some Flood Control Release occurs in 93% of wet water years, 58% of normal water years, and 31% of dry water years.

On average, the reservoirs release about 62,000 afy of Environmental Releases (27,000 afy of fish and wildlife habitat releases and 35,000 afy of fish passage releases) under the Tunnel-Only scenario with 2070 Climate Change, about 23,000 afy more than under the Tunnel-Only scenario. The increase in Environmental Releases is due almost entirely to increased fish passage releases. Of the average annual Environmental Release volume, 54% (about 34,000 afy) comes from Nacimiento Reservoir, with the remaining 46% (about 28,000 afy) coming from San Antonio Reservoir. Fish and wildlife habitat releases make up about 43% of the Environmental Releases, and are very uniform across year types (Figure 26). Fish passage releases (made to meet streamflow requirements within the Salinas River to support steelhead migration) make up the remaining 57% of Environmental Releases, and are heavily weighted toward normal and dry year types, when most of the Flow Prescription requirements are active.

On average, the reservoirs release about 130,000 afy of Conservation Releases under the Tunnel-Only scenario with 2070 Climate Change, about 20,000 afy less than under the Tunnel-Only scenario. Of the average annual release volume, 68% (about 88,000 afy) comes from Nacimiento Reservoir, with the remaining 32% (about 42,000 afy) coming from San Antonio Reservoir. Conservation Releases average about 119,000 afy in wet years, 132,000 afy in normal years, and 142,000 afy in dry years (Figure 25). Section 9.2.1.3 provides a more detailed analysis of the Conservation Releases.

The average reservoir release numbers for the Tunnel-Only scenario with 2070 Climate Change indicate that the generally wetter climate conditions lead to much larger average annual release volumes across all year types. This is almost entirely manifested as an increase in the average annual Flood Control Release (about 50,000 afy more than under the Tunnel-Only scenario), with almost no change in non-Flood Control Release (about 2,000 afy more than under the Tunnel-Only scenario), with some rearrangement from Conservation Release (about 20,000 afy less than under the Tunnel-Only scenario) to Environmental Release (about 23,000 afy more than under the Tunnel-Only scenario).

9.2.1.3 Conservation Releases

This section provides further detail on Conservation Releases under the Tunnel-Only scenario with 2070 Climate Change. See Section 4.2.3 for information on how the categorization presented here was performed.

Figure 26 shows the average annual releases, with Conservation Releases broken up into subcategories; averages are included in Table 3. Of the 130,000 afy of average annual Conservation Release, 6% (about 8,000 afy) is diverted at SRDF, with the remaining 94% (about 122,000 afy) leaves the Salinas River along the riparian corridor. During wet years, SRDF Diversion makes up 7% of Conservation Releases (about 9,000 afy) and Conveyance Losses 93% (about 110,000 afy). During normal years, SRDF Diversion makes up 6% of Conservation Releases (about 8,000 afy) and Conveyance Losses 94% (about 124,000 afy). During dry years, SRDF Diversion makes up 5% of Conservation Releases (about 8,000 afy), and Conveyance Losses 95% (about 134,000 afy). All of the percentages presented here are nearly identical to those simulated under the Tunnel-Only scenario, indicating that more than 90% of Conservation Releases are lost along the riparian corridor, largely irrespective of the year type or magnitude of release.

9.2.1.4 SRDF Operations

Table 4 provides details on the SRDF operations for the Tunnel-Only scenario with 2070 Climate Change, as well as a comparison to the SRDF Operations simulated under the Tunnel-Only scenario (see Section 4.2.4 for more description of the SRDF and its operations). Across all year types, an average Conservation Release Season sees 168 days of diversion (19 days longer than under the Tunnel-Only scenario), with about 12,000 afy diverted (about 1,000 af more than under the Tunnel-Only scenario). Wet years average 214 days of diversion, with about 15,000 afy diverted; normal years average 159 days of diversion, with about 11,000 afy diverted; and dry years average 126 days of diversion, with about 9,000 afy diverted. All told, 66% of Conservation Release Seasons are full (214 days long), 21% are partial, and 13% are failed. For the partial seasons, the average length was about 125 days.

These results indicate that the SRDF is able to operate more often and for a longer duration under the simulated 2070 climate change conditions. The average SRDF season is longer (by 19 days), with additional diversion. SRDF seasons are substantially more successful (66% full seasons versus 55% under the Tunnel-Only scenario and 21% partial seasons versus 19% under the Tunnel-Only scenario), but partial seasons are substantially shorter (125 days on average versus 160 days under the Tunnel-Only scenario) as partial seasons under the Tunnel-Only scenario convert to full seasons under the Tunnel-Only scenario with 2070 Climate Change.

9.2.1.5 Water Rights

As discussed in Section 5.2.5, water rights limitations were not in place for the Tunnel-Only scenario with 2070 Climate Change, but water rights accounting was still performed.

9.2.1.6 Tunnel Operations

Operations of the Interlake Tunnel are summarized in Table 1, with more detail provided in Table 7. On average, about 32,000 afy is transferred through the Interlake Tunnel under the Tunnel-Only scenario with 2070 Climate Change (about 2,000 afy more than under the Tunnel- Only scenario). The Interlake Tunnel is used in 60% of the Model Years, and on average operates for 53 days per year. Usage of the Interlake Tunnel is highly dependent on water year type. During wet water years, the Interlake Tunnel transfers about 75,000 afy under the Tunnel- Only scenario with 2070 Climate Change, transferring at least some water every year and on average operating for 108 days per year. During normal water years, the Interlake Tunnel transfers about 16,000 afy, transferring at least some water in 63% of years and on average operating for 42 days per year. During dry years, the Interlake Tunnel transfers about 6,000 afy, transferring at least some water in 8% of years and on average operating for 7 days per year.

As noted in Section 2.1, the Interlake Tunnel only transfers water if four conditions are met (stage in Nacimiento Reservoir is at least 760 feet above msl, stage in Nacimiento Reservoir is higher than stage in San Antonio Reservoir, San Antonio Reservoir has capacity available to receive the transferred water, and Nacimiento Reservoir stage is below 800 feet above msl). As noted above, the Interlake Tunnel on average transfers water 53 days per year under the Tunnel-Only scenario with 2070 Climate Change. Of the remaining days, the majority (220 days per year) had stage in Nacimiento Reservoir that was too low (i.e., below 760 feet above msl). An additional 48 days per year had stage in San Antonio Reservoir that was too close to the Flood Rule Curve, and 43 days per year had no tunnel transfer because stage in San Antonio Reservoir was at or above stage in Nacimiento Reservoir. Nacimiento Reservoir stage rising above 800 feet above msl was very rare, averaging less than one day per year. Figure 14 shows the distribution of Interlake Tunnel operations averaged across all water year types, and for wet, normal, and dry years.

9.2.1.7 Groundwater Budget

Details on the groundwater budget approach for this TM are provided in Section 4.2.5. Figure 27 and Table 5 provide details on the groundwater budget for the Tunnel-Only scenario with 2070 Climate Change for the entire model domain. The largest groundwater budget components are groundwater-surface water exchange (Q_{sw} = +103,000 afy) and groundwater pumping (Q_{well} = -99,000 afy). Net exchange through the root zone indicates that evapotranspiration of groundwater is greater than percolation (Q_{rz} = -21,000 afy). Net seawater intrusion at the aquifer-ocean interface is about 4,000 afy (Q_{swi} = +4,000 afy). Net exchange with the drains (Q_{drain}) and exchange with adjacent basins (Q_{land}) are very minor (<1,000 afy).

The sum of all these water budget components is a net loss of storage averaging about 14,000 afy (ΔS = -14,000 afy). These water budget numbers, compared to the Tunnel-Only scenario, show slightly more stream loss, less groundwater pumping, and more evapotranspiration of groundwater, with a net result of a slightly decreased average annual storage loss (14,000 afy compared to 16,000 afy under the Tunnel-Only scenario).

Water budget components for wet, normal, and dry water years are also shown on Figure 27 and Table 5. As under the Tunnel-Only scenario, most of the individual water budget components do not change substantially in different year types. The biggest differences are in net groundwater/surface water exchange (Q_{sw} is about +144,000 afy in wet years, +95,000 afy in normal years, and +73,000 afy in dry years) and change in storage (ΔS is about +26,000 afy in wet years, -23,000 afy in normal years, and -41,000 afy in dry years).

The groundwater budget results presented here indicate that, under the Tunnel-Only scenario with 2070 Climate Change, the groundwater basin remains out of balance by about 14,000 afy, slightly less than was simulated without climate change (see Section 5.2.7). An overall increase in wetness in the basin results in an increase in streamflow losses, more access to groundwater within the root zone, and less groundwater pumping to supply crop demands under a higher potential evapotranspiration. The overall effect (as measured by storage loss) is relatively minor.

9.2.1.8 Scenario Summary

The Tunnel-Only scenario with 2070 Climate Change is identical to the Tunnel-Only scenario, except for the changes to hydrology and land use described in Section 9.1. Therefore, comparing the results of this scenario to the Tunnel-Only scenario demonstrates the impact of the selected climate change future on the system with the Interlake Tunnel in place.

- 2070 climate change results in more water in storage in Nacimiento Reservoir (average of about 161,000 af, about 29,000 af more than under the Tunnel-Only scenario) and in San Antonio Reservoir (average of about 213,000 af, about 25,000 af more than under the Tunnel-Only scenario), with the combined storage in the two reservoirs higher (average of about 375,000 af, about 55,000 af more than under the Tunnel-Only scenario).
- Flood Control Releases more than double (about 96,000 afy, about 50,000 afy more than under the Tunnel-Only scenario), with 65% of releases coming from

Nacimiento Reservoir (versus 59% under the Tunnel-Only scenario) and 35% coming from San Antonio Reservoir (versus 41% under the Tunnel-Only scenario).

- Conservation Releases decrease by 13% (about 130,000 afy under the Tunnel-Only scenario with 2070 Climate Change, about 20,000 afy lower than under the Tunnel-Only scenario), with 68% of releases coming from Nacimiento Reservoir (versus 59% under the Tunnel-Only scenario) and 32% coming from San Antonio Reservoir (versus 41% under the Tunnel-Only scenario); Conservation Releases decrease in all year types.
- Operation of the SRDF is increased in terms of length of the season (168 days on average, 19 days longer than the average season under the Tunnel-Only scenario) with more water diverted, and fewer seasons where there is no diversion at SRDF.
- The Interlake Tunnel transfers about 32,000 afy (2,000 afy more than under the Tunnel-Only scenario), operating during 60% of years and for 53 days per year on average.
- Overall impact on the groundwater budget is fairly small, with an increase in streamflow loss, decrease in groundwater pumping, and increase in groundwater evapotranspiration leading to a slight decrease in average annual storage loss (14,000 afy, about 2,000 afy less than under the Tunnel-Only scenario).

These results demonstrate the impact of the chosen climate future on conditions within the basin with the Interlake Tunnel active. Overall, there is more water in the reservoirs because the watershed is wetter. This results in a large increase in the amount of Flood Control Release (about 50,000 afy) as the reservoirs are usually fuller than they were under the Tunnel-Only scenario. The relatively minor increase in non-Flood Control Releases (about 2,000 afy) indicates that, although the reservoirs are generally fuller than they are without climate change, that additional water is not put to beneficial use. However, because the system is generally wetter overall, SRDF operates more frequently and for longer duration.

9.2.2 Tunnel Plus 7' Spillway Raise Scenario with 2070 Climate Change

This section describes the results of the Tunnel Plus 7’ Spillway Raise scenario under 2070 climate change conditions. This scenario is compared only to the Tunnel Plus 7’ Spillway Raise scenario because a comparison to the Baseline or Tunnel-Only scenario would not be informative, since differences between this scenario and the Baseline or Tunnel-Only scenario would be due to a combination of the Interlake Tunnel, the raised spillway at San Antonio Dam, and climate change, and it would be impossible to tease out which is driving each difference.

9.2.2.1 Storage and Stage

Figure 28 shows time series of storage and stage in Nacimiento and San Antonio Reservoirs under the Tunnel Plus 7′ Spillway Raise scenario with 2070 climate change. The reservoirs attain a maximum storage of about 800,000 af, about 32,000 af higher than the maximum storage under the Tunnel Plus 7′ Spillway Raise scenario. Nacimiento Reservoir reaches a maximum stage of 804 feet above msl (storage of about 404,000 af), about four feet above the spillway elevation. San Antonio Reservoir reaches a maximum stage of 791 feet above msl (storage of about 401,000 af); this is about four feet above the spillway crest elevation. These maximum storage and stage values are all higher than those attained under the Tunnel Plus 7′ Spillway Raise scenario.

Figure 23 shows the entire range of storage and stage values for the two reservoirs (and storage for the combined reservoirs), colored by quartile. The charts in this figure show that storage in Nacimiento Reservoir under the Tunnel Plus 7′ Spillway Raise scenario with 2070 Climate Change tends to be substantially higher than under the Tunnel Plus 7′ Spillway Raise scenario (the average storage of about 170,000 af is about 35,000 af higher than the Tunnel Plus 7′ Spillway Raise scenario average storage, while the median storage of about 170,000 af is about 64,000 af higher than the Tunnel Plus 7′ Spillway Raise scenario median storage). In San Antonio Reservoir, storage under the Tunnel Plus 7′ Spillway Raise scenario with 2070 Climate Change is also substantially higher than under the Tunnel Plus 7′ Spillway Raise scenario (the average storage of about 234,000 af is about 35,000 af higher than the Tunnel Plus 7′ Spillway Raise scenario average storage, while the median storage of about 305,000 af is about 50,000 af higher than the Tunnel Plus 7′ Spillway Raise scenario median storage). Combined storage is similarly much higher than under the Tunnel Plus 7′ Spillway Raise scenario (the average storage of about 404,000 af is about 70,000 af higher than the Tunnel Plus 7′ Spillway Raise scenario average storage, while the median storage of about 462,000 af is about 101,000 af higher than the Tunnel Plus 7′ Spillway Raise scenario median storage). These results indicate that the effect of the climate change used for this analysis is to greatly increase the amount of water typically in storage in the reservoirs.

Figure 29 shows the monthly average and median storage and stage for the Tunnel Plus 7′ Spillway Raise scenario with 2070 Climate Change. At Nacimiento Reservoir, monthly average storage is noticeably higher (by 31,000 to 40,000 af) than under the Tunnel Plus 7′ Spillway

Raise scenario, as is stage (by 8 to 11 feet). Both average and median storage and stage are higher for every month under every year type. At San Antonio Reservoir, monthly average storage is higher (by 31,000 to 41,000 af) than under the Tunnel Plus 7′ Spillway Raise scenario, as is stage (by 8 to 12 feet). The largest changes at San Antonio Reservoir occur during dry years (average monthly storage increased by 44,000 to 65,000 af and average monthly stage increased by 12 to 24 feet), particularly near the end of the Conservation Release Season. Changes to median monthly storage and stage are almost entirely positive in direction, except for Septembers of dry years, which see a slight decrease in median storage (by 7,000 af) and stage (by 8 feet) compared to the Tunnel Plus 7′ Spillway Raise scenario; this indicates that there are more occurrences of very low storage in San Antonio Reservoir at the end of the Conservation Release Season, a consequence of the reservoirs being able to operate for longer periods of time under climate change conditions.

The simulated storage and stage values for the Tunnel Plus 7′ Spillway Raise scenario with 2070 Climate Change demonstrate that the system is substantially wetter under the particular set of climate change conditions provided by DWR. This results in increased storage in both reservoirs across a variety of conditions.

9.2.2.2 Reservoir Releases

As noted in Section 3.3, reservoir releases are categorized into four different types, depending on their purpose: Flood Control Release, Environmental Release, Conservation Release, and Over-Release. Figure 25 shows the average annual release volume (in af) for all water year types as well as for wet, normal, and dry water years. These average volumes are also presented in Table 11.

Releases under the Tunnel Plus 7′ Spillway Raise scenario with 2070 Climate Change averaged about 296,000 acre-feet per year (afy) from the two reservoirs combined, about 50,000 afy more than under the Tunnel Plus 7′ Spillway Raise scenario, since inflow to the reservoirs is increased. About 190,000 afy of the total release comes from Nacimiento Reservoir (about 38,000 afy more than under the Tunnel Plus 7′ Spillway Raise scenario) and about 106,000 afy comes from San Antonio Reservoir (about 13,000 afy more than under the Tunnel Plus 7′ Spillway Raise scenario). During wet water years, releases averaged about 388,000 afy (about 71,000 afy more than under the Tunnel Plus 7′ Spillway Raise scenario), with about 287,000 afy coming from Nacimiento Reservoir and about 101,000 afy from San Antonio Reservoir. Normal water years saw about 269,000 afy of release (about 38,000 afy more than under the Tunnel Plus 7’ Spillway Raise scenario), with about 171,000 afy from Nacimiento Reservoir and about 98,000 afy from San Antonio Reservoir. Dry water years had about 229,000 afy of release on average (about 34,000 afy more than under the Tunnel Plus 7’ Spillway Raise scenario), with about 106,000 afy coming from Nacimiento Reservoir and about 123,000 afy from San Antonio Reservoir.

On average, the reservoirs release about 88,000 acre-feet per year (afy) as Flood Control Releases under the Tunnel Plus 7’ Spillway Raise scenario with 2070 Climate Change (about 48,000 afy more than under the Tunnel Plus 7’ Spillway Raise scenario), with about 75% (about 66,000 afy) coming from Nacimiento Reservoir and 25% (about 32,000 afy) coming from San Antonio Reservoir. As under the Tunnel Plus 7’ Spillway Raise scenario, Flood Control Releases occur most prominently during wet water years (averaging 229,000 afy). Some Flood Control Release occurs in 93% of wet water years, 42% of normal water years, and 8% of dry water years.

On average, the reservoirs release about 67,000 afy of Environmental Releases (27,000 afy of fish and wildlife habitat releases and 40,000 afy of fish passage releases) under the Tunnel Plus 7’ Spillway Raise scenario with 2070 climate change, about 27,000 afy more than under the Tunnel Plus 7’ Spillway Raise scenario. The increase in Environmental Releases is due to increased fish passage releases. Of the average annual Environmental Release volume, 51% (about 34,000 afy) comes from Nacimiento Reservoir, with the remaining 49% (about 33,000 afy) coming from San Antonio Reservoir. Fish and wildlife habitat releases make up about 40% of the Environmental Releases, and are very uniform across year types (Figure 26). Fish passage releases (made to meet streamflow requirements within the Salinas River to support steelhead migration) make up the remaining 60% of Environmental Releases, and are heavily weighted toward normal and dry year types, when most of the Flow Prescription requirements are active.

On average, the reservoirs release about 131,000 afy of Conservation Releases under the Tunnel Plus 7’ Spillway Raise scenario with 2070 Climate Change, about 23,000 afy less than under the Tunnel Plus 7’ Spillway Raise scenario. Of the average annual release volume, 63% (about 83,000 afy) comes from Nacimiento Reservoir, with the remaining 37% (about 48,000 afy) coming from San Antonio Reservoir. Conservation Releases average about 120,000 afy in wet years, 131,000 afy in normal years, and 143,000 afy in dry years (Figure 25). Section 9.2.2.3 provides a more detailed analysis of the Conservation Releases.

The average reservoir release numbers for the Tunnel Plus 7′ Spillway Raise scenario with 2070 Climate Change indicate that the generally wetter climate conditions lead to much larger average annual release volumes across all year types. This is almost entirely manifested as an increase in the average annual Flood Control Release (about 48,000 afy more than under the Tunnel Plus 7′ Spillway Raise scenario), with almost no change in non-Flood Control Release (about 2,000 afy more than under the Tunnel Plus 7′ Spillway Raise scenario), with some rearrangement from Conservation Release (about 23,000 afy less than under the Tunnel Plus 7′ Spillway Raise scenario) to Environmental Release (about 27,000 afy more than under the Tunnel Plus 7′ Spillway Raise scenario).

9.2.2.3 Conservation Releases

This section provides further detail on Conservation Releases under the Tunnel Plus 7′ Spillway Raise scenario with 2070 Climate Change. See Section 4.2.3 for information on how the categorization presented here was performed.

Figure 26 shows the average annual releases, with Conservation Releases broken up into subcategories; averages are included in Table 3. Of the 131,000 afy of average annual Conservation Release, 6% (about 8,000 afy) is diverted at SRDF, with the remaining 94% (about 123,000 afy) leaves the Salinas River along the riparian corridor. During wet years, SRDF Diversion makes up 7% of Conservation Releases (about 9,000 afy) and Conveyance Losses 93% (about 111,000 afy). During normal years, SRDF Diversion makes up 6% of Conservation Releases (about 8,000 afy) and Conveyance Losses 94% (about 123,000 afy). During dry years, SRDF Diversion makes up 5% of Conservation Releases (about 8,000 afy), and Conveyance Losses 95% (about 136,000 afy). All of the percentages presented here are nearly identical to those simulated under the Tunnel Plus 7′ Spillway Raise scenario, indicating that more than 90% of Conservation Releases are lost along the riparian corridor, largely irrespective of the year type or magnitude of release.

9.2.2.4 SRDF Operations

Table 4 provides details on the SRDF operations for the Tunnel Plus 7′ Spillway Raise scenario with 2070 Climate Change, as well as a comparison to the SRDF Operations simulated under the Tunnel Plus 7′ Spillway Raise scenario (see Section 4.2.4 for more description of the SRDF and its operations). Across all year types, an average Conservation Release Season sees 173 days of diversion (22 days longer than under the Tunnel Plus 7′ Spillway Raise scenario), with about 12,000 afy diverted (about 2,000 af more than under the Tunnel Plus 7′ Spillway Raise scenario). Wet years average 214 days of diversion, with about 15,000 afy diverted; normal years average 167 days of diversion, with about 12,000 afy diverted; and dry years average 133 days of diversion, with about 9,000 afy diverted. All told, 70% of Conservation Release Seasons are full (214 days long), 17% are partial, and 13% are failed. For the partial seasons, the average length was about 131 days.

These results indicate that the SRDF is able to operate more often and for a longer duration under the simulated 2070 climate change conditions. The average SRDF season is longer (by 22 days), with additional diversion. SRDF seasons are substantially more successful (70% full seasons versus 60% under the Tunnel Plus 7′ Spillway Raise scenario and 17% partial seasons versus 15% under the Tunnel Plus 7′ Spillway Raise scenario), but partial seasons are shorter (131 days on average versus 152 days under the Tunnel Plus 7′ Spillway Raise scenario) as partial seasons under the Tunnel Plus 7′ Spillway Raise scenario convert to full seasons under the Tunnel Plus 7′ Spillway Raise scenario with 2070 Climate Change.

9.2.2.5 Water Rights

As discussed in Section 5.2.5, water rights limitations were not in place for the Tunnel Plus 7′ Spillway Raise scenario with 2070 Climate Change, but water rights accounting was still performed.

9.2.2.6 Tunnel Operations

Operations of the Interlake Tunnel are summarized in Table 1, with more detail provided in Table 7. On average, about 32,000 afy is transferred through the Interlake Tunnel under the Tunnel Plus 7′ Spillway Raise scenario with 2070 Climate Change (about 2,000 afy more than under the Tunnel Plus 7′ Spillway Raise scenario). The Interlake Tunnel is used in 60% of the Model Years, and on average operates for 53 days per year. Usage of the Interlake Tunnel is highly dependent on water year type. During wet water years, the Interlake Tunnel transfers about 76,000 afy under the Tunnel Plus 7′ Spillway Raise scenario with 2070 Climate Change, transferring at least some water every year and on average operating for 108 days per year. During normal water years, the Interlake Tunnel transfers about 14,000 afy, transferring at least some water in 63% of years and on average operating for 42 days per year. During dry years, the Interlake Tunnel transfers about 6,000 afy, transferring at least some water in 8% of years and on average operating for 7 days per year.

As noted in Section 2.1, the Interlake Tunnel only transfers water if four conditions are met (stage in Nacimiento Reservoir is at least 760 feet above msl, stage in Nacimiento Reservoir is higher than stage in San Antonio Reservoir, San Antonio Reservoir has capacity available to receive the transferred water, and Nacimiento Reservoir stage is below 800 feet above msl). As noted above, the Interlake Tunnel on average transfers water 53 days per year under the Tunnel Plus 7′ Spillway Raise scenario with 2070 Climate Change. Of the remaining days, the majority (220 days per year) had stage in Nacimiento Reservoir that was too low (i.e., below 760 feet above msl). An additional 48 days per year had stage in San Antonio Reservoir that was too close to the Flood Rule Curve, and 43 days per year had no tunnel transfer because stage in San Antonio Reservoir was at or above stage in Nacimiento Reservoir. Nacimiento Reservoir stage rising above 800 feet above msl was very rare, averaging less than one day per year. Figure 14 shows the distribution of Interlake Tunnel operations averaged across all water year types, and for wet, normal, and dry years.

9.2.2.7 Groundwater Budget

Details on the groundwater budget approach for this TM are provided in Section 4.2.5. Figure 30 and Table 5 provide details on the groundwater budget for the Tunnel Plus 7’ Spillway Raise scenario with 2070 Climate Change for the entire model domain. The largest groundwater budget components are groundwater-surface water exchange (Q_{sw} = +103,000 afy) and groundwater pumping (Q_{well} = -99,000 afy). Net exchange through the root zone indicates that evapotranspiration of groundwater is greater than percolation (Q_{rz} = -21,000 afy). Net seawater intrusion at the aquifer-ocean interface is about 4,000 afy (Q_{swi} = +4,000 afy). Net exchange with the drains (Q_{drain}) and exchange with adjacent basins (Q_{land}) are very minor (<1,000 afy). The sum of all these water budget components is a net loss of storage averaging about 14,000 afy (ΔS = -14,000 afy). These water budget numbers, compared to the Tunnel Plus 7’ Spillway Raise scenario, show slightly more stream loss, less groundwater pumping, and more evapotranspiration of groundwater, with a net result of a slightly decreased average annual storage loss (14,000 afy compared to 16,000 afy under the Tunnel Plus 7’ Spillway Raise scenario). These water budget numbers are all approximately the same as under the Tunnel-Only scenario with 2070 Climate Change.

Water budget components for wet, normal, and dry water years are also shown on Figure 30 and Table 5. As under the Tunnel Plus 7’ Spillway Raise scenario, most of the individual water budget components do not change substantially in different year types. The biggest differences are in net groundwater/surface water exchange (Q_{sw} is about +143,000 afy in wet years, +95,000 afy in normal years, and +75,000 afy in dry years) and change in storage (ΔS is about +26,000 afy in wet years, -23,000 afy in normal years, and -41,000 afy in dry years).

The groundwater budget results presented here indicate that, under the Tunnel Plus 7’ Spillway Raise scenario with 2070 Climate Change, the groundwater basin remains out of balance by about 14,000 afy, slightly less than was simulated without climate change (see Section 6.2.7). An overall increase in wetness in the basin results in an increase in streamflow losses, more access to groundwater within the root zone, and less groundwater pumping to supply crop demands under a higher potential evapotranspiration. The overall effect (as measured by storage loss) is relatively minor.

9.2.2.8 Scenario Summary

The Tunnel Plus 7′ Spillway Raise scenario with 2070 Climate Change is identical to the Tunnel Plus 7′ Spillway Raise scenario, except for the changes to hydrology and land use described in Section 9.1. Therefore, comparing the results of this scenario to the Tunnel Plus 7′ Spillway Raise scenario demonstrates the impact of the selected climate change future on the system with the Interlake Tunnel in place and the raised spillway at San Antonio Dam.

- 2070 climate change results in more water in storage in Nacimiento Reservoir (average of about 170,000 af, about 35,000 af more than under the Tunnel Plus 7′ Spillway Raise scenario) and in San Antonio Reservoir (average of about 234,000 af, about 35,000 af more than under the Tunnel Plus 7′ Spillway Raise scenario), with the combined storage in the two reservoirs higher (average of about 404,000 af, about 70,000 af more than under the Tunnel Plus 7′ Spillway Raise scenario).
- Flood Control Releases more than double (about 88,000 afy, about 48,000 afy more than under the Tunnel-Only scenario), with 75% of releases coming from Nacimiento Reservoir (versus 69% under the Tunnel Plus 7′ Spillway Raise scenario) and 25% coming from San Antonio Reservoir (versus 31% under the Tunnel Plus 7′ Spillway Raise scenario).
- Conservation Releases decrease by 15% (about 131,000 afy under the Tunnel Plus 7′ Spillway Raise scenario with 2070 Climate Change, about 23,000 afy lower than under the Tunnel Plus 7′ Spillway Raise scenario), with 63% of releases coming from Nacimiento Reservoir (versus 56% under the Tunnel Plus 7′ Spillway Raise scenario) and 37% coming from San Antonio Reservoir (versus 44% under the Tunnel Plus 7′ Spillway Raise scenario); Conservation Releases decrease in all year types.
- Operation of the SRDF is increased in terms of length of the season (173 days on average, 22 days longer than the average season under the Tunnel Plus 7′ Spillway Raise scenario) with more water diverted, and fewer seasons where there is no diversion at SRDF.
- The Interlake Tunnel transfers about 32,000 afy (2,000 afy more than under the Tunnel Plus 7′ Spillway Raise scenario), operating during 60% of years and for 53 days per year on average.
- Overall impact on the groundwater budget is fairly small, with an increase in streamflow loss, decrease in groundwater pumping, and increase in groundwater evapotranspiration leading to a slight decrease in average annual storage loss (14,000 afy, about 2,000 afy less than under the Tunnel Plus 7′ Spillway Raise scenario).

These results demonstrate the impact of the chosen climate future on conditions within the basin with the Interlake Tunnel active and the spillway elevation at San Antonio Dam raised. Overall, there is more water in the reservoirs because the watershed is wetter. This results in a large increase in the amount of Flood Control Release (about 48,000 afy) as the reservoirs are usually fuller than they were under the Tunnel Plus 7′ Spillway Raise scenario. The relatively minor increase in non-Flood Control Releases (about 2,000 afy) indicates that, although the reservoirs are generally fuller than they are without climate change, that additional water is not put to beneficial use. However, because the system is generally wetter overall, SRDF operates more frequently and for longer duration.

The differences between the results of this scenario and those of the Tunnel Plus 7′ Spillway Raise scenario are very similar to the differences between the results of the Tunnel-Only scenario with 2070 Climate Change and the Tunnel-Only scenario. The main point of divergence is seen in the reservoir storage numbers. With just the Interlake Tunnel in operation, climate change leads to an increase in average combined reservoir storage of about 55,000 af (see Section 9.2.1.1). With the addition of the spillway raise, average combined reservoir storage with climate change is about 75,000 af higher than without climate change.

10.0 SUMMARY

This TM describes the results of a modeling investigation undertaken to quantify the potential benefit of construction of an Interlake Tunnel connecting Nacimiento and San Antonio Reservoirs and raising the elevation of the spillway at San Antonio Dam. This investigation utilized the numerical groundwater-surface water interaction model SVOM, built by the USGS. This model is built using MODFLOW-OWHM and simulates three-dimensional groundwater flow, surface water routing, groundwater-surface water interaction, agricultural supply and demand, and reservoir operations in an iterative manner. This TM discusses seven different scenarios run using SVOM:

- Baseline scenario: current reservoir operations, historical (Oct 1967 to Dec 2014) hydrology, 2014 land use conditions
- Tunnel-Only scenario: as Baseline, but with Interlake Tunnel connecting Nacimiento and San Antonio Reservoirs
- Tunnel Plus 7′ Spillway Raise scenario: as Tunnel-Only, but with spillway crest elevation at San Antonio Reservoir increased by 7 feet
- Modified Nacimiento Dam LLOW scenario: as Baseline, but with the release capacity

at Nacimiento Reservoir increased at low reservoir stage

- Tunnel-Only scenario with 2070 Climate Change: as Tunnel-Only, but with climate, hydrology, and land use conditions representative of projected 2070 conditions
- Tunnel Plus 7′ Spillway Raise scenario with 2070 Climate Change: as Tunnel Plus 7′ Spillway Raise, but with climate, hydrology, and land use conditions representative of projected 2070 conditions

By examining the differences between the results of the above scenarios, we can consider the effect of individual changes to the system in isolation. For example, the difference between the results of the Tunnel-Only and Baseline scenarios is due entirely to the introduction of the Interlake Tunnel (and associated changes).

The expected benefits of these projects relates to their ability to store additional water during periods of plenty for use during drier periods. This manifests as a reduction in Flood Control Release and an increase in non-Flood Control Release. It is not necessarily reflected in an increase in average storage, since the projects may result in increased usage of the stored water.

10.1 INTERLAKE TUNNEL

The Nacimiento-San Antonio Interlake Tunnel would move water from Nacimiento Reservoir, which has a relatively high inflow and frequently has relatively low storage capacity, to San Antonio Reservoir, which typically has lower inflow and more available storage capacity. The ability to move water through the tunnel depends on the stage in both reservoirs, as detailed in Section 2.1. The Interlake Tunnel would only move water between the reservoirs, and would not change the storage capacity of the reservoirs. Results of the Tunnel-Only scenario are presented in Section 5, with comparison to the Baseline scenario showing the effect of the Interlake Tunnel. Results are summarized in Table 6.

Overall, the Interlake Tunnel results in more water stored in the reservoirs (about +39,000 af on average), with less water in Nacimiento Reservoir (about -52,000 af) and more water in San Antonio Reservoir (about +90,000 af). This is reflected in the Tunnel's effects on stage as well, which is lower in Nacimiento Reservoir (about -18 feet) and higher in San Antonio Reservoir (about +29 feet). Combined reservoir storage is higher in every year type.

Reservoir releases generally shift away from Flood Control Release (about -12,000 afy) and toward Conservation Release (about +15,000 afy). The reduction in Flood Control Release is largest in wet years (about -40,000 afy), when most Flood Control Release occurs. There is little change in Conservation Release outside of dry years, when the difference is quite large (about +65,000 afy).

This indicates that the Interlake Tunnel successfully moves water from Nacimiento Reservoir to San Antonio Reservoir (about 30,000 afy), keeping more water in the reservoirs that would otherwise be lost as Flood Control Release, saving that water for more beneficial uses later, during drier times. This results in an increase in the amount of SRDF diversion (about +1,000 afy) and a lengthening of the average SRDF season (about +13 days). The increased success of SRDF operations is mostly seen in dry years (about +3,000 afy diverted, about +43 diversion days).

10.2 SAN ANTONIO DAM SPILLWAY RAISE

The San Antonio Dam Spillway Raise would result in an increase of seven feet in the elevation of the spillway crest, from its current elevation of 780 feet above msl to 787 feet above msl. This would result in an increase in the total reservoir capacity (at the spillway crest elevation) from 335,000 af to 376,200 af. The Spillway Raise is described in more detail in Section 2.2. The Spillway Raise would increase the storage capacity of San Antonio Reservoir, but would not change the release capacity of the reservoirs. Results of the Tunnel Plus 7' Spillway Raise scenario are presented in Section 6; comparison against the Tunnel-Only scenario shows the effect of the Spillway Raise. Results are summarized in Table 8.

Overall, the Spillway Raise results in more water stored in the reservoirs (about +15,000 af on average). There is more water in both Nacimiento Reservoir (about +3,000 af) and San Antonio Reservoir (about +12,000 af). The storage increase is smallest in dry years (about +5,000 af on average for the combined reservoirs) and largest in normal years (about +20,000 af).

The Spillway Raise results in a further decrease in Flood Control Release (about -5,000 afy) and increase in Conservation Release (about +4,000 afy). The reduction in Flood Control Release is largest in normal years (about -8,000 afy), as is the increase in Conservation Release (about +6,000 afy). The operation of the SRDF is largely unchanged, with only a slight increase in the length of the average diversion season (+1 day); diversion seasons during dry years are lengthened by about 3 days.

These results indicate that the Spillway Raise generally increases the amount of water held in storage in the reservoirs, with that water contributing to an increase in the amount of water that can be used for Conservation Release. The overall impact on the operation of the SRDF is quite small.

10.3 NACIMIENTO DAM LOW-LEVEL OUTLET WORKS MODIFICATION

A modification to the Low-Level Outlet Works (LLOW) at Nacimiento Dam could result in an increased release capacity that would allow MCWRA to operate the reservoirs with more flexibility (currently, the LLOW is limited to a release capacity of 460 cfs). This would allow Nacimiento Reservoir, which typically receives more inflow than San Antonio Reservoir, to carry more of the burden of releases during the Conservation Release Season. The LLOW modification is described in more detail in Section 2.3. The LLOW modification would result in a higher release capacity from Nacimiento Reservoir, but would not change the storage capacity of the reservoirs. Results of the Modified Nacimiento Dam LLOW scenario are presented in Section 8; comparison against the results of the Baseline scenario provide an estimate of the effect of the LLOW modification. Results are summarized in Table 9.

The LLOW modification would result in less water in storage on average (combined reservoirs about -14,000 af; Nacimiento Reservoir about -17,000 af; San Antonio Reservoir about +3,000 af). This effect is seen most strongly during dry years (combined reservoirs about -18,000 af; Nacimiento Reservoir about -20,000 af; San Antonio Reservoir about +2,000 af). The reduction in average storage results from an increase in the ability of the reservoirs to use the water stored in Nacimiento Reservoir.

As for the Interlake Tunnel, reservoir releases with the LLOW modification shift away from Flood Control Release (about -7,000 afy on average) toward Conservation Release (about +12,000 afy on average). The reduction in Flood Control Release is largely seen during wet years (about -31,000 afy). The increase in Conservation Release is substantial in normal (about +14,000 afy) and dry (about +21,000 afy) years.

The ability to release more water from Nacimiento Reservoir slightly improves the operation of the SRDF (about +1,000 afy diverted, about +8 diversion days). This improvement can be seen in both normal (about +1,000 afy diverted, about +9 diversion days) and dry (about +1,000 afy diverted, about +14 diversion days) years. The most substantial change to SRDF operations with the modified LLOW may be that percentage of failed SRDF seasons (when the SRDF season is unable to start) drops from about 30% under the Baseline scenario to about 19%.

Overall, the modified LLOW at Nacimiento Reservoir results in an increase in Conservation Release during normal and dry years, which typically leaves less water in storage in the reservoirs (largely in Nacimiento Reservoir). Benefits in terms of Flood Control Release are realized because reduced storage in Nacimiento Reservoir entering wet winters leaves more storage capacity available, meaning that more water can be kept in the reservoirs before they have to make Flood Control Releases. Allowing the reservoirs to operate deeper into the Conservation Release Season results in extended operations of SRDF.

10.4 CLIMATE CHANGE EFFECTS

The two scenarios incorporating the Interlake Tunnel (the Tunnel-Only and Tunnel Plus 7' Spillway Raise scenarios) were modified to incorporate projected 2070 climate conditions, using inputs provided by DWR and the USGS. It is important to note that the climate conditions used do not represent a gradual climatic progression from current conditions to 2070 conditions, but rather apply the amount of change expected by 2070 across the entire model duration. The changes incorporated to simulate climate change conditions are described in Section 9.1. Results of the two scenarios are provided in Section 9.2. 2070 climate conditions were not applied to the Baseline scenario, so the results of these scenarios cannot be used to calculate the benefit of the Interlake Tunnel or Spillway Raise under this set of climate conditions in the same way as was done for the non-climate change scenarios. The Tunnel-Only scenario with 2070 Climate Change is compared to the Tunnel-Only scenario, while the Tunnel Plus 7' Spillway Raise scenario with 2070 Climate Change is compared to the Tunnel Plus 7' Spillway Raise scenario. Results are summarized in Tables 10 and 11.

In general, the 2070 climate envisioned in the DWR products is substantially wetter than the historical climate in the Salinas River watershed, resulting in about 20% more inflow to the reservoirs compared to the non-climate change scenarios. This results in much more storage in the reservoirs. For the Tunnel-Only scenario, 2070 climate conditions result in about +29,000 af in Nacimiento Reservoir, about +25,000 af in San Antonio Reservoir, and about +55,000 af in the combined reservoirs. For the Tunnel Plus 7' Spillway Raise scenario, 2070 climate conditions result in about +35,000 af in Nacimiento Reservoir, about +35,000 af in San Antonio Reservoir, and about +70,000 af in the combined reservoirs. Storage is increased across all year types[11], but for both scenarios the increase was largest in dry years (about +69,000 af for the Tunnel-Only scenario, about +89,000 af for the Tunnel Plus 7' Spillway Raise scenario).

With the greatly increased reservoir inflows, average annual reservoir release is much higher with 2070 climate change than without (about +51,000 afy for the Tunnel-Only scenario, about +50,000 afy for the Tunnel Plus 7' Spillway Raise scenario). Most of this increase is due to much higher Flood Control Release (about +50,000 afy for the Tunnel-Only scenario, about +48,000 afy for the Tunnel Plus 7' Spillway Raise scenario). Flood Control Release during wet years increases by about 95,000 afy for the Tunnel-Only scenario and about 96,000 afy for the Tunnel Plus 7' Spillway Raise scenario, and during normal years by about 34,000 afy for the Tunnel-Only scenario and about 30,000 afy for the Tunnel Plus 7' Spillway Raise scenario. Non-Flood Control Release decreases during wet years (about -23,000 afy for the Tunnel-Only scenario and about -25,000 afy for the Tunnel Plus 7' Spillway Raise scenario) and increases during normal (about +7,000 afy for the Tunnel-Only scenario and about +8,000 afy for the Tunnel Plus 7' Spillway Raise scenario) and dry (about +29,000 afy for the Tunnel-Only scenario and about +34,000 afy for the Tunnel Plus 7' Spillway Raise scenario) years.

The 2070 climate change conditions result in a modest increase (by about 2,000 afy) in transfer through the Interlake Tunnel for both the Tunnel-Only and Tunnel Plus 7' Spillway Raise scenarios. For both scenarios, transfer is lower in wet years and higher in normal years.

The 2070 climate change conditions result in a slight increase in the success of SRDF operations (about +1,000 afy diverted and +19 diversion days per year for the Tunnel-Only scenario and about +2,000 afy diverted and +22 diversion days per year for the Tunnel Plus 7' Spillway Raise scenario). The difference is largest during dry years (about +3,000 afy diverted and +37 diversion days per year for the Tunnel-Only scenario and about +3,000 afy diverted and +41 diversion days per year for the Tunnel Plus 7' Spillway Raise scenario). The percentage of years with no SRDF season at all drops from about 26% to 13% for both scenarios.

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[11] Year types for certain model years changed compared to the non-climate change scenarios because streamflow in Arroyo Seco was different at the time when year type was determined.

10.5 CONCLUSIONS

This TM describes the results of modeling undertaken to simulate the effects of the proposed Nacimiento-San Antonio Interlake Tunnel, the San Antonio Dam Spillway Raise, and the Nacimiento Dam LLOW modification. The modeling approach taken is able to estimate the benefit of major changes to the groundwater-surface water-reservoir system. These changes have been designed to increase the flexibility of the reservoirs and increase the amount of water available to be used for purposes other than flood control. None of these changes creates new water, but rather they change how the water already coming into the system is stored and used to increase its benefit to the system.

Benefits of the Interlake Tunnel and other changes to the system are described in individual sections above. Overall, each of the investigated changes behaves as expected, either decreasing or increasing average storage in the reservoirs, decreasing Flood Control Release, and increasing non-Flood Control Release. They do so to varying degrees. The Interlake Tunnel results in the largest decrease in Flood Control Release of the investigated changes (about -12,000 afy), followed by the Nacimiento Dam LLOW modification (about -7,000 afy) and the San Antonio Dam Spillway Raise (about -5,000 afy). The Interlake Tunnel also results in the largest increase in non-Flood Control Release (about +10,000 afy), followed by the Nacimiento Dam LLOW modification (about +9,000 afy) and the San Antonio Dam Spillway Raise (about +5,000 afy). All three changes also result in improvements in the ability of the SRDF to operate for longer and divert more water. Finally, the Interlake Tunnel has the largest impact on average storage conditions (about +39,000 af), followed by the San Antonio Dam Spillway Raise (about +15,000 af) and the Nacimiento Dam LLOW modification, which results in a decrease in overall average storage (about -14,000 af).

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TABLES

TABLE 1

SUMMARY RESULTS FOR ALL MODEL SCENARIOS

	Average Storage (af)			Avg. Stage (ft above msl)		Average Annual Releases (afy)						
Scenario	**Nacimiento Reservoir**	**San Antonio Reservoir**	**Combined**	**Nacimiento Reservoir**	**San Antonio Reservoir**	**Total**	**Flood Control**	**Environ-mental**	**Conserva-tion**	**Over-Release**	**Tunnel Transfer (afy)**	**Tunnel Transfer Days Per Year**
Baseline	183,000	98,000	281,000	754	704	248,000	58,000	43,000	135,000	13,000	--	--
Tunnel-Only	132,000	188,000	320,000	735	734	247,000	46,000	39,000	150,000	11,000	30,000	40
Difference from Baseline Scenario	*-52,000*	*+90,000*	*+39,000*	*-18*	*+29*	*-2,000*	*-12,000*	*-4,000*	*+15,000*	*-2,000*	--	--
Tunnel Plus 7' Spillway Raise	135,000	200,000	335,000	736	736	246,000	40,000	40,000	154,000	11,000	30,000	37
Difference from Baseline Scenario	*-49,000*	*+102,000*	*+54,000*	*-17*	*+32*	*-3,000*	*-17,000*	*-3,000*	*+19,000*	*-2,000*	--	--
Difference from Tunnel-Only Scenario	*+3,000*	*+12,000*	*+15,000*	*+1*	*+3*	*-1,000*	*-5,000*	*0*	*+4,000*	*0*	*0*	*-3*
Modified Nacimiento Dam LLOW	167,000	101,000	267,000	746	706	250,000	50,000	39,000	146,000	14,000	--	--
Difference from Baseline Scenario	*-17,000*	*+3,000*	*-14,000*	*-8*	*+1*	*+1,000*	*-7,000*	*-4,000*	*+12,000*	*+1,000*	--	--
Tunnel-Only with 2070 Climate Change	161,00	213,000	375,000	743	742	298,000	96,000	62,000	130,000	10,000	32,000	53
Difference from Tunnel-Only Scenario	*+29,000*	*+25,000*	*+55,000*	*+8*	*+8*	*+51,000*	*+50,000*	*+23,000*	*-20,000*	*-1,000*	*+2,000*	*+13*
Tunnel Plus 7' Spillway Raise with 2070 Climate Change	170,000	234,000	404,000	746	747	296,000	88,000	67,000	131,000	10,000	32,000	53
Difference from Tunnel Plus 7' Spillway Raise Scenario	*+35,000*	*+35,000*	*+70,000*	*+10*	*+11*	*+50,000*	*+48,000*	*+27,000*	*-23,000*	*-1,000*	*+2,000*	*+16*

Notes:

- Abbreviations: af = acre-feet; afy = acre-feet per year; avg = average; ft above msl = feet above mean sea level.
- Average storage values are rounded to the nearest 1,000 af; average releases/transfers are rounded to the nearest 1,000 afy; transfer days are rounded to the nearest whole day. Differences between scenarios are calculated from unrounded numbers, and sums may not total due to rounding.

Provisional data subject to revision.

TABLE 2

DETAILED RESULTS FOR BASELINE SCENARIO

	Average Storage (af)			Avg. Stage (ft above msl)		Average Annual Releases (afy)				
	Nacimiento Reservoir	**San Antonio Reservoir**	**Combined Reservoirs**	**Nacimiento Reservoir**	**San Antonio Reservoir**	**Total**	**Flood Control**	**Environ-mental**	**Conserva-tion**	**Over-Release**
All Water Year Types	183,000	98,000	281,000	754	704	248,000	58,000	43,000	135,000	13,000
Wet Water Years	250,000	128,000	378,000	771	719	370,000	178,000	32,000	147,000	13,000
Normal Water Years	181,000	110,000	291,000	755	711	242,000	18,000	51,000	156,000	17,000
Dry Water Years	116,000	43,000	158,000	732	677	128,000	0	39,000	82,000	6,000

Notes:
- Abbreviations: af = acre-feet; afy = acre-feet per year; avg = average; ft above msl = feet above mean sea level.
- Average storage values are rounded to the nearest 1,000 af; average releases/transfers are rounded to the nearest 1,000 afy; transfer days are rounded to the nearest whole day. Sums may not total due to rounding.
- Determination of water year types is described in Appendix A.

Provisional data subject to revision.

TABLE 3

CONSERVATION RELEASE SUBCATEGORIZATION

Scenario	Water Year Type	Diversion at SRDF (afy)	% of Total	Conveyance Losses (afy)	% of Total	Total (afy)
Baseline	All	8,000	6%	127,000	94%	135,000
	Wet	9,000	6%	138,000	94%	147,000
	Normal	9,000	6%	147,000	94%	156,000
	Dry	4,000	5%	78,000	95%	82,000
Tunnel-Only	All	9,000	6%	141,000	94%	150,000
	Wet	10,000	7%	133,000	93%	143,000
	Normal	9,000	6%	146,000	94%	155,000
	Dry	7,000	5%	140,000	95%	147,000
Tunnel Plus 7' Spillway Raise	All	9,000	6%	145,000	94%	154,000
	Wet	10,000	7%	135,000	93%	145,000
	Normal	9,000	6%	153,000	94%	162,000
	Dry	7,000	5%	143,000	95%	150,000
Modified Nacimiento Dam LLOW	All	8,000	5%	138,000	95%	146,000
	Wet	9,000	6%	136,000	94%	145,000
	Normal	9,000	5%	162,000	95%	171,000
	Dry	5,000	5%	98,000	95%	103,000
Tunnel-Only with 2070 Climate Change	All	8,000	6%	122,000	94%	130,000
	Wet	9,000	8%	110,000	92%	119,000
	Normal	8,000	6%	124,000	94%	132,000
	Dry	8,000	6%	134,000	94%	142,000
Tunnel Plus 7' Spillway Raise with 2070 Climate Change	All	8,000	6%	123,000	94%	131,000
	Wet	9,000	8%	111,000	93%	120,000
	Normal	8,000	6%	123,000	94%	131,000
	Dry	8,000	6%	135,000	95%	143,000

Notes:
- Abbreviations: afy = acre-feet per year.
- Average annual flows are rounded to the nearest 1,000 afy; percentages are rounded to the nearest whole percentage. Sums may not total due to rounding.
- Determination of water year types is described in Appendix A.

Provisional data subject to revision.

TABLE 4

SRDF OPERATIONS FOR ALL MODEL SCENARIOS

	All Water Year Types						Wet Water Years		Normal Water Years		Dry Water Years	
Scenario	Avg. Annual Diversion (afy)	Avg. Annual Diversion Days	Percentage of Full Seasons	Percentage of Partial Seasons	Percentage of Failed Seasons	Avg. Length of Partial Season (Days)	Avg. Annual Diversion (afy)	Avg. Annual Diversion Days	Avg. Annual Diversion (afy)	Avg. Annual Diversion Days	Avg. Annual Diversion (afy)	Avg. Annual Diversion Days
Baseline	10,000	136	53%	17%	30%	128	15,000	214	10,000	138	3,000	47
Tunnel-Only	11,000	149	55%	19%	26%	160	15,000	214	10,000	143	6,000	89
Difference from Baseline Scenario	*+1,000*	*+13*	*+2%*	*+2%*	*-4%*	*+31*	*0*	*0*	*0*	*+5*	*+3,000*	*+43*
Tunnel Plus 7' Spillway Raise	11,000	150	60%	15%	26%	152	15,000	214	10,000	144	7,000	92
Difference from Baseline Scenario	*+1,000*	*+15*	*+6%*	*-2%*	*-4%*	*+24*	*0*	*0*	*+1,000*	*+6*	*+3,000*	*+45*
Difference from Tunnel-Only Scenario	*0*	*+1*	*+4%*	*-4%*	*0%*	*-7*	*0*	*0*	*0*	*+1*	*0*	*+3*
Modified Nacimiento Dam LLOW	10,000	143	49%	32%	19%	121	15,000	214	10,000	147	4,000	60
Difference from Baseline Scenario	*+1,000*	*+8*	*-4%*	*+15%*	*-11%*	*-8*	*0*	*0*	*+1,000*	*+9*	*+1,000*	*+14*
Tunnel-Only with 2070 Climate Change	12,000	168	66%	21%	13%	125	15,000	214	11,000	159	9,000	126
Difference from Tunnel-Only Scenario	*+1,000*	*+19*	*+11%*	*+2%*	*-13%*	*-35*	*0*	*0*	*+1,000*	*+16*	*+3,000*	*+37*
Tunnel Plus 7' Spillway Raise with 2070 Climate Change	12,000	173	70%	17%	13%	131	15,000	214	12,000	167	9,000	133
Difference from Tunnel Plus 7' Spillway Raise Scenario	*+2,000*	*+22*	*+11%*	*+2%*	*-13%*	*-21*	*0*	*0*	*+2,000*	*+23*	*+3,000*	*+41*

Notes:

- Abbreviations: afy = acre-feet per year; avg = average.
- Average annual diversion volumes are rounded to the nearest 1,000 afy, percentages to the nearest whole percentage, and days to the nearest whole day. Differences between scenarios are calculated from unrounded numbers, and sums may not total due to rounding.
- See Section 4.2.4 for more information on full, partial, and failed seasons.
- Determination of water year types is described in Appendix A.

Provisional data subject to revision.

TABLE 5

GROUNDWATER BUDGET FOR ALL MODEL SCENARIOS (IN AFY)

Scenario	Water Year Type	Change in Storage ΔS	Net Flux Through Aquifer-Ocean Boundary Q_{swi}	Net Flux Into/Out of Neighboring Basins Q_{ghb}	Net Flux Into/Out of Agricultural Drains Q_{drain}	Net Groundwater/ Surface Water Exchange Q_{sw}	Net Groundwater Extraction from Wells Q_{well}	Net Flux Across Base of Root Zone Q_{rz}
Baseline	**All**	-17,000	+4,000	< 1,000	< 1,000	+98,000	-109,000	-10,000
	Wet	+28,000	+4,000	< 1,000	< 1,000	+145,000	-103,000	-16,000
	Normal	-23,000	+3,000	< 1,000	< 1,000	+91,000	-107,000	-11,000
	Dry	-53,000	+6,000	< 1,000	< 1,000	+58,000	-119,000	0
Tunnel-Only	**All**	-16,000	+4,000	< 1,000	< 1,000	+99,000	-109,000	-10,000
	Wet	+25,000	+4,000	< 1,000	< 1,000	+141,000	-103,000	-16,000
	Normal	-25,000	+3,000	< 1,000	< 1,000	+91,000	-107,000	-12,000
	Dry	-44,000	+6,000	< 1,000	< 1,000	+69,000	-118,000	-2,000
Tunnel Plus 7' Spillway Raise	**All**	-16,000	+4,000	< 1,000	< 1,000	+99,000	-109,000	-10,000
	Wet	+24,000	+4,000	< 1,000	< 1,000	+141,000	-103,000	-16,000
	Normal	-25,000	+3,000	< 1,000	< 1,000	+91,000	-107,000	-12,000
	Dry	-44,000	+6,000	< 1,000	< 1,000	+69,000	-118,000	-2,000
Modified Nacimiento Dam LLOW	**All**	-17,000	+4,000	< 1,000	< 1,000	+99,000	-109,000	-10,000
	Wet	+26,000	+4,000	< 1,000	< 1,000	+143,000	-103,000	-16,000
	Normal	-23,000	+3,000	< 1,000	< 1,000	+93,000	-107,000	-12,000
	Dry	-51,000	+6,000	< 1,000	< 1,000	+62,000	-118,000	-1,000
Tunnel-Only with 2070 Climate Change	**All**	-14,000	+4,000	< 1,000	< 1,000	+103,000	-99,000	-21,000
	Wet	+26,000	+4,000	< 1,000	< 1,000	+144,000	-94,000	-26,000
	Normal	-23,000	+3,000	< 1,000	< 1,000	+95,000	-98,000	-22,000
	Dry	-41,000	+5,000	< 1,000	< 1,000	+73,000	-107,000	-14,000
Tunnel Plus 7' Spillway Raise with 2070 Climate Change	**All**	-14,000	+4,000	< 1,000	< 1,000	+103,000	-99,000	-21,000
	Wet	+26,000	+4,000	< 1,000	< 1,000	+143,000	-94,000	-26,000
	Normal	-23,000	+3,000	< 1,000	< 1,000	+95,000	-98,000	-22,000
	Dry	-41,000	+5,000	< 1,000	< 1,000	+75,000	-107,000	-14,000

Notes:

- Abbreviations: afy = acre-feet per year.
- All groundwater budget components rounded to the nearest 1,000 afy. Sums may not total due to rounding.
- Net fluxes sum inflow and outflow components. Positive groundwater budget components indicate water is being added to the aquifer.
- Determination of water year types is described in Appendix A.

Provisional data subject to revision.

TABLE 6

DETAILED RESULTS FOR TUNNEL-ONLY SCENARIO

Water Year Type	Average Storage (af)			Avg. Stage (ft above msl)		Average Annual Releases (afy)				
	Nacimiento Reservoir	San Antonio Reservoir	Combined Reservoirs	Nacimiento Reservoir	San Antonio Reservoir	Total	Flood Control	Environ-mental	Conserva-tion	Over-Release
All Water Year Types	132,000	188,000	320,000	735	734	247,000	46,000	39,000	150,000	11,000
Difference from Baseline Scenario	*-52,000*	*+90,000*	*+39,000*	*-18*	*+29*	*-2,000*	*-12,000*	*-4,000*	*+15,000*	*-2,000*
Wet Water Years	197,000	228,000	425,000	756	748	321,000	139,000	29,000	143,000	10,000
Difference from Baseline Scenario	*-53,000*	*+100,000*	*+47,000*	*-16*	*+28*	*-49,000*	*-40,000*	*-3,000*	*-3,000*	*-3,000*
Normal Water Years	138,000	204,000	341,000	740	739	233,000	16,000	51,000	155,000	10,000
Difference from Baseline Scenario	*-43,000*	*+94,000*	*+51,000*	*-14*	*+28*	*-10,000*	*-1,000*	*-1,000*	*-1,000*	*-6,000*
Dry Water Years	51,000	116,000	167,000	704	709	192,000	0	30,000	147,000	15,000
Difference from Baseline Scenario	*-64,000*	*+73,000*	*+9,000*	*-28*	*+32*	*+64,000*	*0*	*-9,000*	*+65,000*	*+8,000*

Notes:

- Abbreviations: af = acre-feet; afy = acre-feet per year; avg = average; ft above msl = feet above mean sea level.
- Average storage values are rounded to the nearest 1,000 af; average releases/transfers are rounded to the nearest 1,000 afy; transfer days are rounded to the nearest whole day. Sums may not total due to rounding.
- Determination of water year types is described in Appendix A.

Provisional data subject to revision.

TABLE 7

TUNNEL OPERATIONS FOR ALL MODEL SCENARIOS

Scenario	All Water Year Types		Wet Water Years		Normal Water Years		Dry Water Years	
	Avg. Annual Tunnel Transfer (afy)	Avg. Annual Transfer Days per Year	Avg. Annual Tunnel Transfer (afy)	Avg. Annual Transfer Days per Year	Avg. Annual Tunnel Transfer (afy)	Avg. Annual Transfer Days per Year	Avg. Annual Tunnel Transfer (afy)	Avg. Annual Transfer Days per Year
Tunnel-Only	30,000	40	92,000	104	6,000	21	6,000	7
Tunnel-Only with 2070 Climate Change	32,000	53	75,000	108	16,000	42	6,000	7
Difference from Tunnel-Only Scenario	*+2,000*	*+13*	*-17,000*	*+4*	*+9,000*	*+21*	*0*	*0*
Tunnel Plus 7' Spillway Raise	30,000	37	93,000	97	6,000	18	6,000	7
Difference from Tunnel-Only Scenario	*0*	*-3*	*0*	*-7*	*-1,000*	*-2*	*0*	*0*
Tunnel Plus 7' Spillway Raise with 2070 Climate Change	32,000	53	76,000	108	14,000	42	6,000	7
Difference from Tunnel Plus 7' Spillway Raise Scenario	*+2,000*	*+16*	*-16,000*	*+12*	*+8,000*	*+24*	*0*	*0*

Notes:
- Abbreviations: afy = acre-feet per year; avg = average.
- Average storage values are rounded to the nearest 1,000 af; average releases/transfers are rounded to the nearest 1,000 afy; transfer days are rounded to the nearest whole day. Sums may not total due to rounding.
- Determination of water year types is described in Appendix A.

Provisional data subject to revision.

TABLE 8

DETAILED RESULTS FOR TUNNEL PLUS 7' SPILLWAY RAISE SCENARIO

	Average Storage (af)			Avg. Stage (ft above msl)		Average Annual Releases (afy)				
Water Year Type	**Nacimiento Reservoir**	**San Antonio Reservoir**	**Combined Reservoirs**	**Nacimiento Reservoir**	**San Antonio Reservoir**	**Total**	**Flood Control**	**Environ-mental**	**Conserva-tion**	**Over-Release**
All Water Year Types	135,000	200,000	335,000	736	736	246,000	40,000	40,000	154,000	11,000
Difference from Baseline Scenario	*-49,000*	*+102,000*	*+53,000*	*-17*	*+32*	*-3,000*	*-17,000*	*-3,000*	*+19,000*	*-2,000*
Difference from Tunnel-Only Scenario	*+3,000*	*+12,000*	*+15,000*	*+1*	*+3*	*-1,000*	*-5,000*	*0*	*+4,000*	*0*
Wet Water Years	198,000	241,000	439,000	756	751	317,000	133,000	29,000	145,000	10,000
Difference from Baseline Scenario	*-52,000*	*+113,000*	*+61,000*	*-15*	*+31*	*-52,000*	*-45,000*	*-3,000*	*-2,000*	*-3,000*
Difference from Tunnel-Only Scenario	*+1,000*	*+13,000*	*+14,000*	*0*	*+3*	*-3,000*	*-5,000*	*0*	*+2,000*	*0*
Normal Water Years	142,000	219,000	362,000	742	742	231,000	8,000	51,000	162,000	10,000
Difference from Baseline Scenario	*-39,000*	*+110,000*	*+71,000*	*-13*	*+31*	*-12,000*	*-10,000*	*0*	*+5,000*	*-7,000*
Difference from Tunnel-Only Scenario	*+5,000*	*+16,000*	*+20,000*	*+2*	*+3*	*-2,000*	*-8,000*	*+1,000*	*+6,000*	*0*
Dry Water Years	52,000	120,000	172,000	705	711	195,000	0	30,000	150,000	15,000
Difference from Baseline Scenario	*-63,000*	*+77,000*	*+14,000*	*-28*	*+34*	*+68,000*	*0*	*-9,000*	*+68,000*	*+9,000*
Difference from Tunnel-Only Scenario	*+1,000*	*+4,000*	*+5,000*	*0*	*+2*	*+3,000*	*0*	*0*	*+3,000*	*0*

Notes:

- Abbreviations: af = acre-feet; afy = acre-feet per year; avg = average; ft above msl = feet above mean sea level.
- Average storage values are rounded to the nearest 1,000 af; average releases/transfers are rounded to the nearest 1,000 afy; transfer days are rounded to the nearest whole day. Sums may not total due to rounding.
- Determination of water year types is described in Appendix A.

Provisional data subject to revision.

TABLE 9
DETAILED RESULTS FOR MODIFIED NACIMIENTO DAM LLOW SCENARIO

Water Year Type	Average Storage (af)			Avg. Stage (ft above msl)		Average Annual Releases (afy)				
	Nacimiento Reservoir	San Antonio Reservoir	Combined Reservoirs	Nacimiento Reservoir	San Antonio Reservoir	Total	Flood Control	Environ-mental	Conserva-tion	Over-Release
All Water Year Types	167,000	101,000	267,000	746	706	250,000	50,000	39,000	146,000	14,000
Difference from Baseline Scenario	*-17,000*	*+3,000*	*-14,000*	*-8*	*+1*	*+1,000*	*-7,000*	*-4,000*	*+12,000*	*+1,000*
Wet Water Years	237,000	132,000	369,000	766	721	339,000	154,000	29,000	145,000	11,000
Difference from Baseline Scenario	*-13,000*	*+4,000*	*-9,000*	*-6*	*+2*	*-31,000*	*-24,000*	*-3,000*	*-2,000*	*-2,000*
Normal Water Years	164,000	113,000	277,000	746	711	252,000	17,000	46,000	171,000	18,000
Difference from Baseline Scenario	*-17,000*	*+3,000*	*-14,000*	*-8*	*+1*	*+10,000*	*-1,000*	*-5,000*	*+14,000*	*+2,000*
Dry Water Years	95,000	45,000	140,000	722	678	149,000	0	35,000	103,000	10,000
Difference from Baseline Scenario	*-20,000*	*+2,000*	*-18,000*	*-10*	*+1*	*+21,000*	*0*	*-4,000*	*+21,000*	*+4,000*

Notes:
- Abbreviations: af = acre-feet; afy = acre-feet per year; avg = average; ft above msl = feet above mean sea level.
- Average storage values are rounded to the nearest 1,000 af; average releases/transfers are rounded to the nearest 1,000 afy; transfer days are rounded to the nearest whole day. Sums may not total due to rounding.
- Determination of water year types is described in Appendix A.

Provisional data subject to revision.

TABLE 10
DETAILED RESULTS FOR TUNNEL-ONLY SCENARIO WITH 2070 CLIMATE CHANGE

Water Year Type	Average Storage (af)			Avg. Stage (ft above msl)		Average Annual Releases (afy)				
	Nacimiento Reservoir	San Antonio Reservoir	Combined Reservoirs	Nacimiento Reservoir	San Antonio Reservoir	Total	Flood Control	Environ-mental	Conserva-tion	Over-Release
All Water Year Types	161,000	213,000	375,000	743	742	298,000	96,000	62,000	130,000	10,000
Difference from Tunnel-Only Scenario	*+29,000*	*+25,000*	*+55,000*	*+8*	*+8*	*+51,000*	*+50,000*	*+23,000*	*-20,000*	*-1,000*
Wet Water Years	229,000	258,000	487,000	764	756	393,000	234,000	31,000	119,000	10,000
Difference from Tunnel-Only Scenario	*+32,000*	*+30,000*	*+62,000*	*+8*	*+9*	*+72,000*	*+95,000*	*+1,000*	*-25,000*	*0*
Normal Water Years	168,000	214,000	381,000	748	742	274,000	50,000	85,000	132,000	7,000
Difference from Tunnel-Only Scenario	*+30,000*	*+10,000*	*+40,000*	*+8*	*+3*	*+41,000*	*+34,000*	*+34,000*	*-24,000*	*-3,000*
Dry Water Years	74,000	162,000	236,000	713	724	223,000	2,000	66,000	142,000	14,000
Difference from Tunnel-Only Scenario	*+23,000*	*+46,000*	*+69,000*	*+9*	*+15*	*+31,000*	*+2,000*	*+36,000*	*-5,000*	*-1,000*

Notes:
- Abbreviations: af = acre-feet; afy = acre-feet per year; avg = average; ft above msl = feet above mean sea level.
- Average storage values are rounded to the nearest 1,000 af; average releases/transfers are rounded to the nearest 1,000 afy; transfer days are rounded to the nearest whole day. Sums may not total due to rounding.
- Determination of water year types is described in Appendix A.

Provisional data subject to revision.

TABLE 11

DETAILED RESULTS FOR TUNNEL PLUS 7' SPILLWAY RAISE SCENARIO WITH 2070 CLIMATE CHANGE

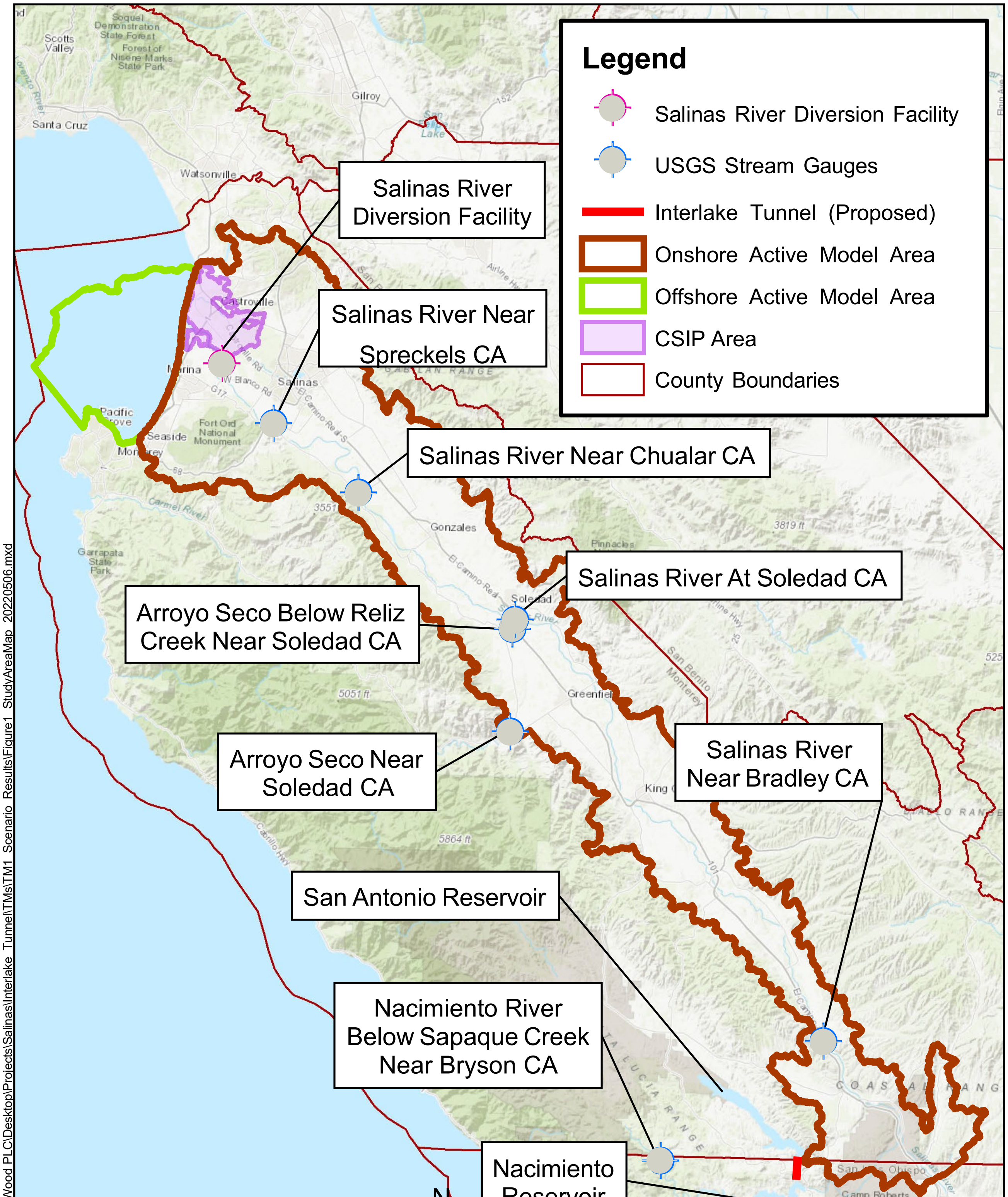
Water Year Type	Average Storage (af)			Avg. Stage (ft above msl)		Average Annual Releases (afy)				
	Nacimiento Reservoir	San Antonio Reservoir	Combined Reservoirs	Nacimiento Reservoir	San Antonio Reservoir	Total	Flood Control	Environ-mental	Conserva-tion	Over-Release
All Water Year Types	170,000	234,000	404,000	746	747	296,000	88,000	67,000	131,000	10,000
Difference from Tunnel Plus 7' Spillway Raise Scenario	*+35,000*	*+35,000*	*+70,000*	*+10*	*+11*	*+50,000*	*+48,000*	*+27,000*	*-23,000*	*-1,000*
Wet Water Years	233,000	279,000	512,000	765	761	388,000	229,000	30,000	120,000	10,000
Difference from Tunnel Plus 7' Spillway Raise Scenario	*+36,000*	*+38,000*	*+73,000*	*+9*	*+10*	*+71,000*	*+96,000*	*0*	*-25,000*	*0*
Normal Water Years	177,000	240,000	417,000	750	750	269,000	38,000	93,000	131,000	7,000
Difference from Tunnel Plus 7' Spillway Raise Scenario	*+35,000*	*+21,000*	*+55,000*	*+8*	*+8*	*+38,000*	*+30,000*	*+41,000*	*-30,000*	*-3,000*
Dry Water Years	85,000	175,000	261,000	717	729	229,000	0	72,000	143,000	14,000
Difference from Tunnel Plus 7' Spillway Raise Scenario	*+33,000*	*+55,000*	*+89,000*	*+12*	*+18*	*+34,000*	*0*	*+42,000*	*-7,000*	*-1,000*

Notes:

- Abbreviations: af = acre-feet; afy = acre-feet per year; avg = average; ft above msl = feet above mean sea level.
- Average storage values are rounded to the nearest 1,000 af; average releases/transfers are rounded to the nearest 1,000 afy; transfer days are rounded to the nearest whole day. Sums may not total due to rounding.
- Determination of water year types is described in Appendix A.

Provisional data subject to revision.

FIGURES



Study Area Map

Salinas Valley Operational Model Report

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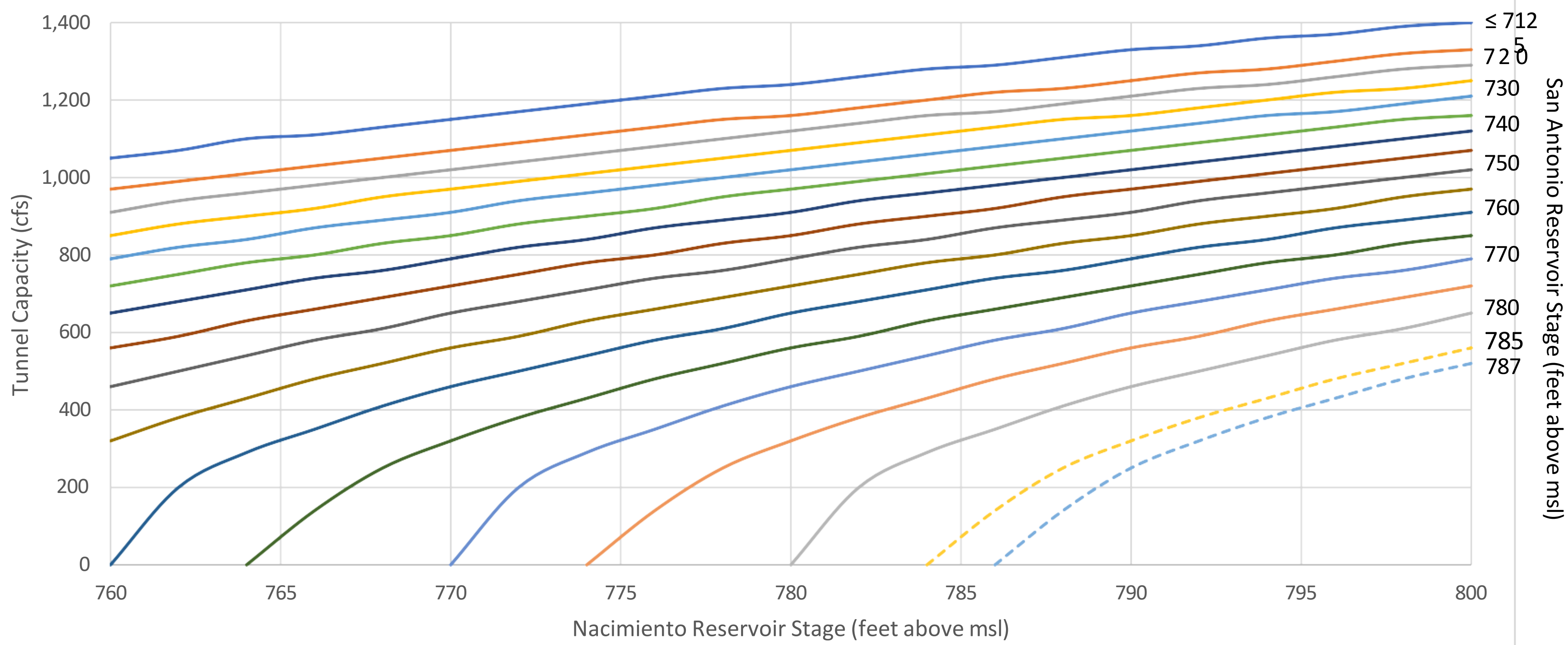
Figure 1

Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

C:\Users\matt.baillie\OneDrive - Wood PLC\Desktop\Projects\Salinas\Interlake Tunnel\TMs\TM1 Scenario Results\Figure1 StudyAreaMap 20220506.mxd



Note: Individual curves represent the rating curve for flow through the Interlake Tunnel for a given San Antonio Reservoir stage elevation. The rating curves above San Antonio Reservoir Stage Elevation of 780 feet above msl (dashed lines) are not in effect for scenarios that do not include a raised spillway elevation at San Antonio Dam.

Rating Curve for Proposed Nacimiento-San Antonio Interlake Tunnel

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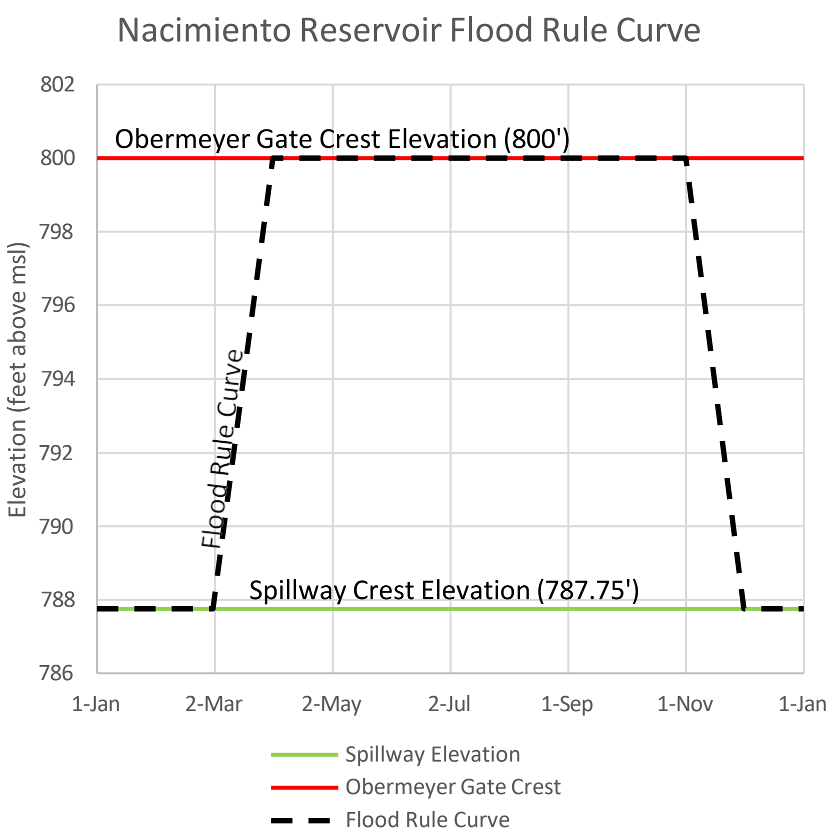
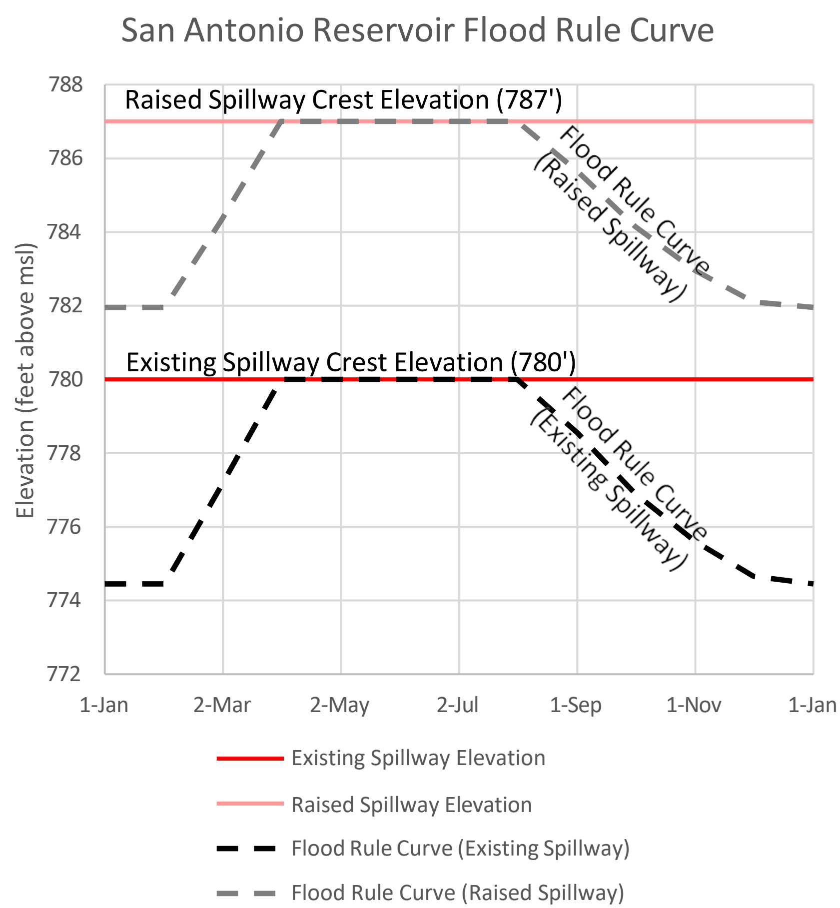
Figure 2





Flood Rule Curves for Nacimiento and San Antonio Reservoirs

Salinas Valley Operational Model Report
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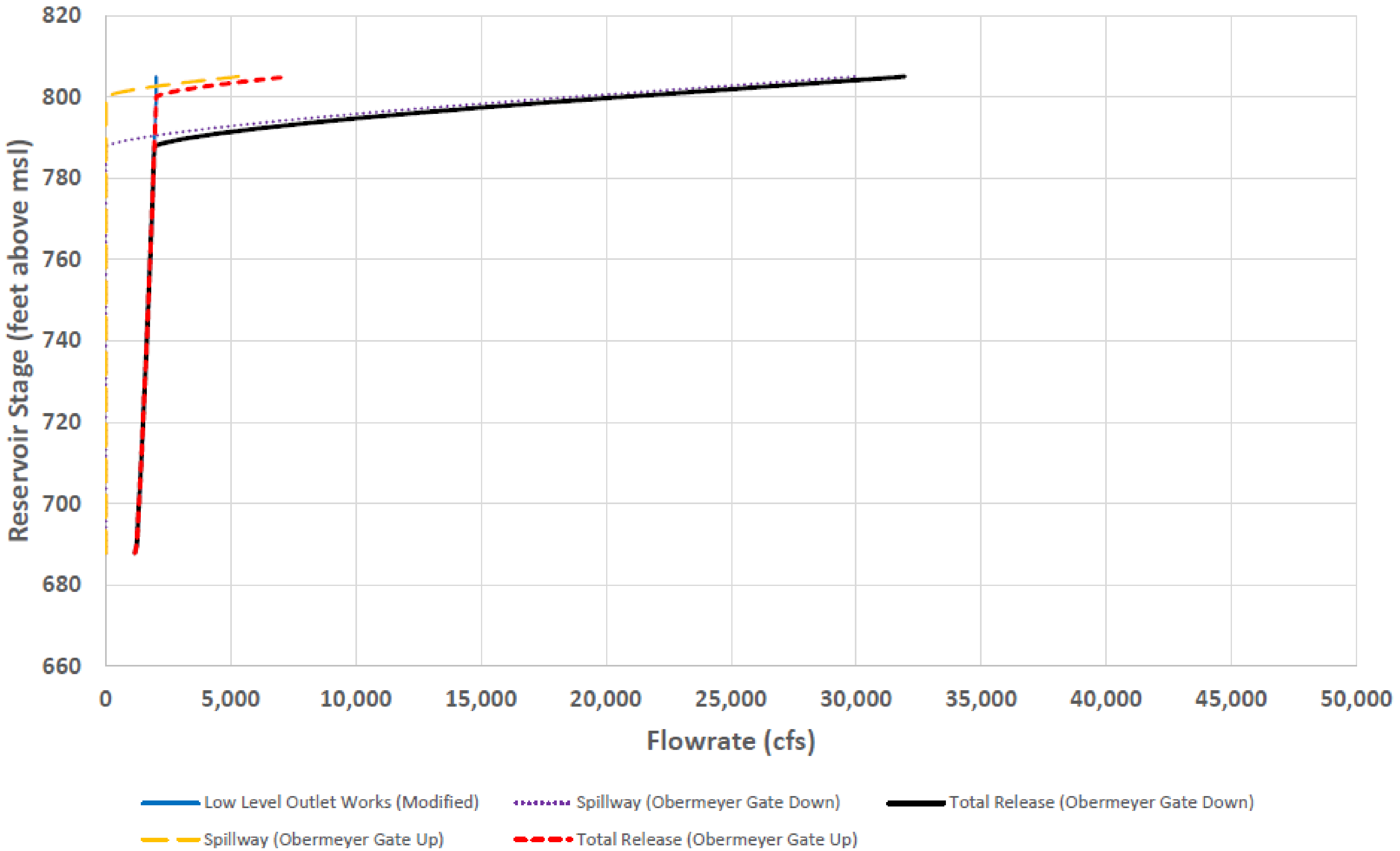
Figure 3



Rating Curve for Nacimiento Dam with Modified Low-Level Outlet Works

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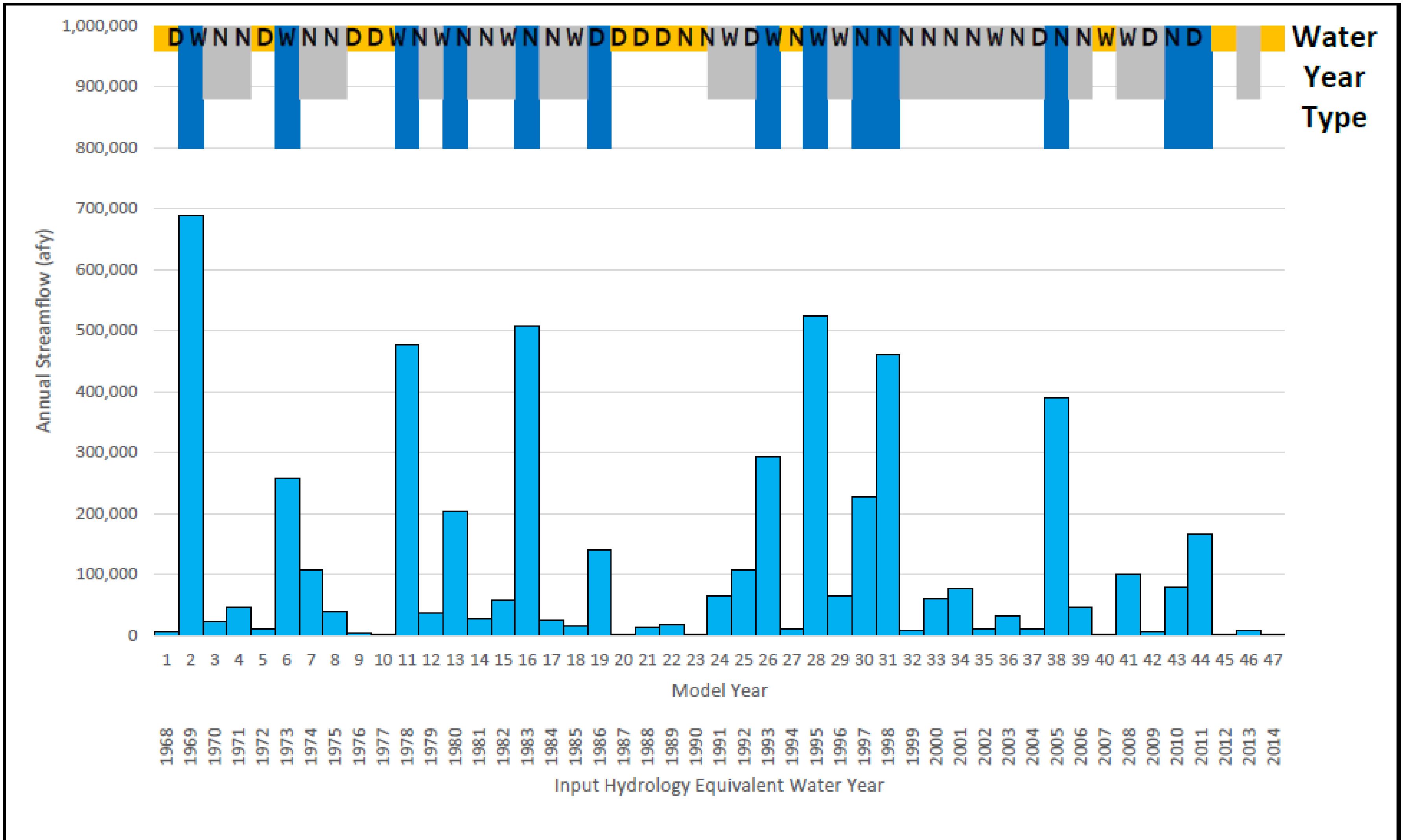
May 2022
wood.
Figure 4

Provisional data subject to revision.



Water Year Type:

- Wet
- Normal
- Dry

Salinas River Annual Streamflow at Upstream Boundary Condition

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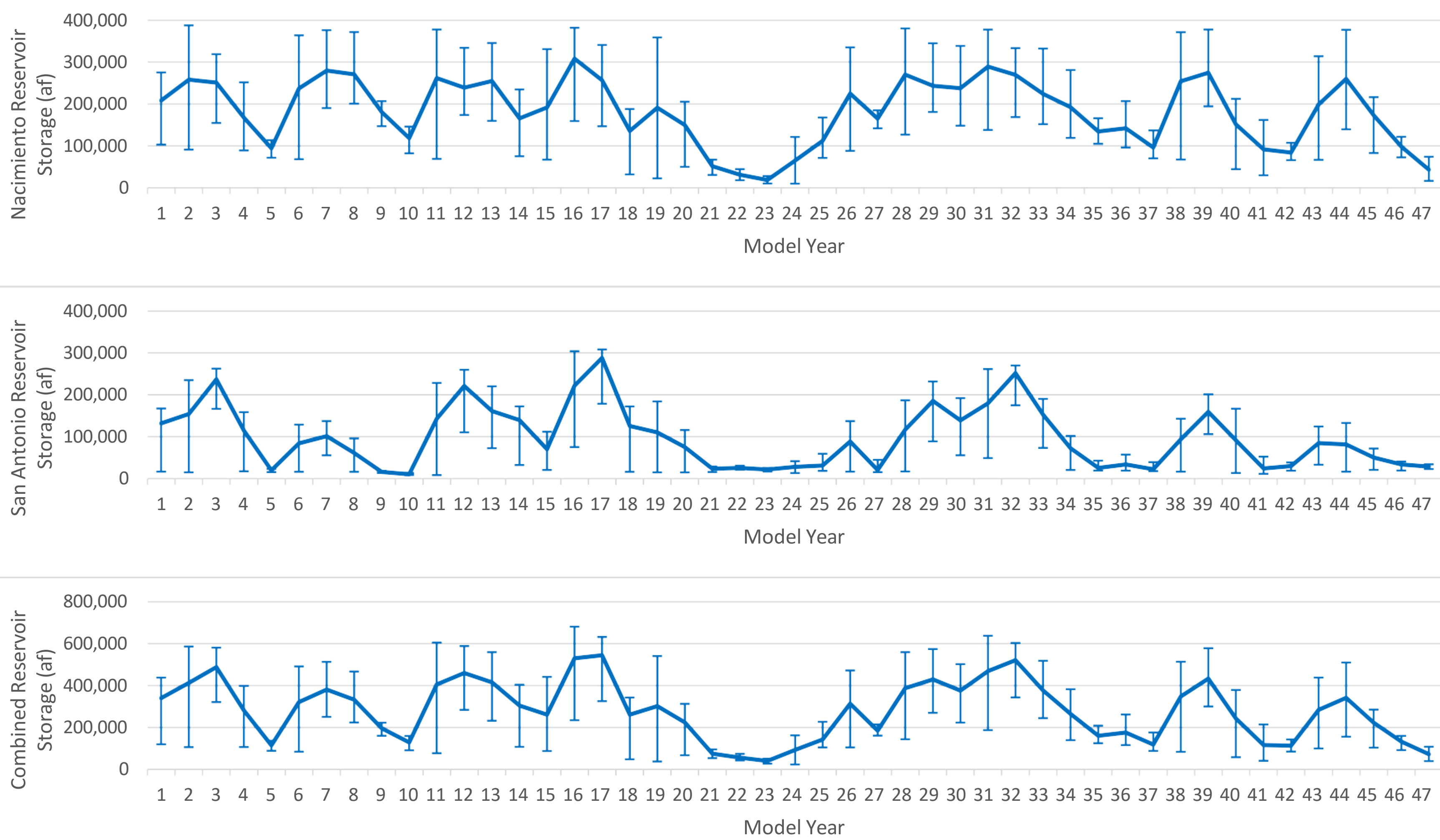
Figure 5

Provisional data subject to revision.



Note: Vertical bars represent the range of storage values simulated during each model year.

Baseline Scenario: Time Series of Reservoir Storage and Stage

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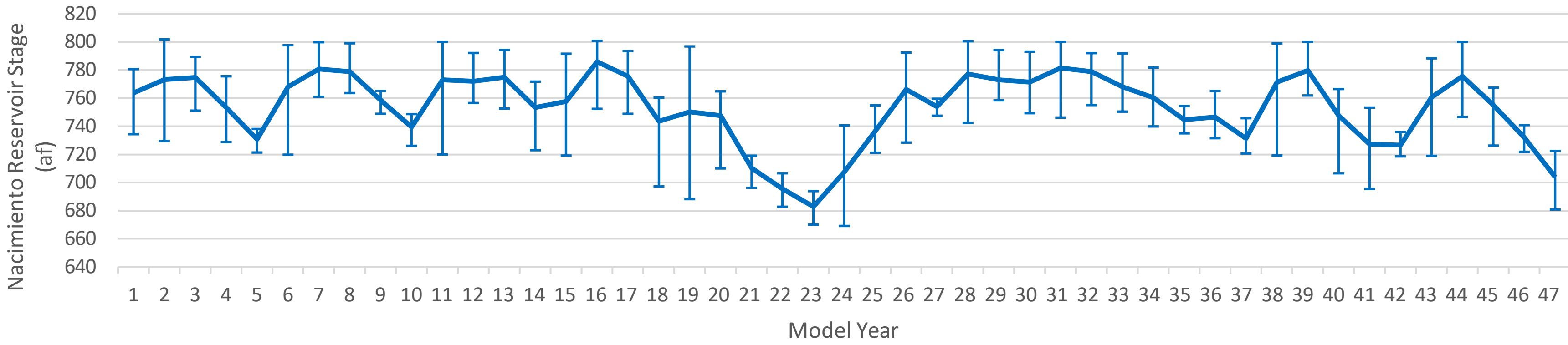
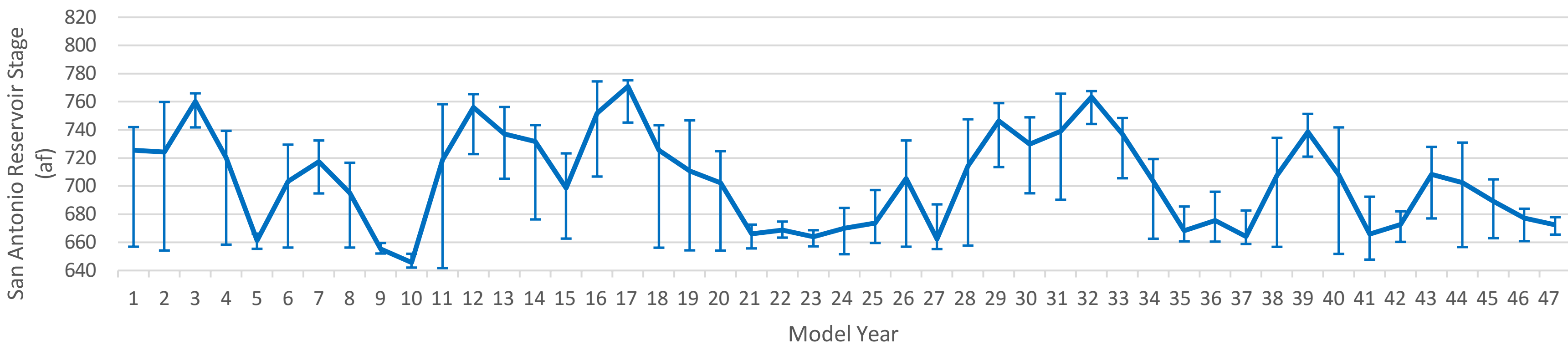
Figure 6a

wood.

Provisional data subject to revision.





Note: Vertical bars represent the range of stage values simulated during each model year.

Baseline Scenario: Time Series of Reservoir Storage and Stage

Salinas Valley Operational Model Report
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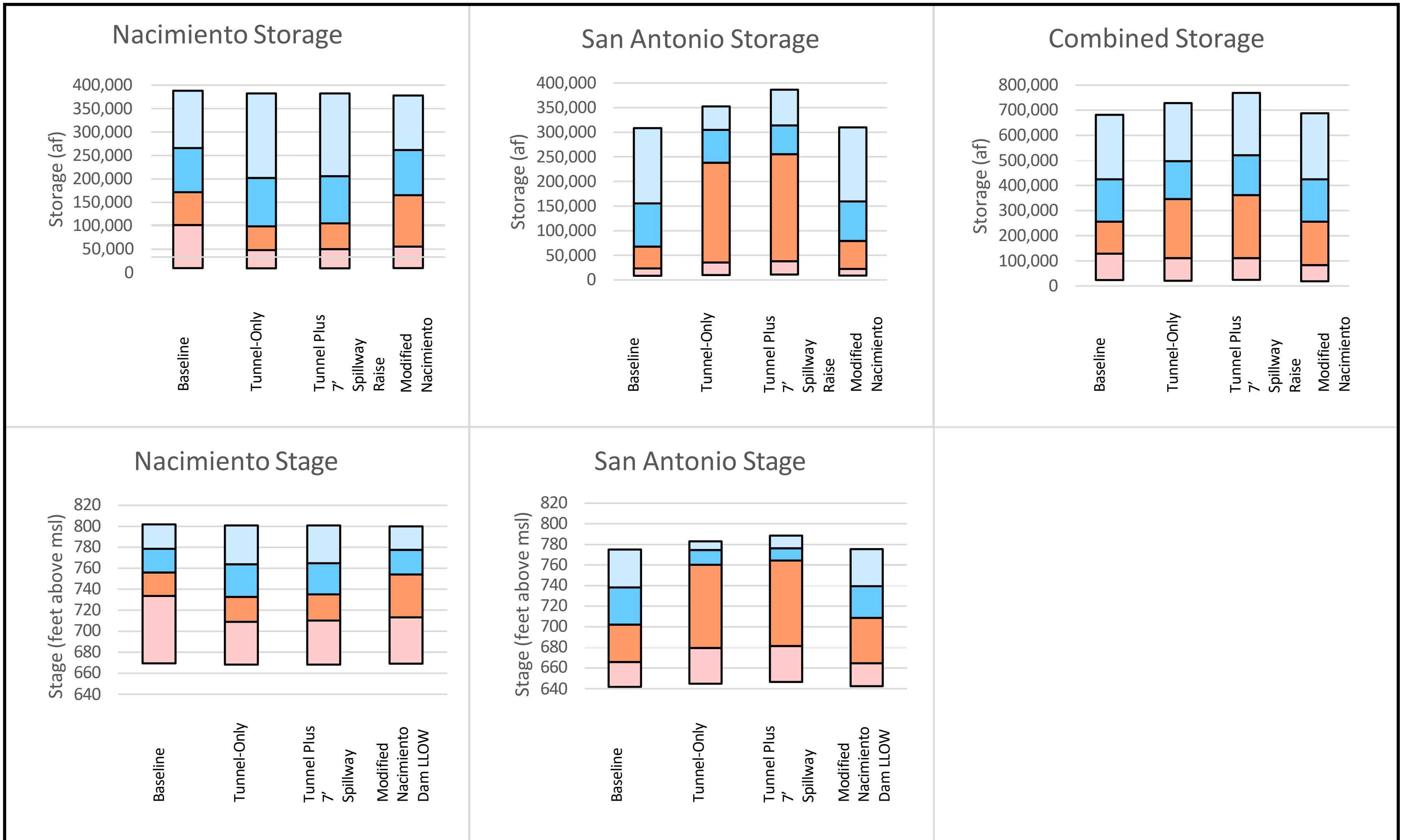
Figure 6b

Provisional data subject to revision.



1st Quartile
2nd Quartile
3rd Quartile
4th Quartile

Quartile Charts of Reservoir Storage and Stage

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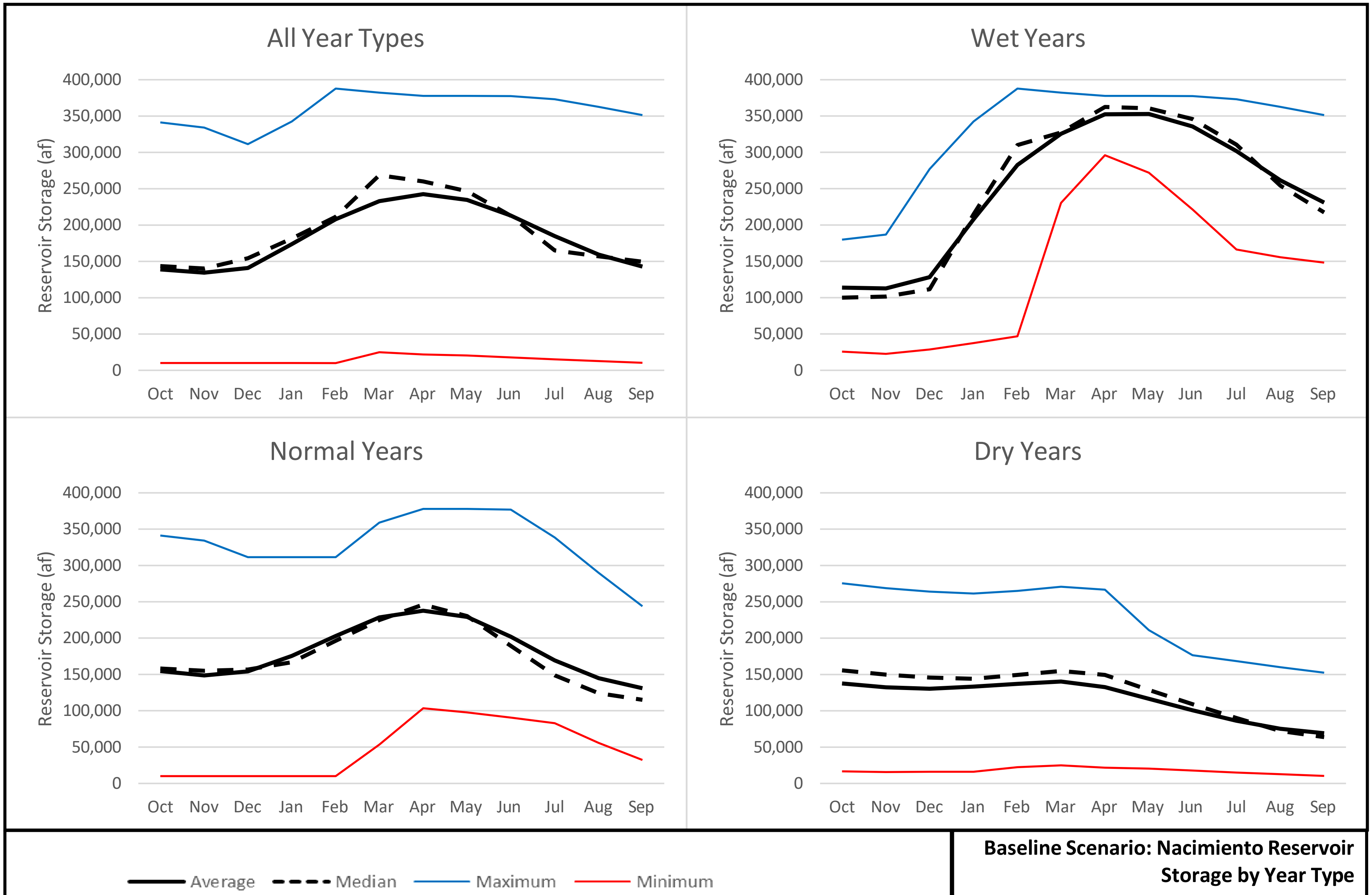
Figure 7

Provisional data subject to revision.



Baseline Scenario: Nacimiento Reservoir Storage by Year Type

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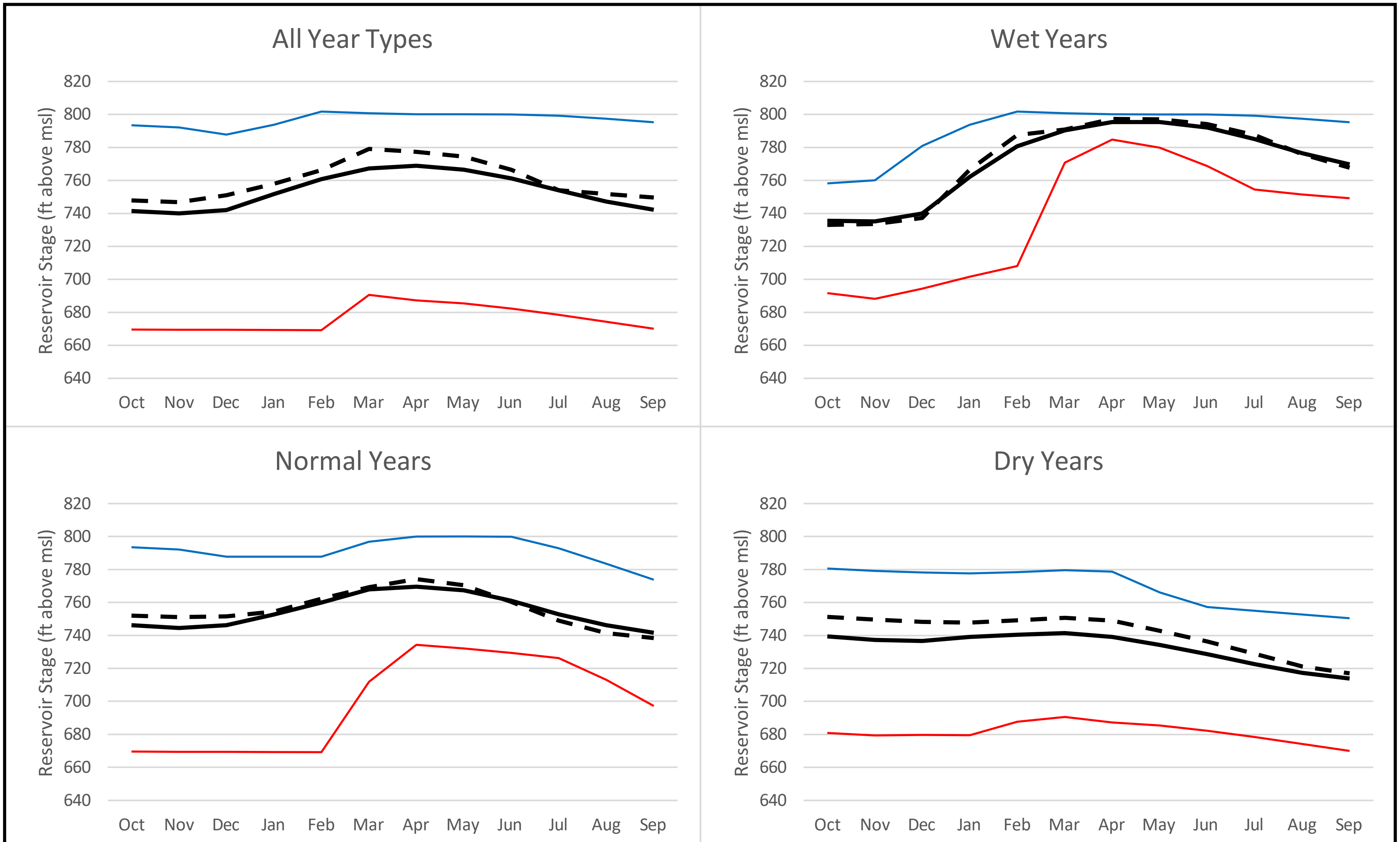
Figure 8a

Provisional data subject to revision.



Average Median Maximum Minimum

Baseline Scenario: Nacimiento Reservoir Stage by Year Type

Salinas Valley Operational Model Report
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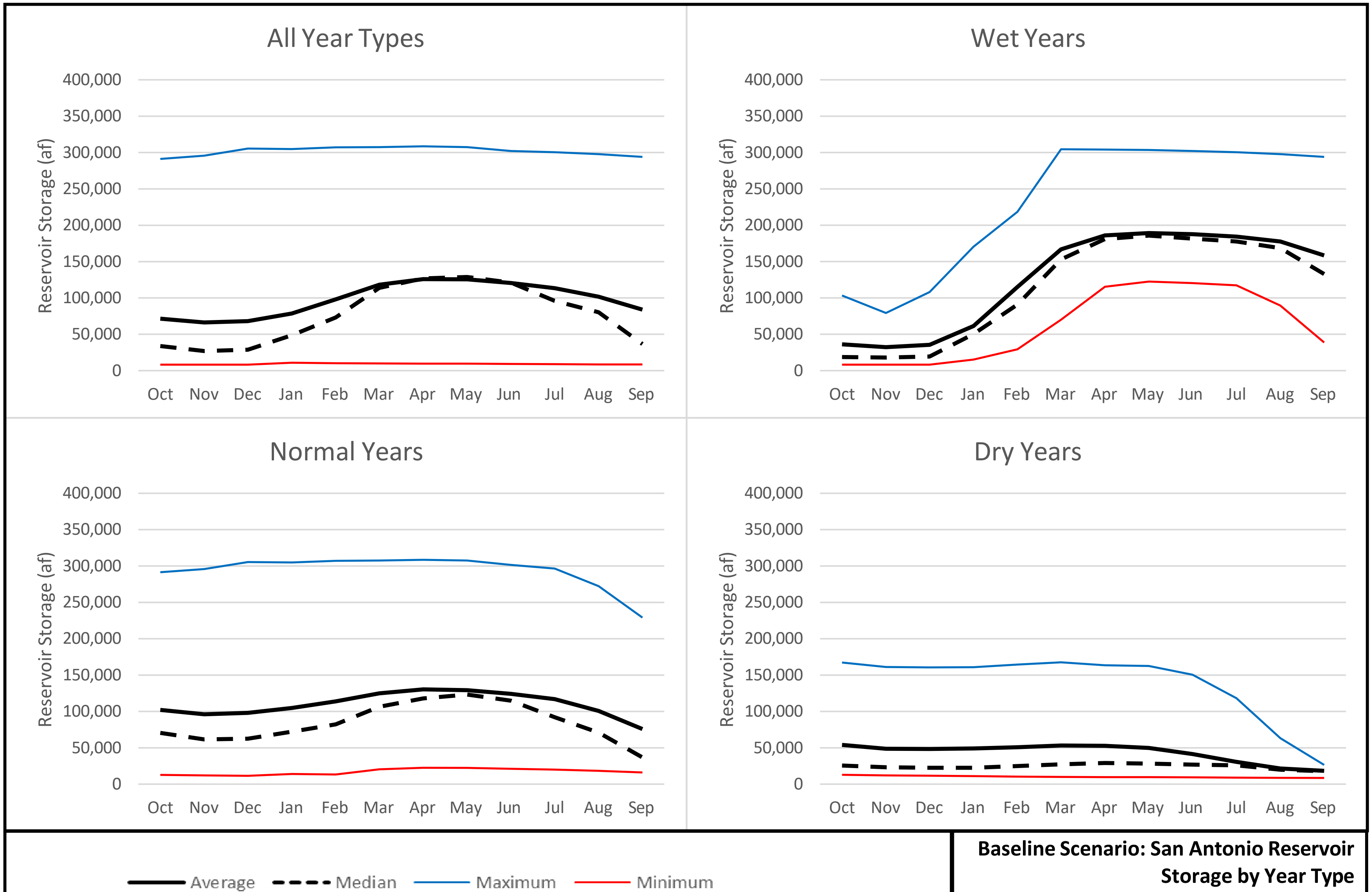
Figure 8b

wood.

Provisional data subject to revision.



Baseline Scenario: San Antonio Reservoir Storage by Year Type

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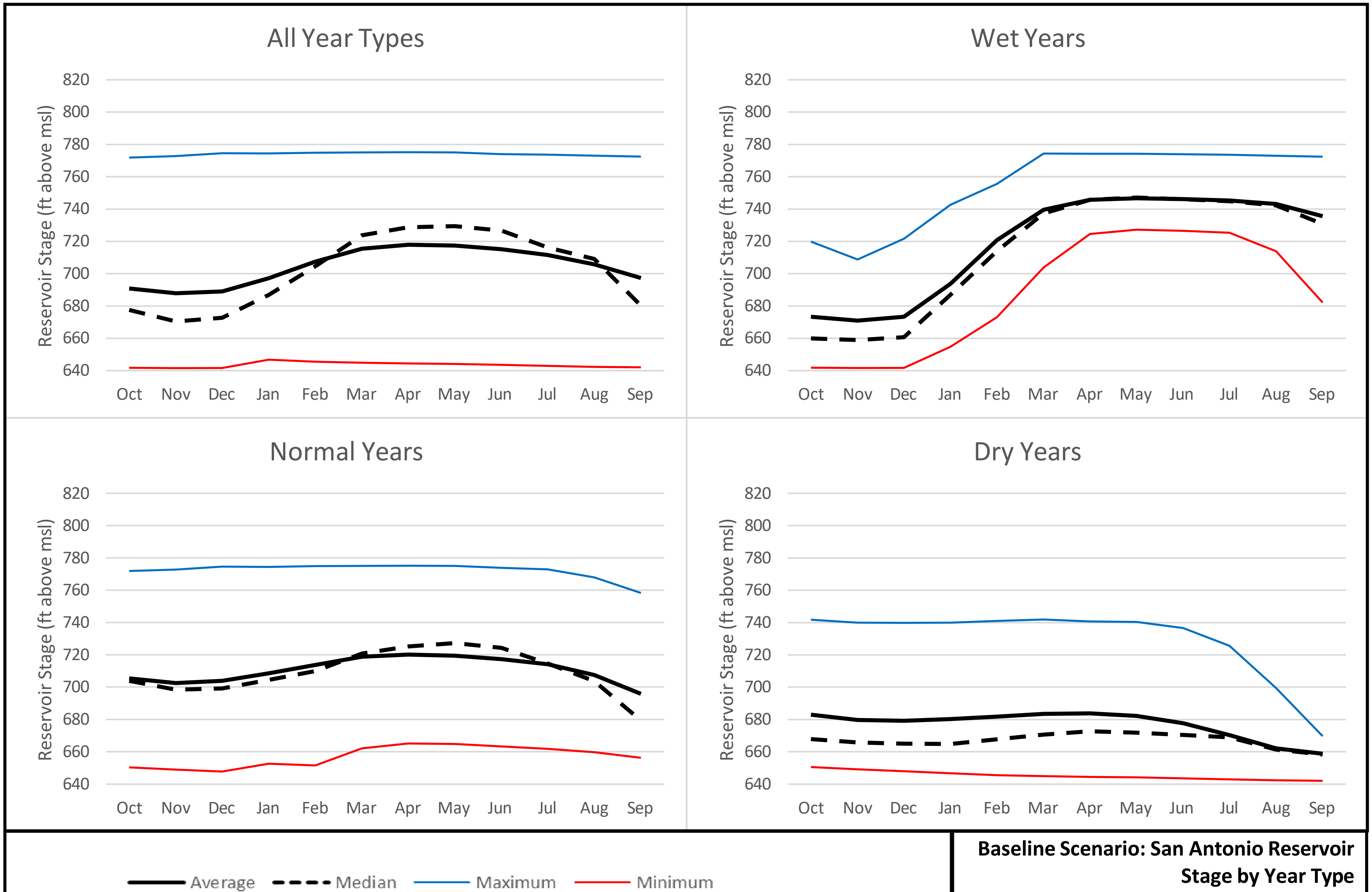
Figure 8c

Provisional data subject to revision.



Baseline Scenario: San Antonio Reservoir Stage by Year Type

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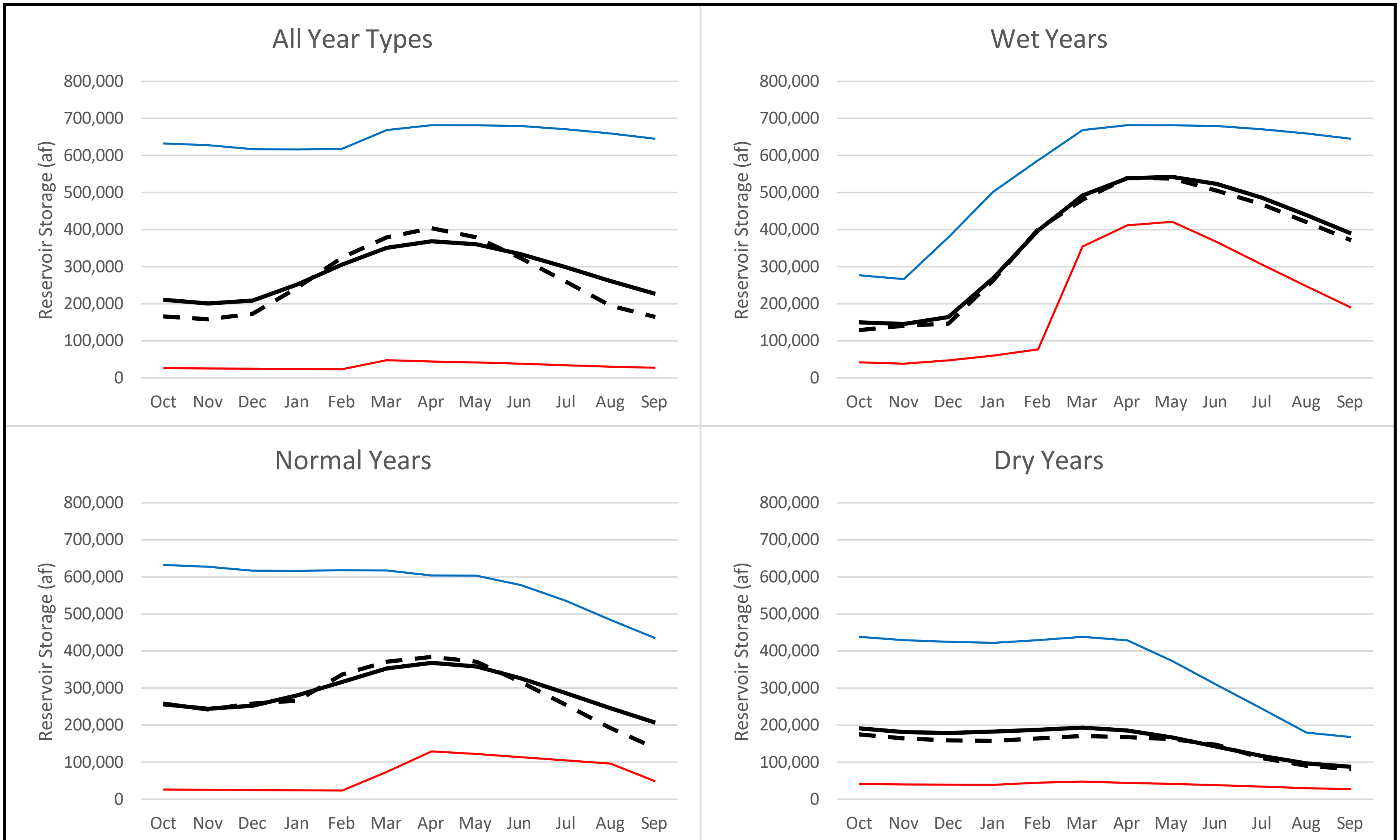
Figure 8d

Provisional data subject to revision.



Baseline Scenario: Combined Reservoir Storage by Year Type

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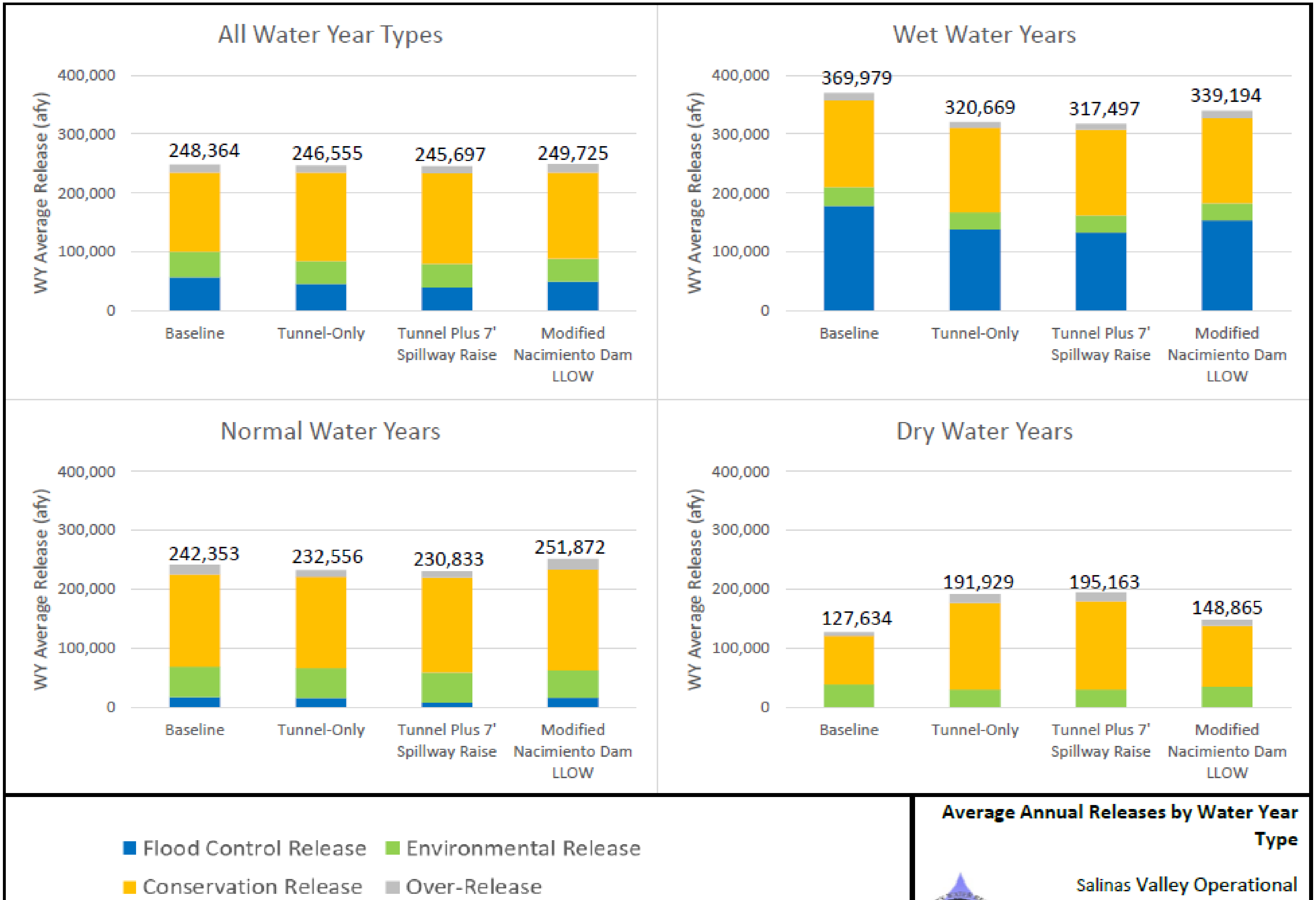
Figure 8e

Provisional data subject to revision.



Average Annual Releases by Water Year Type

Salinas Valley Operational Model Report
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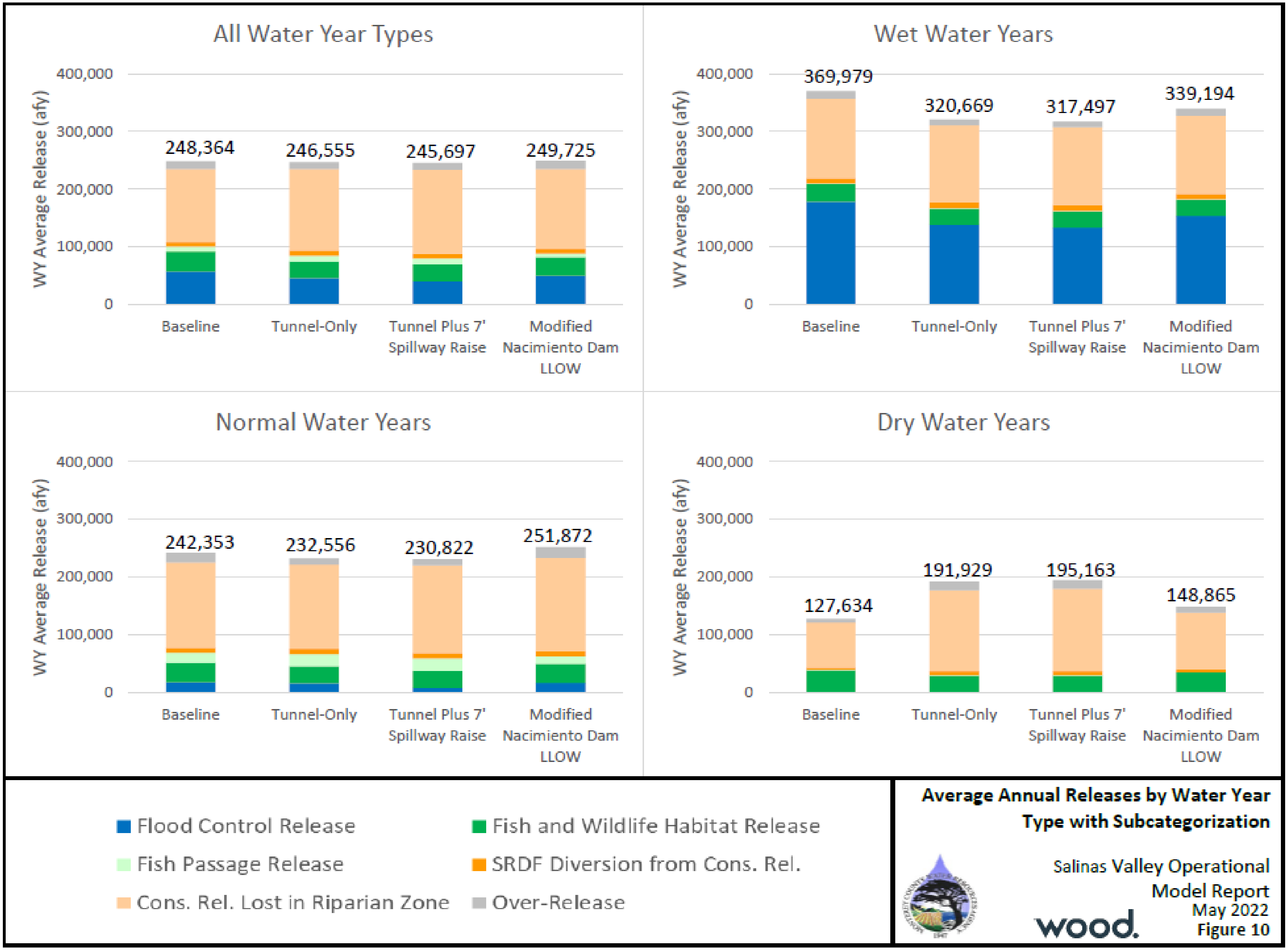
Figure 9

wood.

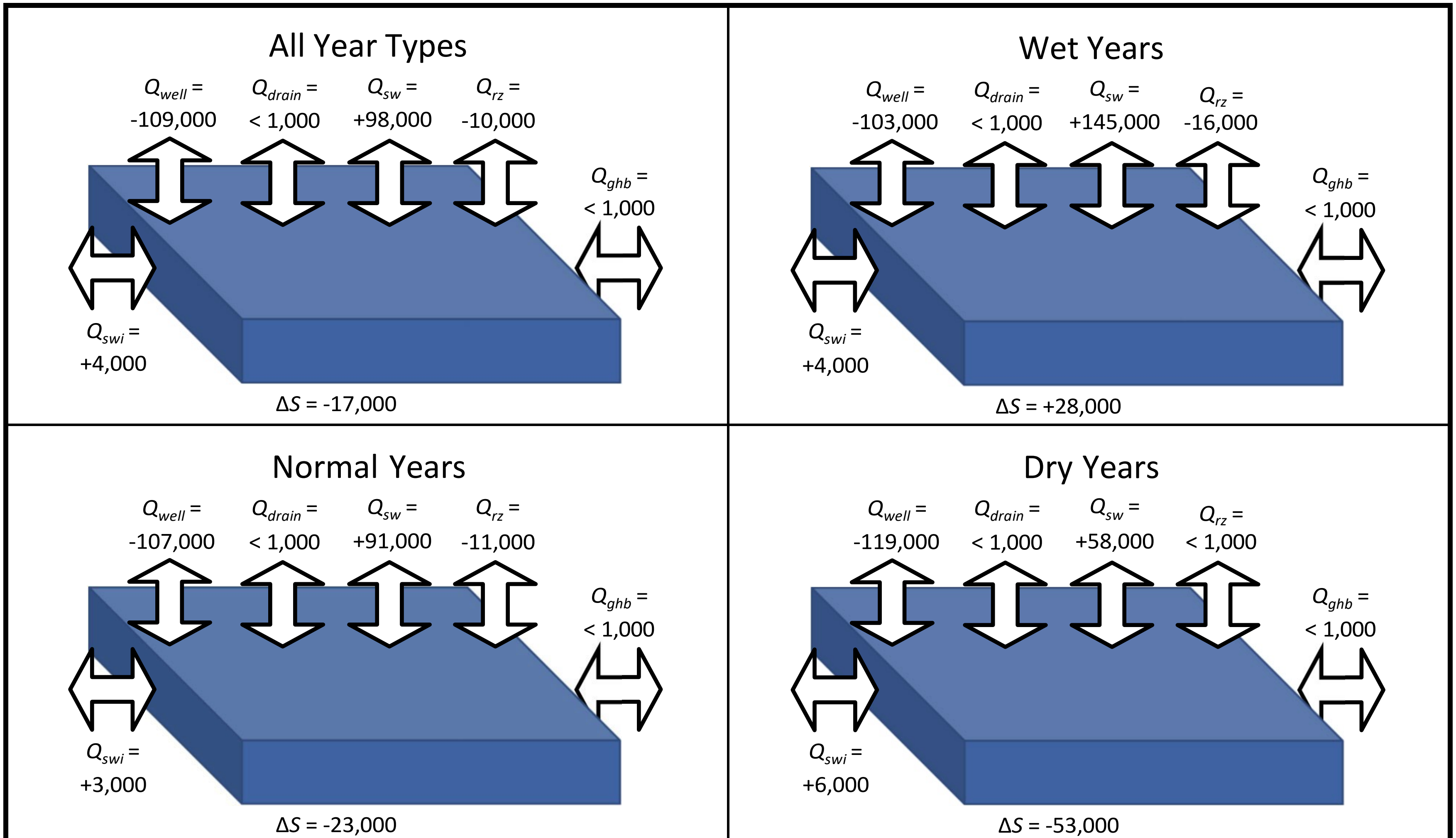
Provisional data subject to revision.



Average Annual Releases by Water Year Type with Subcategorization

Salinas Valley Operational Model Report
May 2022
Figure 10

Provisional data subject to revision.



Notes:
All water budget components are reported in acre-feet per year (afy)
See Section 4.2.6 for variable definitions.
Positive values of ΔS represent a loss of storage, negative values represent a gain in storage.

Baseline Scenario: Groundwater Budget by Water Year Type

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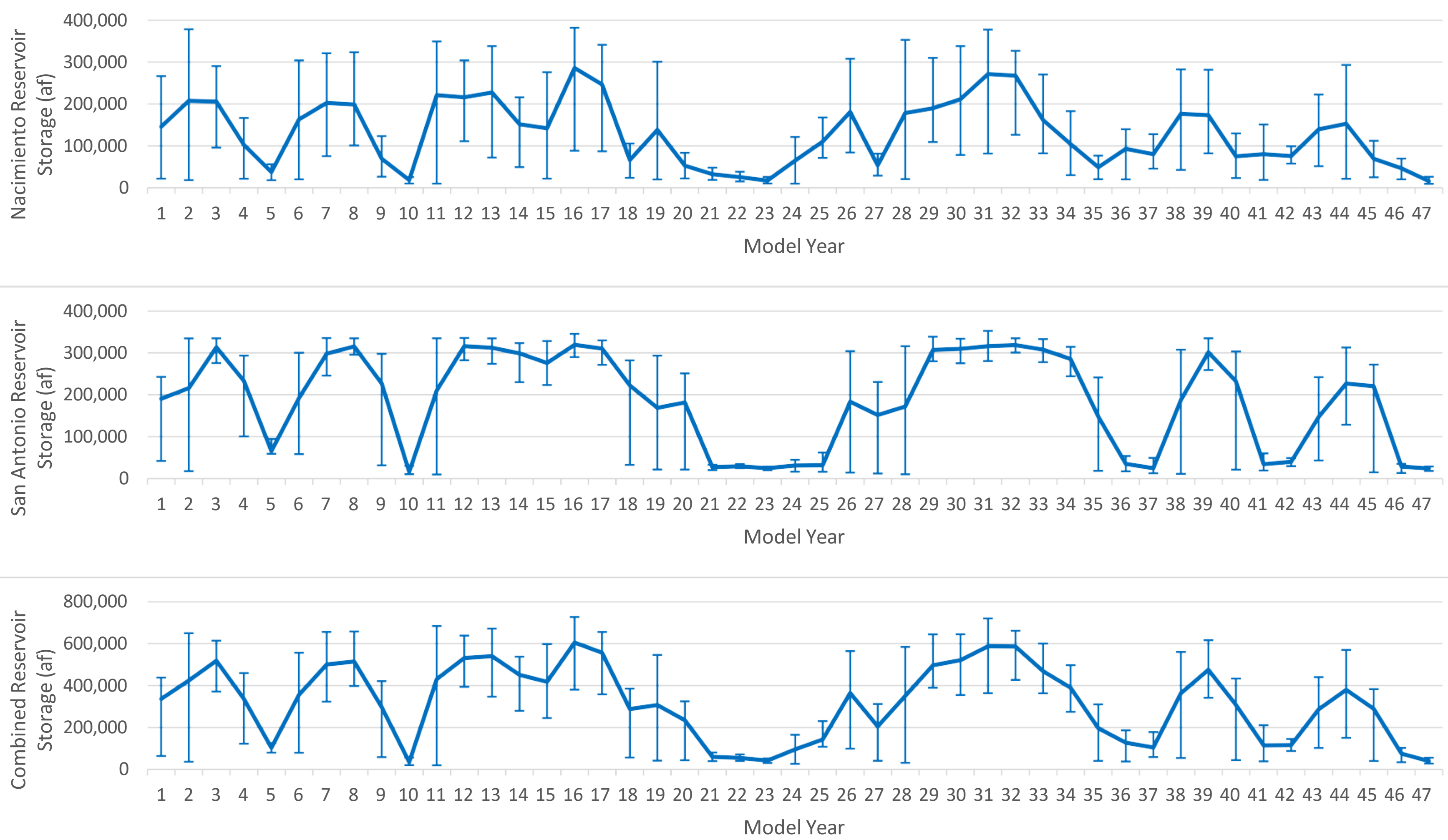
Figure 11

Provisional data subject to revision.



Note: Vertical bars represent the range of storage values simulated during each model year.

Tunnel-Only Scenario: Time Series of Reservoir Storage and Stage

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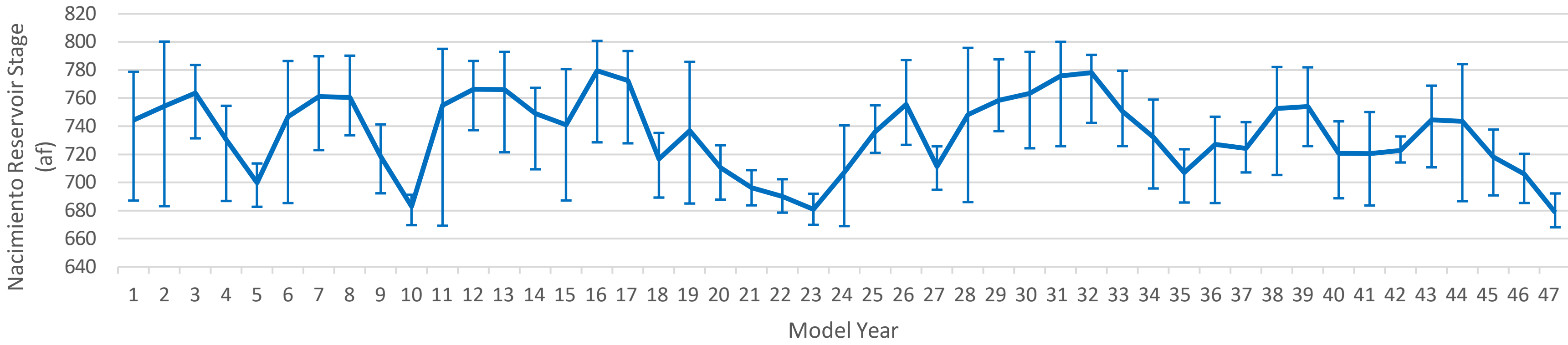
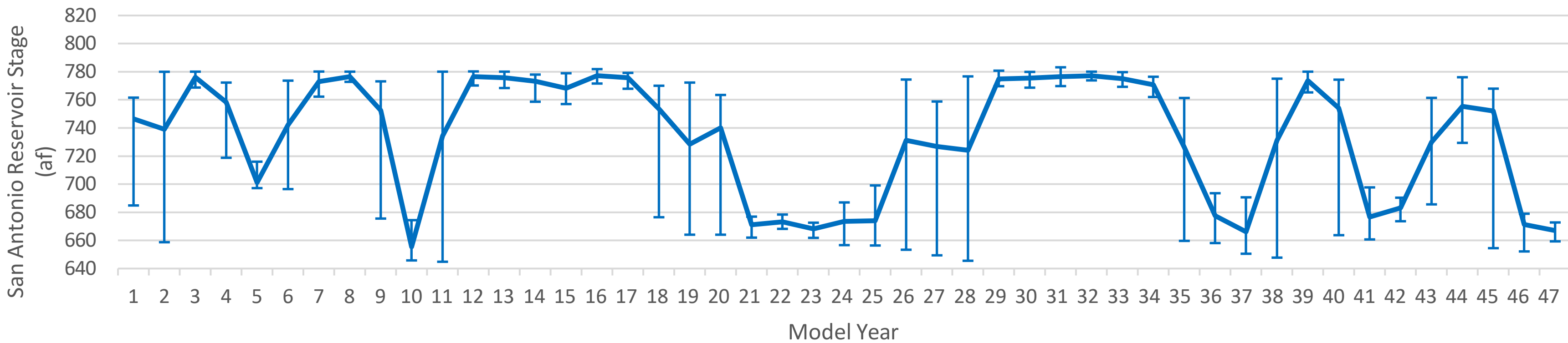
Figure 12a

Provisional data subject to revision.





Note: Vertical bars represent the range of stage values simulated during each model year.

Tunnel-Only Scenario: Time Series of Reservoir Storage and Stage

Salinas Valley Operational Model Report
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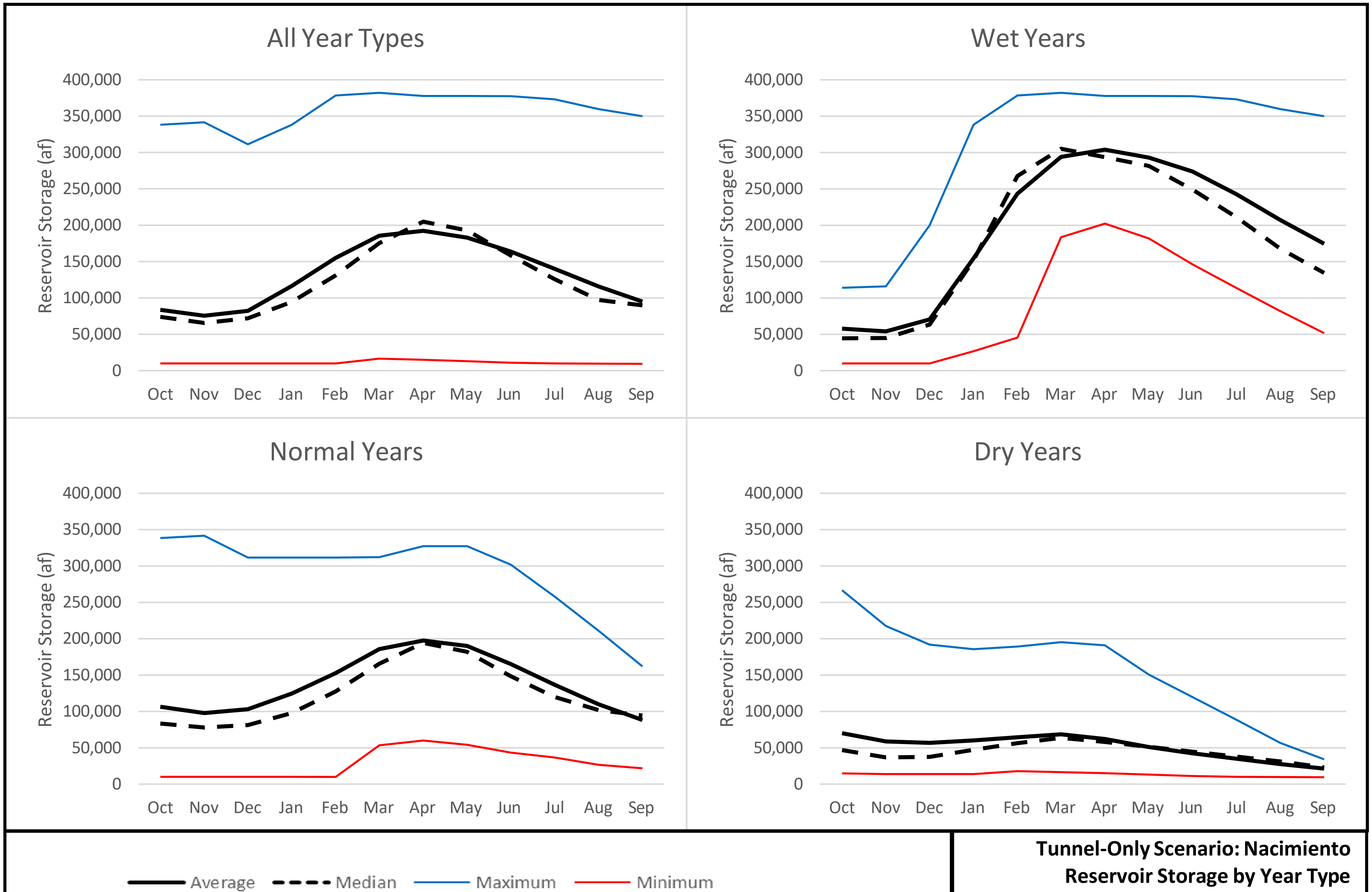
Figure 12b

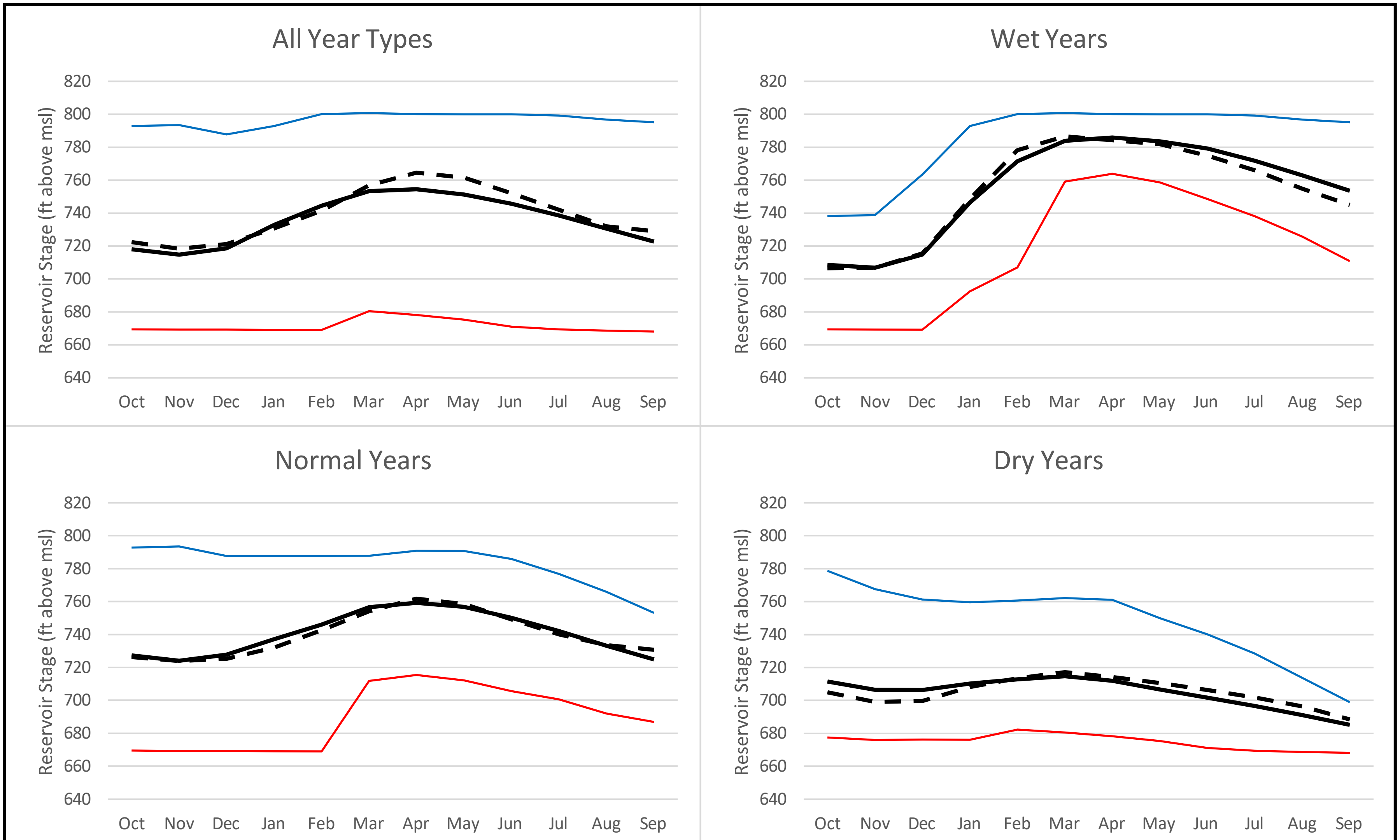
Provisional data subject to revision.



Tunnel-Only Scenario: Nacimiento Reservoir Storage by Year Type

Salinas Valley Operational Model Report
May 2022
Figure 13a

Provisional data subject to revision.



Tunnel-Only Scenario: Nacimiento Reservoir Stage by Year Type

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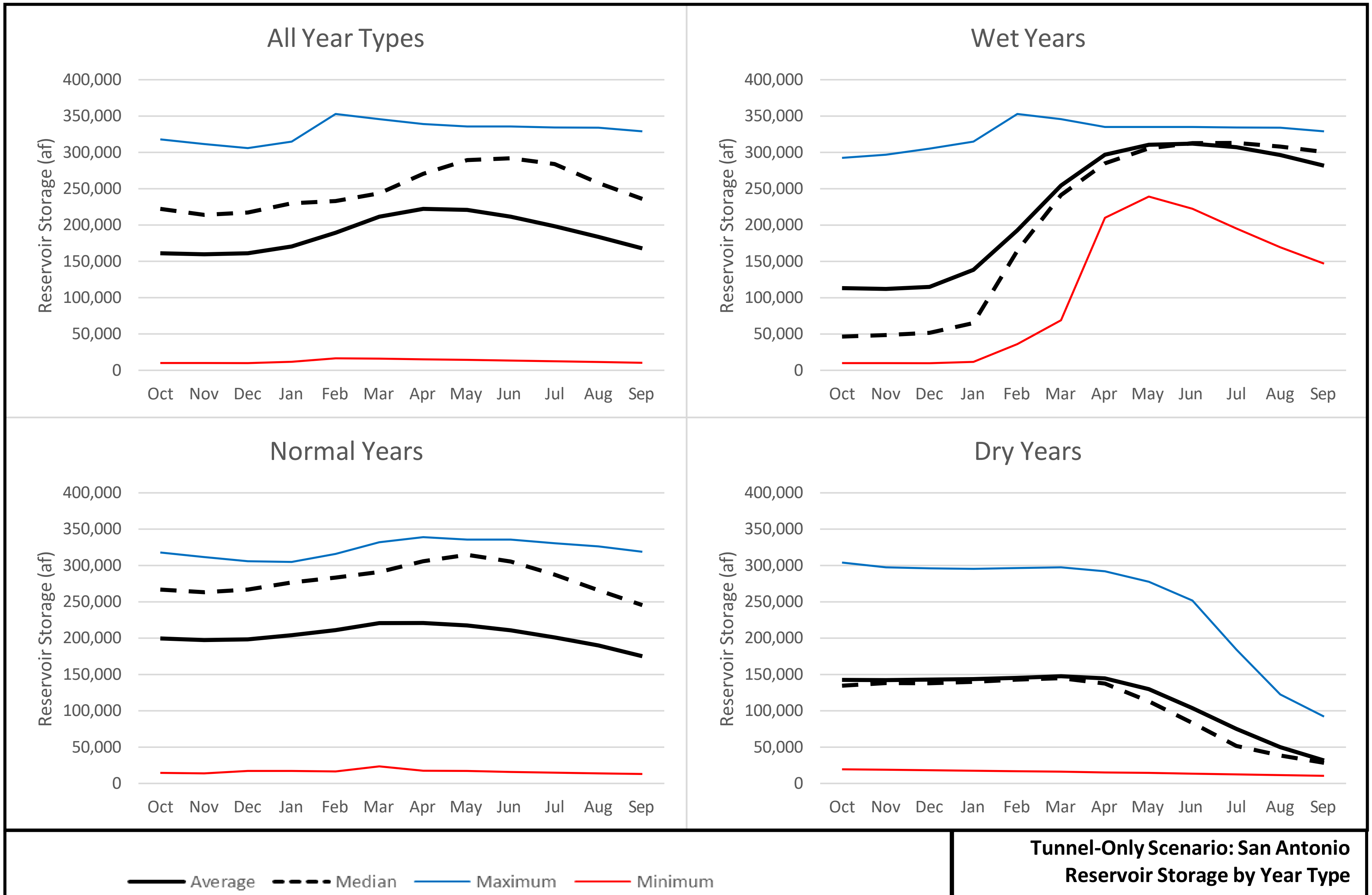
Figure 13b

Provisional data subject to revision.



Tunnel-Only Scenario: San Antonio Reservoir Storage by Year Type

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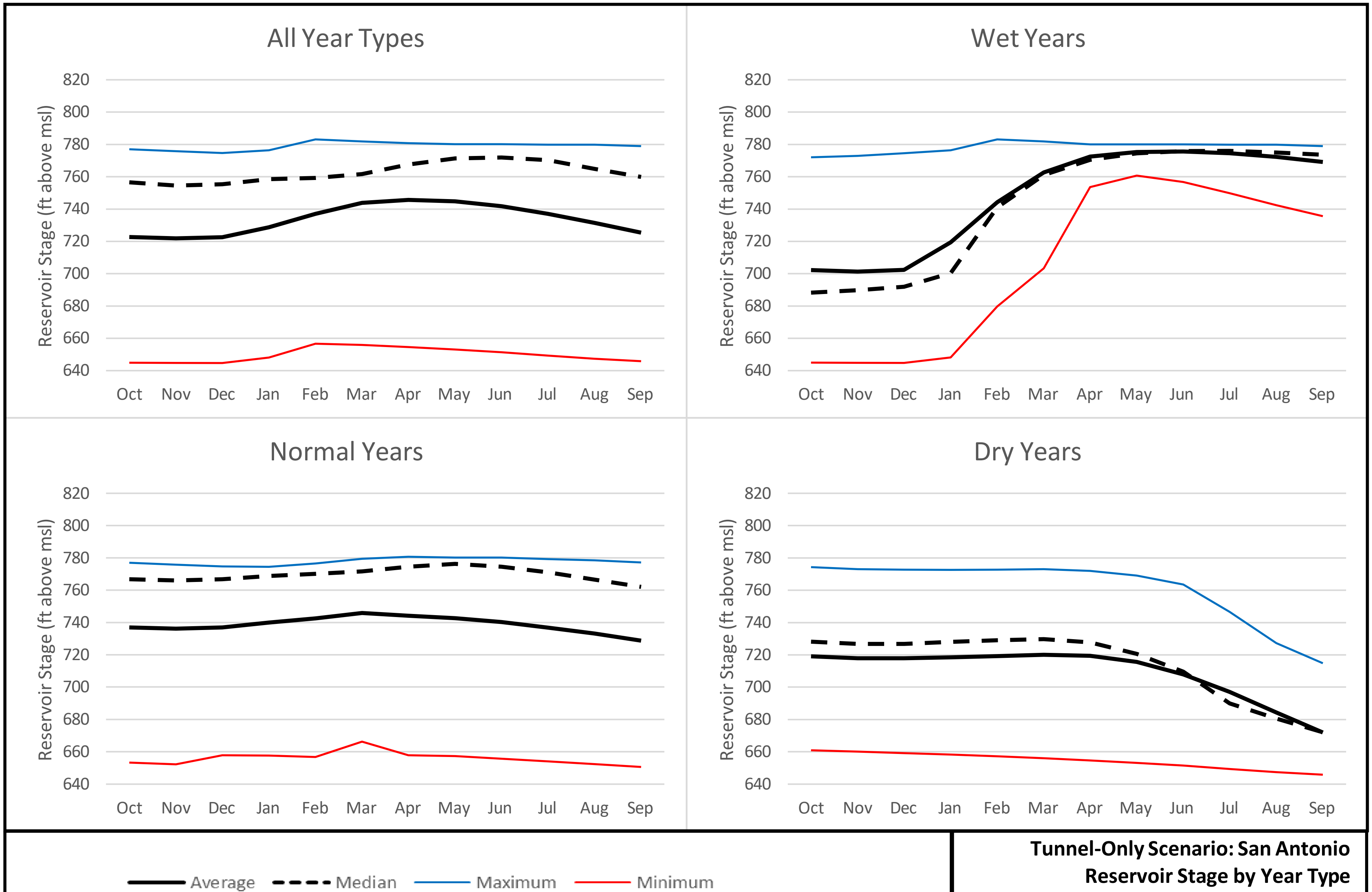
Figure 13c

Provisional data subject to revision.



Tunnel-Only Scenario: San Antonio Reservoir Stage by Year Type

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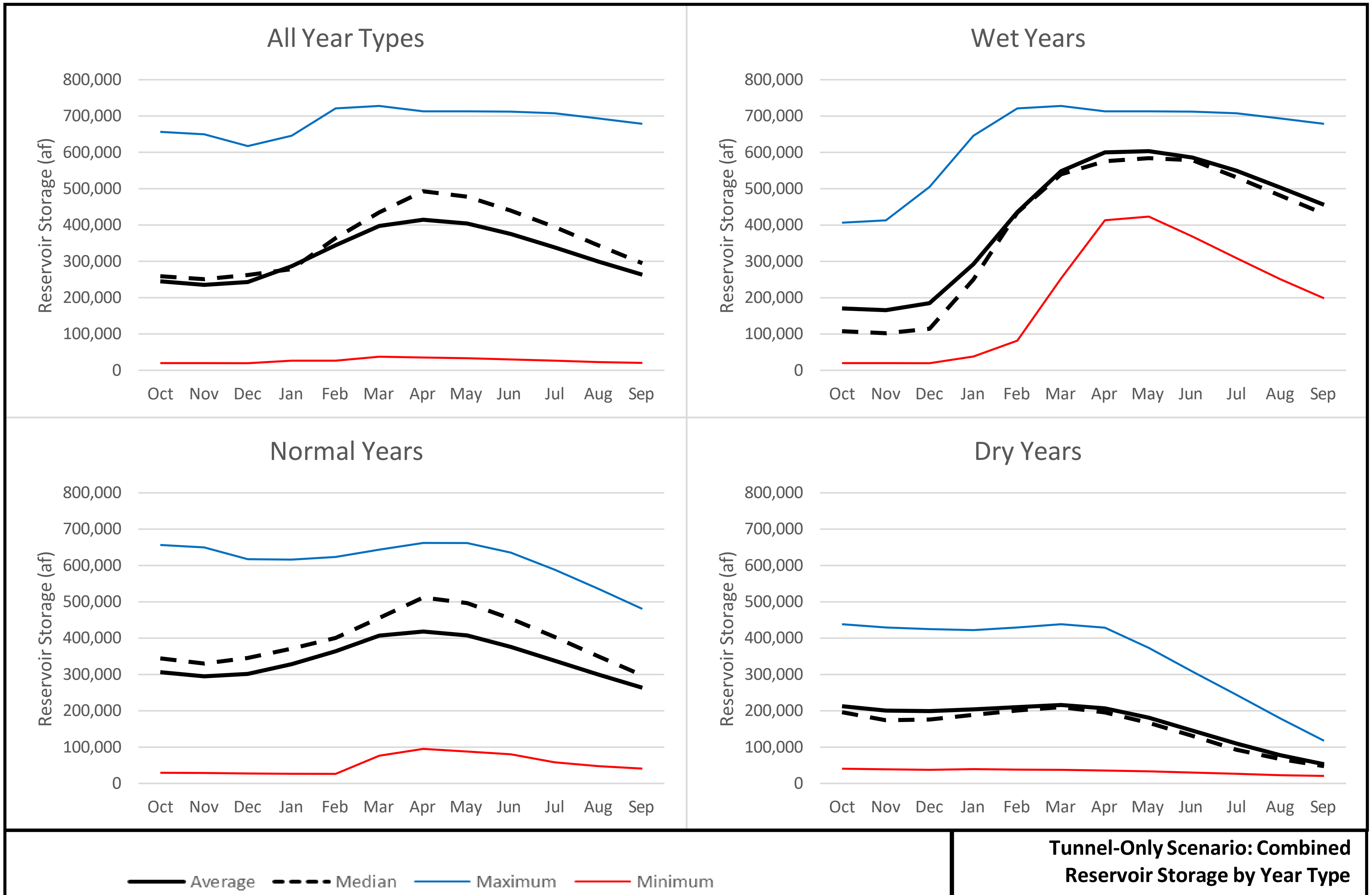
Figure 13d

Provisional data subject to revision.



Tunnel-Only Scenario: Combined Reservoir Storage by Year Type

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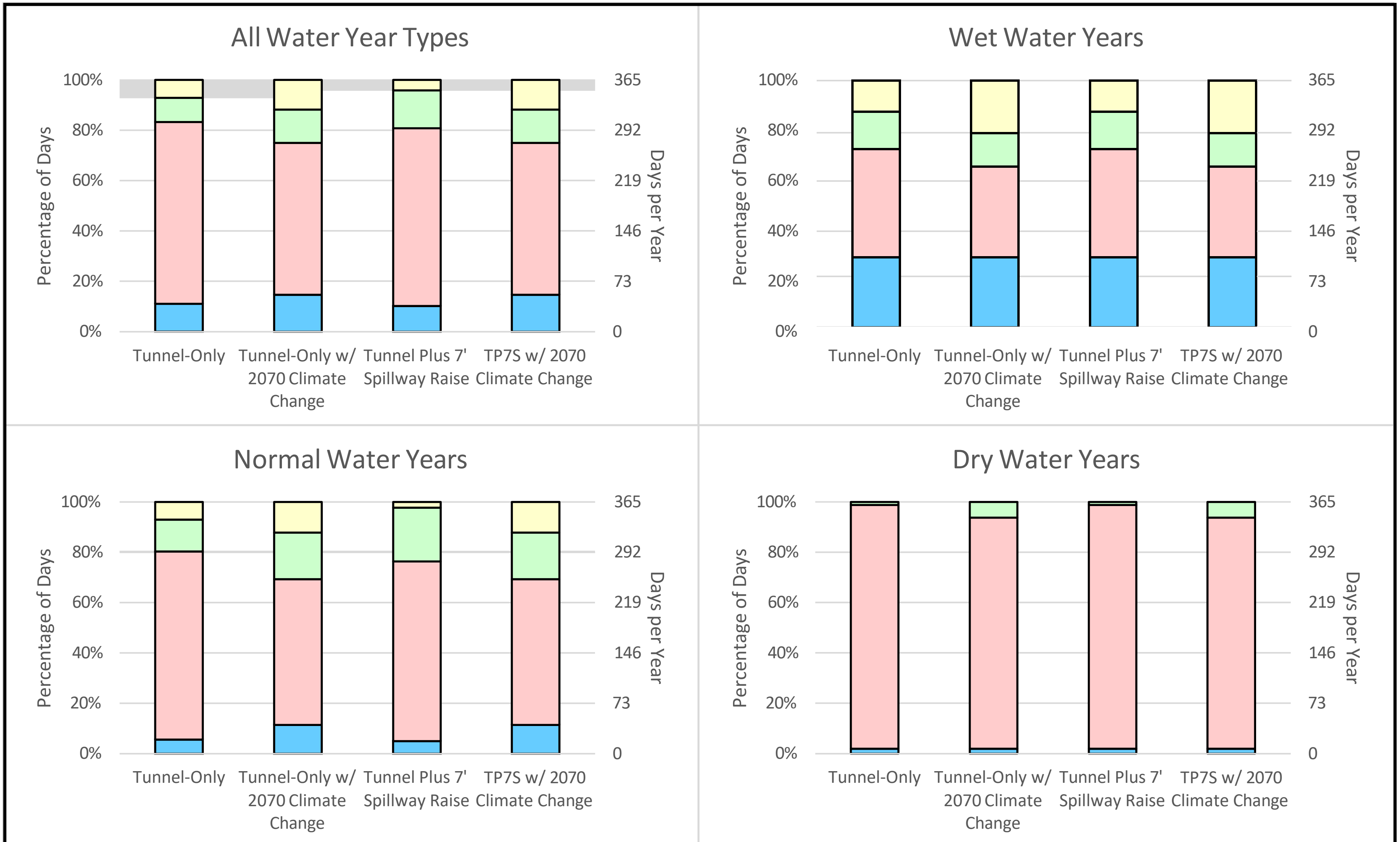
Figure 13e

Provisional data subject to revision.



Tunnel Flowing
Nacimiento Reservoir Stage Below Threshold (760 feet above msl)
San Antonio Reservoir Stage At or Near Flood Rule Curve
San Antonio Reservoir Stage At or Above Nacimiento Reservoir Stage
Nacimiento Reservoir Stage Above 800 feet above msl

Tunnel Operations for All Scenarios

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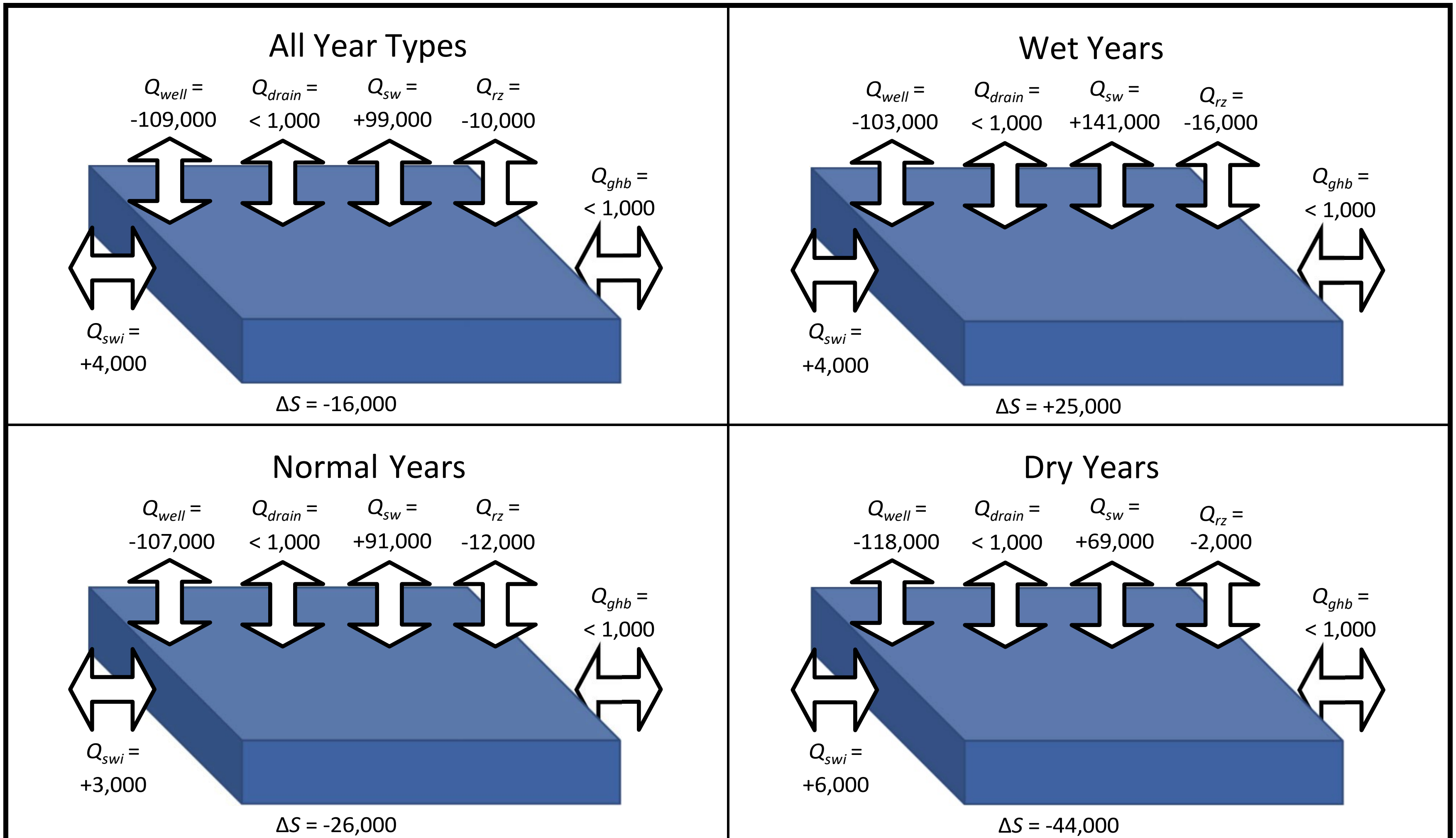
Figure 14

Provisional data subject to revision.



Notes:
All water budget components are reported in acre-feet per year (afy)
See Section 4.2.6 for variable definitions.
Positive values of Δ*S* represent a loss of storage, negative values represent a gain in storage.

Tunnel-Only Scenario: Groundwater Budget by Water Year Type

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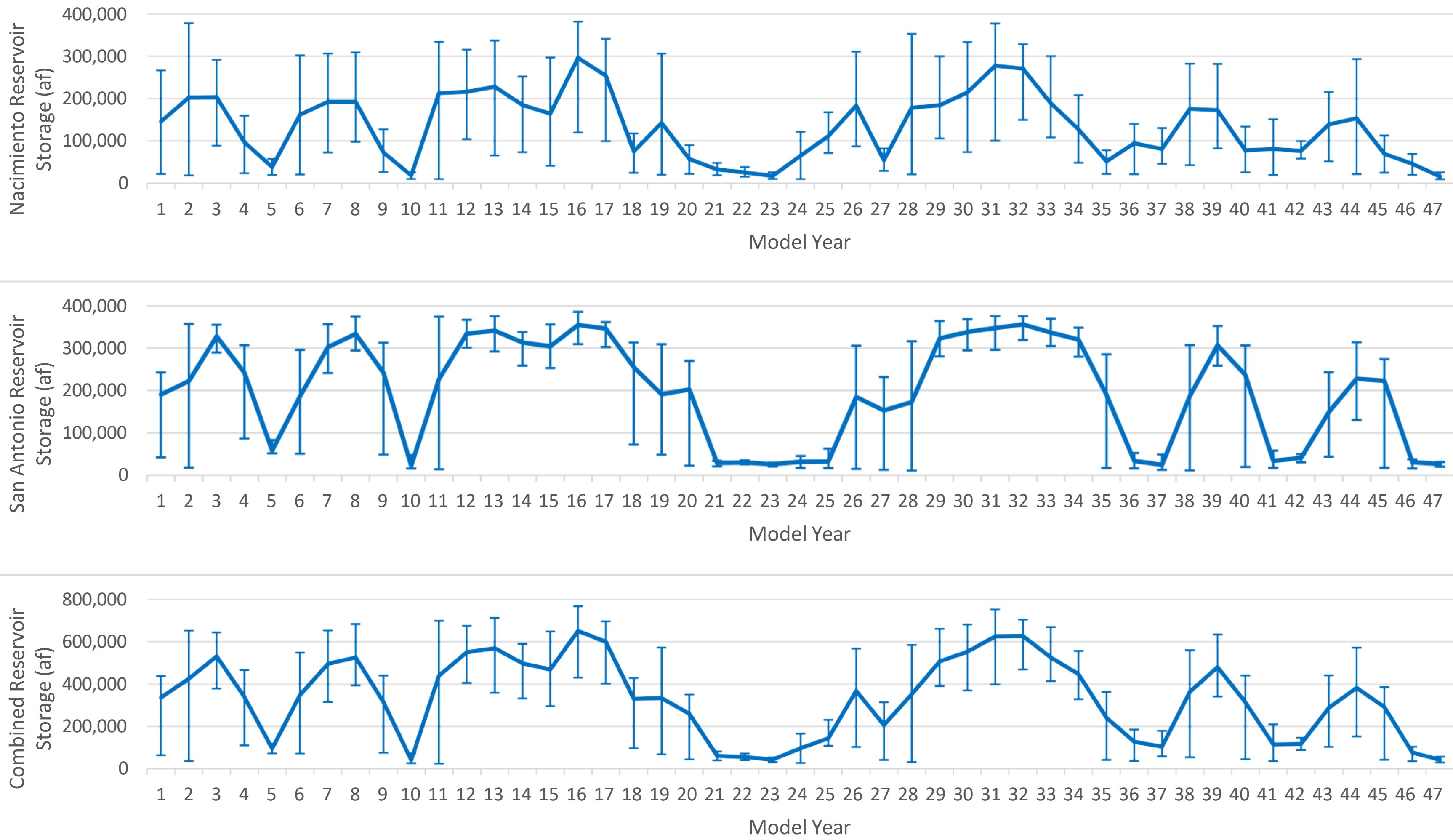
Figure 15

Provisional data subject to revision.



Note: Vertical bars represent the range of storage values simulated during each model year.

Tunnel Plus 7' Spillway Raise Scenario: Time Series of Reservoir Storage and Stage

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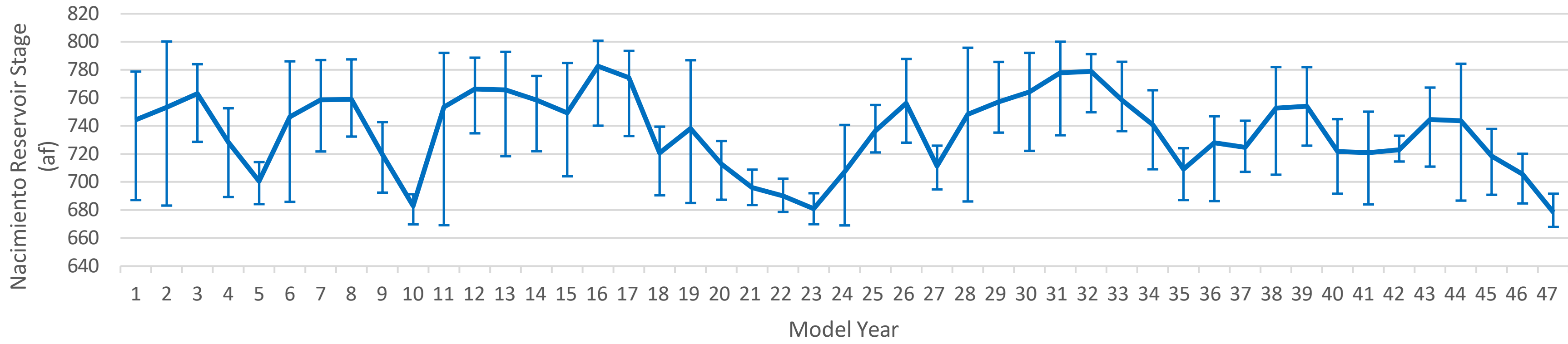
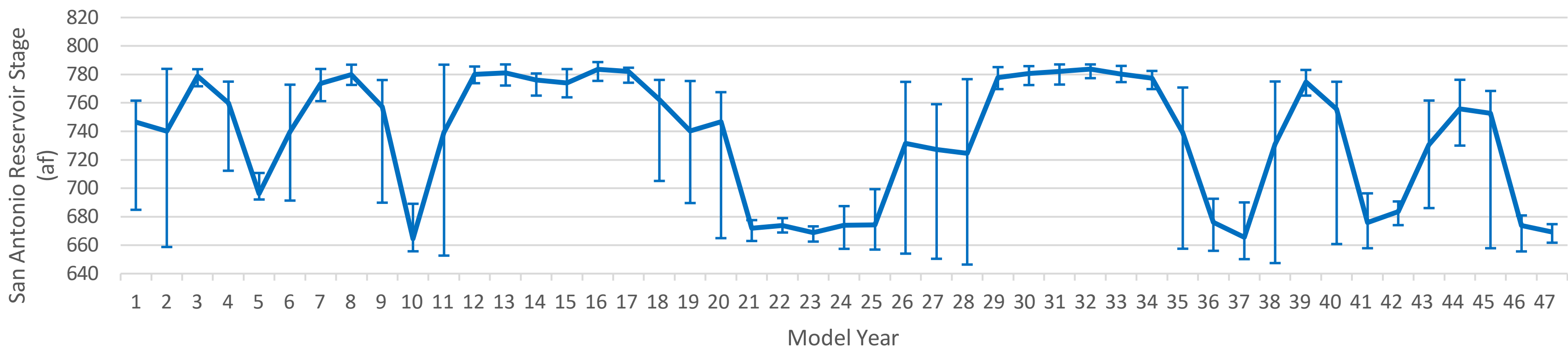
Figure 16a

Provisional data subject to revision.





Note: Vertical bars represent the range of stage values simulated during each model year.

Tunnel Plus 7' Spillway Raise Scenario: Time Series of Reservoir Storage and Stage

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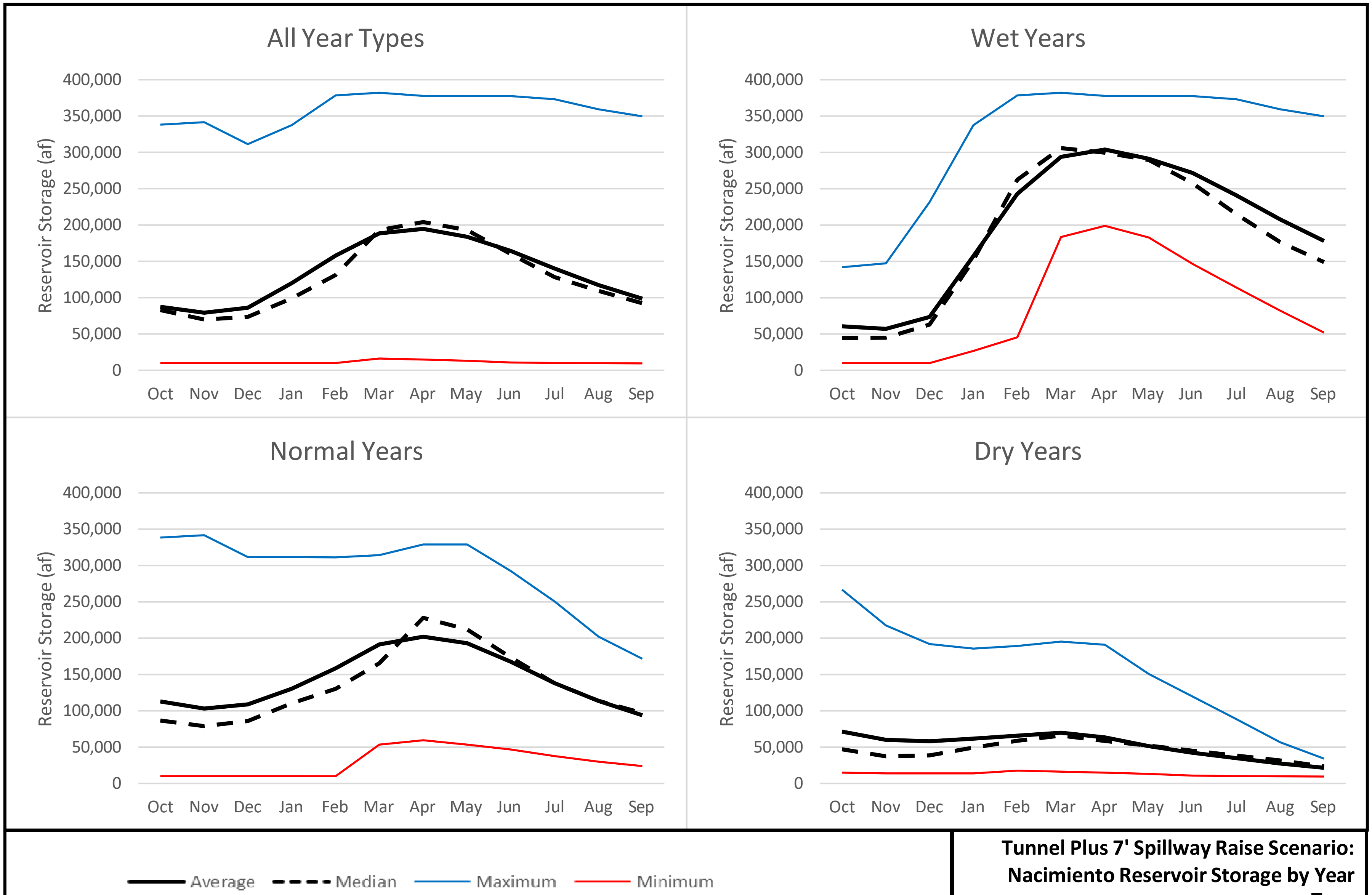
Figure 16b

Provisional data subject to revision.



Tunnel Plus 7' Spillway Raise Scenario: Nacimiento Reservoir Storage by Year Type

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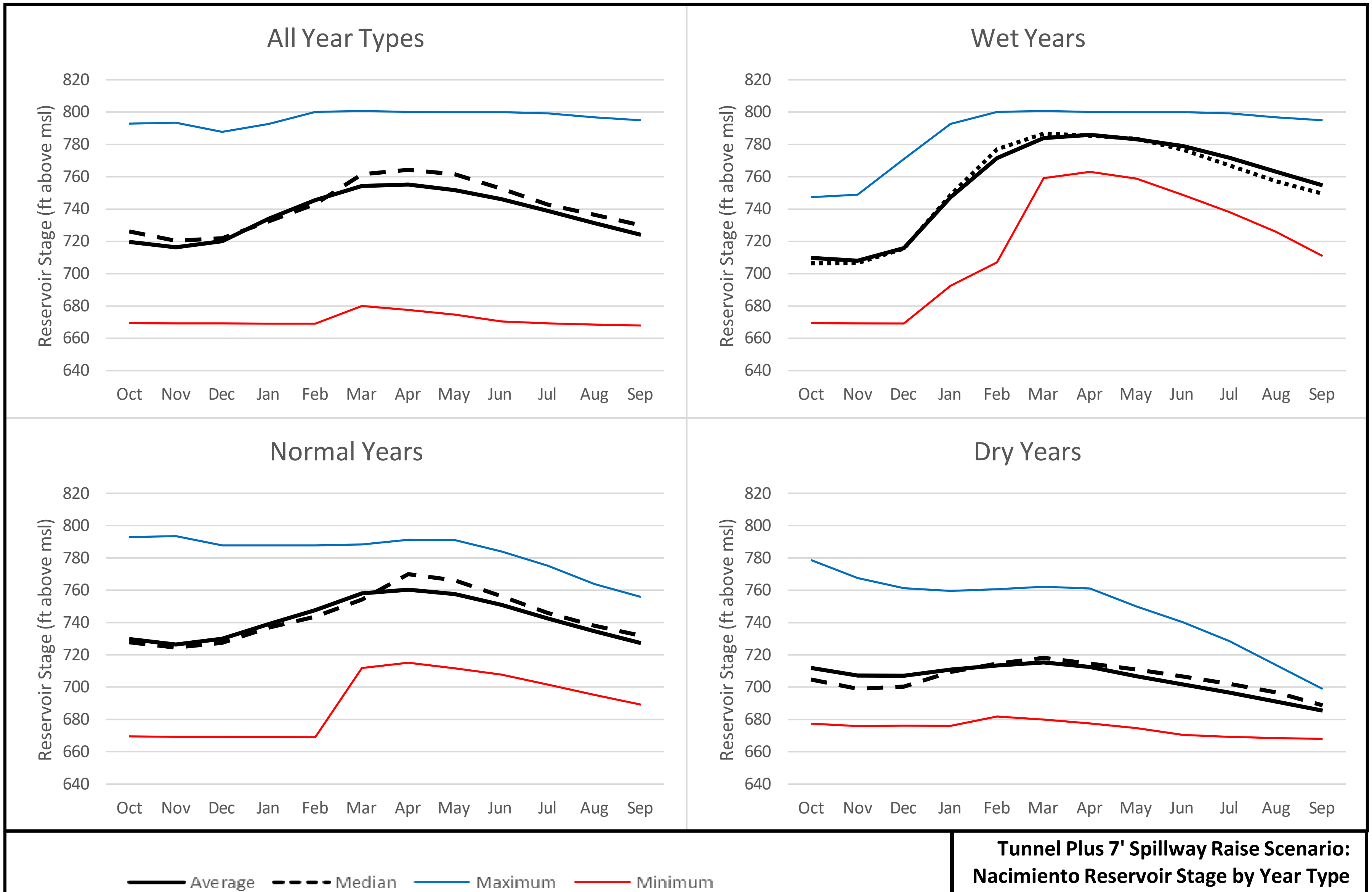
Figure 17a

Provisional data subject to revision.



Tunnel Plus 7' Spillway Raise Scenario: Nacimiento Reservoir Stage by Year Type

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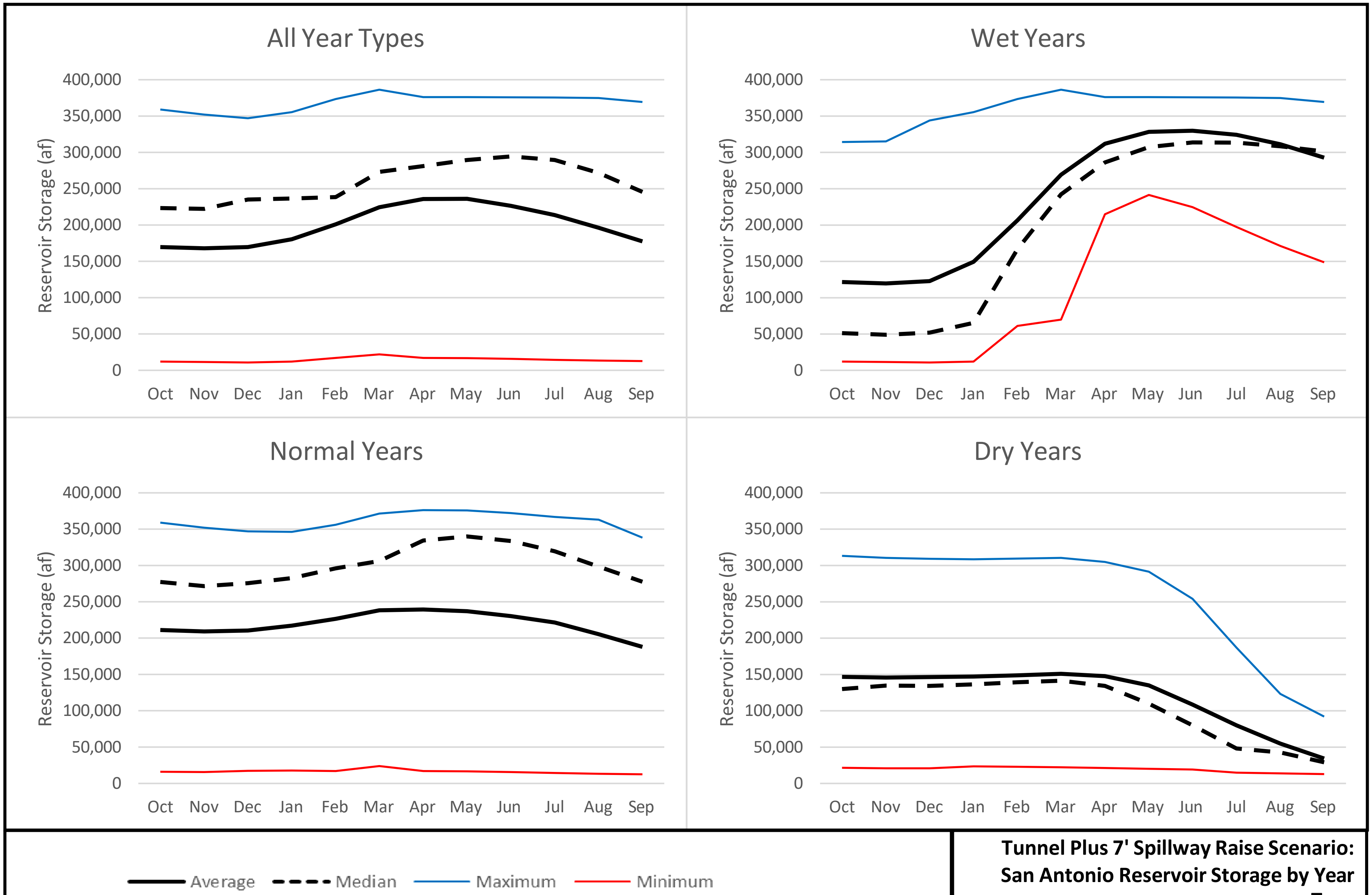
Figure 17b

Provisional data subject to revision.



Tunnel Plus 7' Spillway Raise Scenario: San Antonio Reservoir Storage by Year Type

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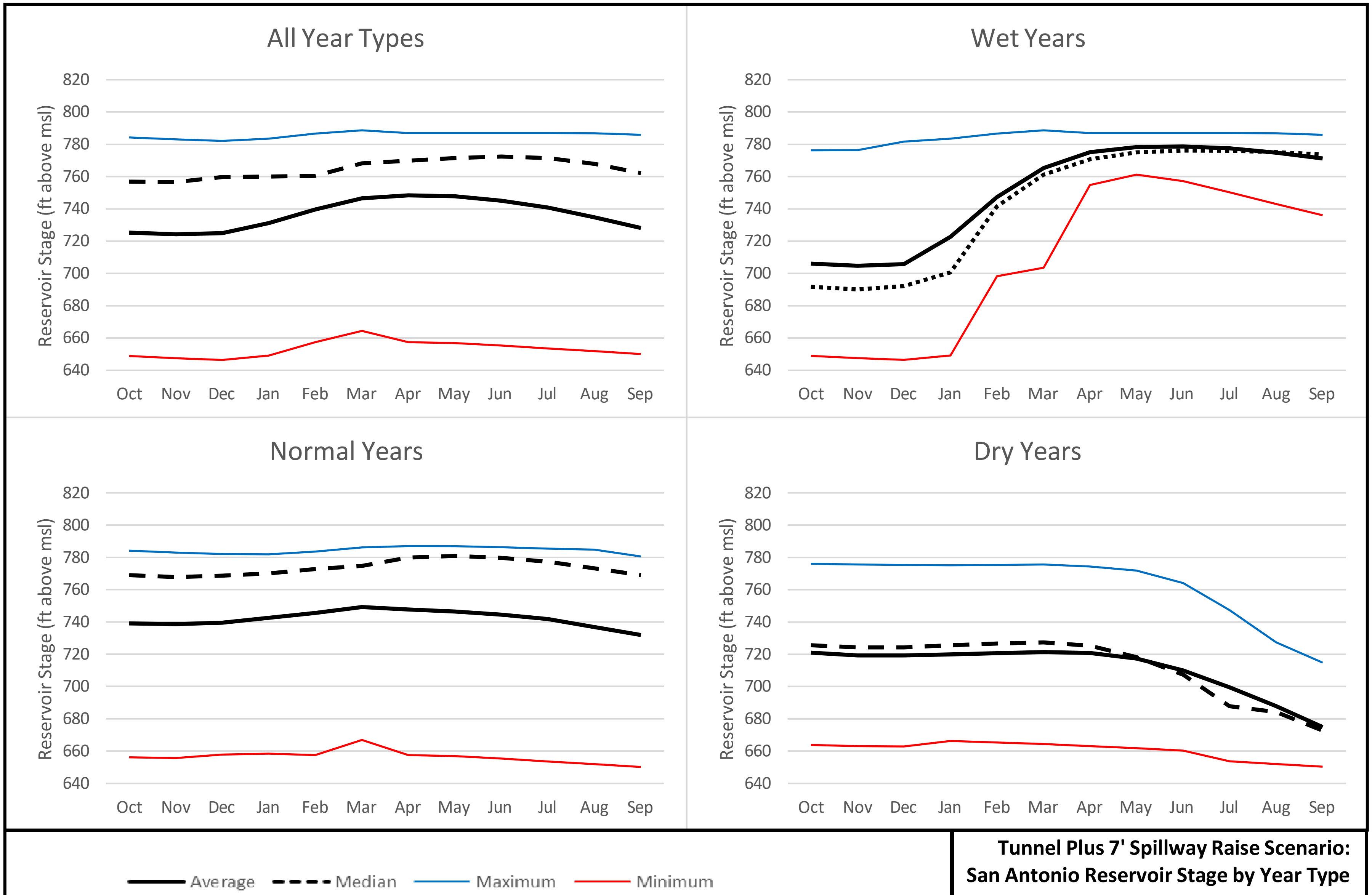
Figure 17c

Provisional data subject to revision.



Tunnel Plus 7' Spillway Raise Scenario:
San Antonio Reservoir Stage by Year Type

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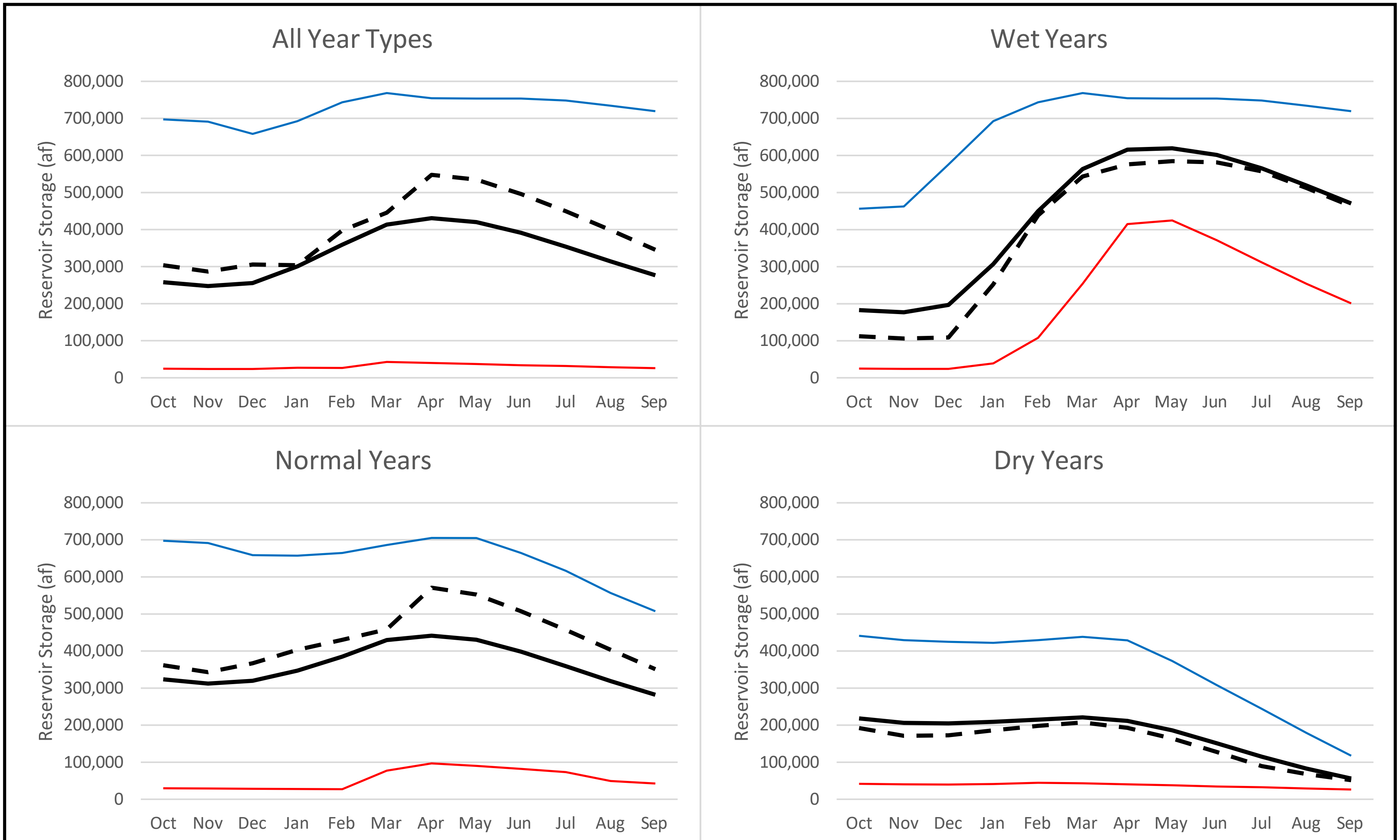
Figure 17d

Provisional data subject to revision.



Tunnel Plus 7' Spillway Raise Scenario: Combined Reservoir Storage by Year Type

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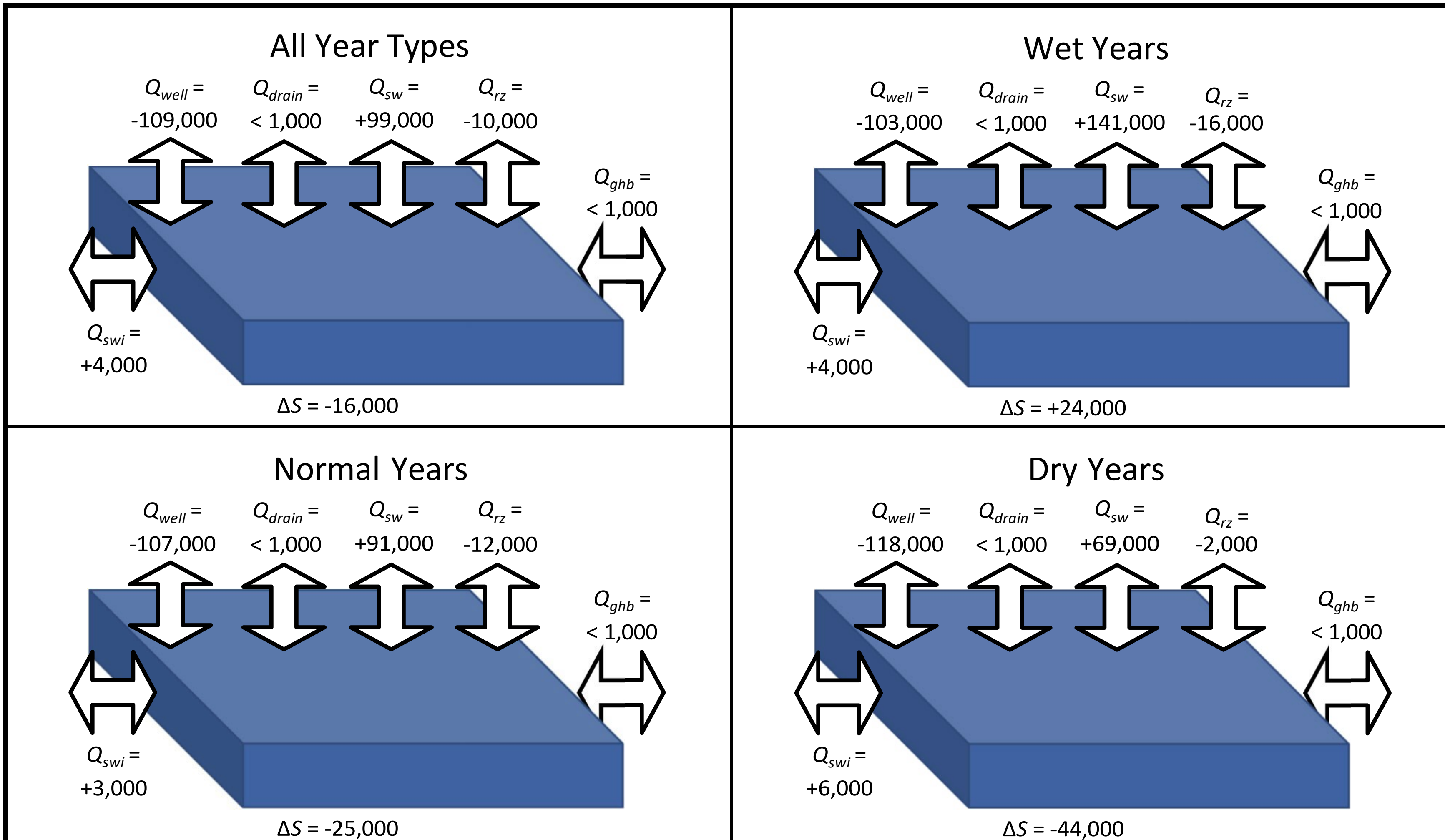
Figure 17e

Provisional data subject to revision.



Notes:

All water budget components are reported in acre-feet per year (afy)

See Section 4.2.6 for variable definitions.

Positive values of Δ*S* represent a loss of storage, negative values represent a gain in storage.

Provisional data subject to revision.

Tunnel Plus 7' Spillway Raise Scenario: Groundwater Budget by Water Year Type

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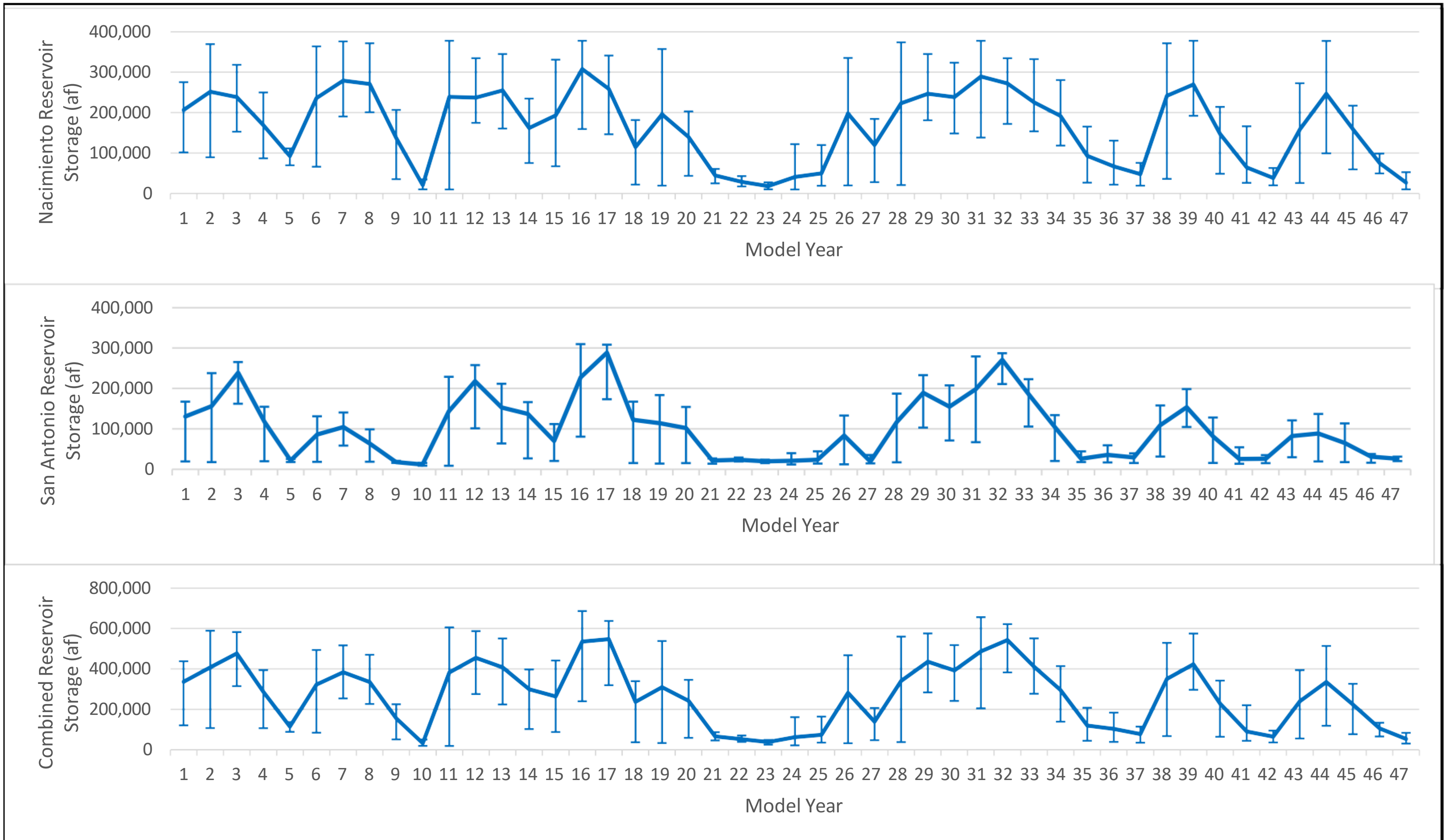
Figure 18



Note: Vertical bars represent the range of storage values simulated during each model year.

Provisional data subject to revision.

Tunnel Plus 7' Spillway Raise Scenario: Time Series of Reservoir Storage and Stage

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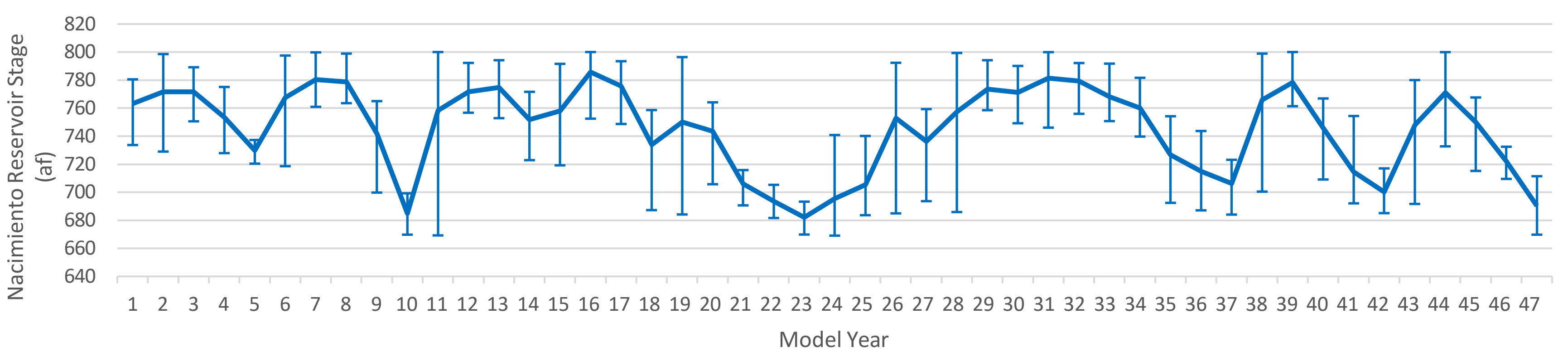
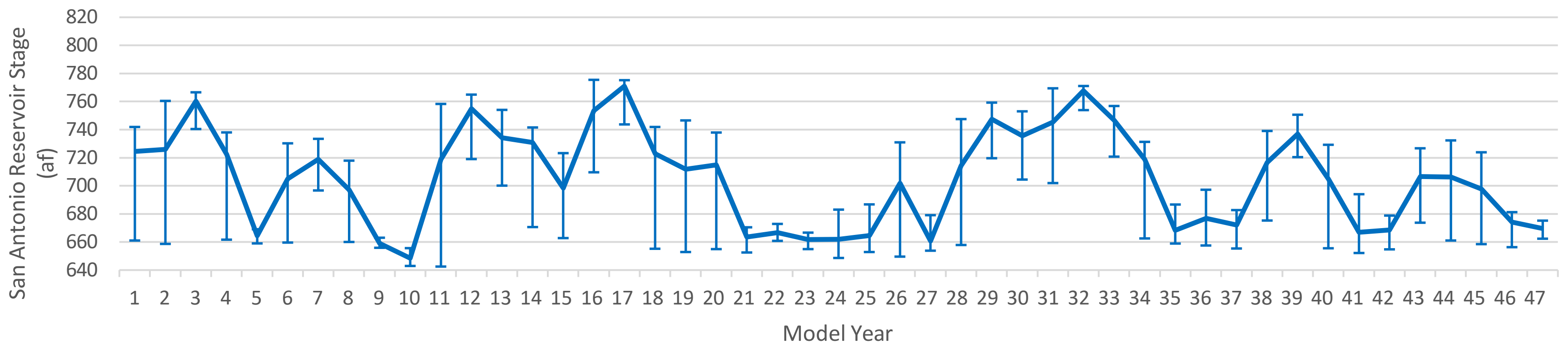
wood.

May 2022

Figure 19a





Note: Vertical bars represent the range of stage values simulated during each model year.

Provisional data subject to revision.

Tunnel Plus 7' Spillway Raise Scenario: Time Series of Reservoir Storage and Stage

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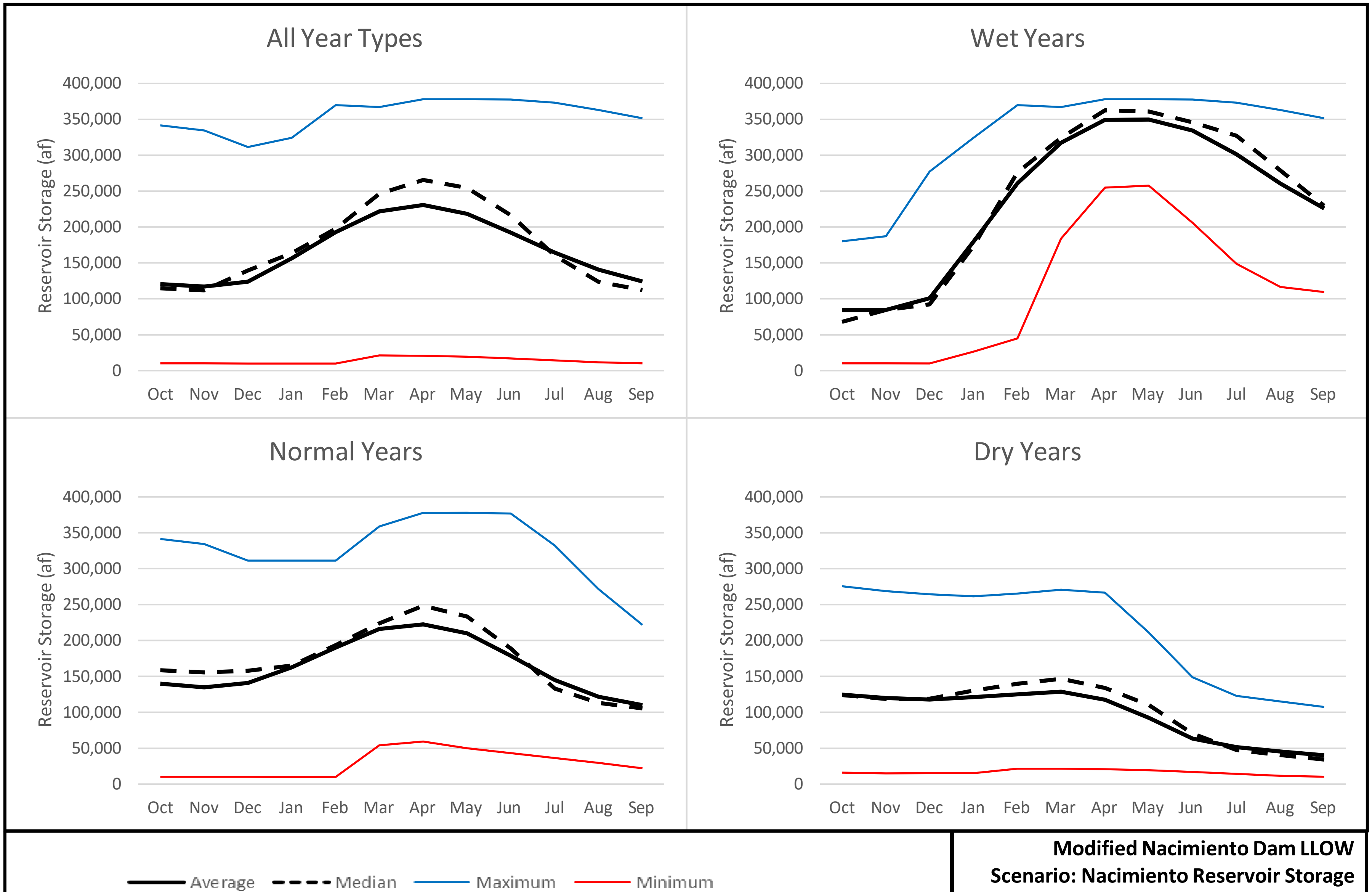
Figure 19b



Modified Nacimiento Dam LLOW Scenario: Nacimiento Reservoir Storage by Year Type

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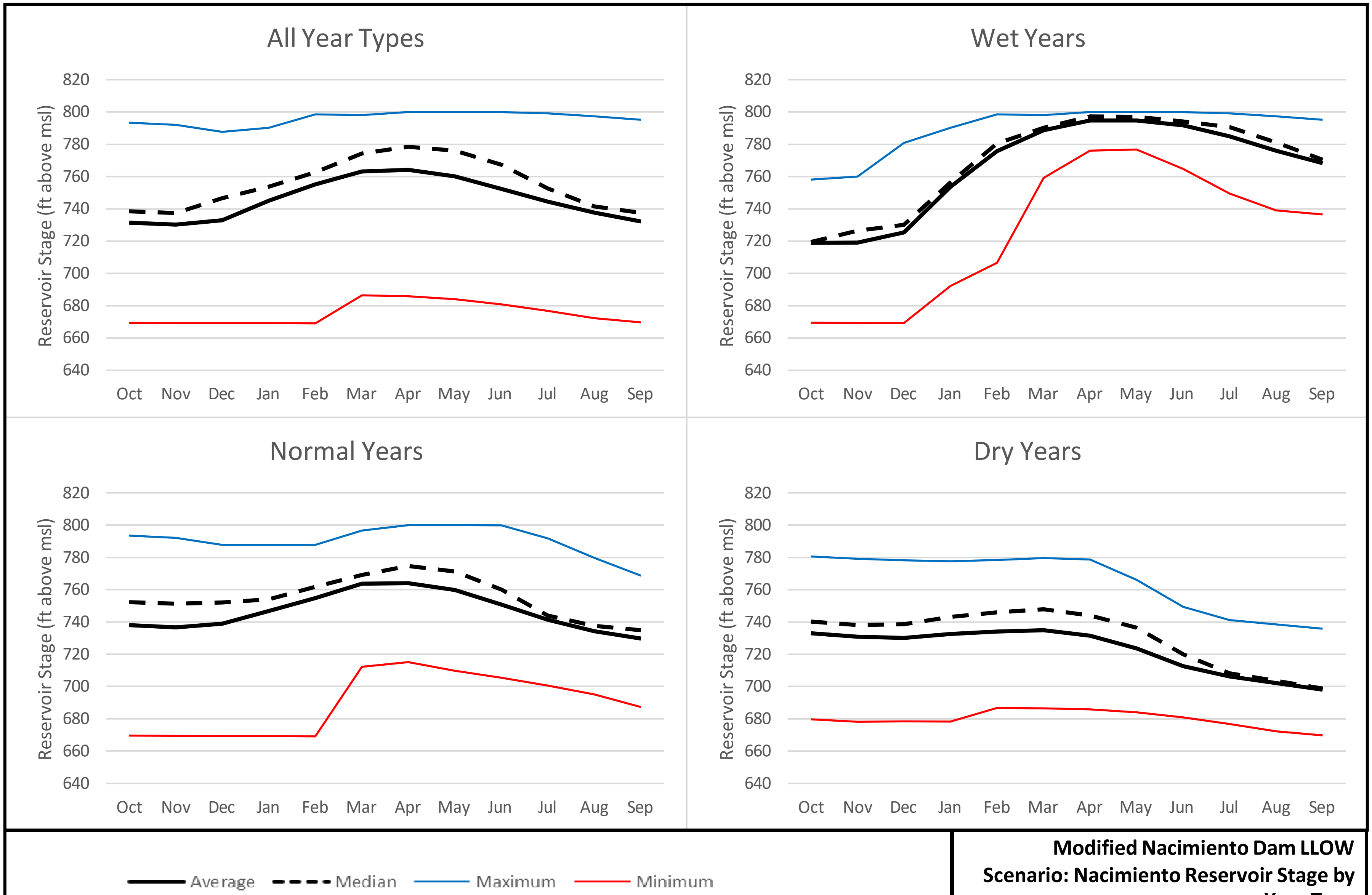
Figure 20a



Modified Nacimiento Dam LLOW Scenario: Nacimiento Reservoir Stage by Year Type

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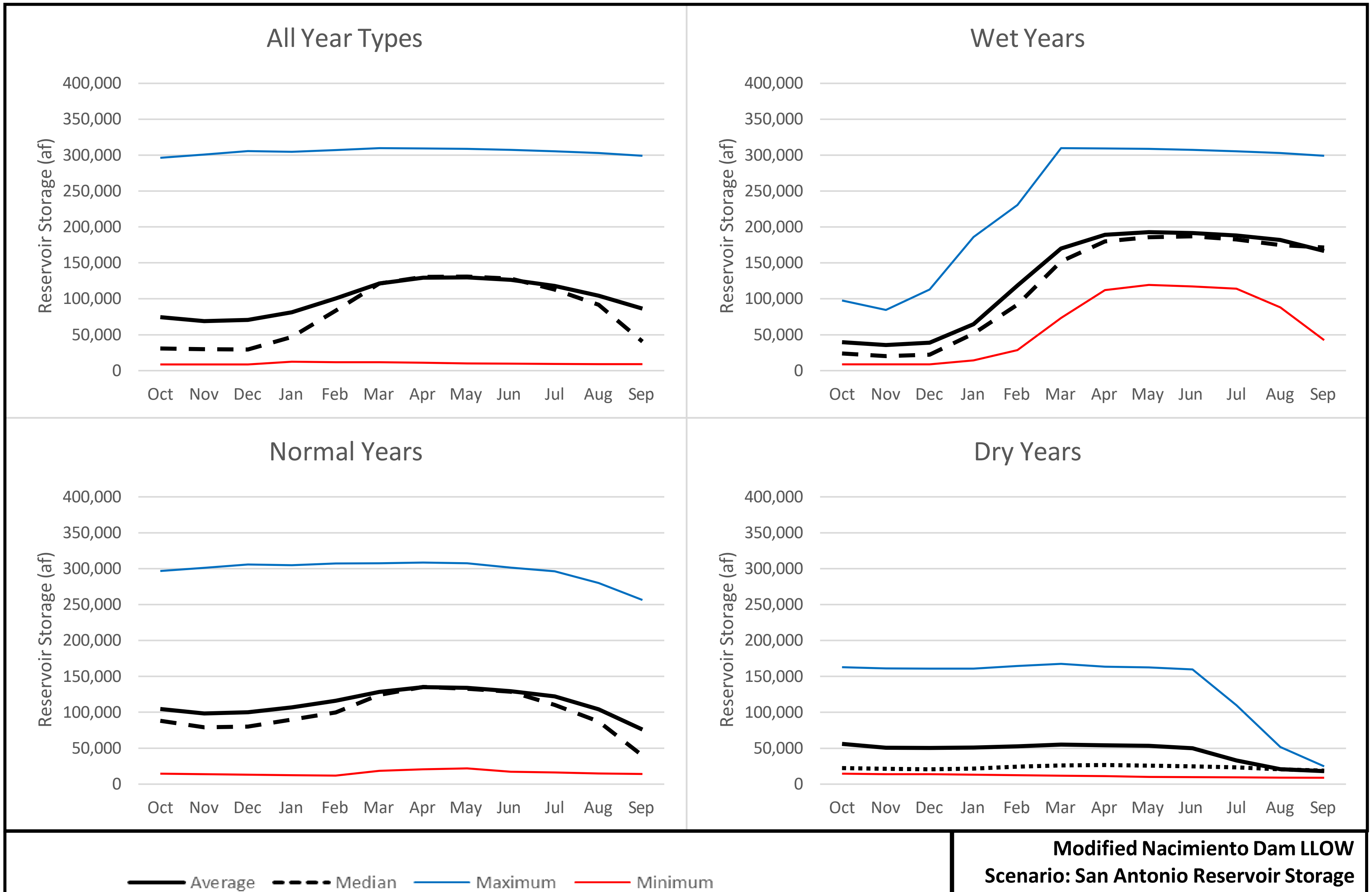
Figure 20b

Provisional data subject to revision.



Modified Nacimiento Dam LLOW Scenario: San Antonio Reservoir Storage by Year Type

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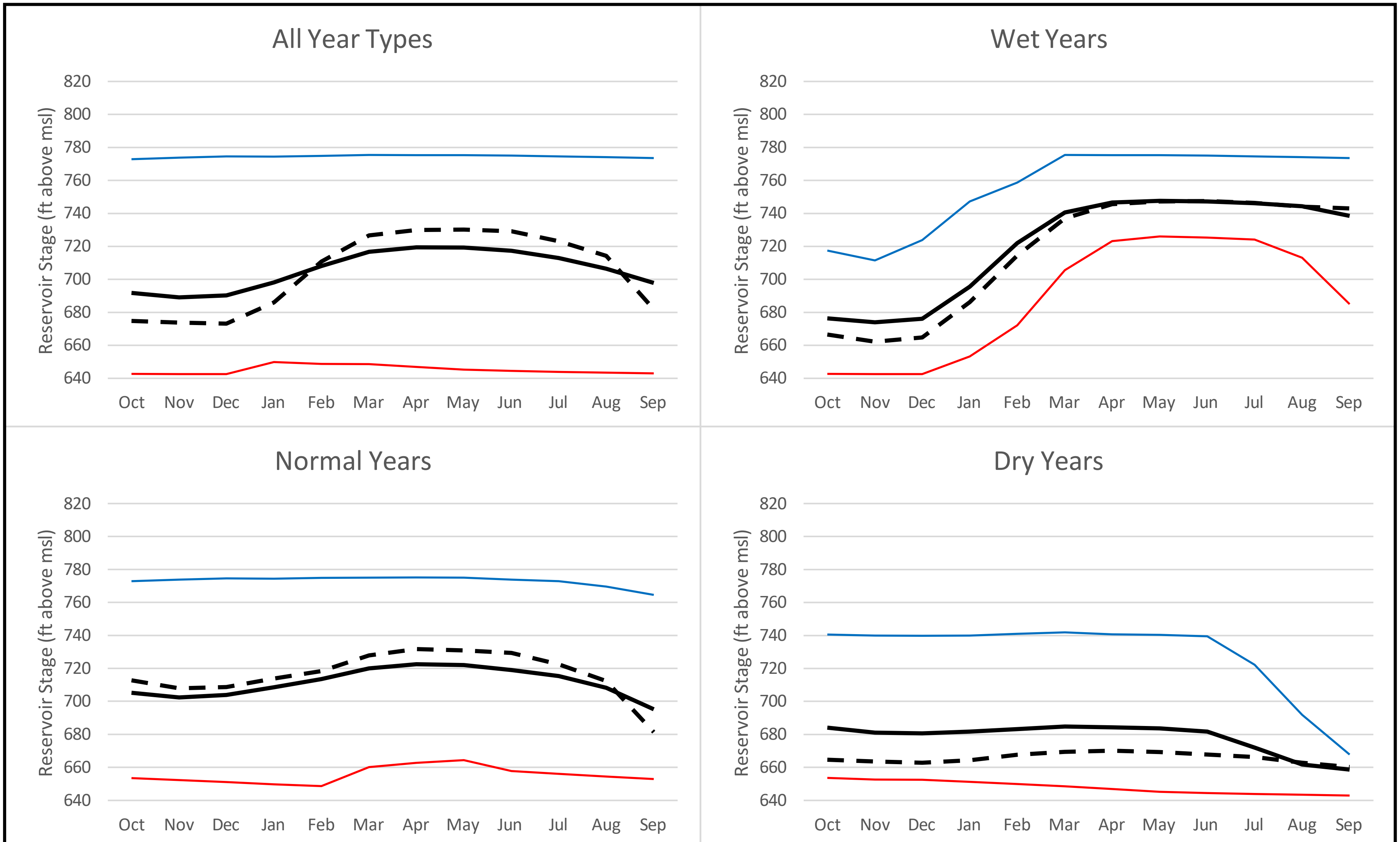
Figure 20c

Provisional data subject to revision.



Modified Nacimiento Dam LLOW Scenario: San Antonio Reservoir Stage by Year Type

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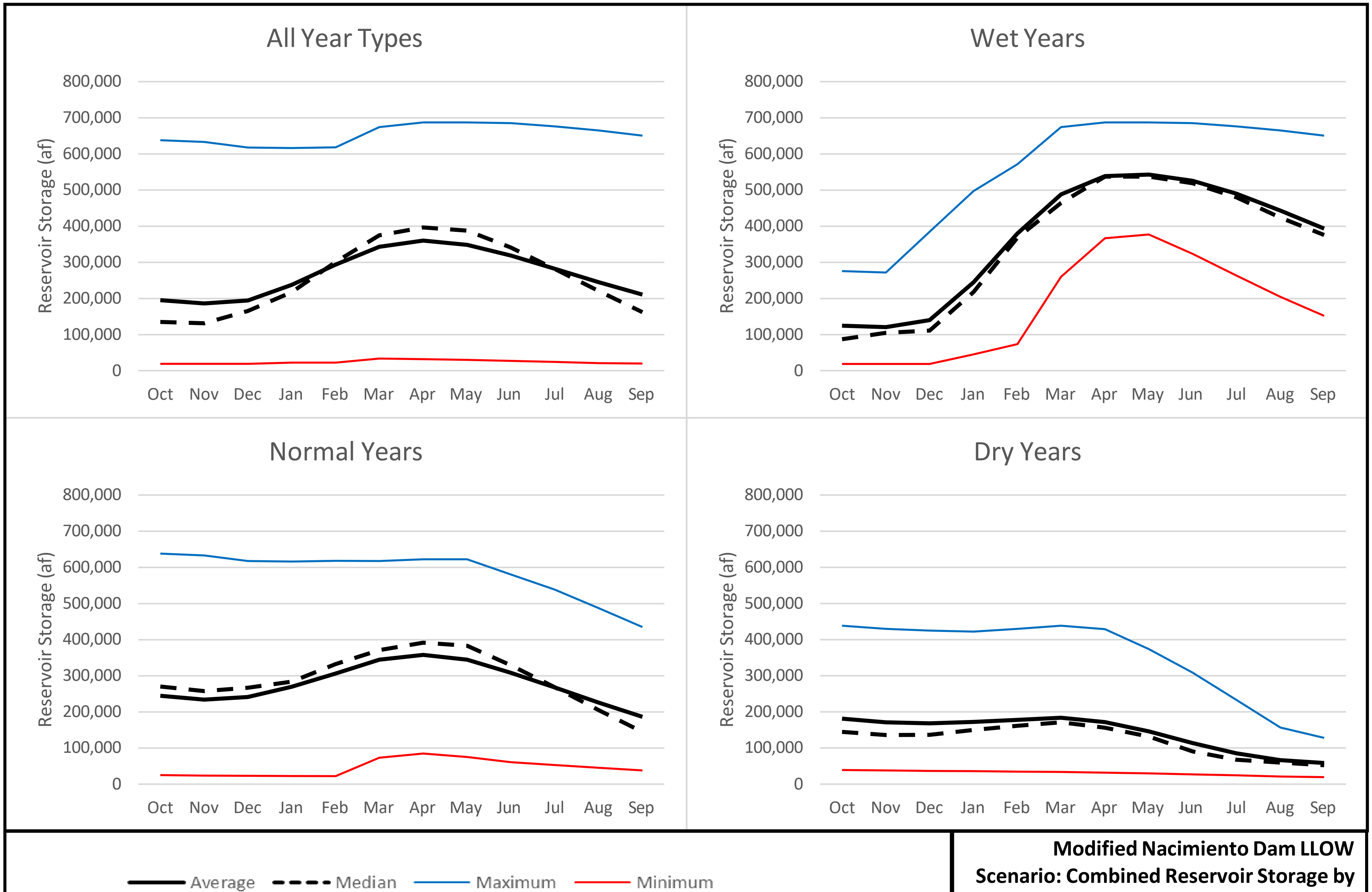
Figure 20d

Provisional data subject to revision.



Modified Nacimiento Dam LLOW Scenario: Combined Reservoir Storage by Year Type

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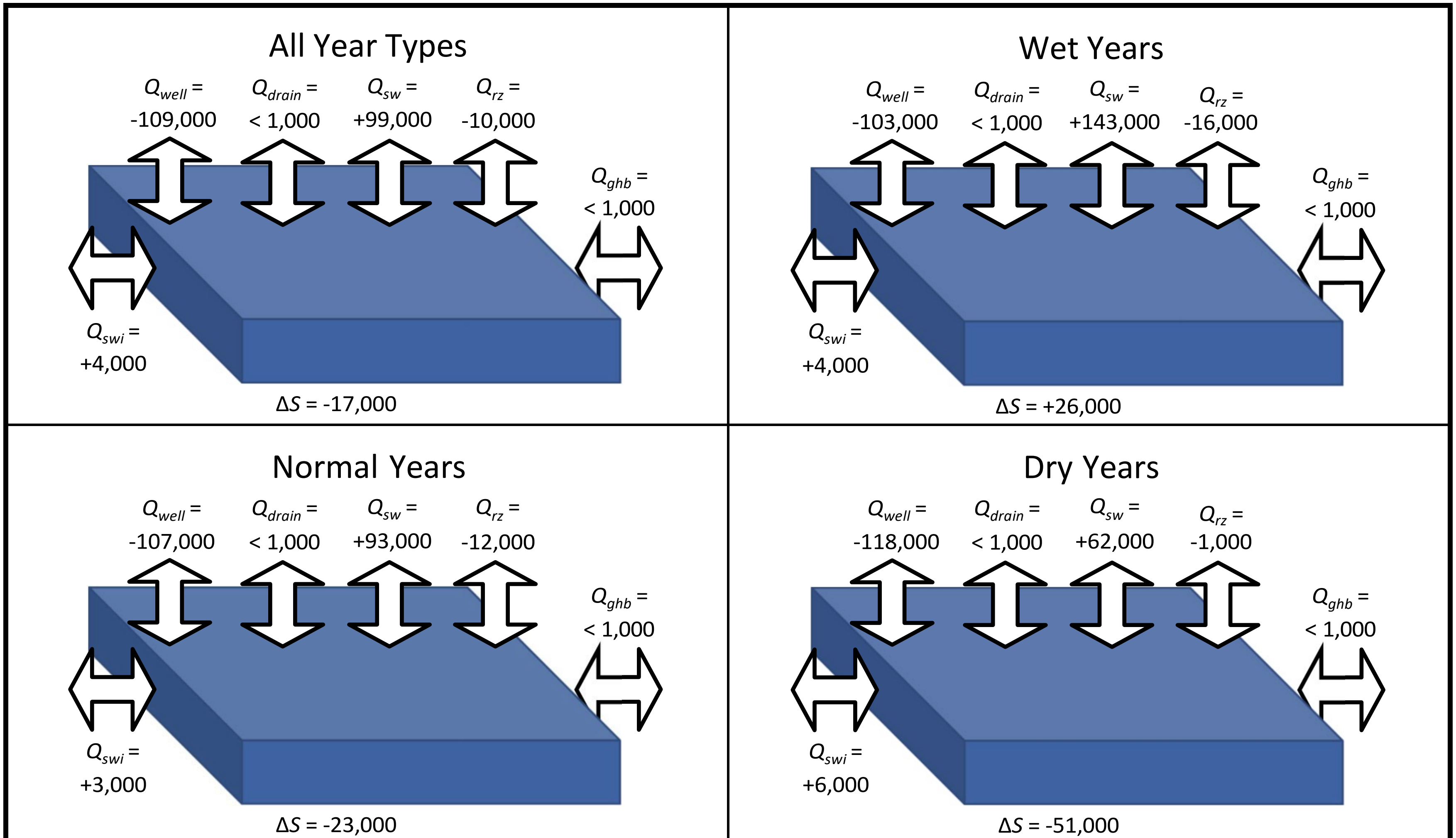
Figure 20e

Provisional data subject to revision.



Notes:

All water budget components are reported in acre-feet per year (afy)

See Section 4.2.6 for variable definitions.

Positive values of Δ*S* represent a loss of storage, negative values represent a gain in storage.

Provisional data subject to revision.

Modified Nacimiento Dam LLOW Scenario: Groundwater Budget by Water Year Type

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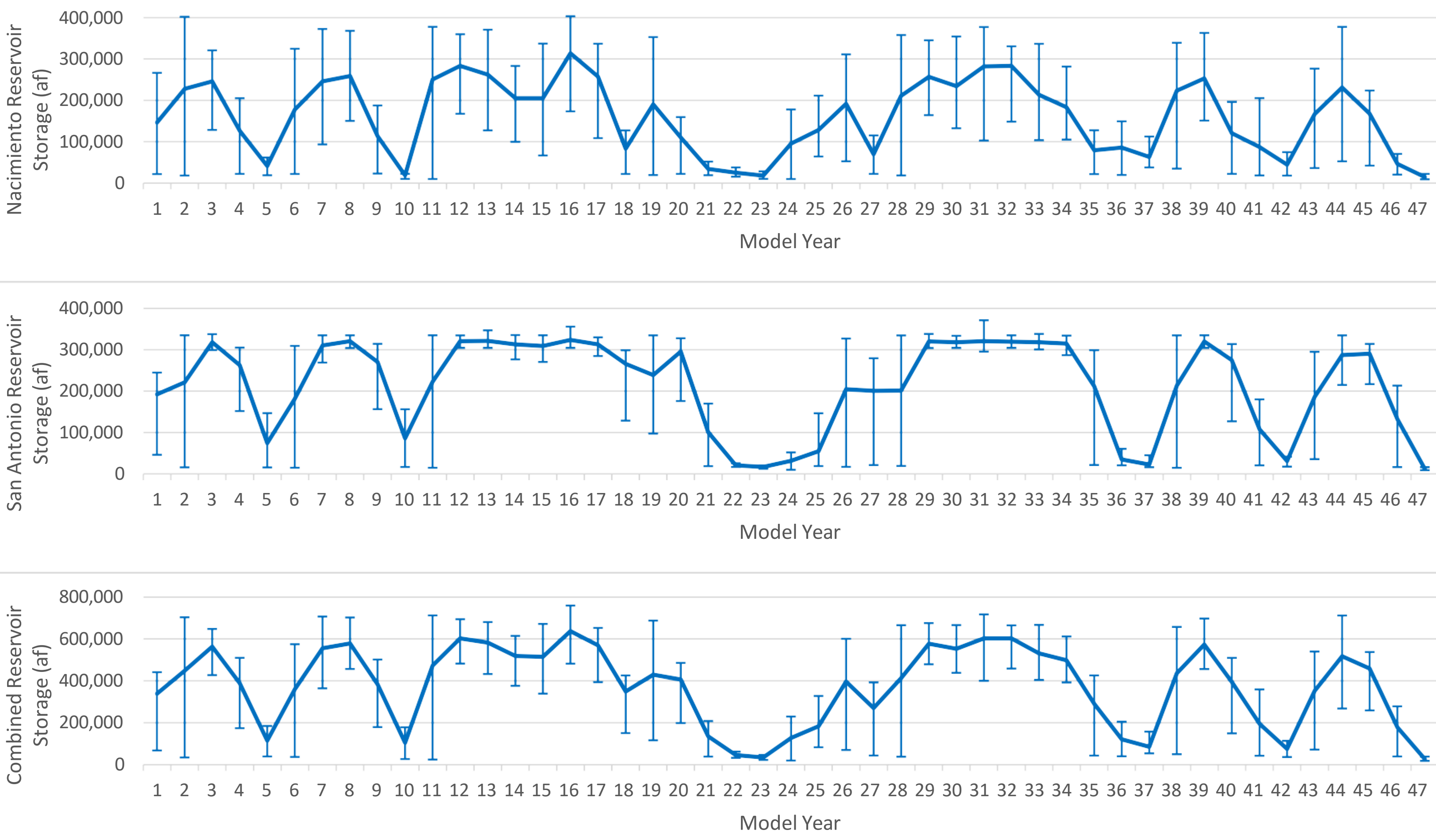
Figure 21



Note: Vertical bars represent the range of storage values simulated during each model year.

Provisional data subject to revision.

Tunnel-Only Scenario with 2070 Climate Change: Time Series of Reservoir Storage and Stage

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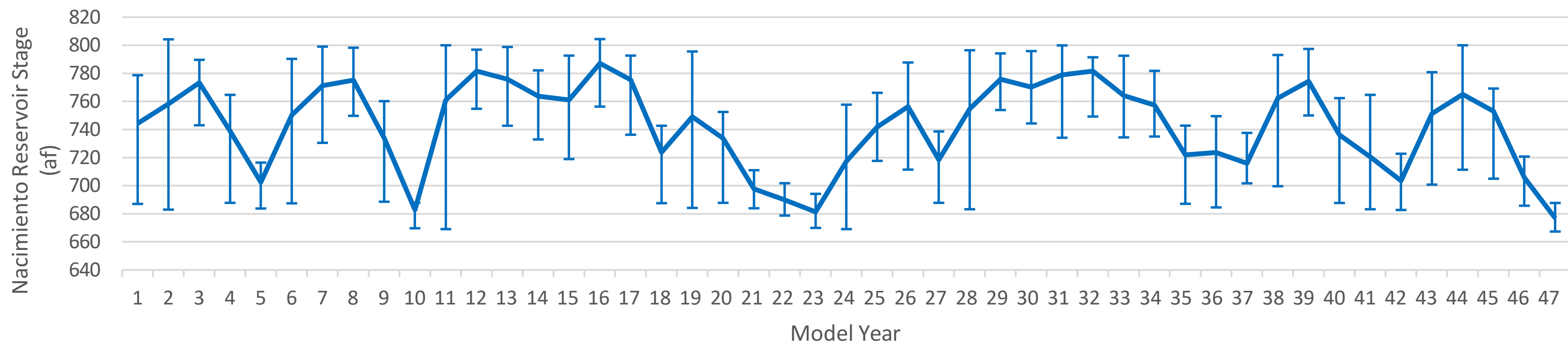
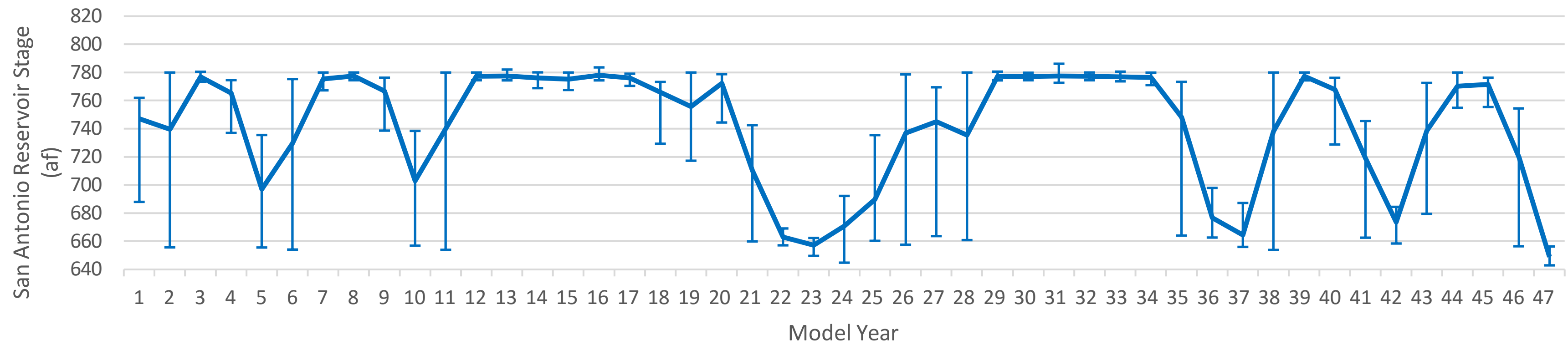
Figure 22a





Note: Vertical bars represent the range of stage values simulated during each model year.
Provisional data subject to revision.

Tunnel-Only Scenario with 2070 Climate Change: Time Series of Reservoir Storage and Stage
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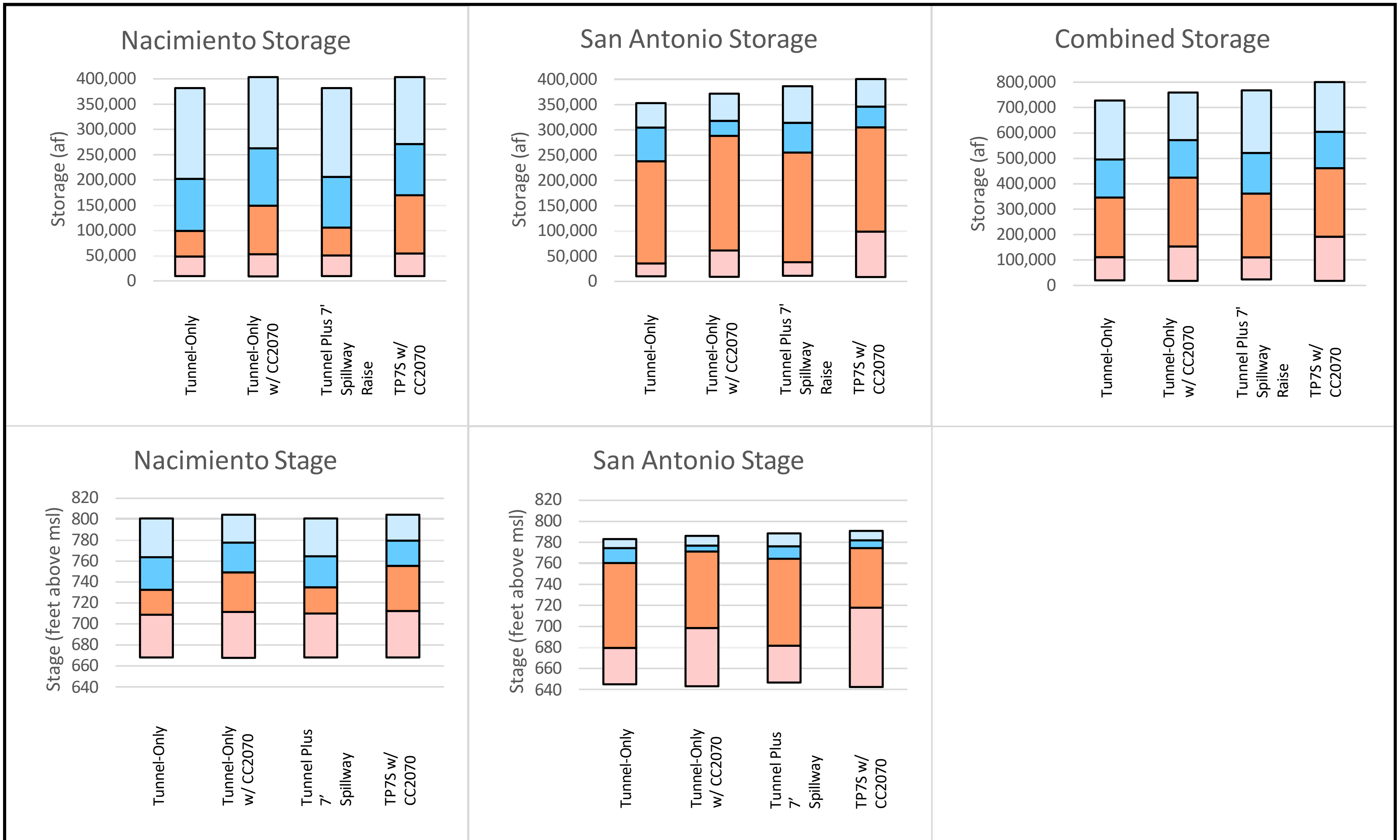
Figure 22b



Quartile Charts of Reservoir Storage and Stage, Climate Change Scenarios

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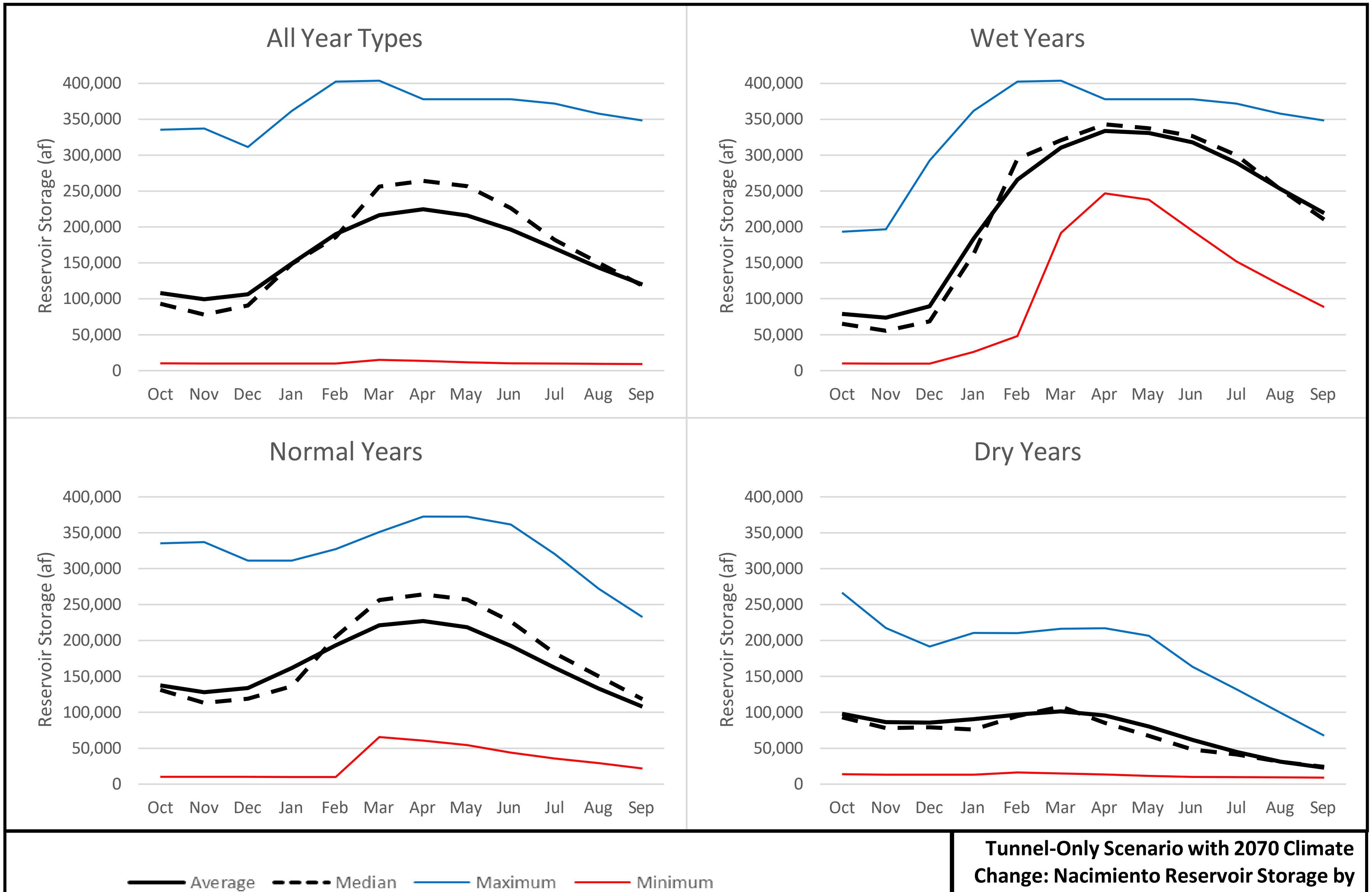
Figure 23

Provisional data subject to revision.



Tunnel-Only Scenario with 2070 Climate Change: Nacimiento Reservoir Storage by Year Type

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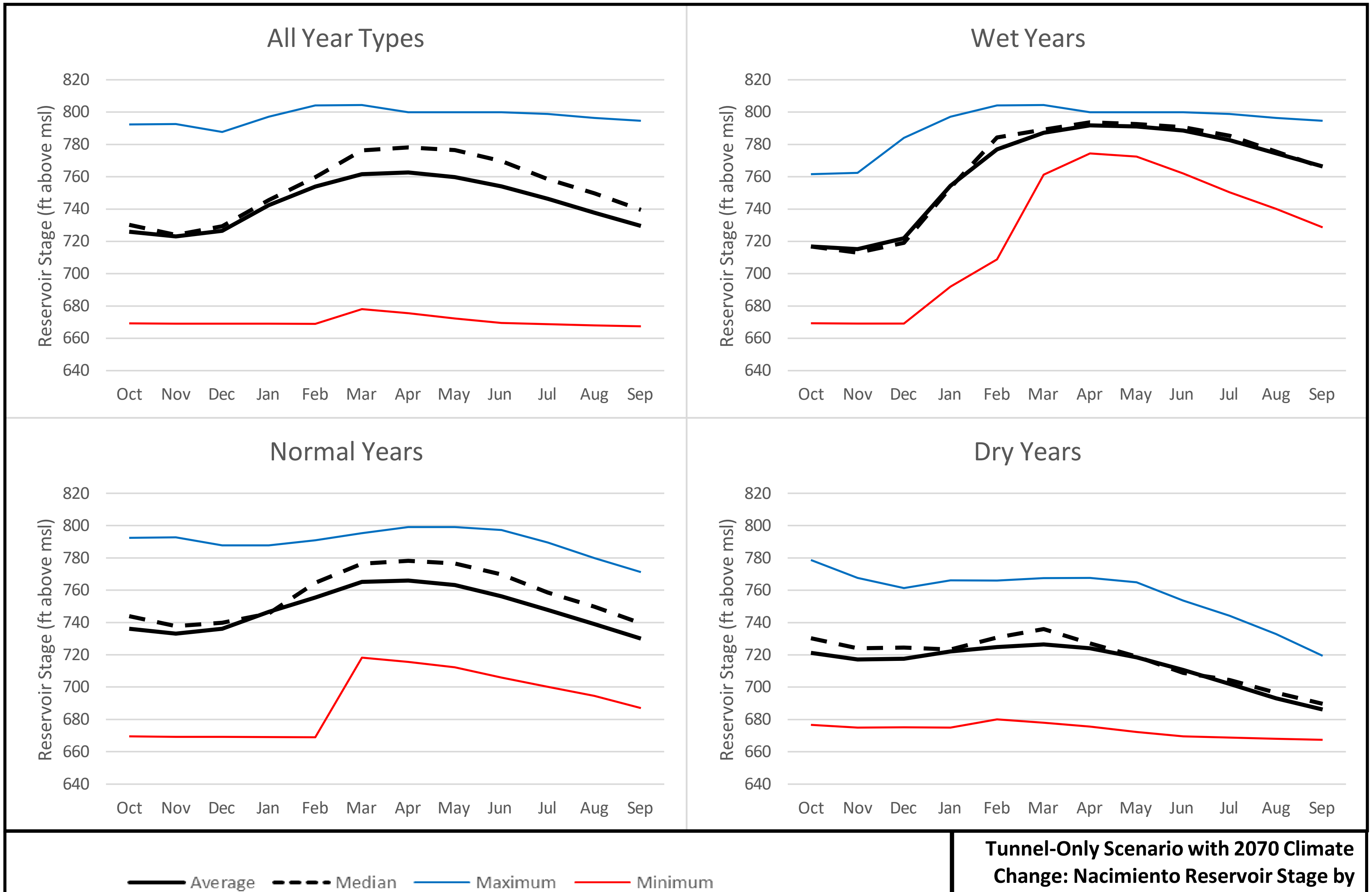
Figure 24a

Provisional data subject to revision.



Tunnel-Only Scenario with 2070 Climate Change: Nacimiento Reservoir Stage by Year Type

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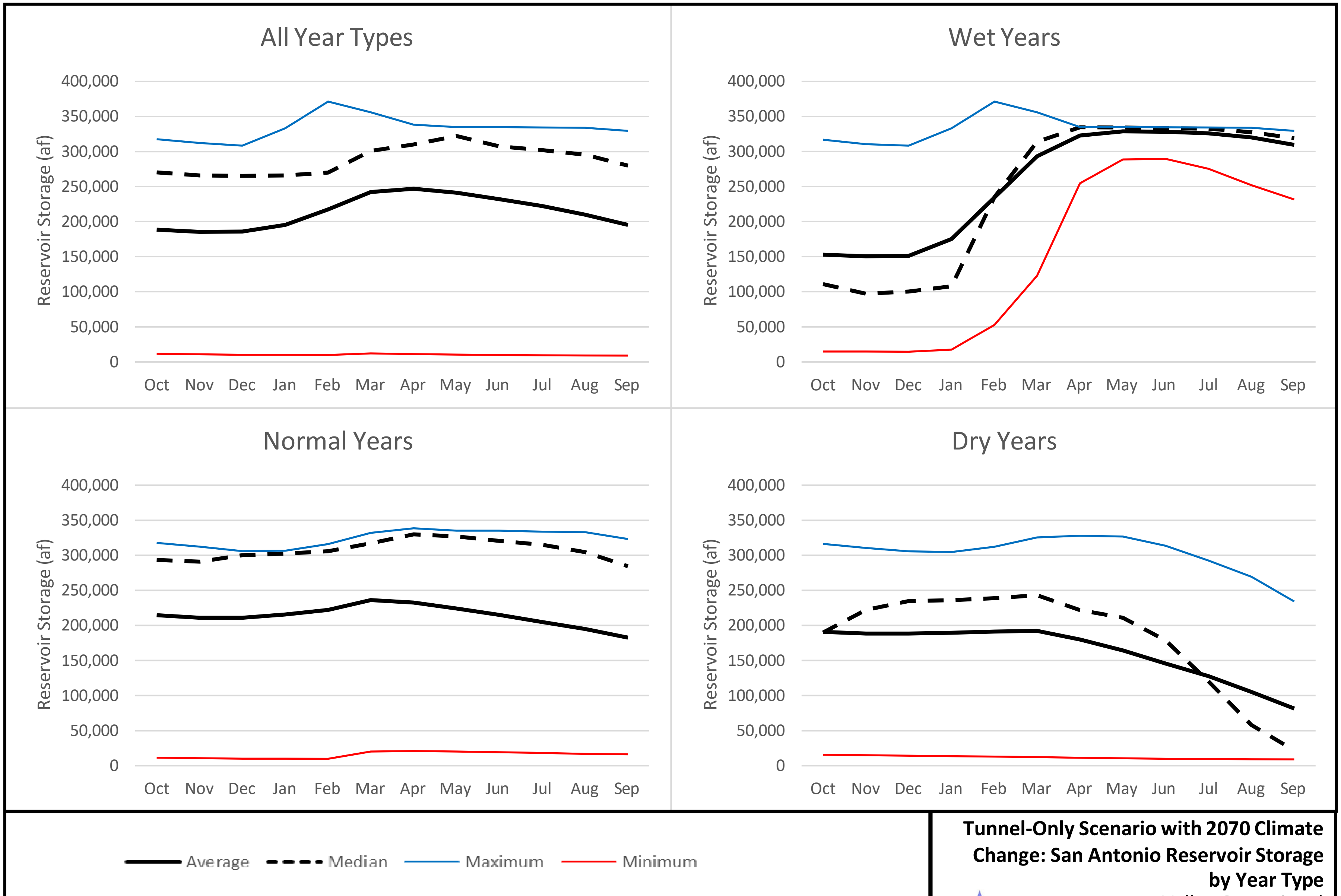
Figure 24b

Provisional data subject to revision.



Tunnel-Only Scenario with 2070 Climate Change: San Antonio Reservoir Storage by Year Type

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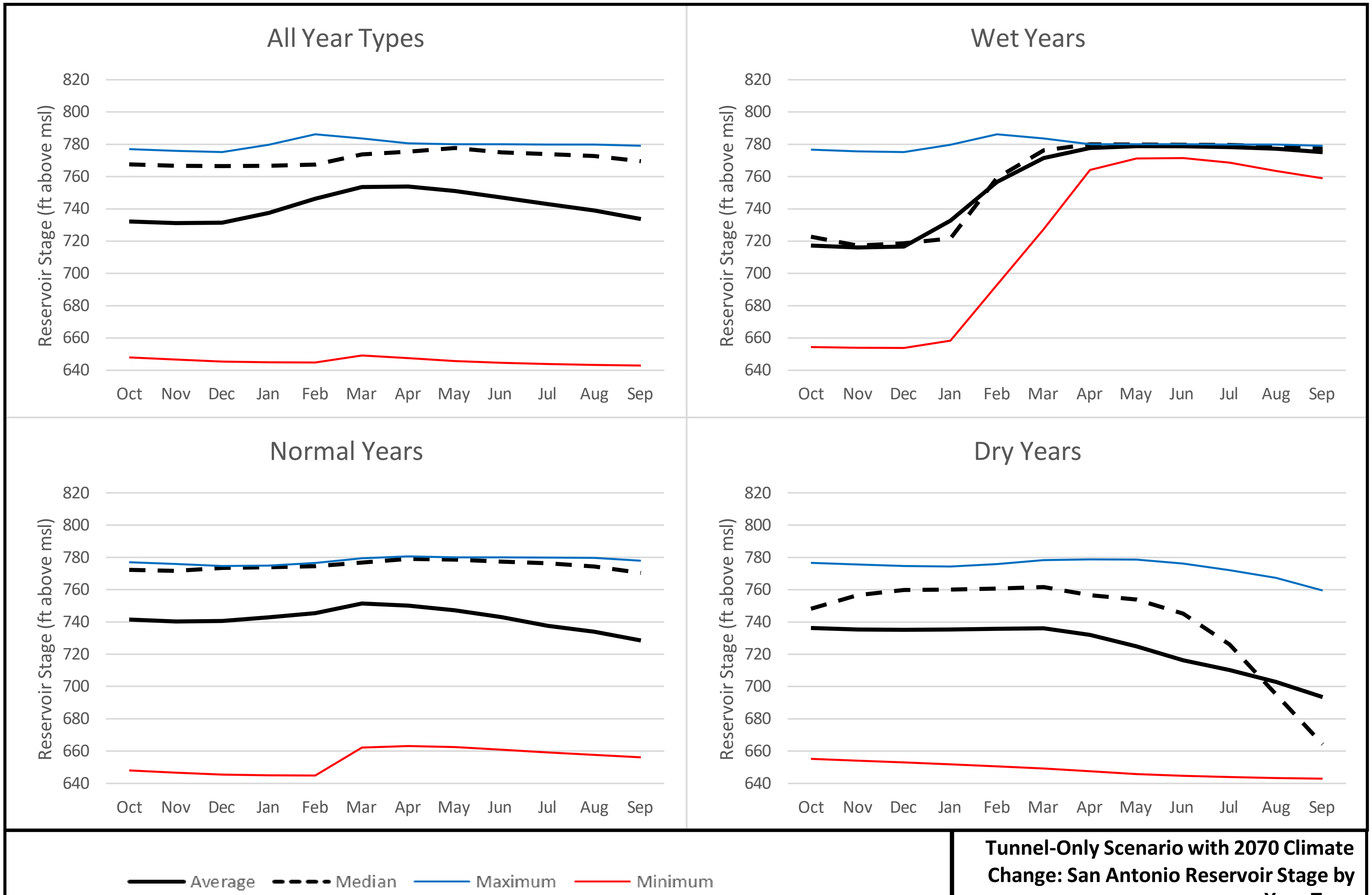
Figure 24c

Provisional data subject to revision.



Tunnel-Only Scenario with 2070 Climate Change: San Antonio Reservoir Stage by Year Type

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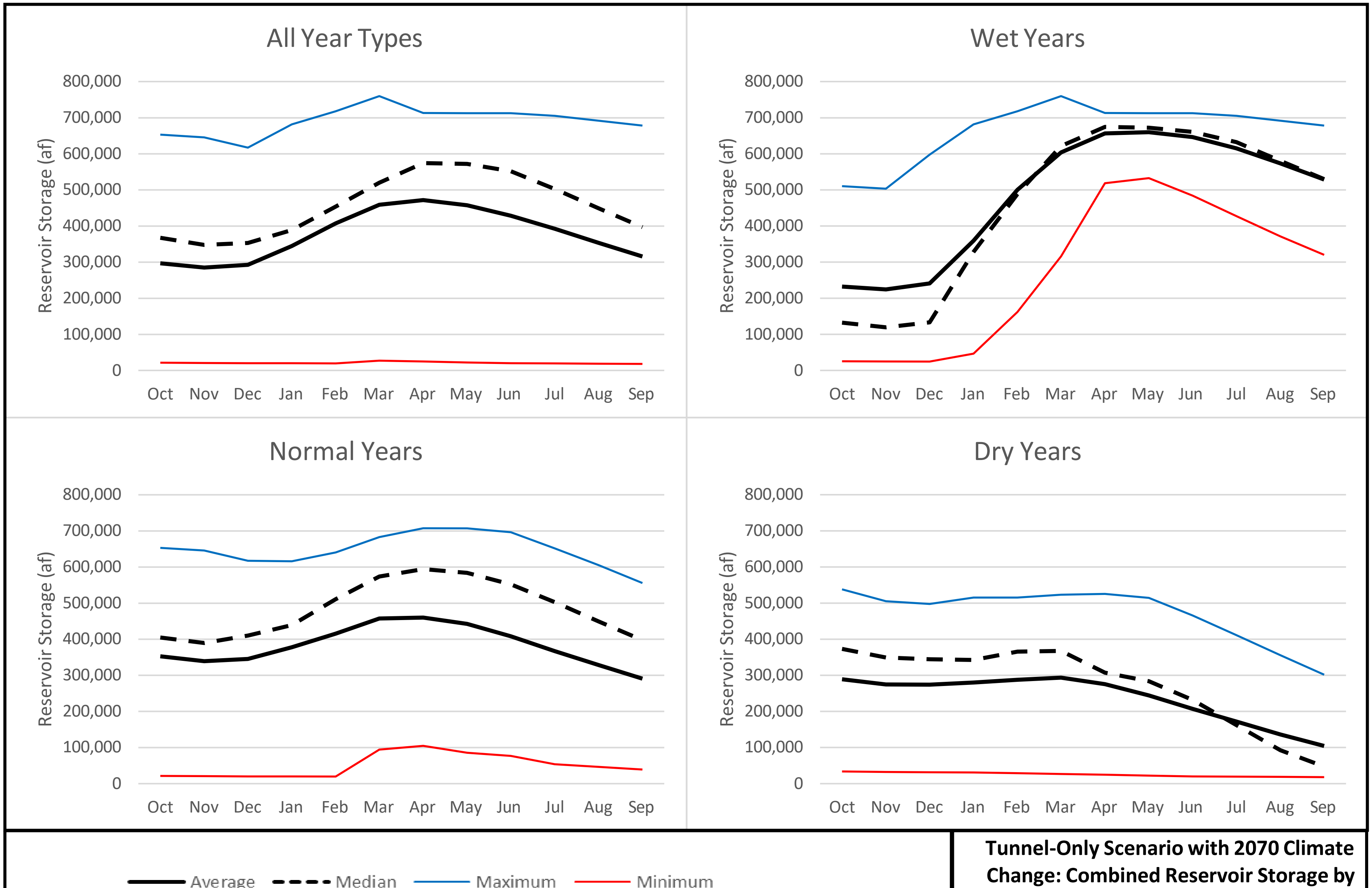
Figure 24d

Provisional data subject to revision.



Tunnel-Only Scenario with 2070 Climate Change: Combined Reservoir Storage by Year Type
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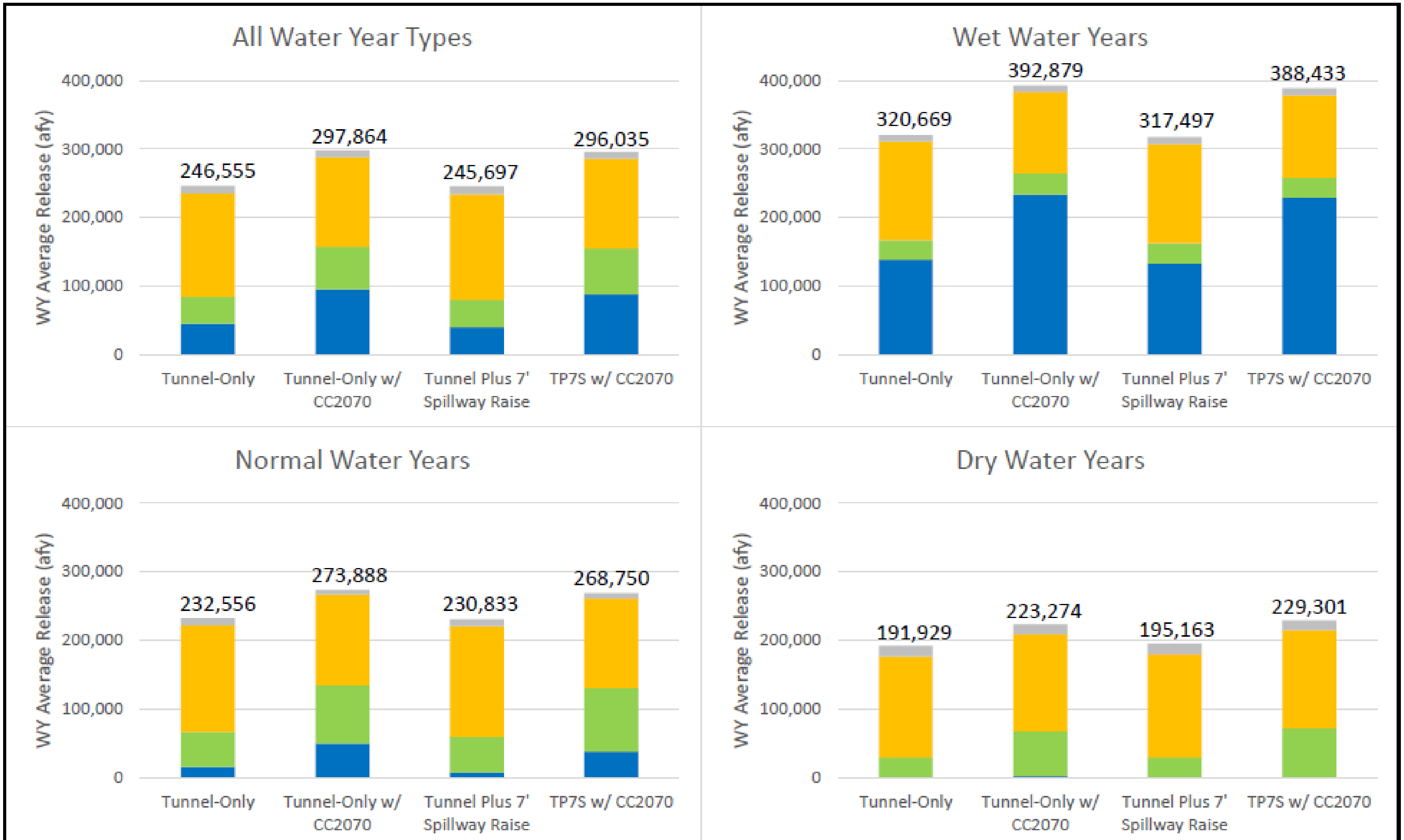
Figure 24e

Provisional data subject to revision.



Flood Control Release   Environmental Release
Conservation Release   Over-Release

Average Annual Releases by Water Year Type, Climate Change Scenarios

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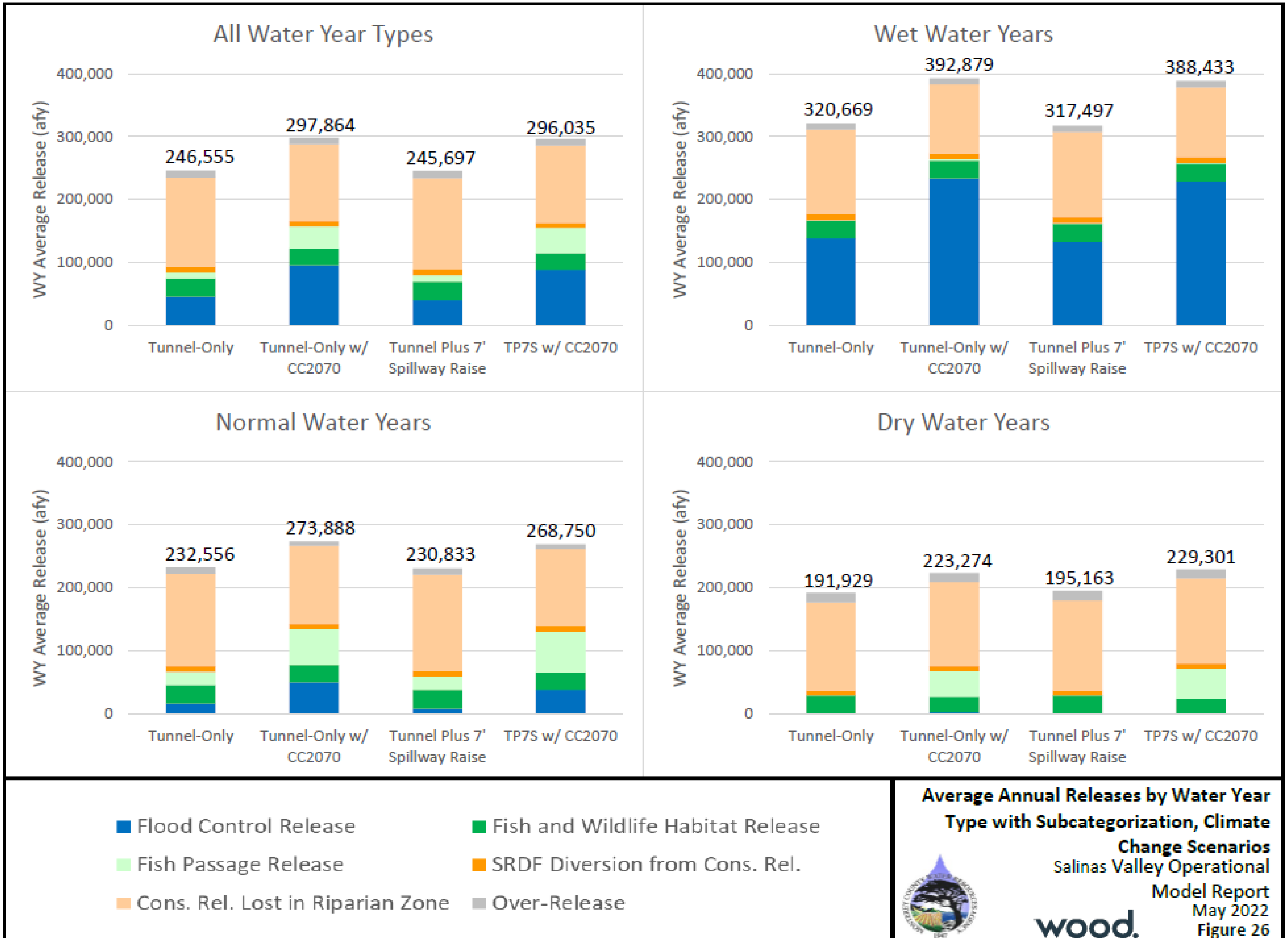
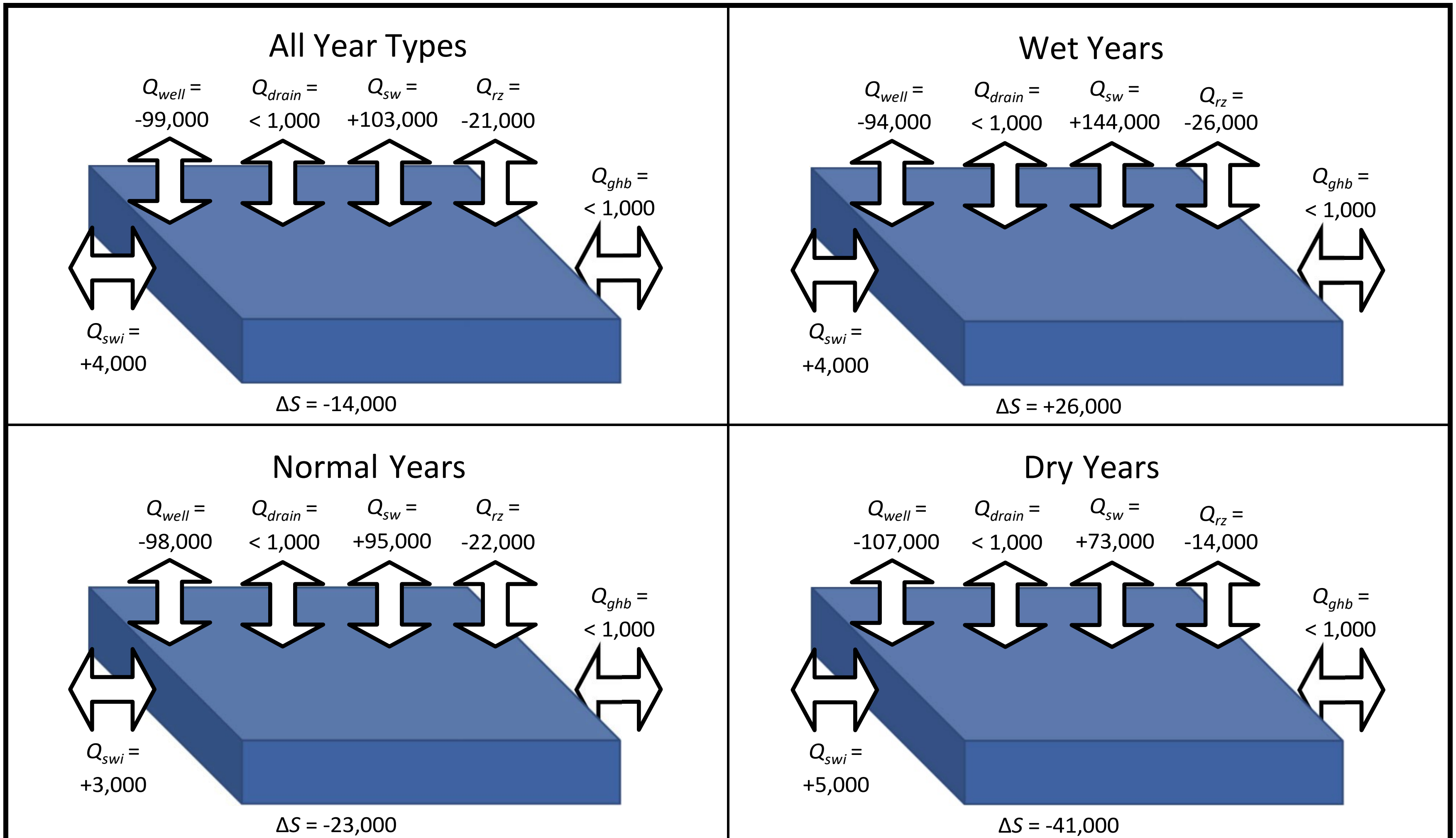
Figure 25

Provisional data subject to revision.



Average Annual Releases by Water Year Type with Subcategorization, Climate Change Scenarios
Salinas Valley Operational Model Report
wood.
May 2022
Figure 26

Provisional data subject to revision.



Notes:

All water budget components are reported in acre-feet per year (afy)

See Section 4.2.6 for variable definitions.

Positive values of ΔS represent a loss of storage, negative values represent a gain in storage.

Provisional data subject to revision.

Tunnel-Only Scenario with 2070 Climate Change: Groundwater Budget by Water Year Type

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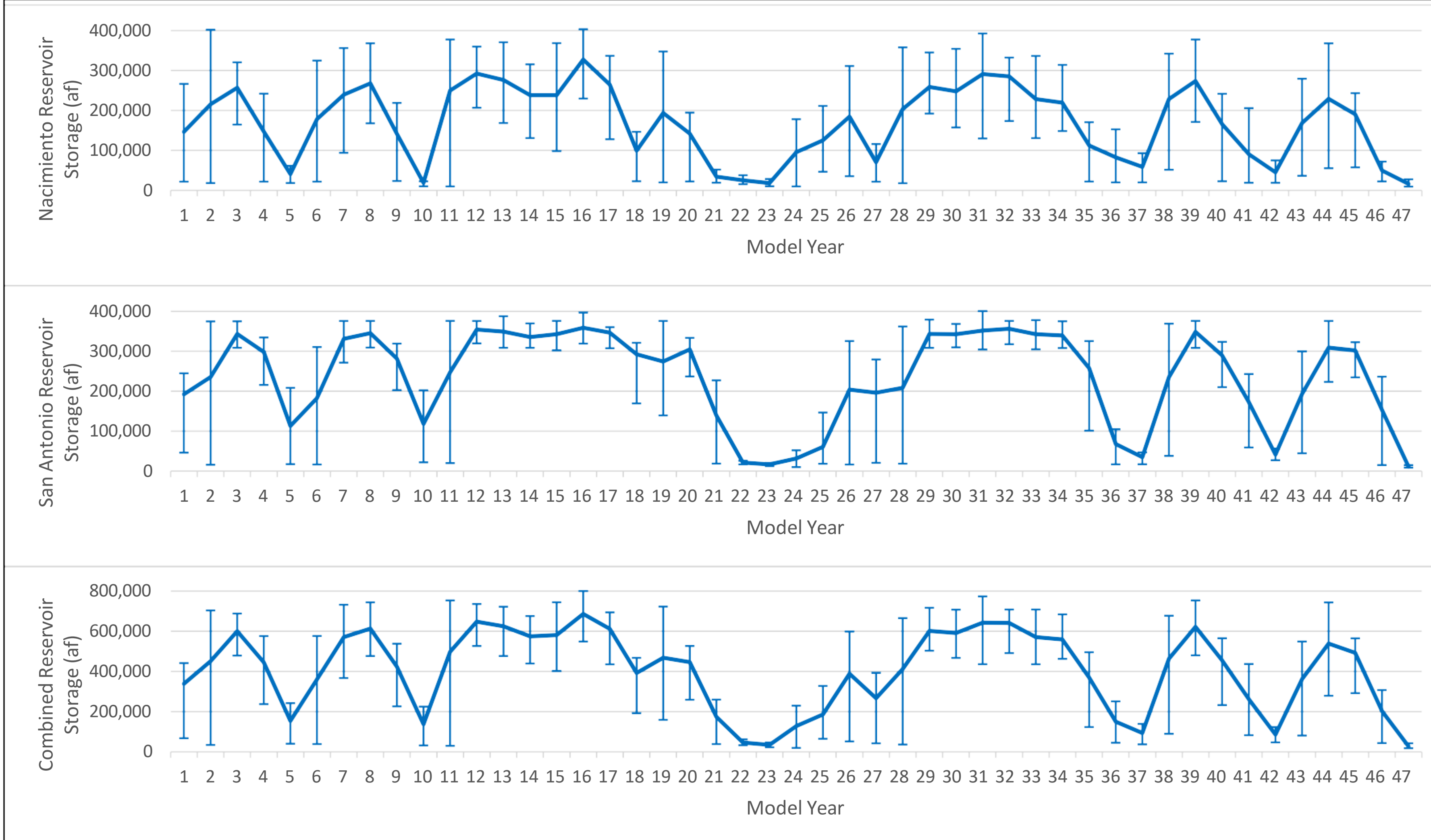
Figure 27



Note: Vertical bars represent the range of storage values simulated during each model year.

Provisional data subject to revision.

Tunnel Plus 7' Spillway Raise Scenario with 2070 Climate Change: Time Series of Reservoir Storage and Stage

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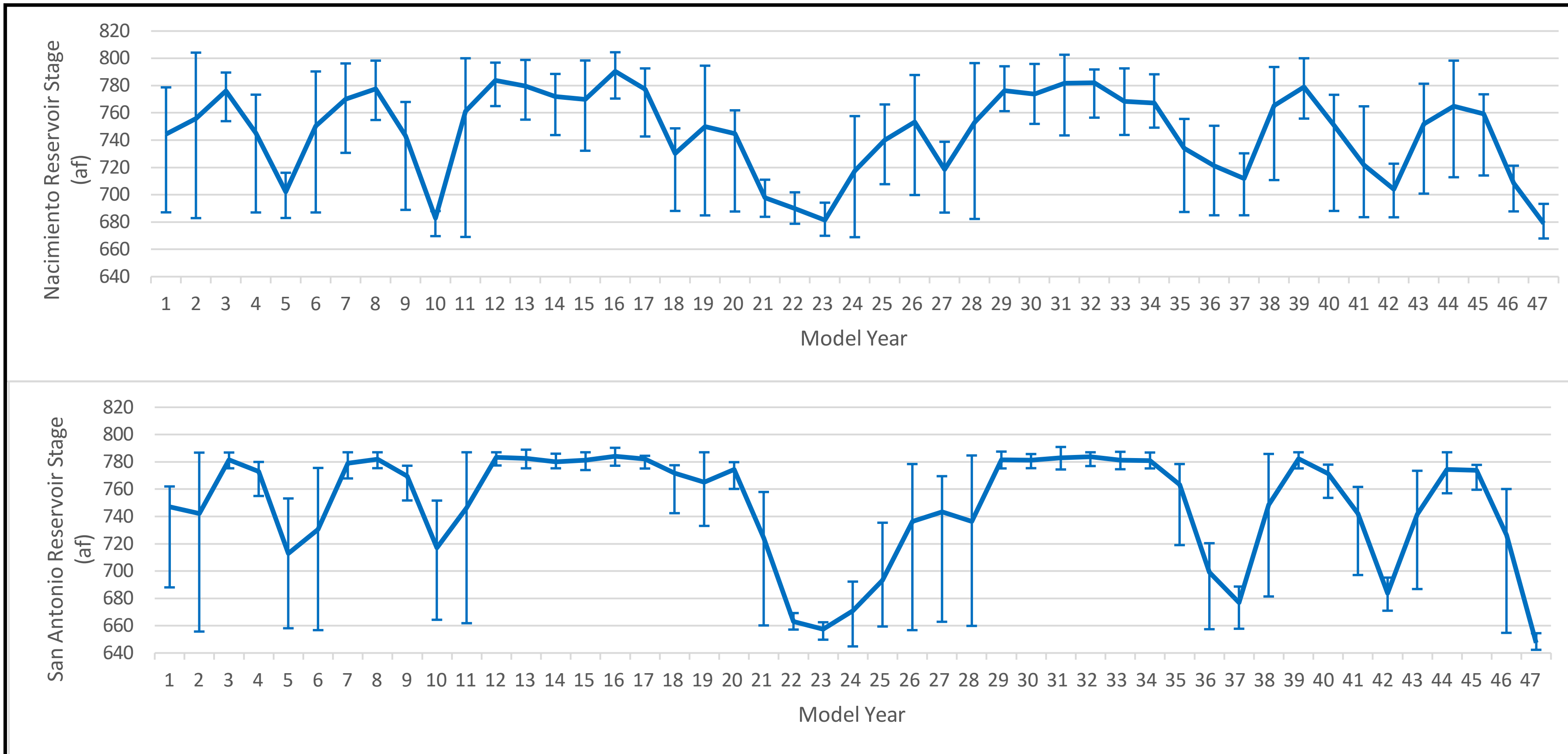
Figure 28a



Note: Vertical bars represent the range of stage values simulated during each model year.

Provisional data subject to revision.

Tunnel Plus 7' Spillway Raise Scenario with 2070 Climate Change: Time Series of Reservoir Storage and Stage

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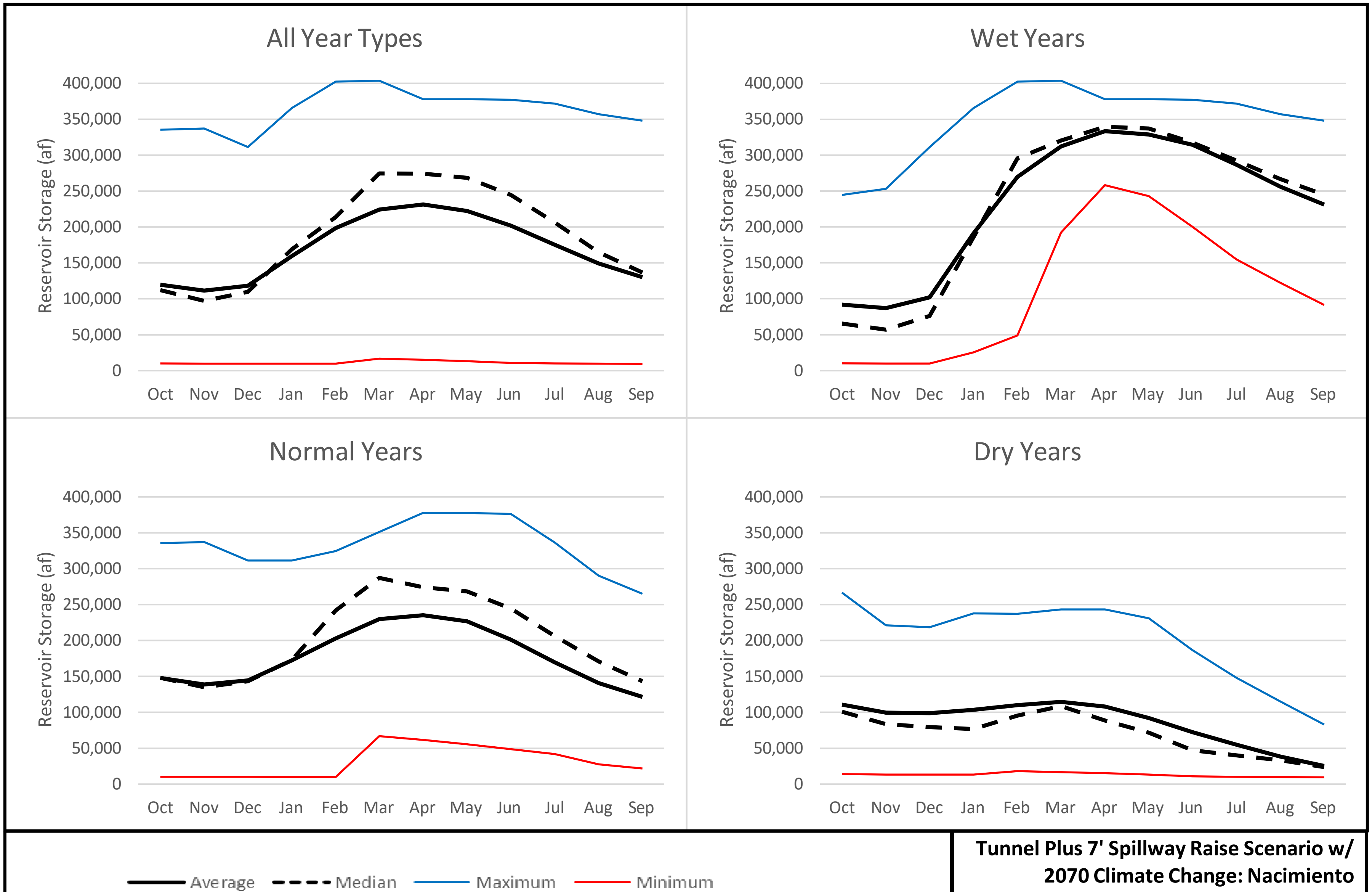
Figure 28b



Tunnel Plus 7' Spillway Raise Scenario w/ 2070 Climate Change: Nacimiento Reservoir Storage by Year Type

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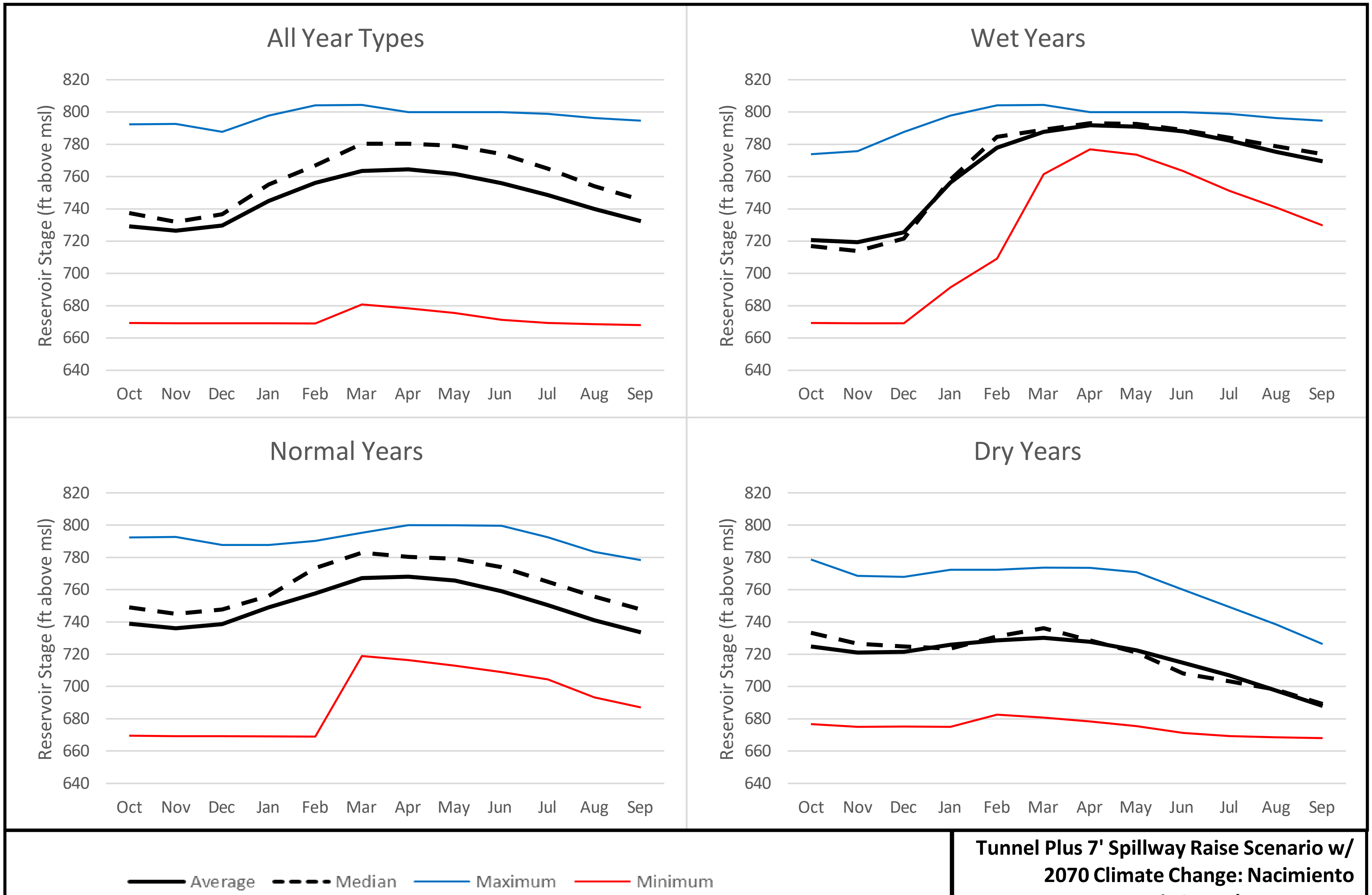
Figure 29a

Provisional data subject to revision.



Tunnel Plus 7' Spillway Raise Scenario w/ 2070 Climate Change: Nacimiento Reservoir Stage by Year Type

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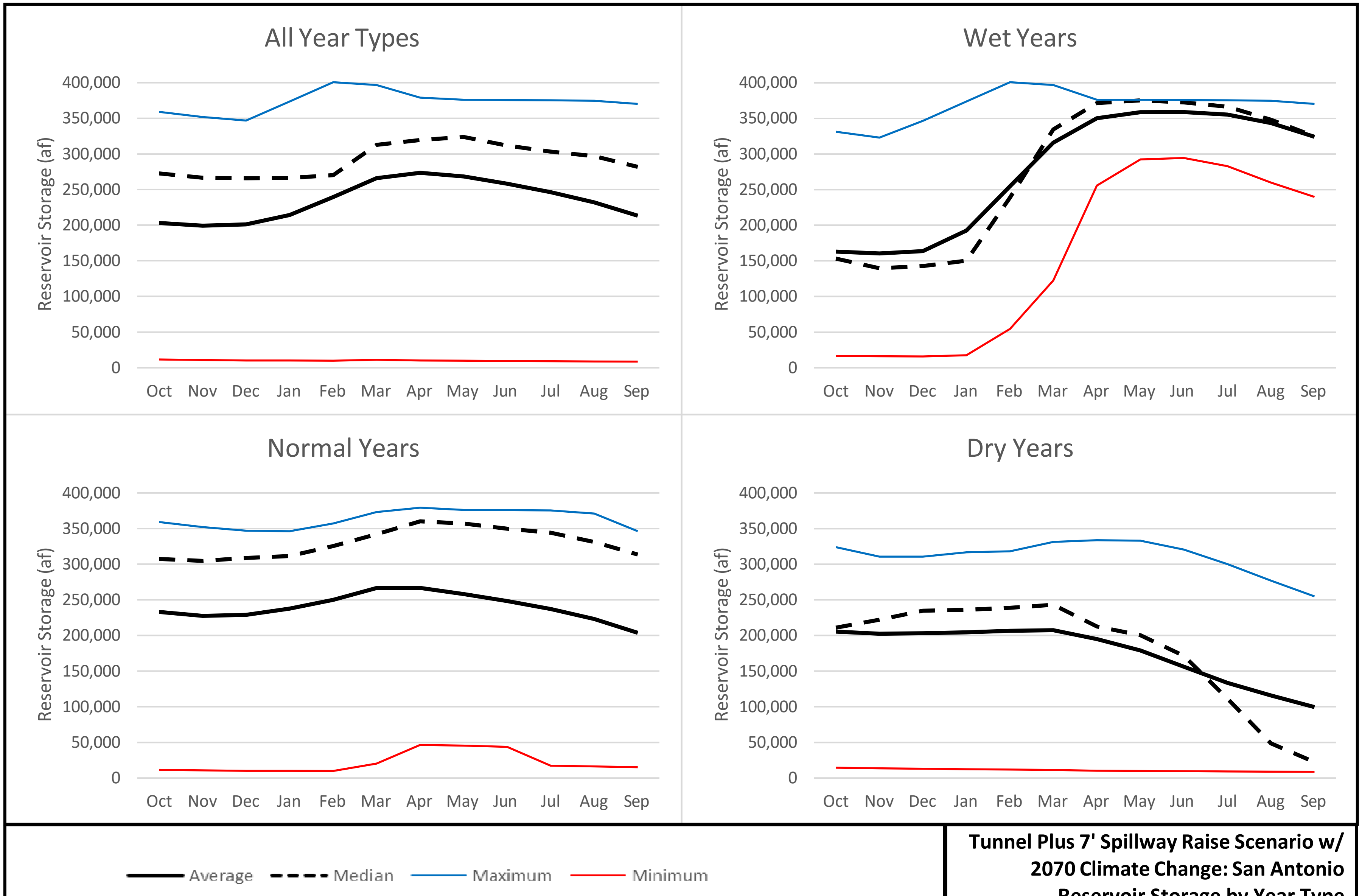
Figure 29b

Provisional data subject to revision.



Tunnel Plus 7' Spillway Raise Scenario w/ 2070 Climate Change: San Antonio Reservoir Storage by Year Type

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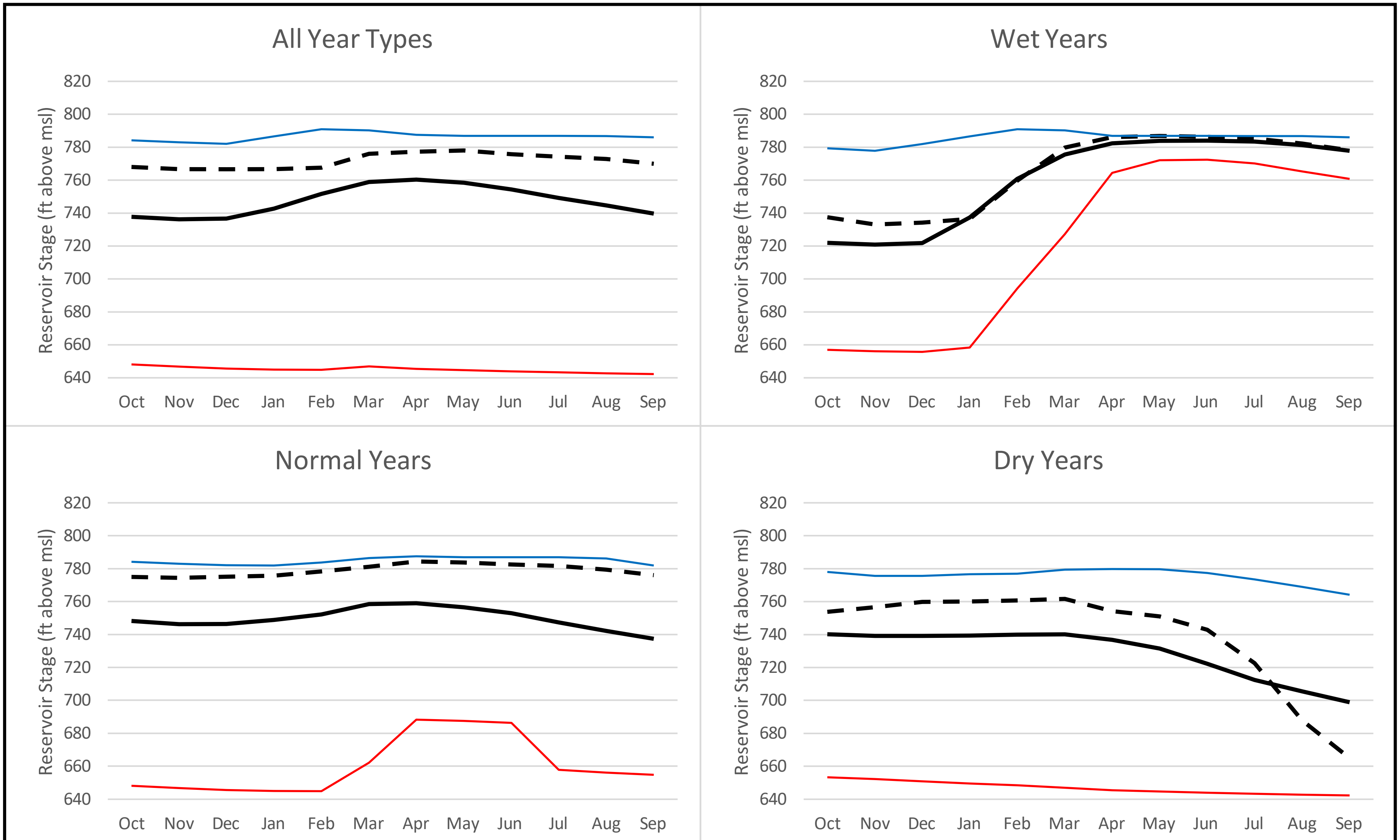
Figure 29c

Provisional data subject to revision.



Average — Median — Maximum — Minimum

Tunnel Plus 7' Spillway Raise Scenario w/ 2070 Climate Change: San Antonio Reservoir Stage by Year Type

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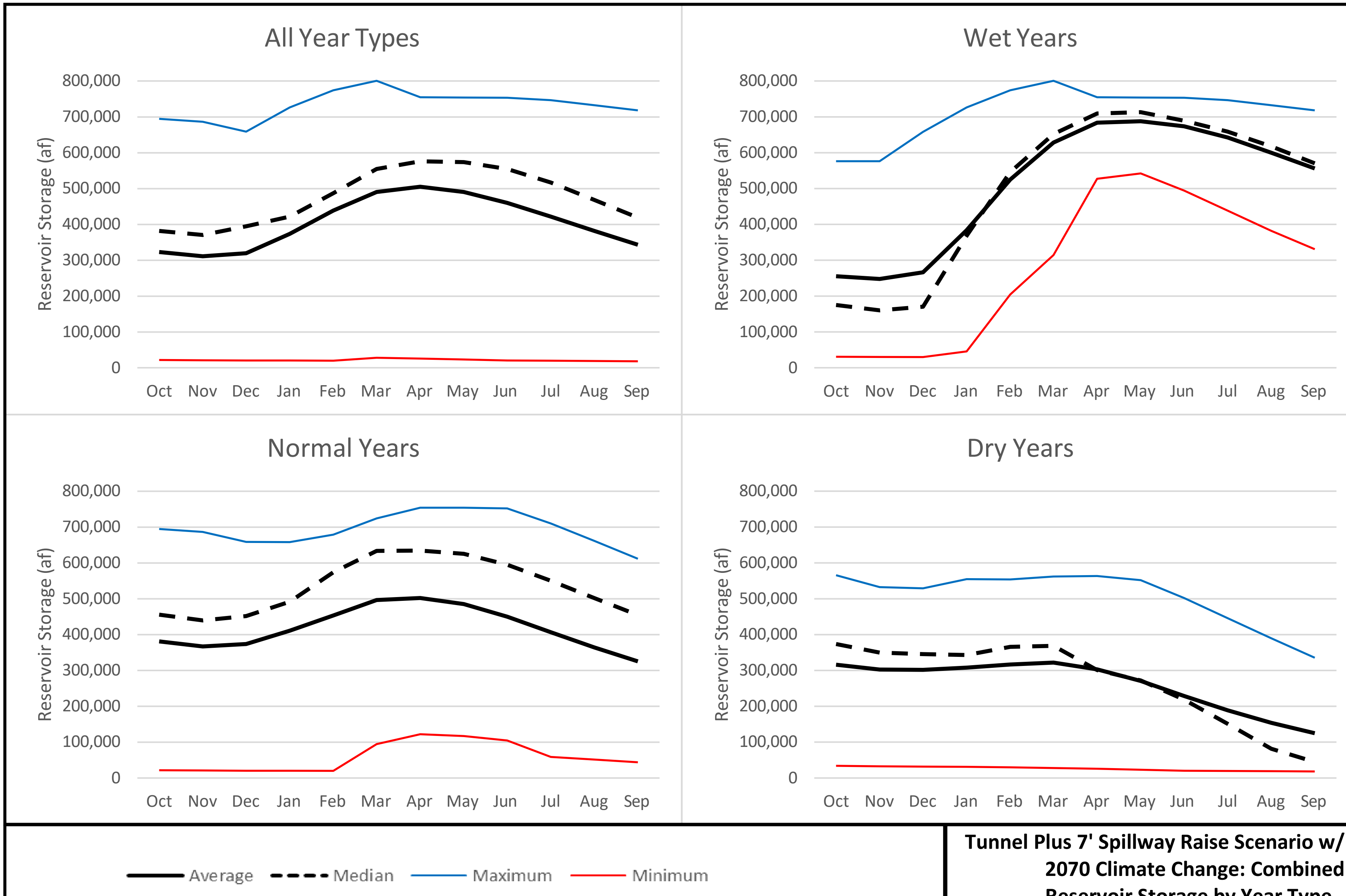
Figure 29d

Provisional data subject to revision.



Tunnel Plus 7' Spillway Raise Scenario w/ 2070 Climate Change: Combined Reservoir Storage by Year Type

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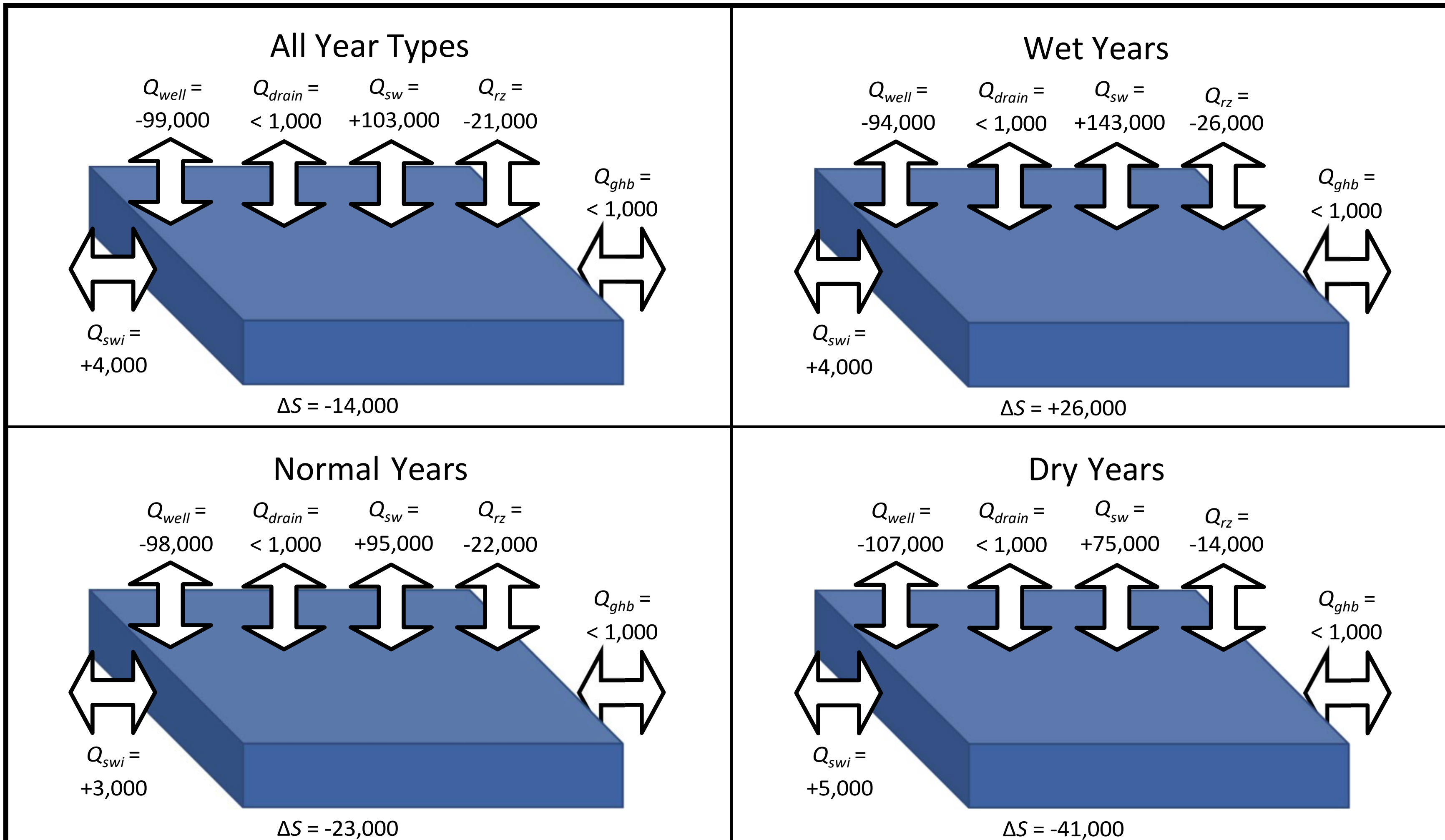
Figure 29e

Provisional data subject to revision.



Notes:

All water budget components are reported in acre-feet per year (afy)

See Section 4.2.6 for variable definitions.

Positive values of ΔS represent a loss of storage, negative values represent a gain in storage.

Provisional data subject to revision.

Tunnel Plus 7' Spillway Raise Scenario with 2070 Climate Change: Groundwater Budget by Water Year Type

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Figure 30

APPENDIX A

Current Reservoir and River Operations

TABLES:

FIGURES:

APPENDIX A: CURRENT RESERVOIR AND RIVER OPERATIONS

This appendix provides a description of the current approach to reservoir and river operations employed by MCWRA. These operations are complex and depend on a variety of conditions within the system, including streamflow at various locations within the basin. The purpose of this appendix is to provide a working understanding of the current operational approach as implemented in the Salinas Valley Operational Model (SVOM) Baseline scenario, not to give exhaustive detail on every aspect of the reservoirs or their operations. Additional details on current reservoir operations are available from MCWRA at https://www.co.monterey.ca.us/home/showpublisheddocument/63151/636628427976500000. Modifications to these operations implemented for additional scenarios are described in Appendix B.

The study area contains two major surface water storage facilities, Nacimiento and San Antonio Reservoirs (Figure A1). Together, these two reservoirs can store approximately 713,000 acre-feet (af) of water, capturing streamflow during the winter wet season for release during the dry season. Both reservoirs are owned and operated by MCWRA, and operations consider multiple factors: flood protection, environmental and fisheries habitat, groundwater recharge, water conservation, operation of the Salinas River Diversion Facility, and recreation.

This appendix describes the two reservoirs in terms of the physical configuration of the dams and reservoirs; how water is stored and categorized; how the amount, timing, and duration of reservoir releases are determined; and how the reservoir operations are constrained by water rights. For the purposes of this appendix, all released water is placed into one of three categories based on the purpose of the release:

- Flood Control Releases: Releases made to keep reservoir storage below the elevation of the flood rule curve, which changes through the year.
- Environmental Releases: Releases made to support fish and wildlife habitat below each of the dams (minimum releases), as well as releases made to support the migration of Steelhead within the Salinas River and its tributaries (fish passage releases).
- Conservation Releases: Releases made to support groundwater levels in the basin and to support operation of the Salinas Valley Water Project (SVWP) via diversions at the Salinas River Diversion Facility (SRDF).

An Operation Policy for Nacimiento Reservoir was published in 2018 (MCWRA, 2018). Much of the information presented in this appendix is also presented in the Operation Policy, as it reflects the current operational approach for Nacimiento Reservoir. Differences stem from the fact that this appendix describes the operation of both Nacimiento and San Antonio Reservoirs together. Additionally, this appendix deals with the operations of the river and reservoirs as implemented in the SVOM, which requires certain assumptions and limitations (see Section A11), in particular with regard to certain aspects of reservoir operations, such as Adaptive Flow Management (see Section A9.2) and the reliance on weather and streamflow forecasts for flood control operations, that the SVOM is not currently capable of simulating.

A1 NACIMIENTO AND SAN ANTONIO RESERVOIRS AND DAMS

Nacimiento Reservoir is located entirely within San Luis Obispo County (Figure A1) and was completed in 1957. The dam crest is at an elevation of 825 feet above mean sea level (msl), and the spillway crest elevation is 787.75 feet above msl; the spillway is equipped with an inflatable Obermeyer gate that can raise the spillway elevation to 800 feet above msl. This is done from

April 1st to November 1st each year; however, if stage in Nacimiento Reservoir gets to 801 feet above msl while the Obermeyer gate is raised, the Obermeyer gate must be deflated and remain deflated for the remainder of the year. Nacimiento Reservoir has a capacity of about 311,000 af with the Obermeyer gate deflated, and about 378,000 af with the Obermeyer gate raised. The area-stage-capacity curve for Nacimiento Reservoir is presented on Figure A2a.

Nacimiento Dam has two outlets, a High Level Outlet Works (HLOW) and a Low Level Outlet Works (LLOW). The inlet of the HLOW is located at an elevation of 755 feet above msl, while the LLOW inlet is at an elevation of 670 feet above msl. Each of the two outlets has its own rating curve relating reservoir stage to outflow capacity through the outlet (Figure A3a). The HLOW has a maximum capacity of 5,500 cubic feet per second (cfs) at a reservoir stage of 800 feet above msl, while the LLOW has a maximum capacity of 460 cfs at the same stage. The dam is also equipped with power generation capabilities, which function at releases between 25 and 400 cfs (not included in the model rating curves). Above a reservoir stage of 787.75 feet above msl (or 800 feet above msl when the Obermeyer gate is inflated), water can be released over the spillway, with very high release capacity (Figure A3a).

San Antonio Reservoir is located entirely within Monterey County (Figure A1), and was completed in 1967. The dam crest is at an elevation of 802 feet above msl, and the spillway crest elevation is 780 feet above msl. San Antonio Reservoir has a capacity of about 335,000 af with reservoir stage at the spillway crest. The area-stage-capacity curve for San Antonio Reservoir is presented on Figure A2b.

San Antonio Dam has a single outlet works, with an inlet elevation of 645 feet above msl. Its maximum capacity is 2,200 cfs at a reservoir stage of 780 feet above msl (Figure A3b). Above a reservoir stage of 780 feet above msl, water can be released over the spillway, with very high release capacity (Figure A3b).

A2 RESERVOIR OPERATIONAL POOLS

Storage in each of the two reservoirs is divided into several different operational pools (Figure A2). These pools earmark stored water for the reservoirs' various uses, ensuring that the reservoirs maintain sufficient storage or storage capacity to support their goals.

In Nacimiento Reservoir, storage is divided into four pools: the dead pool, the operational minimum pool, the conservation pool, and the flood pool. The dead pool extends from the base of the reservoir to a stage of 670 feet above msl, equating to 10,300 af of storage, and represents water that cannot be released by gravity from the reservoir, as the invert of the lowest intake structure (the LLOW) is at an elevation of 670 feet above msl. The operational minimum pool, extending from 670 to 687.8 feet above msl (10,300 to 22,300 af of storage), is water that is reserved for a water entitlement for San Luis Obispo County, including limited lakeside users along Nacimiento Reservoir[1]. The conservation pool stretches from 687.8 to 787.75 feet above msl (22,300 to 311,300 af), from the top of the operational minimum pool to the elevation of the spillway crest. The conservation pool is released to support fish and wildlife habitat, fish passage, SRDF operation, and groundwater recharge. The highest pool is the flood pool, which contains any water between 787.75 and 800[2] feet above msl (311,300 to 383,700 af of storage); this pool provides flood protection for the basin by maintaining capacity during the wet season for the probable maximum flood without reaching the crest of the dam. Water stored in the flood pool is available to support the same release types as the conservation pool. For both reservoirs, the size of the flood pool varies through the year (see below).

San Antonio Reservoir storage is also divided into the same four pools, although their stage limits and operational uses are different. The dead pool in San Antonio Reservoir extends from the base of the reservoir to a stage of 645 feet above msl (equivalent to 10,000 af of storage), the elevation of the invert of the outlet structure, below which water cannot be released from the reservoir by gravity. Above this is the operational minimum pool, extending from 645 to 666 feet above msl (10,000 to 23,000 af of storage), water that is reserved for supporting fish and wildlife habitat (specifically fish and wildlife habitat below the dam). The conservation pool extends from 666 to 774.5 feet above msl (23,000 to 305,000 af of storage); this water is used to support fish and wildlife habitat, fish passage, SRDF operation, and groundwater recharge. Above this is the flood pool, which stretches from 774.5 to 780 feet above msl (305,000 to 335,000 af of storage), the elevation of the spillway crest at San Antonio Dam; this water is designed to provide capacity for the reservoir to protect the basin from flooding during the wet

[1] Note that the annual entitlement for San Luis Obispo County (15,750 af) and the lakeside users (1,750 af) is larger than the operational minimum pool (12,000 af). San Luis Obispo County can also take water from the conservation and flood pools, but the minimum pool is reserved for them.

[2] The upper limit of the flood pool, 800 feet above msl, represents the elevation of the crest of the Obermeyer gate; if reservoir stage rises above 801 feet above msl, the Obermeyer gate drops immediately and remains lowered for the rest of the year.

season by capturing the probable maximum flood without reaching the crest of the dam. Water stored in the flood pool is available to support the same release types as the conservation pool.

To help achieve the flood control goals of the reservoirs, the maximum storage in each reservoir at any given time is determined by a Flood Rule Curve that varies through the year. Any water above the Flood Rule Curve elevation is released by the reservoirs as Flood Control Releases. The Flood Rule Curves for Nacimiento and San Antonio Reservoirs are shown on Figure A4. Nacimiento Reservoir's Flood Rule Curve has a value of 787.75 feet above msl (the elevation of the spillway crest) from December 1 to March 1, and an elevation of 800 feet above msl (the elevation of the crest of the Obermeyer gate) from April 1 to November 1. San Antonio Reservoir's Flood Rule Curve is set to an elevation of 774.45 feet above msl from January 1 to February 1, rising to 780 feet above msl for the period from April 1 to August 1. In each case, the Flood Rule Curve is low in the winter wet season, leaving available storage capacity to absorb high flow events that occur during this period. For each reservoir, the flood pool contains the volume of water that is within the variation of the Flood Rule Curve; depending on the elevation of the Flood Rule Curve, sometimes this water is available to support fish and wildlife habitat, fish passage, SVWP operation, and groundwater recharge, while at other times it is quickly drained (released as Flood Control Releases) to maintain storage capacity to absorb wet season inflow.

Although not related to the operational pools, MCWRA maintains minimum storage values in Nacimiento Reservoir to protect the San Luis Obispo County (SLO) allotment (see Section A7) and fish and wildlife habitat releases (see Section A9.1). If possible, MCWRA targets having at least 22,300 af in storage in Nacimiento Reservoir on October 1 each year (i.e. a full operational minimum pool) so that they can continue to provide water to SLO per their agreement. To ensure this, MCWRA may curtail operations responding to downstream demands (i.e., to supply SRDF operations and groundwater recharge and to assist with fish migration) so that storage does not fall below this value before October 1. The minimum storage, shown on Figure A5, takes into account the SLO allotment, expected reservoir evaporation, and projected fish and wildlife habitat releases from January 1 to October 1, and assumes no reservoir inflow or precipitation. The minimum storage is at a maximum of about 83,000 af on January 1, decreasing to 22,300 af on October 1. If storage in Nacimiento Reservoir is below this minimum storage, it will not contribute to releases to meet downstream demands until such time as storage rises above the minimum storage.

A3 STREAMFLOW CHECK LOCATIONS

Operation of the reservoirs depends in part on streamflow conditions at various locations along the Salinas River and its largest tributary within the basin, Arroyo Seco; streamflow at selected locations dictates the amount and duration of various environmental and conservation releases, and releases target specific amounts and durations of streamflow. These locations are mainly ones where the USGS has operated stream gauges with long-term records. The locations are shown on Figure A1, and are also listed on Table A1, along with pertinent information regarding the gauges and what aspect of reservoir and river operations streamflow at each location informs. As described below in Section A11, the "Lagoon" location is placed next to the Salinas River Diversion Facility (SRDF) to aid in accurate quantification of the bypass flows that are required by the Flow Prescription. This is several miles upstream of the actual location of the Salinas River Lagoon.

A4 RESERVOIR WATER RIGHTS

Both Nacimiento and San Antonio Reservoirs have associated water rights licenses and permits that give MCWRA access to the water stored in and released from them. These water rights limit the amount of water that can be added to and taken from storage each year in each reservoir.

Figure A6 provides a sample hydrograph of a hypothetical reservoir, showing how periods of increasing and decreasing storage count against the water right limitations (SWRCB, 2013). This figure is an example of how water right limitations can be tracked and a similar accounting methodology was implemented in the SVOM.

The water right limitations are applied to the total collection to storage and withdrawal from storage, and do not apply to regulated or abandoned water. As shown by Figure A6, accounting for water entering and leaving a reservoir can be quite complex, and depends on careful tracking and analysis. This accounting also does not rely on estimates of inflow to or outflow from the reservoirs; collection to and withdrawal from storage are entirely based on changes in the amount of water stored in the reservoirs. This means, for example, that evaporation from the reservoir surface can be accounted as a withdrawal from storage.

Nacimiento and San Antonio Reservoirs operate under a number of different water rights:

- Nacimiento Reservoir
  - License 7543 (Application 16124), issued in 1965 and last amended in 2008, limits collection to storage to 350,000 af from October 1 to July 1 of the following year, and withdrawal from storage to 180,000 af per calendar year, with a maximum reservoir capacity of 377,900 af; this license is subject to the 1959 agreement with San Luis Obispo County that gives that county access to 17,500 afy from Nacimiento Reservoir.
  - Permit 21089 (Application 30532), issued in 2001, increases the limit to collection to storage by 27,900 af (to 377,900 af) from October 1 to July 1 of the following year, based on a detailed reanalysis of the capacity of Nacimiento Reservoir; no change is made to the maximum reservoir capacity (377,900 af) or withdrawal from storage.
  - Permit 19940 (Application 26901), issued in 1986, allows MCWRA to divert up to 500 cfs through the hydroelectric plant in Nacimiento Dam all year; these releases are incidental to other releases, and only count against the withdrawal limit as determined under License 7543. This water right has no impact on reservoir and river operations as implemented in the SVOM.
- San Antonio Reservoir
  - License 12624 (Application 16761), issued in 1965 and last amended in 2008, limits collection to storage to 220,000 af from October 1 to July 1 of the following year, and withdrawal from storage to 210,000 af per calendar year, with a maximum reservoir capacity of 335,000 af.

A5 WATER YEAR TYPE DETERMINATION

Several aspects of reservoir and river operations, including the types, timing, duration, and amount of releases, depend on how wet the basin is. This is expressed by means of the year type. MCWRA uses 5 year type categories in its reporting (wet, wet-normal, normal, dry-normal, and dry), based on historical measured streamflow at the Arroyo Seco near Soledad stream gauge (MCWRA, 2005). However, the wet-normal, normal, and dry-normal year types are lumped together in the Flow Prescription rules (i.e., wet-normal and dry-normal years are treated the same as normal years). Therefore, the reservoir operations simulated in SWO simplify the year type categories to wet, normal, and dry.

The year type is determined on March 15 of each year based on the average streamflow at the Arroyo Seco near Soledad streamflow gauge (see Figure A1) since October 1 of the previous year (i.e., the start of the water year). This streamflow gauge is used because Arroyo Seco is an unregulated stream (i.e., there is no surface water impoundment in the watershed above the gauge), and is therefore used as a proxy of natural streamflow conditions, and has a long duration of data that make the gauge suitable for statistical analyses. If average streamflow over the specified period at the gauge has been 352 cfs or higher, the year is classified as a wet year. If average streamflow has been below 87 cfs, the year is classified as a dry year. Anything else is considered a normal year.

A second year type check is performed on April 1 of each year, with the resulting year type overriding the one determined on March 15. If average streamflow from October 1 to April 1 at the Arroyo Seco near Soledad streamflow gauge has averaged 397 cfs or higher, the year is classified as a wet year. If average streamflow has been below 98 cfs, the year is classified as a dry year. Anything else is considered a normal year.

MCWRA modifies the water year type definitions year by year based on re-analysis of the Arroyo Seco near Soledad streamflow data. The values given above represent the water year type thresholds as implemented in the SVOM, and were determined based on streamflow data through 2017.

A6 RESERVOIR RELEASE RATIO

Some types of reservoir release are determined solely by conditions at each reservoir. Flood Control Releases are made whenever reservoir stage is above the Flood Rule Curve, and fish and wildlife habitat releases are made whenever other types of release do not add up to the target minimum release for each reservoir. Other types of release (i.e., Conservation Releases and fish passage releases) are made to respond to a downstream demand. These releases responding to downstream demand may be made from one or both reservoirs; they are apportioned in SWO by setting a value for the percentage of these release types to be made from each reservoir.

In general, MCWRA prioritizes releases from Nacimiento Reservoir because its watershed generally produces substantially more flow than does the San Antonio Reservoir watershed. Representing this is accomplished in SWO by setting a target release percentage of 99% from Nacimiento Reservoir (the percentage is not set to 100% because SWO can have difficulty with variables set to 0, a value that the San Antonio Reservoir release percentage would be set to, and because San Antonio Reservoir has to make a minimum amount of fish and wildlife habitat release anyway). The 99% target is not always reachable, either because it would require Nacimiento Reservoir to release above its capacity, or would lower its storage below a threshold value, or would cause the water right withdrawal from storage to go too high. In these cases, the percentage of release from Nacimiento Reservoir will be lower than 99% by necessity and San Antonio Reservoir makes additional releases to compensate.

As part of the Interlake Tunnel modeling, MCWRA analyzed five different release ratios with only the Interlake Tunnel added: prioritizing Nacimiento Reservoir; a 3:1 ratio (Nacimiento: San Antonio); establishing a release ratio based on relative storage in the reservoirs on February 1; a 1:1 ratio; and, a 1:9 (Nacimiento: San Antonio) ratio. In this exercise, all of the simulations except for the one using a 1:9 ratio showed that releases are made with approximately 60% of coming from Nacimiento and 40% coming from San Antonio. With the Interlake Tunnel in place, this ratio flips in dry water years such that more water is released from San Antonio.

A7 SAN LUIS OBISPO WATER ENTITLEMENT

Per the 1959 Nacimiento Water Agreement between MCWRA and San Luis Obispo County (SLO), Nacimiento Reservoir provides 17,500 afy of water to the Nacimiento Water Project (NWP) and lakeside users along Nacimiento Reservoir. Of the total 17,500 afy, 10% (1,750 afy) is reserved for lakeside users, with the remainder (15,750 afy) going to communities in San Luis Obispo County via a 45-mile transmission pipeline that moves water from Nacimiento Reservoir to as far as the city of San Luis Obispo.

San Luis Obispo County is entitled to the operational minimum pool in Nacimiento Reservoir (between 670 and 687.8 feet above msl), which contains 12,000 af of storage. As noted in Section A2, San Luis Obispo County can also take water from the conservation and flood pools. If storage in Nacimiento Reservoir falls to the dead pool (10,300 af), deliveries to San Luis Obispo County are no longer possible.

There is no set monthly amount that San Luis Obispo County receives from the reservoirs (only an annual total); the Operational Model uses the monthly amounts provided in Table A2, which represent Water Year 2014 transfers. Historically, the water deliveries requested by San Luis Obispo County are relatively consistent from year to year.

As noted in Sections A2 and A4, the amount of the SLO allotment is protected in Nacimiento Reservoir. The SVOM uses a dynamic minimum storage and a dynamic water right withdrawal limit in Nacimiento Reservoir to try to ensure that the SLO allotment can continue to be delivered. It is possible for Nacimiento Reservoir to have insufficient storage to supply the SLO allotment, particularly during extended (multi-year) drought periods, but the SWO rules are written to minimize the likelihood of this occurring.

A8 FLOOD CONTROL RELEASES

The reservoirs make Flood Control Releases to maintain reservoir stage at or below their maximum desired stage. As noted in Section A2, the maximum stage in each reservoir changes throughout the year, as dictated by the Flood Rule Curve, which is lower during the winter wet season to leave capacity for large flow events to enter the reservoirs without overtopping the dams.

Flood Control Releases can occur for two different reasons. First, high inflow to a reservoir may cause rising stage, necessitating releases to stay below the Flood Rule Curve. Alternatively, Flood

Control Releases can also happen as the elevation of the Flood Rule Curve is decreased leading into the winter wet season. In this situation, reservoir stage may be below the Flood Rule Curve at one point, but a subsequent decline in the Flood Rule Curve would cause the Flood Rule Curve to fall below the reservoir stage, requiring reservoir stage to be lowered.

Depending on the magnitude of inflow to a reservoir, reservoir release capacity may limit Flood Control Releases to a rate too low to prevent the reservoir stage from rising above the Flood Rule Curve in the SVOM. In such cases, the reservoir stage will rise temporarily above the Flood Rule Curve; Flood Control Releases will continue beyond the peak of the high inflow period until the reservoir stage is back below the Flood Rule Curve. Outside the modeling environment, MCWRA has greater operational flexibility to incorporate streamflow and reservoir inflow forecasts that can inform operational decisions and may allow for closer adherence to the Flood Rule Curve.

A9 ENVIRONMENTAL RELEASES

The reservoirs make Environmental Releases to support fish and wildlife habitat below the two dams (i.e., minimum releases; see Section A9.1) and the passage of Steelhead Trout during various stages of their life cycle (i.e., fish passage releases). Steelhead travel from Monterey Bay up the Salinas River to Arroyo Seco and other parts of the system to spawn; maintaining connectivity between Monterey Bay and these critical habitats is an important goal of releases from the reservoirs.

In 2005, MCWRA published the *Salinas Valley Water Project Flow Prescription for Steelhead Trout in the Salinas River* (Flow Prescription; MCWRA, 2005). This document dictates the timing, duration, and amount of fish passage releases. The Flow Prescription defines four stages of the Steelhead life cycle relevant to migration up and down the stream system:

- Adult – mature steelhead migrating upstream to spawn (see Section A9.2);
- Smolt – immature steelhead migrating downstream from spawning areas to the ocean (see Section A9.3);
- Kelt – mature steelhead returning to the ocean after spawning (see Section A9.4); and
- Juvenile – immature steelhead migrating downstream from spawning areas to the Salinas River lagoon (see Section A9.5).

The goal of the fish passage releases, as defined in the Flow Prescription, is to provide sufficient water to allow Steelhead to migrate up and down the stream system at critical periods of their life cycle. This requires supplying a certain amount of flow at specific points in the stream system for a defined period of time; the releases performed for this purpose are referred to in the Flow Prescription as Block Flows. These releases are made according to a logic-based decision process that considers reservoir storage, year type, and streamflow at various locations along the stream system; the decision-making process is visualized as flowcharts in the Flow Prescription, reproduced here as Figure A8. As noted in Section A5, streamflow at the Arroyo Seco near Soledad gauge is generally used as a proxy for natural streamflow conditions in the decision-making process.

The Flow Prescription identifies known Steelhead habitat in the Upper Arroyo Seco, as well as potential habitat elsewhere in the system, including the Salinas River and lower Nacimiento River. Block flows aim to support streamflow in these important habitat areas, as well as connectivity to the mouth and lagoon of the Salinas River.

A9.1 Fish and Wildlife Habitat Releases

Whenever possible, both reservoirs maintain a minimum amount of release to support fish and wildlife habitat in the Nacimiento and San Antonio Rivers between the dams and their respective confluences with the Salinas River; releases made for this purpose are considered Environmental Releases. The minimum release required for Nacimiento Reservoir is 60 cfs, while the target for San Antonio Reservoir is 10 cfs.

In the SVOM, two conditions are necessary for a reservoir to make minimum releases. The first is a storage requirement: Nacimiento Reservoir must be above its operational minimum pool (22,300 af), while San Antonio Reservoir must be above its dead pool (10,000 af). The second is that other releases already taking place do not add up to more than the minimum release target. Minimum releases may be made in conjunction with other releases to get total releases to add up to the minimum release target. For example, if Nacimiento Reservoir is releasing 45 cfs of Conservation Releases, SWO will make an additional 15 cfs of minimum releases to get to the 60 cfs minimum release target. If releases are already being made at or above the minimum release target, these releases are assumed to be supporting the fish and wildlife habitat below the dams, obviating the need for specific releases for this purpose.

The conditions for making minimum releases are considered independently at the two reservoirs. Nacimiento Reservoir can make minimum releases when San Antonio Reservoir does not (either because storage in San Antonio Reservoir is at the dead pool or other releases add up to 10 cfs or more), and vice versa.

As described in Section A2, the operational rules attempt to protect these fish and wildlife habitat releases at Nacimiento Reservoir, potentially curtailing Conservation Releases and fish passage releases earlier in the year than might otherwise be necessary to ensure that sufficient storage remains in Nacimiento Reservoir to supply fish and wildlife habitat releases through October 1. In addition, as described in Section A4, the water rights withdrawal from storage limit is structured to attempt to protect fish and wildlife habitat releases through the end of the calendar year; this may also affect reservoir operations during the Conservation Release Season.

A9.2 Adult Upstream Migration

Migration of adult Steelhead upstream to spawning habitat is assumed to occur from the beginning of January through April. January migration is assumed to be adequately supported by natural streamflow, while April migration is supported by smolt outmigration releases and releases supporting SRDF operation. Therefore, releases to support adult upstream migration can be made from February 1 to March 31. The decision-making process for fish passage releases to support Adult Upstream Migration is reproduced here as Figure A8a.

Releasing water to support adult upstream migration requires the following conditions be met:

1) Combined storage in Nacimiento and San Antonio Reservoirs is 220,000 af or more;
2) Mean daily streamflow at Arroyo Seco near Soledad, CA (USGS gauge number 11152000) is 340 cfs (±10%) or higher; and
3) Mean daily streamflow at Arroyo Seco near below Reliz Creek near Soledad, CA (USGS gauge number 11152050) is 173 cfs (±10%) or higher.

If all of these conditions are met and natural mean daily streamflow does not equal at least 260 cfs (±10%) at the Salinas River near Chualar (USGS gauge number 11152300), then the reservoirs will release water to reach a mean daily streamflow of 260 cfs at the Salinas River near Chualar. Releases will be made to maintain this streamflow at the Salinas River near Chualar gauge for 5 or more consecutive days, as long as the Salinas River mouth is open to the ocean.

MCWRA may make additional releases during the receding limb of storm hydrographs to maintain mean daily streamflow of 260 cfs or more at the Salinas River near Chualar. Termed Adaptive Flow Management, an example is provided in the Flow Prescription. However, since these releases would be made on an *ad hoc* basis, they are not included in the reservoir management as codified in the Operational Model.

A9.3 Smolt Outmigration

Downstream migration of immature Steelhead (known as smolts) from spawning beds to the Pacific Ocean (via the Salinas River Lagoon) is believed to occur from about mid-March through May (MCWRA, 2005). Under appropriate conditions, the reservoirs make fish passage releases during this period to support this outmigration.

In order to make releases to support Smolt outmigration, the following criteria need to be met (see Figure A8b):

1) Combined storage in Nacimiento and San Antonio Reservoirs is above 150,000 af on March 15;
2) The year type is normal (dry-normal, normal, or wet-normal) on either March 15 or April 1; and
3) Mean daily streamflow at Nacimiento River below Sapaque Creek near Bryson, CA (USGS gauge number 11148900) averages 125 cfs or higher, or mean daily streamflow at Arroyo Seco below Reliz Creek near Soledad, CA (USGS gauge number 11152050) averages 70 cfs or higher.

Meeting the third criterion (streamflow) can trigger block flows at any time until the check ceases (after May 31). In other words, block flows can start any date up to (and including) May 31.

Once smolt outmigration block flows are triggered, the reservoirs begin releasing water to meet streamflow targets at specified locations along the Salinas River:

- Mean daily streamflow of 700 cfs or higher at Salinas River at Soledad, CA (USGS gauge number 11151700) for 5 days, followed by
- Mean daily streamflow of 300 cfs or higher at Salinas River near Spreckels, CA (USGS gauge number 11152500) until the end of the block flow.

The total duration of the block flow varies depending on the start date; the block flow ends on April 20 or after 20 total days of releases, whichever is later. The total number of block flow days can vary from 20 to 45, depending on start date, ending at any point between April 20 and June 20. From the Flow Prescription:

> "A successful engineered block flow is considered to consist of stream flow in the Salinas River near Soledad of 700 cfs, or more, for five consecutive days, and flow near Spreckels of 300 cfs, or more, for at least 15 consecutive days thereafter, totaling a minimum of 20 days to a maximum of 45 days."

If the reservoirs are unable to meet the block flow requirements for three consecutive timesteps, smolt outmigration releases cease.

A9.4 Kelt Outmigration

Subsequent to the smolt outmigration block flows, fish passage releases may be made to support the migration of kelts (adult Steelhead returning to the Ocean). If a smolt outmigration block flow has occurred during any given year, additional kelt outmigration releases will be made. Streamflow of 45 cfs will be maintained to the Lagoon for 10 days following the cessation of the smolt outmigration block flow, or until the Lagoon closes to the Ocean (which is assumed to occur when streamflow at Spreckels drops below 80 cfs), whichever happens first.

A9.5 Juvenile Outmigration

MCWRA also releases block flows to help immature Steelhead, termed juveniles, migrate downstream from spawning areas to the Salinas River Lagoon. This is believed to occur from early April through late June (MCWRA, 2005), slightly longer than the smolt outmigration period. Fish passage releases to support juvenile migration are generally made after smolt outmigration and kelt outmigration releases cease. Figure A8c shows the decision-making process for making releases to support juvenile outmigration.

Juvenile outmigration releases can be made only while the combined storage in Nacimiento and San Antonio Reservoirs is above 220,000 af. If storage falls below this level, these releases cease. If storage later rises back above 220,000 af, juvenile outmigration releases can resume. Additionally, releases to support juvenile outmigration are not made during dry years.

The occurrence of juvenile outmigration releases depends on whether or not smolt and kelt outmigration block flows occurred during a given year. If no block flow occurred and the Lagoon is open to the Ocean, releases are made to maintain a streamflow of 45 cfs to the

Lagoon for 10 days or until the Lagoon closes, whichever comes first, followed by a streamflow of 15 cfs to the Lagoon until June 30. If a smolt outmigration block flow did occur, releases will be made to maintain a streamflow of 15 cfs to the Lagoon from the end of smolt and kelt outmigration releases until June 30.

A9.6 Bypass Flows

As long as the SRDF is in operation (see Section X1-10), reservoir releases must be made to maintain at least 2 cfs of flow to the Salinas River Lagoon. Although these releases are made in conjunction with Conservation Releases, the 2 cfs requirement is considered part of Environmental Releases.

A10 CONSERVATION RELEASES

The reservoirs make Conservation Releases to support downstream demands and groundwater recharge in the basin. Currently, the only downstream diversion point along the Salinas River is the Salinas River Diversion Facility (SRDF), part of the Salinas Valley Water Project (SVWP), which delivers water to the Castroville Seawater Intrusion Project (CSIP) area to replace coastal groundwater pumping in an effort to mitigate ongoing seawater intrusion in this area. Figure A1 shows the location of SRDF and the CSIP area.

SRDF includes a pneumatically controlled rubber dam that stretches across the Salinas River, with an intake structure that takes water out of the Salinas River just above the dam. Water diverted from the Salinas River is filtered and treated before delivery to CSIP users. Diversions at SRDF take place during a defined season, lasting from April 1 to October 31 each year; the dam is raised at the beginning of the diversion season and lowered when operations at SRDF cease. If no SRDF season occurs, the rubber dam is not raised.

In order for Conservation Releases to be made, the reservoirs must have sufficient storage at some point during the period from March 15 to May 1. The minimum storage limits for Conservation Releases are 55,000 af in San Antonio Reservoir and 145,000 af in the two reservoirs combined (note that there is no requirement that Nacimiento Reservoir be holding 90,000 af; the entire 145,000 af could be in San Antonio Reservoir and the storage criteria would still be met).

If sufficient storage is available, the reservoirs will make releases to support operation of the SRDF. In its current configuration, the SRDF can take as much as 36 cfs out of the Salinas River to supply to CSIP. In addition, as long as SRDF is in operation the Salinas River must deliver at least 2 cfs of streamflow to the Salinas River Lagoon (see Section A9.6). As long as enough streamflow can be maintained in the Salinas River to meet the 36 cfs demand at SRDF and the 2 cfs requirement at the Lagoon, and at least one of the reservoirs remains above its operational minimum pool, the reservoirs will make Conservation Releases as necessary (if natural streamflow meets the above requirements, the reservoirs will not make Conservation Releases). Conservation Releases cease either at the end of the season (November 1), if both reservoirs fall below their respective minimum storage thresholds[3], or the reservoirs can no longer release enough water to maintain a streamflow of 20 cfs at the Salinas River near Spreckels (USGS gauge number 11152500). If SRDF operates at 36 cfs for the entire season (April 1 to October 31, 214 days), it diverts a total of 15,280 af.

During years where antecedent conditions are very dry, it may be difficult to supply the required streamflow to SRDF with reservoir releases starting on April 1. In such situations, MCWRA can make channel wetting releases to prepare the Salinas River channel for Conservation Releases. These channel wetting releases take place prior to the start of the Conservation Release season. In the SVOM, channel wetting flows can be initiated between March 15 and April 20 if 1) mean daily streamflow in the Salinas River at Soledad (USGS gauge number 11151700) is below 20 cfs at some point between March 1 and April 1, 2) storage in San Antonio Reservoir is at least 55,000 af and storage in the two reservoirs combined is at least 145,000 af, and 3) mean daily streamflow in the Salinas River near Spreckels (USGS gauge number 11152500) is below 40 cfs when criterion 2 (for storage) is met. Channel wetting releases follow a set release pattern:

1) Total reservoir release of 1,200 cfs for up to 10 days, followed by
2) Total reservoir release of 900 cfs for up to 5 days, followed by
3) Total reservoir release of 600 cfs for up to 20 days.

However, if mean daily streamflow reaches 40 cfs in the Salinas River near Spreckels, channel wetting flows will be immediately ramped down, which entails reducing reservoir release to the

[3] For San Antonio Reservoir, the minimum storage threshold below which Conservation Releases cease is the base of the conservation pool (i.e., reservoir stage of 666 feet above msl). For Nacimiento Reservoir, the minimum storage threshold changes through the year because the operational minimum pool is protected on October 1 each year, to ensure that water is set aside for the SLO allotment; see Section A2.

next lower step in the channel wetting flow pattern (e.g., if the reservoirs are currently releasing 900 cfs, they will immediately be lowered to 600 cfs).

A11 ASSUMPTIONS AND LIMITATIONS

The modeling tools used to simulate the reservoir-stream-groundwater system require a number of trade-offs that limit the ability to perfectly capture reservoir operations within the SVOM, yet result in a usable tool with the powerful capability of representing the system holistically. This section briefly describes some of the assumptions and limitations inherent in the modeling approach of the SVOM. General assumptions and limitations resulting from the use of the tools (including MODFLOW-OWHM) for simulating groundwater and surface water conditions are adequately described in their respective documentation, and are not included here.

The two reservoirs are not simulated as physical features within the active groundwater model domain that take up a specific area and communicate with geological materials connected to them. Instead, they are approximated as isolated buckets with simplified mass balance accounting (i.e., inflows minus outflows equals change in storage). Inflow is instantaneously mixed with the entire reservoir volume, and stage is uniform throughout the reservoir. Precipitation into and evaporation out of the reservoir is based solely on the reservoir area at the beginning of each timestep and an input time series of precipitation and evaporation rates. If changes in reservoir operations lead to changes in reservoir area, this will impact both precipitation and evaporation; for example, if a project scenario simulates 10% less reservoir area during a given timestep compared to the Baseline scenario, there will be 10% less precipitation entering the reservoir – precipitation falling on areas that were open water in the Baseline scenario but not in the project scenario does not reach the reservoir, even as runoff.

Reservoir operations as represented in the SVOM follow a strict set of rules, with exact triggers dictating the timing and amount of releases made from the reservoirs. The SVOM does not allow for any operations of an *ad hoc* nature. In reality, MCWRA may make slightly higher or lower releases than dictated by the rules, or may make them for shorter or longer duration, based on decades of experience operating the reservoirs. The SVOM does not include a provision to maintain stage in Nacimiento Reservoir for recreational uses.

The hydro power plant in Nacimiento Dam is not represented in SVOM. It is not incorporated into the reservoir rating curves, and the model does not track power generation. The rating curve for Nacimiento Dam assumes that all available gates can be operated at the same time; in other words, if water is above the crest of the spillway, then Nacimiento Dam can release from the spillway, the HLOW, and the LLOW. In reality, MCWRA may only use certain gates at certain stages, and may not operate the HLOW and LLOW when the spillway is in use.

As discussed in Section 3.1 of the TM, the SVOM has a timestep length of between 5 and 6 days. This timestep length was chosen to provide the best compromise between the relatively short timescale of surface water processes, the relatively long timescale of groundwater processes, the natural residence time of water in the river between the dams and Monterey Bay, and the runtime of the model. In reality, reservoir operations may change on a day-to-day and even hour-to-hour basis, as informed by conditions above and below the dams.

The timestep length also has an impact on how the SVOM accounts for water as it relates to the water rights limits. Under the water right, for water to be considered to have been collected to or withdrawn from storage, it must have been in residence in the reservoirs for at least 30 days (other than initial collection to storage, as discussed in Section A4). Timestep lengths do not always allow for a look back of exactly 30 days because of the varied timestep length. For the purposes of tracking regulated water, SWO looks back six timesteps; the length of this period is usually either 30 or 31 days, but can be as long as 35 days at the end of February in a leap year. When the six timestep period is over 30 days, the amount of storage gain or withdrawal for the earliest of the six timesteps is scaled to estimate the portion that occurred within 30 days. By necessity this assumes that storage gain and withdrawal are uniform over the length of each timestep.

The SVOM does not include any capability for forecasting inflow to the reservoirs. In reality, MCWRA may take into account weather forecasts to prepare the reservoirs for impending high inflow events by releasing water from one or both reservoirs to increase available capacity. The SVOM can only react after-the-fact to these kinds of inflow events (by making Flood Control Releases, for example).

As noted in Section A9.2, the SVOM does not make releases for the purpose of Adaptive Flow Management, releases made during the receding limb of storm hydrographs to bolster streamflow during the adult upstream migration period. This may artificially shorten the period of adult upstream migration simulated by the model.

As noted in Section 3.2, when the SRDF is operating in SVOM it diverts as much water as it can (up to its limit) whenever it is active, regardless of whether or not the CSIP area crops demand that much water. The CSIP crop demand is determined within the model based on the crop types, crop parameters, and climatic data. Crops in the CSIP area have access to local precipitation, root zone groundwater, and recycled water deliveries, all of which SVOM prioritizes over SRDF diversions when meeting crop demand. Crop demand may be met without the need for the full amount of water diverted at SRDF; in this case, SRDF will still divert up to its limit, but some or all of the diverted water will be returned to the Salinas River downstream of SRDF. The streambed conductance below SRDF is assumed to be zero (i.e., there is no communication between the Salinas River and groundwater below SRDF), so all SRDF diversion that is returned to the River ends up in the Lagoon. In order to prevent this returned water (as well as agricultural return flows that come in below SRDF) from being counted toward the Lagoon requirements (as part of the fish passage release and Conservation Release requirements; see Sections A9 and A10), the SVOM checks the Lagoon requirement one model cell below SRDF, and return flows from CSIP re-enter the Salinas River below the Lagoon requirement check location. This allows determination of whether the SVOM is supplying an appropriate amount of water to the Lagoon completely independent of the amount of demand within CSIP. This equates the amount of the SRDF bypass flows to the Lagoon requirement.

SWO allows the user to define the proportion of those releases made to meet downstream requirements (i.e., Conservation Releases and fish passage releases) that should be made from each of the two reservoirs. As described in the TM, SWO has a recognized bug that prevents setting the proportion of releases from Nacimiento Reservoir to 50% or more. As noted in Section A6, the current operational approach is to prioritize releases from Nacimiento Reservoir whenever possible; the desired reservoir release ratio from Nacimiento Reservoir is typically well above 50%. The bug in SWO forces much of that release to be made from San Antonio Reservoir. Wood developed a fix for this bug that transfers water from Nacimiento Reservoir to San Antonio Reservoir during the timestep subsequent to one during which the SWO bug under-estimates reservoir releases from Nacimiento Reservoir. The amount of this transfer is equal to the volume of water that was erroneously released from San Antonio Reservoir during the previous timestep. The transfer occurs in the timestep following that of the release because the amount of release is not known until all model calculations have been completed (i.e., the timestep is over). The fix considers all applicable release capacity and storage limitations when determining the amount of transfer; the transfer cannot take more water out of Nacimiento Reservoir than it would have been able to release the previous timestep at its stage at that time. Because the fix is applied *post hoc*, the simulated stage and storage for both reservoirs represents uncorrected releases. Although storage values can be adjusted in post-processing, it is important to note that the volume of precipitation added to and evaporation removed from the reservoirs is determined based on the uncorrected stage values. One impact of the release ratio fix is that there may be times when SWO sets the release fraction of Nacimiento Reservoir to zero (which is corrected via transfer in the subsequent timestep), leading to an over-release by up to the amount of the target minimum release (60 cfs for Nacimiento Reservoir). This happens because SWO sees that Nacimiento Reservoir is not making releases to supply downstream demands (because the fraction is set to zero), so instead makes its minimum release to support fish and wildlife habitat. SWO makes this determination after the calculation is made of how much total reservoir release is required to meet the downstream demand, so the 60 cfs from Nacimiento Reservoir is surplus to the requirement.

A12 REFERENCES

California State Water Resources Control Board (SWRCB), 2013, Process for Water Right Licensing, 15p. Available at https://www.waterboards.ca.gov/waterrights/water_issues/programs/applications/docs/licensing.pdf.

Monterey County Water Resources Agency (MCWRA), 2005, Salinas Valley Water Project Flow Prescription for Steelhead Trout in the Salinas River, 140p.

MCWRA, 2018, Nacimiento Dam Operation Policy, 186p.

TABLE A1
STREAM GAUGE LOCATIONS USED IN MODEL

Title	USGS Stream Gauge ID	Latitude	Longitude	Begin Date	End Date	Relevant Aspect of Reservoir and River Operations
Nacimiento River Below Nacimiento Dam Near Bradley CA	11149400	35.761389	-120.854444	10/1/1957	Present	None
Nacimiento River Below Sapaque Creek Near Bryson CA	11148900	35.788611	-121.092778	9/16/1971	Present	Smolt Outmigration
San Antonio River Near Lockwood CA	11149900	35.896667	-121.087222	10/1/1965	Present	None
Salinas River Near Bradley CA	11150500	35.930278	-120.867778	10/1/1948	Present	None
Arroyo Seco Near Soledad CA	11152000	36.280556	-121.321667	10/1/1901	Present	Adult Upstream Migration
Arroyo Seco Below Reliz Creek Near Soledad CA	11152050	36.399722	-121.323056	10/1/1994	Present	Adult Upstream Migration, Smolt Outmigration
Salinas River at Soledad CA	11151700	36.411111	-121.318333	10/1/1968	Present	Smolt Outmigration
Salinas River Near Chualar CA	11152300	36.553611	-121.548333	10/1/1976	Present	Adult Upstream Migration
Salinas River Near Spreckels	11152500	36.631111	-121.671389	10/1/1929	Present	Smolt Outmigration, SRDF Operation
Reclamation Ditch Near Salinas CA	11152650	36.705000	-121.703889	10/1/1970	Present	None

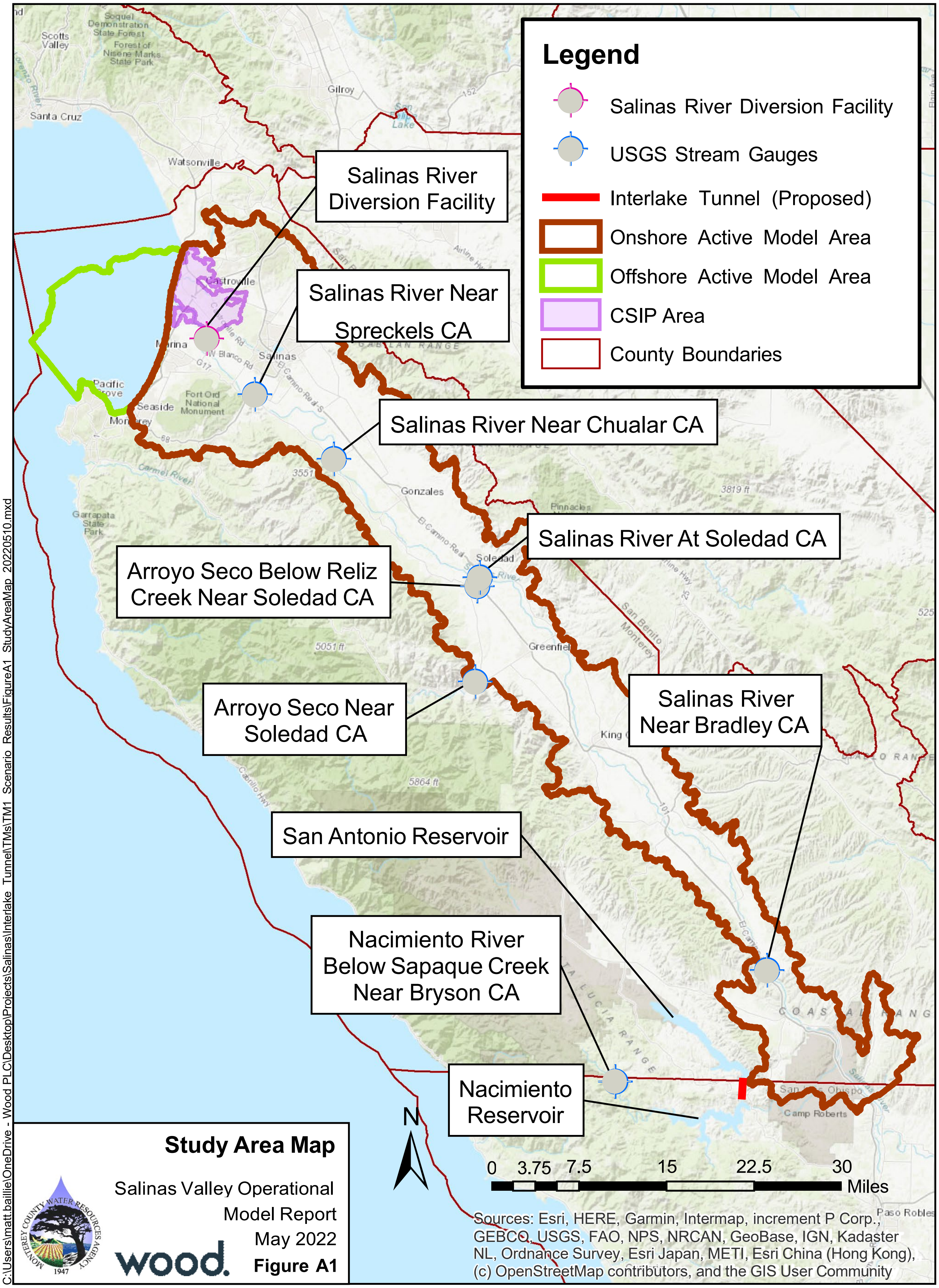
Provisional data subject to revision.

TABLE A2

MONTHLY ALLOCATION TO NACIMIENTO WATER PROJECT AND NACIMIENTO RESERVOIR LAKESIDE USERS

Month	Nacimiento Water Project (af)	Lakeside Users (af)	Total (af)
January	755.25	120.00	875.25
February	1,037.30	121.00	1,158.30
March	1,033.05	130.00	1,163.05
April	1,133.30	145.00	1,278.30
May	1,165.05	157.00	1,322.05
June	1,707.30	166.00	1,873.30
July	1,907.05	175.00	2,082.05
August	1,966.05	169.00	2,135.05
September	1,758.30	180.00	1,938.30
October	1,390.05	141.00	1,531.05
November	1,153.30	128.00	1,281.30
December	744.00	118.00	862.00
Annual Total	**15,750**	**1,750**	**17,500**

Provisional data subject to revision.



Study Area Map

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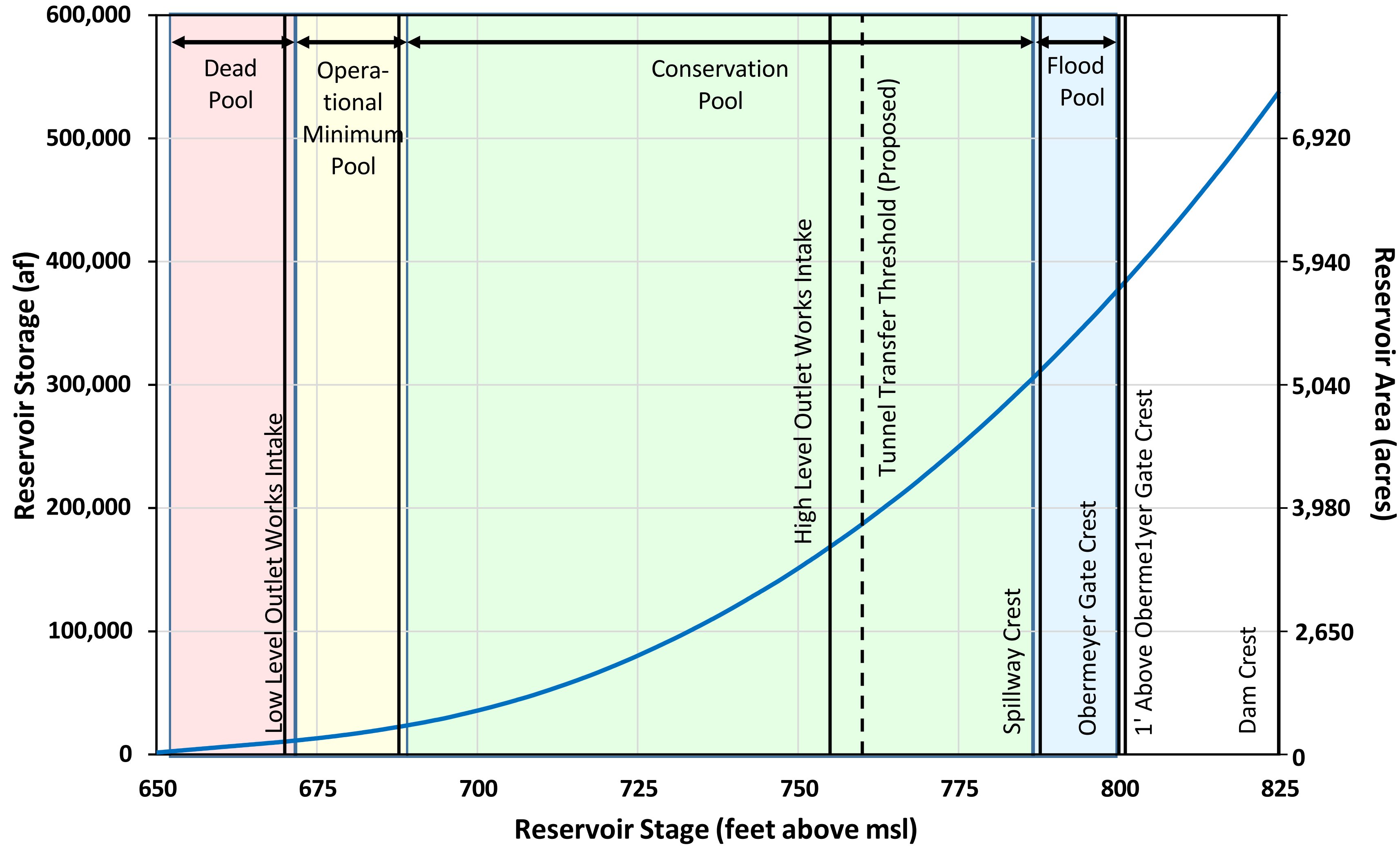
Figure A1

C:\Users\matt.baillie\OneDrive - Wood PLC\Desktop\Projects\Salinas\Interlake Tunnel\TMs\TM1 Scenario Results\FigureA1 StudyAreaMap 20220510.mxd



Legend

- Dead Pool
- Operational Minimum Pool
- Conservation Pool
- Flood Pool
- Stage-Storage-Area Curve
- Transfer Threshold for Interlake Tunnel

Stage-Storage-Area Curve for Nacimiento Reservoir

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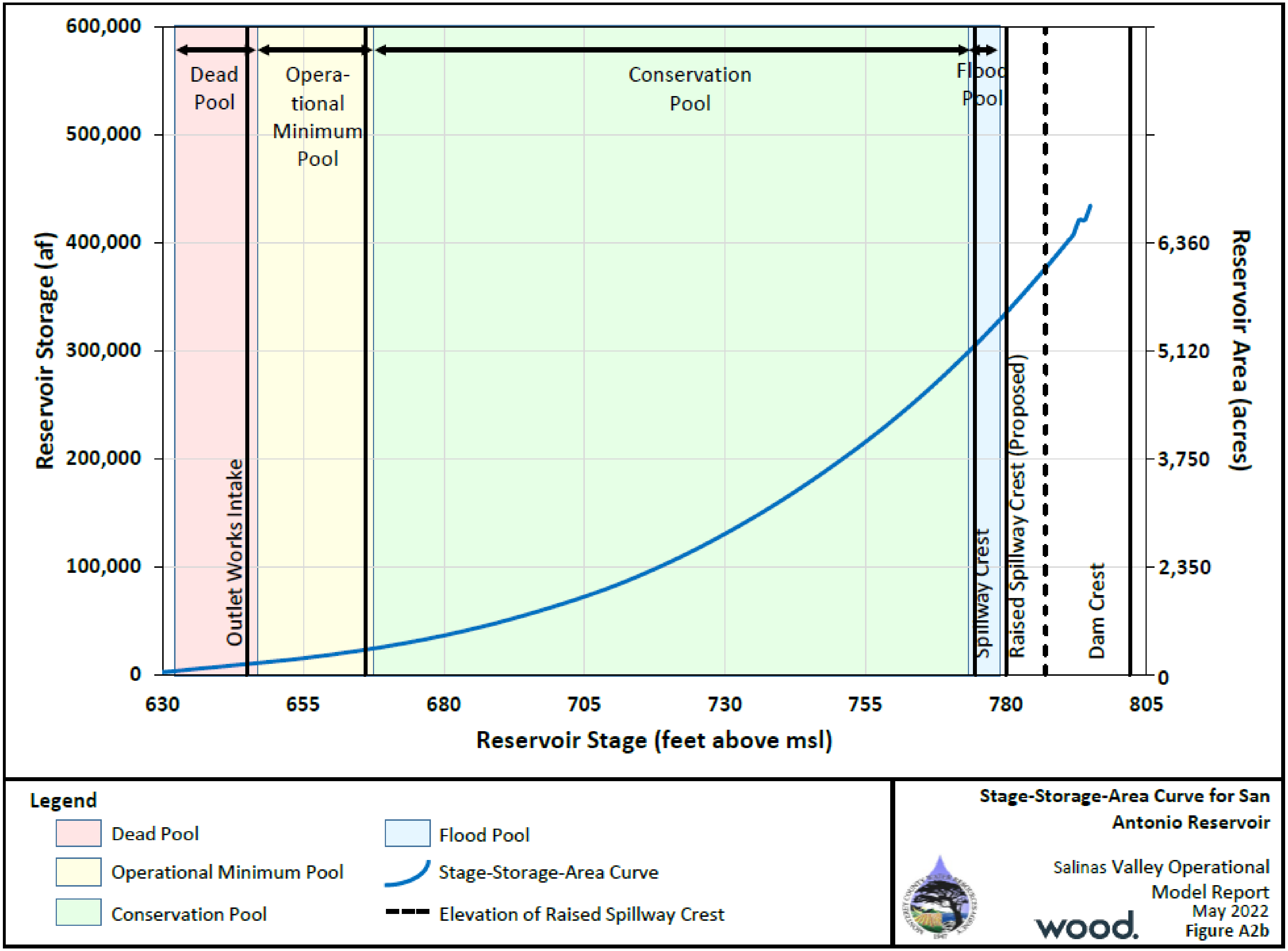
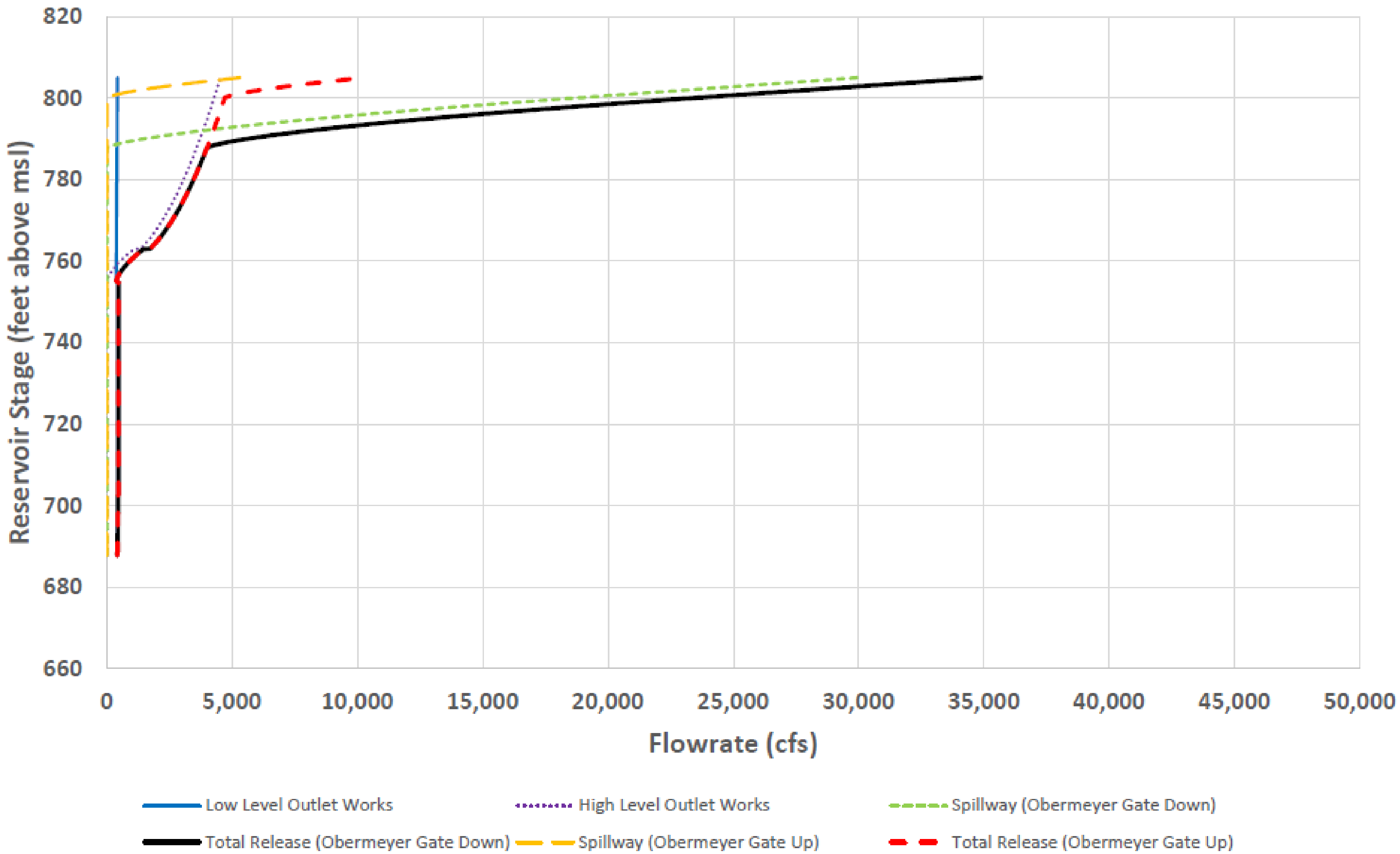
Figure A2a

Provisional data subject to revision.



Provisional data subject to revision.



Rating Curve for Nacimiento Reservoir

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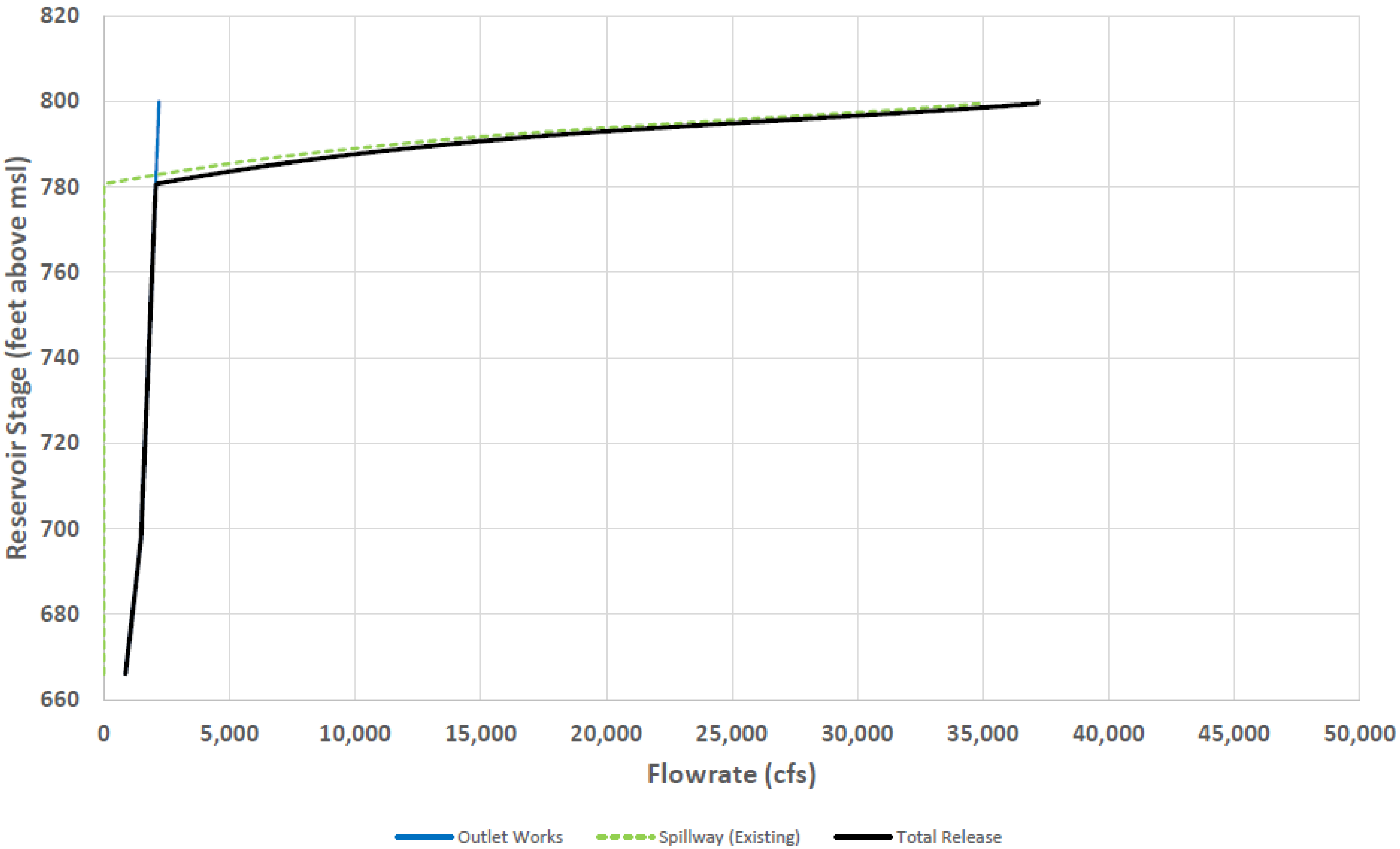
Figure A3a

Provisional data subject to revision.



Rating Curve for San Antonio Reservoir - Existing Spillway

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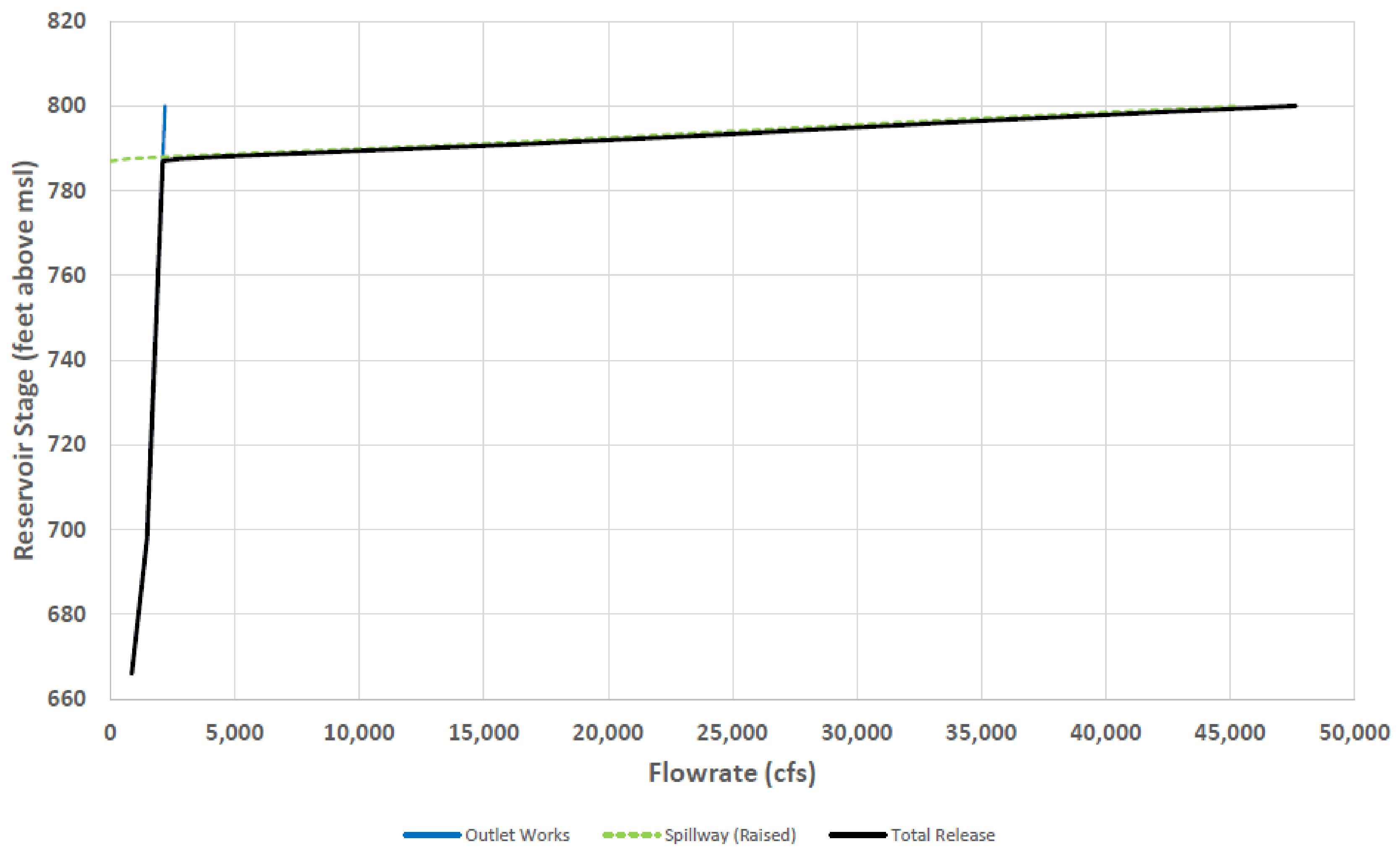
Figure A3b

Provisional data subject to revision.



Rating Curve for San Antonio Reservoir - Raised Spillway

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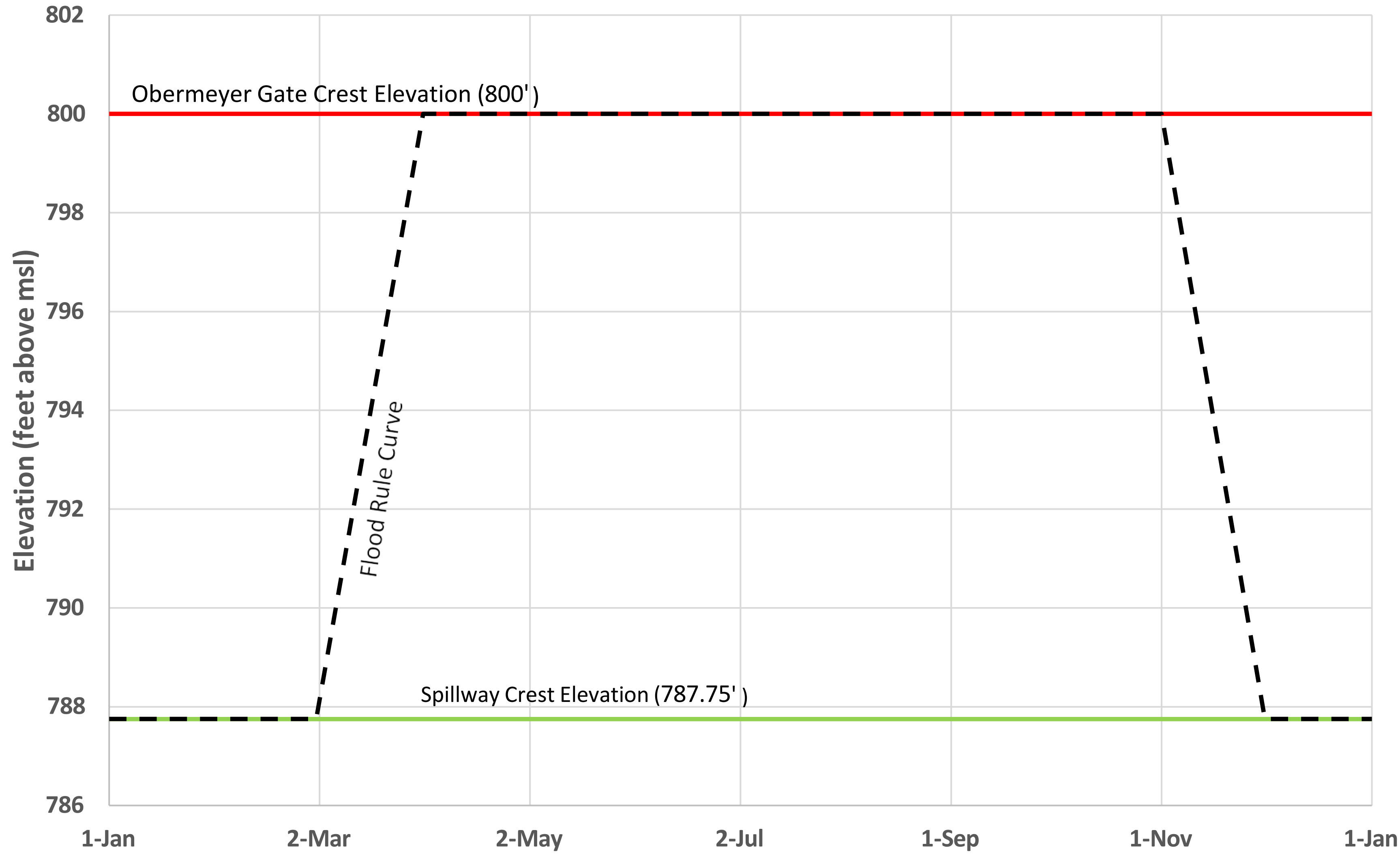
Figure A3c

Provisional data subject to revision.



Legend

- Flood Rule Curve
- Spillway Crest Elevation
- Obermeyer Gate Crest Elevation

Flood Rule Curve for Nacimiento Reservoir

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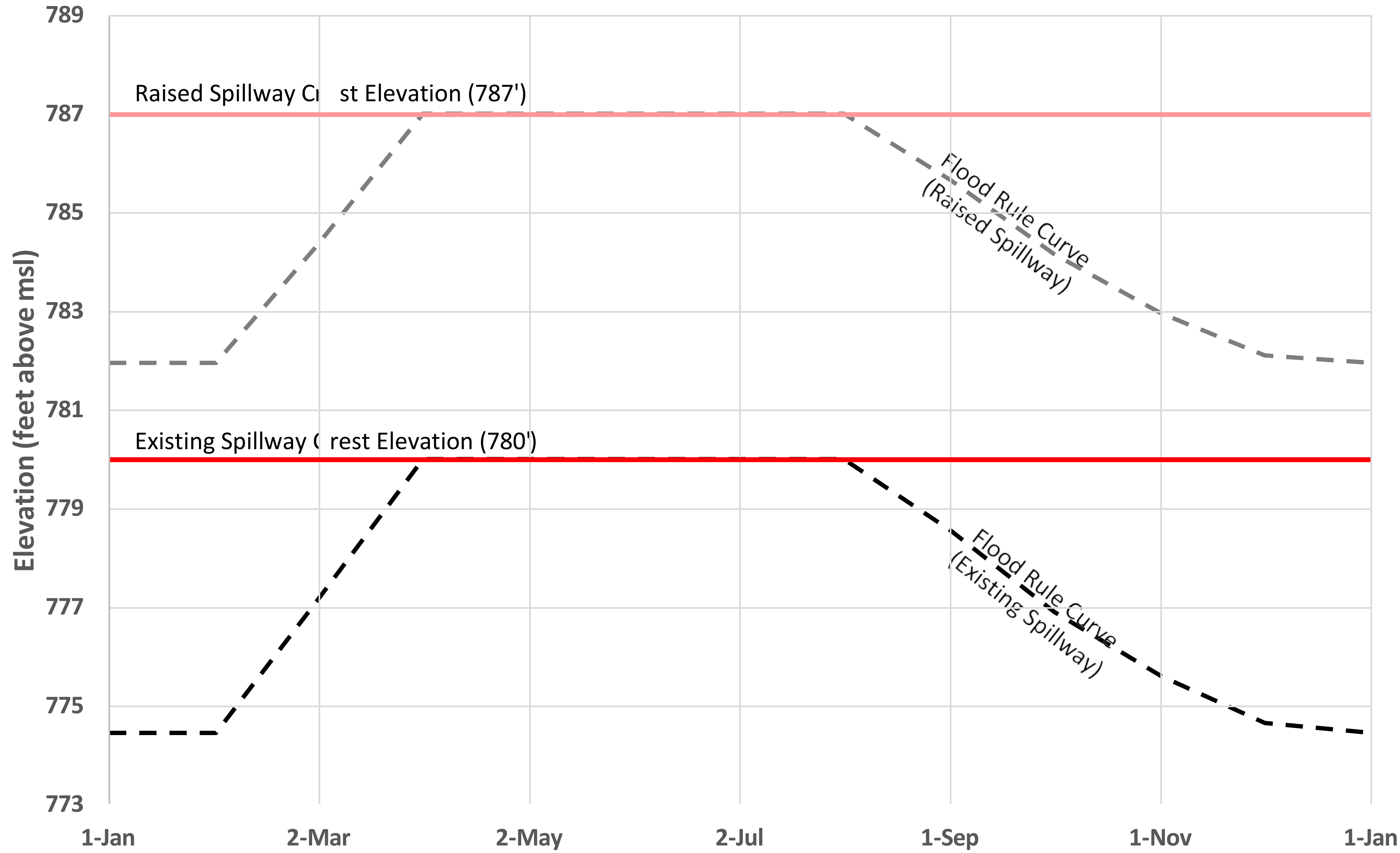
Figure A4a

Provisional data subject to revision.



Legend

- Flood Rule Curve (Existing Spillway)
- Spillway Crest Elevation (Existing Spillway)
- Flood Rule Curve (Raised Spillway)
- Spillway Crest Elevation (Raised Spillway)

Flood Rule Curve for San Antonio Reservoir

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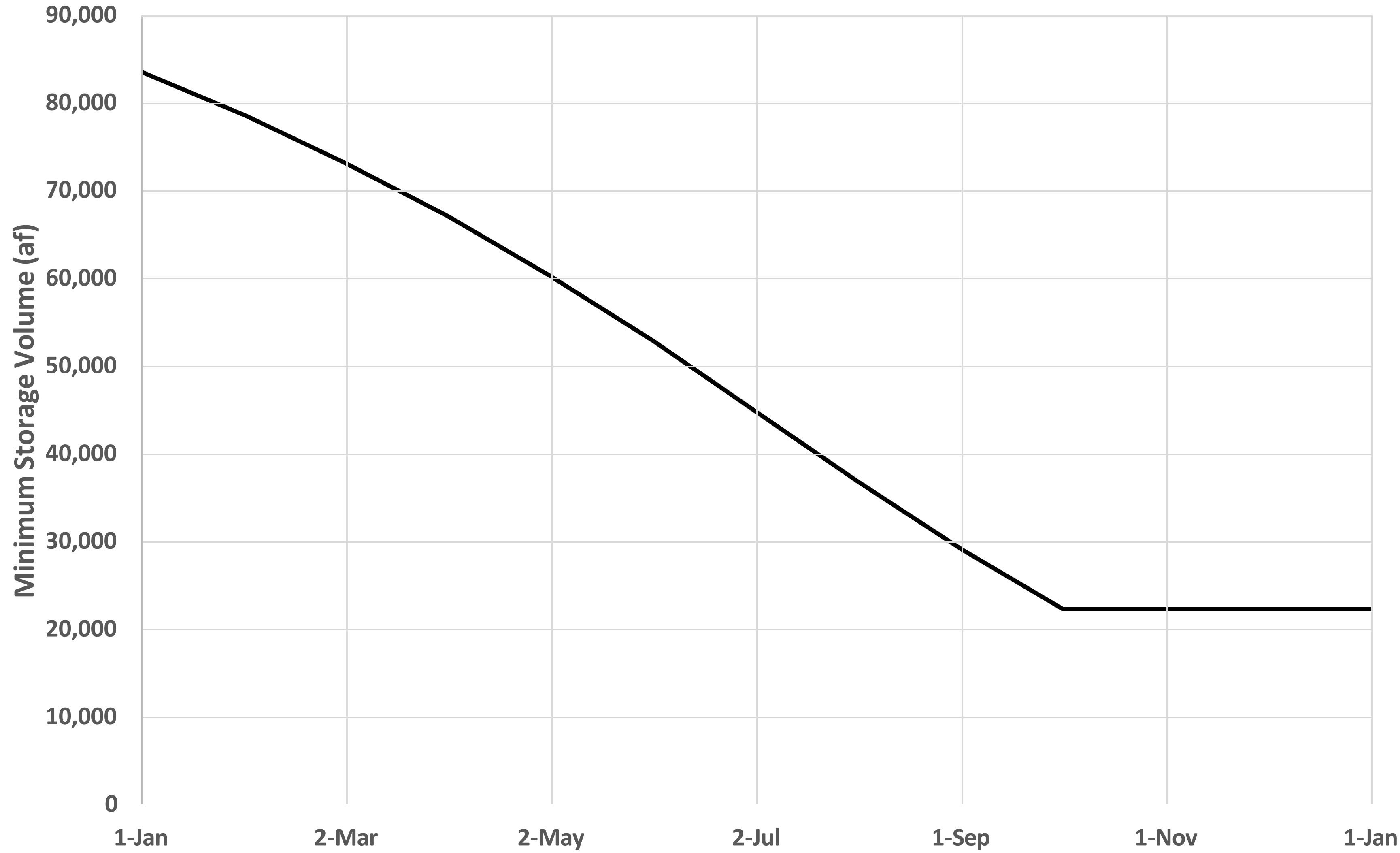
Figure A4b

Provisional data subject to revision.



Dynamic Minimum Storage for Nacimiento Reservoir

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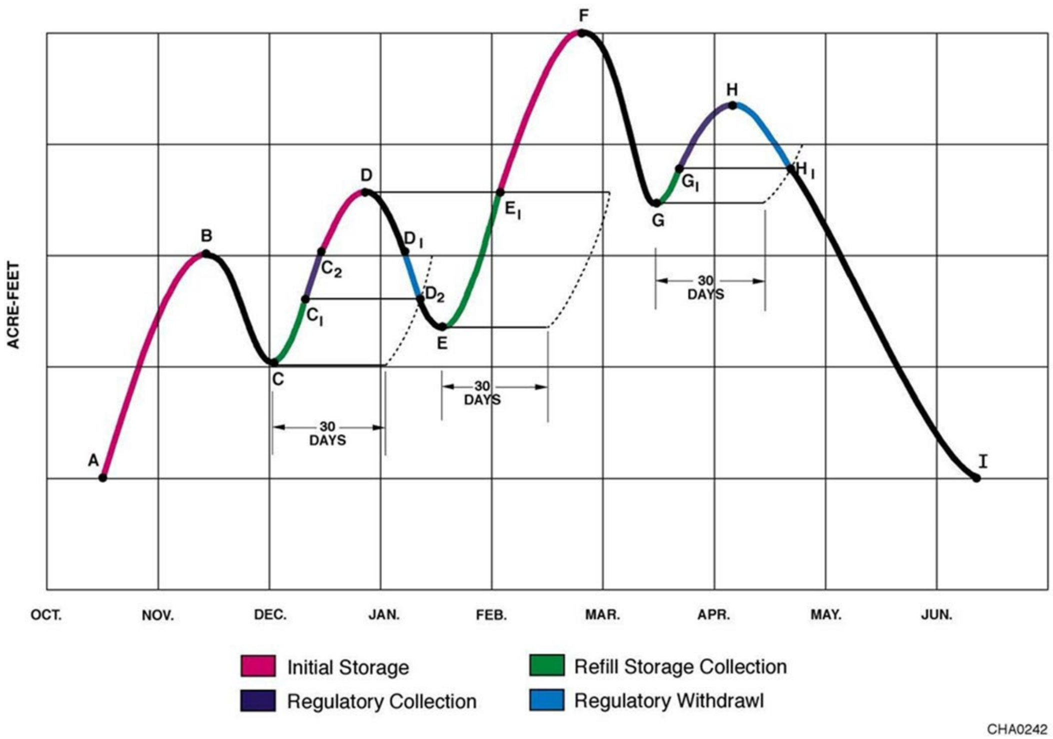
Figure A5

Provisional data subject to revision.

SAMPLE HYDROGRAPH



1. **A-B**, **C2-D** and **E1-F** constitute initial collection to storage.

2. Refill of initial storage C-C2, **E-E1** and G-H must be analyzed to determine if all or part of refills were released within 30 days.
   a. Withdrawal **D1-D2** occurred within 30 days, therefore **C1-C2** is considered regulatory. **C-C1** is determined to be collection to storage.
   b. Analyzing **E-E1** results in no withdrawal of this water within a 30-day period. Therefore **E-E1**is considered collection to storage.
   c. On analyzing G-H, it is determined that **G-G1** is held for 30 days or more and therefore is considered collection to storage. **H-H1** was withdrawn within a 30-day period. Therefore **G1-H** is considered regulatory storage.

3. The total storage is comprised of **A-B**, **C-C1**, **C2-D**, **E-E1**, **E1-F** and **G-G1**.

Since **C1-C2** (**D1-D2**) and **G1-H** (**H-H1**) are considered regulatory, the total withdrawal from storage is comprised of **B-C**, **D-D1**, **D2-E**, **F-G** and **H1-I**.

From: Process for Water Right Licensing (SWRCB, 2013)

Sample Hydrograph Demonstrating Accounting for Water Rights Limitations

Salinas Valley Operational Model Report

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Figure A6

APPENDIX B

Model Modifications for Non-Baseline Scenarios

TABLES

None

FIGURES

APPENDIX B: MODEL MODIFICATIONS FOR NON-BASELINE SCENARIOS

This appendix provides details of the modifications made to reservoir and river operations as they are implemented in the SVOM for each of the model scenarios other than the Baseline scenario, as well as other changes made to the model system. Appendix A describes the current reservoir and river operational approach, which is used in the Baseline scenario. Each section in this appendix describes the various changes made for one of the non-Baseline model scenarios. Changes implemented in multiple different scenarios (such as the Interlake Tunnel) are only described in detail at their first occurrence.

B1 TUNNEL-ONLY SCENARIO

The Tunnel-Only scenario implements the following changes from the Baseline scenario:

- Nacimiento-San Antonio Interlake Tunnel active
- Removal of water rights limitations

B1.1 Nacimiento-San Antonio Interlake Tunnel

The Nacimiento-San Antonio Interlake Tunnel (Interlake Tunnel or Tunnel) would be a hard-rock tunnel drilled between Nacimiento and San Antonio Reservoirs allowing for transfer of water from Nacimiento Reservoir to San Antonio Reservoir (Figure B1). The purpose of the Tunnel is to move water from Nacimiento Reservoir, which has relatively high inflow from its watershed and limited capacity to release water at many reservoir stages, to San Antonio Reservoir, which has a generally drier watershed but a higher release capacity.

Figure B2 shows a conceptual diagram of the Interlake Tunnel. The Tunnel would have an internal diameter of 10 feet and a length of 10,940 feet (McMillen and Associates, 2018). Its minimum diversion elevation on the Nacimiento Reservoir side would be 760 feet above msl (with an invert elevation of 745 feet above msl), and the outlet elevation on the San Antonio Reservoir side would be 697.6 feet above msl (note that these values represent the 30% Design Document for the Interlake Tunnel, which was the latest available at the time of the modeling; later design documents include different values).

As implemented in the SVOM, the Interlake Tunnel would be operated to transfer water from Nacimiento Reservoir to San Antonio Reservoir whenever possible. Transfer is limited by the following considerations:

- Stage in Nacimiento Reservoir must be at least 760 feet above msl;
- Stage in Nacimiento Reservoir must be below the crest of the Obermeyer gate (800 feet above msl);
- Stage in San Antonio Reservoir must be below stage in Nacimiento Reservoir; and
- Stage in San Antonio Reservoir must be below the San Antonio Reservoir Flood Rule Curve.

The last of these considerations is meant to prevent a situation where water is transferred from Nacimiento Reservoir to San Antonio Reservoir that must be immediately released as Flood Control Releases.

The capacity of the Tunnel depends on the stage in both Nacimiento and San Antonio Reservoirs. Figure B3 shows the rating curve for the Interlake Tunnel; each individual curve represents the stage-flow relationship for a given stage in San Antonio Reservoir. For example, the uppermost curve represents the rating curve if San Antonio Reservoir is at or below the elevation of the Tunnel outlet (712 feet above msl), with discharge capacity varying from about 1,050 cfs at a Nacimiento Reservoir stage of 760 feet above msl to 1,400 cfs at a Nacimiento Reservoir stage of 800 feet above msl.

B1.2 Removal of Water Rights Limitations

For any scenario where the Interlake Tunnel is active, the water rights limitations described in Section A4 of Appendix A are deactivated. This does not imply that there is any expectation that the reservoirs would not be subject to their water rights limitations if the Tunnel were constructed. Removing these limitations gives an indication of the potential operations that could be achieved without the limitations imposed by the water rights. The simulated transfers, collection to storage, and withdrawal from storage may inform potential changes to the water rights limitations in the future.

It is also not clear at this moment how water right accounting would occur in a system where Nacimiento and San Antonio Reservoirs are connected by a tunnel. MCWRA has submitted change petitions to the State Water Resources Control Board that would accommodate the Interlake Tunnel, but no changes to the water rights have been finalized as of the writing of this TM.

B2 TUNNEL PLUS 7' SPILLWAY RAISE SCENARIO

The Tunnel Plus 7' Spillway Raise scenario implements the following changes from the Baseline scenario:

- Nacimiento-San Antonio Interlake Tunnel active (see Section B1.1)
- Spillway crest elevation at San Antonio Dam raised by 7 feet
- Modified spillway rating curve at San Antonio Dam
- Modified Flood Rule Curve for San Antonio Reservoir
- Removal of water rights limitations (see Section B1.2)

B2.1 San Antonio Dam Spillway Raise

One potential configuration of the Project includes a modification of the physical spillway at San Antonio Dam. The spillway crest elevation would be raised from its current elevation of 780 feet above mean sea level (msl) to an elevation of 787 feet above msl, an increase of 7 feet. This would increase the maximum reservoir storage (i.e., at the spillway crest elevation) from 335,000 acre-feet (af) to 376,200 af (an increase of 41,200 af).

B2.2 Modified San Antonio Dam Spillway Rating Curve

The changes to the spillway crest elevation would result in changes to the spillway rating curve that relates reservoir stage to the release capacity over the spillway. Figure B4 shows the existing spillway rating curve and the rating curve for the modified spillway. Release capacity for the existing spillway increases from 0 cfs at a stage of 780 feet above msl to 35,000 cfs at a stage of 800 feet above msl. Release capacity for the modified spillway increases from 0 cfs at a stage of 787 feet above msl to over 66,000 cfs at a stage of 805 feet above msl; at a stage of 800 feet above msl, the modified spillway has a release capacity of over 45,000 cfs. The modified spillway would have a substantially higher release capacity at the same amount of freeboard.

B2.3 Modified San Antonio Reservoir Flood Rule Curve

As described in Section A2 of Appendix A, the Flood Rule Curve is the operational maximum stage that varies through the year in each reservoir; water above the Flood Rule Curve must be released as Flood Control Releases. The purpose of the Flood Rule Curve is to maintain an amount of empty storage capacity in the reservoirs during the winter wet season to allow them to absorb significant storm flow events without leading to dangerous conditions within the reservoirs or extreme inundation downstream.

Figure B5 shows the Flood Rule Curves for the existing and modified spillways at San Antonio Dam. The storage capacity below the elevation of the spillway crest is identical for the two curves. The existing Flood Rule Curve maintains an elevation of 780 feet above msl (the spillway crest elevation) from April 1 to August 1 each year, then lowers to 774.45 feet above msl by January 1. Starting after February 1, the Flood Rule Curve again rises to 780 feet above msl. The Flood Rule Curve for the raised spillway is at an elevation of 787 feet above msl (the raised spillway crest elevation) from April 1 to August 1 each year, then lowers to 781.95 feet above msl by January 1. Starting after February 1, the Flood Rule Curve rises to 787 feet above msl. Both Flood Rule Curves maintain a storage capacity of about 30,000 af during the wet season.

B3 Modified Nacimiento Low-Level Outlet Works Scenario

The Modified Nacimiento Low-Level Outlet Works (LLOW) scenario implements the following changes from the Baseline scenario:

- Modified release capacity from Nacimiento Dam's LLOW
- Removal of storage requirement at San Antonio Reservoir for SRDF operations

B3.1 Modified Nacimiento Low-Level Outlet Works Rating Curve

One potential modification that can be made to Nacimiento Dam is to increase the capacity of the Low-Level Outlet Works (LLOW). As currently configured, the LLOW cannot release more than 460 cfs at any reservoir stage (Figure B6). This severely limits the ability of Nacimiento Reservoir to release water below the elevation of the High-Level Outlet Works (HLOW), 755 feet above msl (the HLOW can release water at a substantially higher rate, over 4,000 cfs at a stage equal to the elevation of the Obermeyer gate crest, 800 feet above msl).

The modified LLOW would have a higher release capacity (Figure B6). The capacity would be 0 cfs at a reservoir stage of 670 feet above msl, increasing to 1,244 cfs at a reservoir stage of 690 feet above msl and 1,742 cfs at a reservoir stage of 755 feet above msl, just below the inlet to the HLOW. This represents an increase of more than 1,200 cfs at this stage. This release capacity is similar to that of San Antonio Reservoir's outlet works at stages below its spillway crest elevation.

B3.2 Removal of Storage Requirement at San Antonio Reservoir for SRDF Operations

As described in Section A10 of Appendix A, there is a storage requirement in place for the Salinas River Diversion Facility (SRDF) to operate. Under the current operational approach, there is a requirement of at least 145,000 af in combined reservoir storage, at least 55,000 af of which must be held in San Antonio Reservoir. This requirement is designed to ensure that San Antonio Reservoir can maintain streamflow to the SRDF, since the release capacity of Nacimiento Reservoir is limited at low stage values. With the increased release capacity provided by the modified LLOW, there is no need to hold a substantial portion of the storage in San Antonio Reservoir. Therefore, for the Modified Nacimiento LLOW scenario there is no storage requirement specific to a particular reservoir; instead, there is simply a requirement for 145,000 af to be in combined storage.

B4 TUNNEL-ONLY SCENARIO WITH 2070 CLIMATE CHANGE

The Tunnel-Only scenario with 2070 Climate Change implements the following changes from the Baseline scenario:

- Nacimiento-San Antonio Interlake Tunnel active (see Section B1.1)
- Removal of water rights limitations (see Section B1.2)
- Modified gridded precipitation data within model domain
- Modified gridded potential evapotranspiration data within model domain
- Modified precipitation time series at reservoirs
- Modified evaporation time series at reservoirs
- Modified streamflow inputs to model boundary
- Modified streamflow inputs to SWO
- Modified sea level boundary condition
- Modified land use (i.e., crop patterns)

B4.1 Modified Gridded Precipitation and Potential Evapotranspiration Data within Model Domain

The California Department of Water Resources (DWR) provides downscaled gridded climate change data for several different climate futures (2030 central tendency, 2070 central tendency, 2070 drier with extreme warming, and 2070 wetter with moderate warming; California Water Commission, 2016). These data were downscaled from various general circulation models for DWR's Water Storage Investment Project (WSIP) to a 1/16 degree resolution throughout California (approximately 6 kilometers). DWR converted these downscaled data to change factors that represent the multiplicative difference between historical climate data and projected future climate data . A separate set of change factors is provided for precipitation and potential evapotranspiration for each of the four climate futures. The change factors are monthly values for each of the 1/16 degree grid cells that can be applied to historical data from January 1915 to December 2011.

The Salinas Valley Basin Groundwater Sustainability Agency (SVBGSA), as part of the process of preparation of the Groundwater Sustainability Plans (GSPs) for the Basin, applied the change factors for precipitation and potential evapotranspiration provided by DWR to the active model grid of the SVOM. The SVBGSA provided these modified climate inputs to MCWRA for use in this analysis. The provided data included monthly gridded precipitation and potential evapotranspiration data for the entire active model grid throughout the model duration.

Because the DWR change factors only extend to December 2011, the SVOM includes three model years (January 2012 to December 2014 in the input hydrology) that do not correspond to any provided change factors. SVBGSA utilized change factors from three years that were deemed hydrologically similar to the missing years, and multiplied these change factors by the January 2012 to December 2014 data in the input hydrology. The years that were utilized were 1981 for 2012, 2002 for 2013, and 2004 for 2014.

B4.2 Modified Precipitation and Evaporation Time Series at Reservoirs

Similar to the climate data for the active model grid (see Section 9.1.1), monthly change factors were applied to the precipitation and potential evapotranspiration input time series that feed into the reservoirs. Each of the two reservoirs occupies multiple different 1/16 degree cells, but it would be challenging to determine the proportion of reservoir area falling within each cell considering that the reservoir area grows and shrinks as storage increases and decreases. Additionally, the time series of change factors in the various cells covering the reservoirs are not substantially different from one another. Therefore, change factors for a single cell were chosen as representative for the reservoirs; the two dams happen to fall within the same 1/16 degree cell, so the change factors for that cell were applied to both reservoirs.

As with the climate data applied to the active model grid, change factors are only available through December 2011 in the historical hydrology. Change factors for the same three years were utilized for the January 2012 to December 2014 data as for the active model grid.

B4.3 Modified Streamflow Inputs to Model Boundary

As with the gridded climate data, DWR provides simulated streamflow data representative of changed climate conditions. In the case of streamflow, these data are outputs from the Variable Infiltration Capacity (VIC) model of the entire state of California (California Water Commission, 2016). This VIC model takes gridded climate information and information on soils, vegetation, topography, and land use to estimate time series of runoff.

Unlike the climate data, DWR does not provide spatially detailed streamflow projections outside of the Central Valley. Instead, streamflow change factors are available for individual HUC-8 level watersheds, one of which is the Salinas River watershed; in other words, DWR provides a single time series of change factors that applies to the Salinas River and every stream tributary to it. For the SVOM, these change factors were multiplied by the streamflow at every streamflow boundary condition at the edge of the active model domain. For the years (2012 to 2014) that were not present in the time series of change factors, the same years as for the gridded climate variable change factors were repeated for the last three years of the model duration (see Section 9.1.1).

SVBGSA provided MCWRA with modified streamflow boundary conditions for the SVOM to reflect 2070 climate conditions.

B4.4 Modified Streamflow Inputs to SWO

Similar to the streamflow boundary conditions to the active model grid (see Section 9.1.3), change factors were used to modify the inflow time series for the two reservoirs, as well as time series that are used to inform some of the reservoir operational rules. The time series modified for this section are not average monthly streamflow's, but rather mean daily streamflows; these are multiplied by the appropriate monthly change factors representative of 2070 climate conditions.

The four time series modified for the climate change scenarios are:

- Daily inflow to Nacimiento Reservoir,
- Daily inflow to San Antonio Reservoir,
- Mean daily streamflow at the USGS Arroyo Seco near Soledad stream gauge (used to determine the water year type and as part of the Adult passage rules under the Flow Prescription), and
- Mean daily streamflow at the USGS Nacimiento River below Sapaque Creek near Bryson gauge (used as part of the Smolt passage rules under the Flow Prescription).

Because streamflow in Arroyo Seco is used to determine the year type, there are changes to the distribution of year types under the climate change scenarios. For the Baseline and Project scenarios (without climate change), 28% of model years are wet, 47% are normal, and 26% are dry. For the climate change scenarios, 32% of model years are wet, 40% are normal, and 28% are dry.

Figure B7 shows a comparison between the annual reservoir inflow for the 2070 climate change conditions against the inflows for the non-climate change scenarios. Reservoir inflow is approximately 20% higher for the climate change scenarios, indicating that the modeling tools used to prepare the DWR climate and hydrology products envision a wetter climate in the Salinas River watershed by 2070.

B4.5 Modified Sea Level

Sea level rise is applied to the SVOM through modification of the general head boundaries that are located along the interface between the model layers representing the major aquifers and the open ocean in Monterey Bay. The model applies a time-varying head along these interfaces, representative of historic tidal data.

For the WSIP, the California Water Commission studied various future projections of sea level, and determined that approximately 45 centimeters of sea level rise could be expected by 2070. That amount was added to the sea level throughout the model duration. SVBGSA provided a modified time series of general head boundary head incorporating 45 centimeters of sea level rise.

B4.6 Modified Land Use

Land use in the SVOM is defined as crop types present at the land surface. OWHM has the capability of defining multiple different crop types in each model cell; the user inputs the percentage of each crop type that is present within each cell. The SVOM uses land use inputs that are representative of 2014 conditions repeated throughout the model duration (with a semiannual crop rotation).

For the climate change scenarios, the USGS provided a modified input file for defining land use, consisting of changed crop percentages meant to be indicative of potential land use under 2070 climate conditions. These data were developed for the ongoing Salinas-Carmel Basins Study and are considered preliminary.

B5 Tunnel Plus 7′ Spillway Raise Scenario with 2070 Climate Change

The Tunnel Plus 7′ Spillway Raise scenario with 2070 Climate Change implements the following changes from the Baseline scenario:

- Nacimiento-San Antonio Interlake Tunnel active (see Section B1.1)

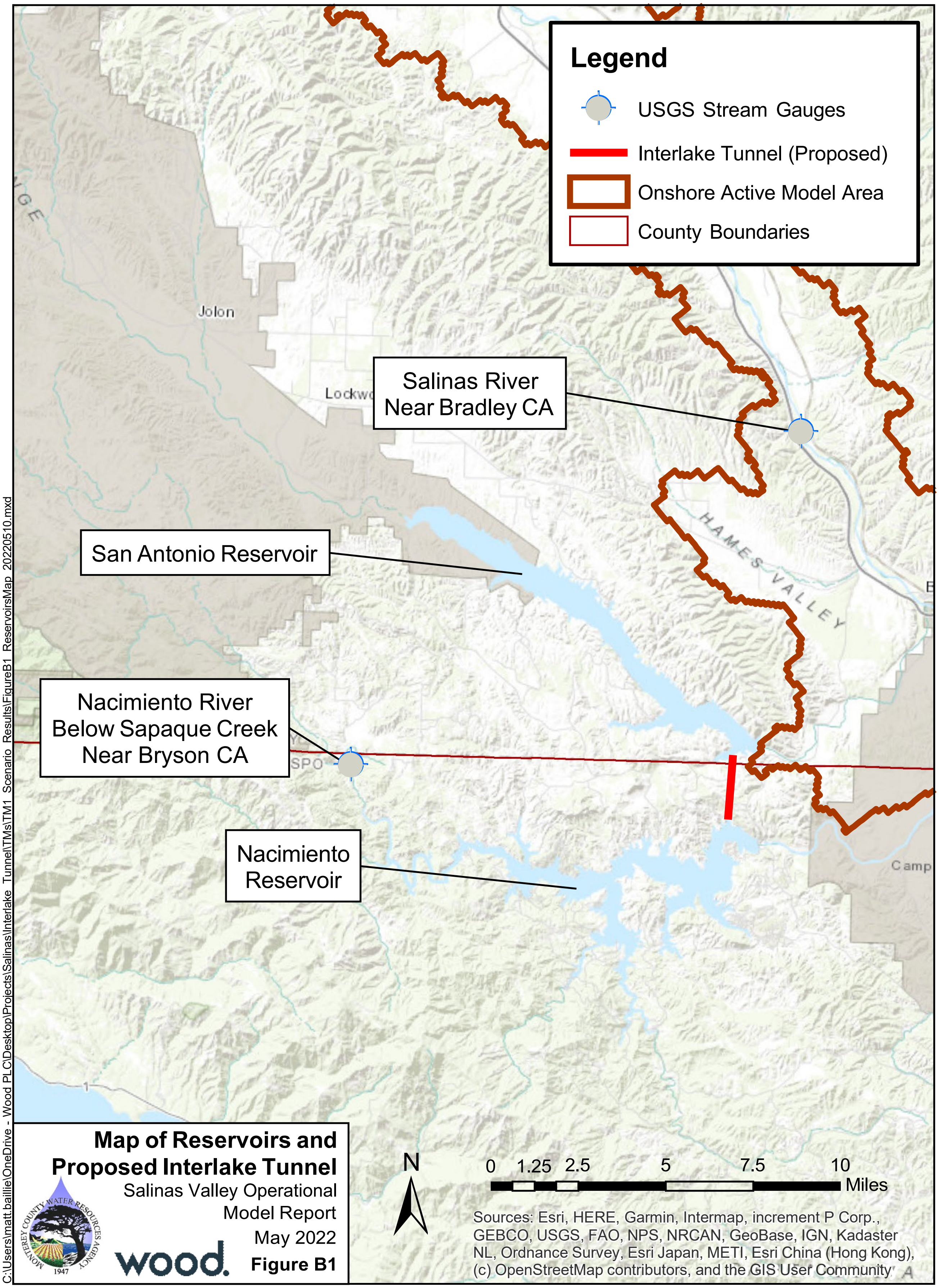
- Spillway crest elevation at San Antonio Dam raised by 7 feet (see Section B2.1)
- Modified spillway rating curve at San Antonio Dam (see Section B2.2)
- Modified Flood Rule Curve for San Antonio Reservoir (see Section B2.3)
- Removal of water rights limitations (see Section B1.2)
- Modified gridded precipitation data within model domain (see Section B4.1)
- Modified gridded potential evapotranspiration data within model domain (see Section B4.1)
- Modified precipitation time series at reservoirs (see Section B4.2)
- Modified evaporation time series at reservoirs (see Section B4.2)
- Modified streamflow inputs to model boundary (see Section B4.3)
- Modified streamflow inputs to SWO (see Section B4.4)
- Modified sea level boundary condition (see Section B4.5)
- Modified land use (i.e., crop patterns) (see Section B4.6)

None of these changes is unique to this scenario.

B6 REFERENCES

California Water Commission, 2016, Water Storage Investment Program Technical Reference, 448p., November.

McMillen and Associates, 2018, Interlake Tunnel – Design Documentation Report, 30% Design Submittal, prepared for Montgomery County Water Resources Agency, 301p.



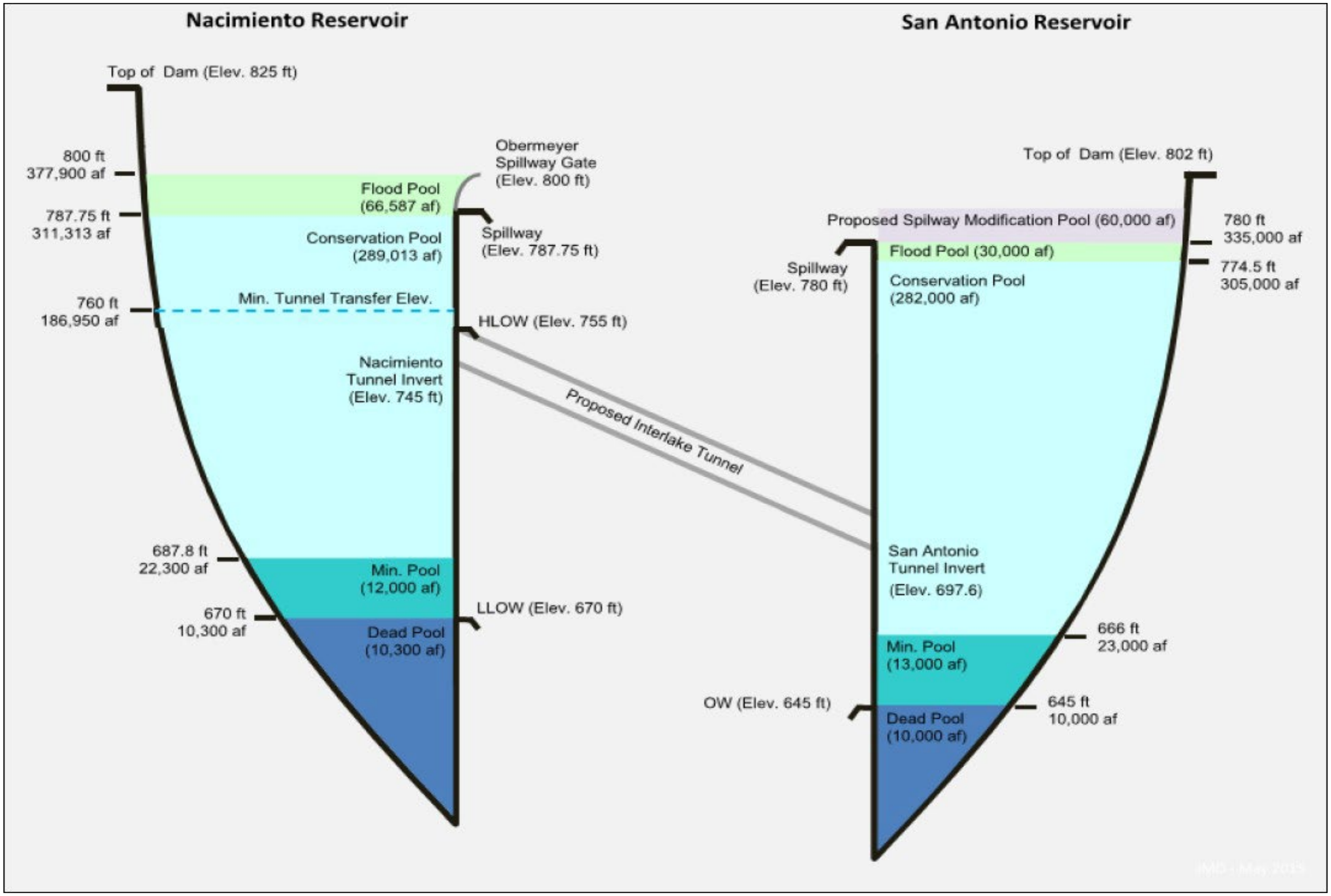
Map of Reservoirs and Proposed Interlake Tunnel

Salinas Valley Operational Model Report

May 2022

Figure B1

C:\Users\matt.baillie\OneDrive - Wood PLC\Desktop\Projects\Salinas\Interlake_Tunnel\TMs\TM1_Scenario_Results\FigureB1_ReservoirsMap_20220510.mxd



From McMillen and Associates, 2018

Schematic of Nacimiento and San Antonio Reservoirs with Proposed Interlake Tunnel

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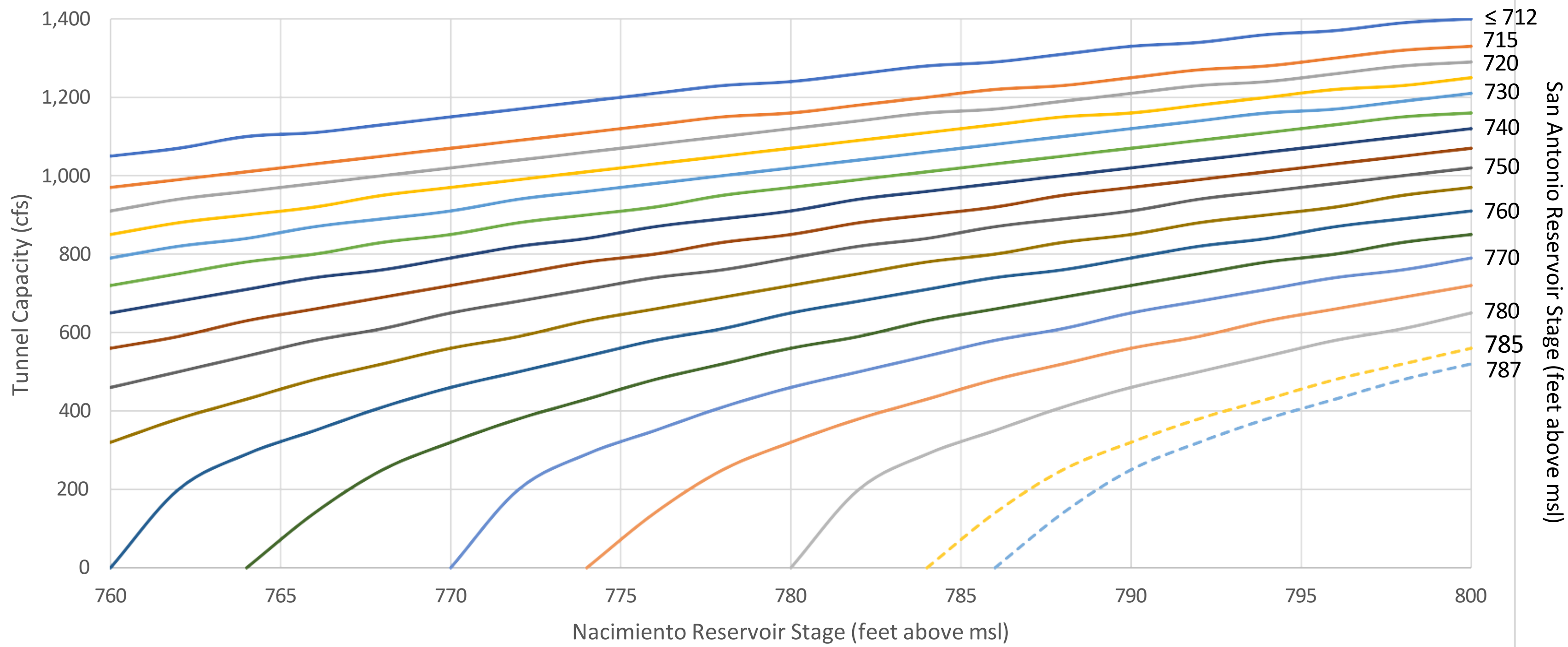
May 2022

wood.

Figure B2



Note: Individual curves represent the rating curve for flow through the Interlake Tunnel for a given San Antonio Reservoir stage elevation. The rating curves above San Antonio Reservoir Stage Elevation of 780 feet above msl (dashed lines) are not in effect for scenarios that do not include a raised spillway elevation at San Antonio Dam.

Rating Curve for Proposed Nacimiento-San Antonio Interlake Tunnel

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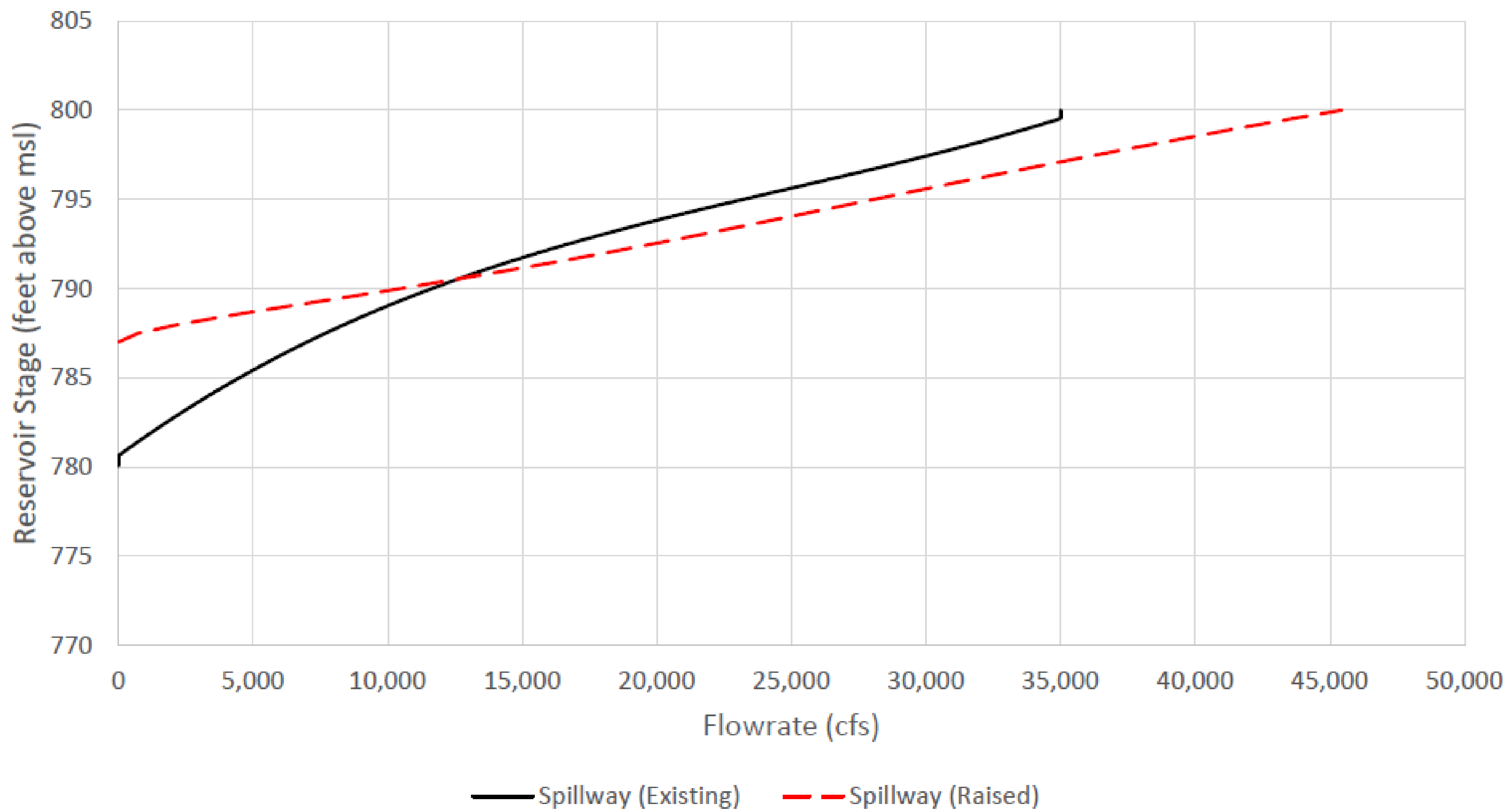
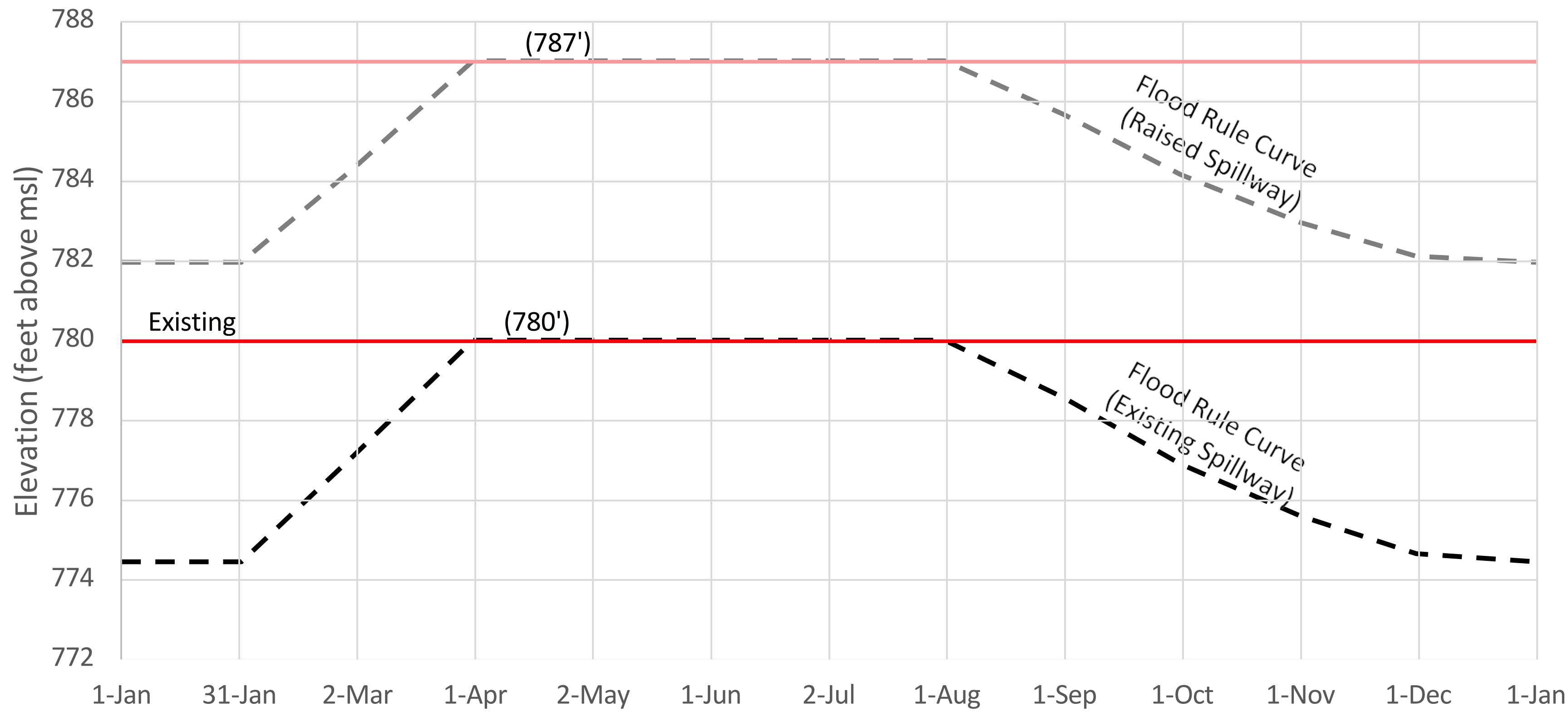
May 2022

Figure B3



Rating Curves for Existing and Modified Spillways at San Antonio Dam

Salinas Valley Operational Model Report
May 2022
Figure B4

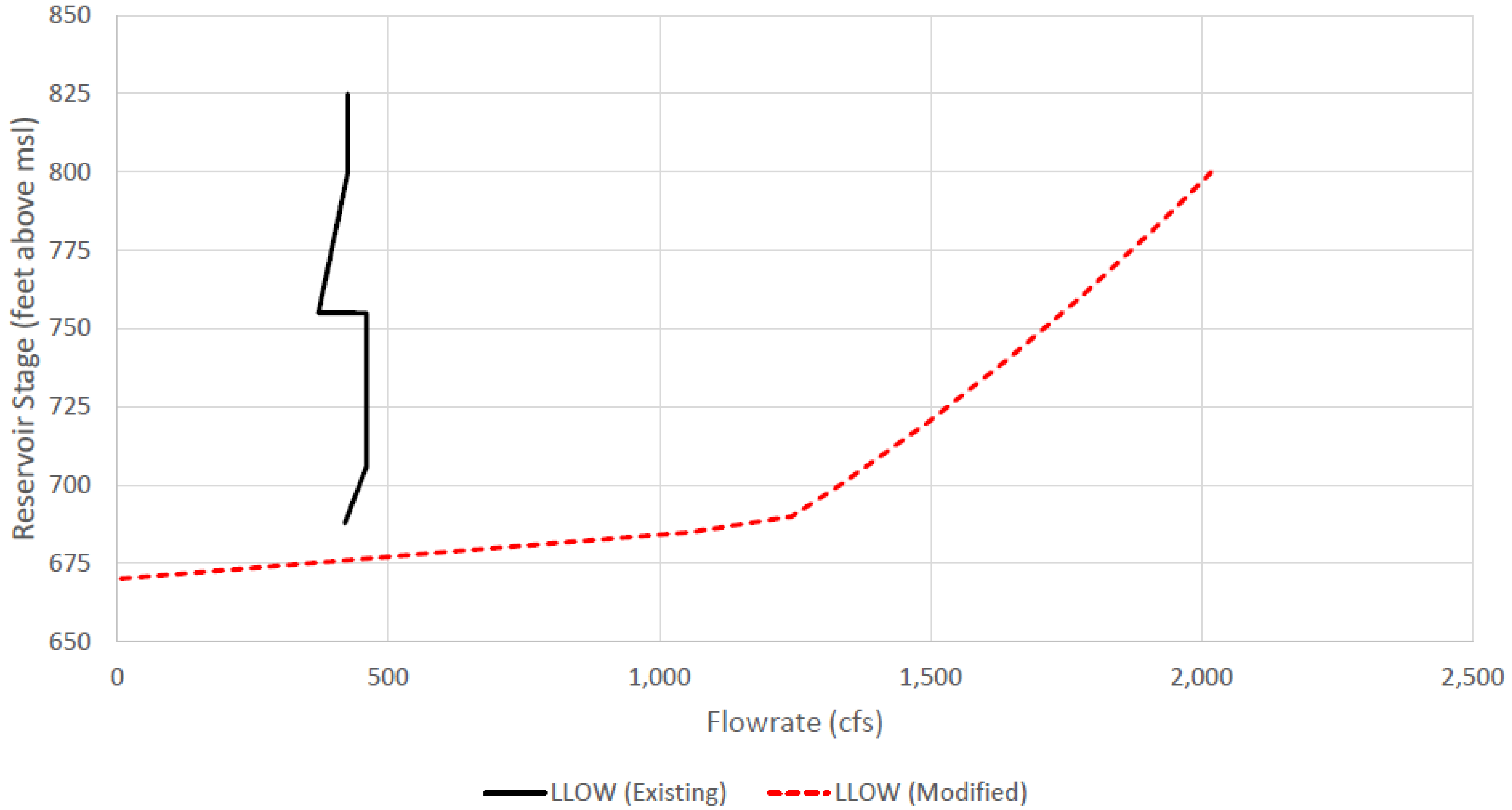


Legend

- Flood Rule Curve (Existing Spillway)
- Spillway Crest Elevation (Existing Spillway)
- Flood Rule Curve (Raised Spillway)
- Spillway Crest Elevation (Raised Spillway)

Flood Rule Curves for Existing and Modified Spillways at San Antonio Dam

Salinas Valley Operational Model Report
May 2022
Figure B5



Rating Curves for Existing and Modified Low-Level Outlet Works at Nacimiento Dam

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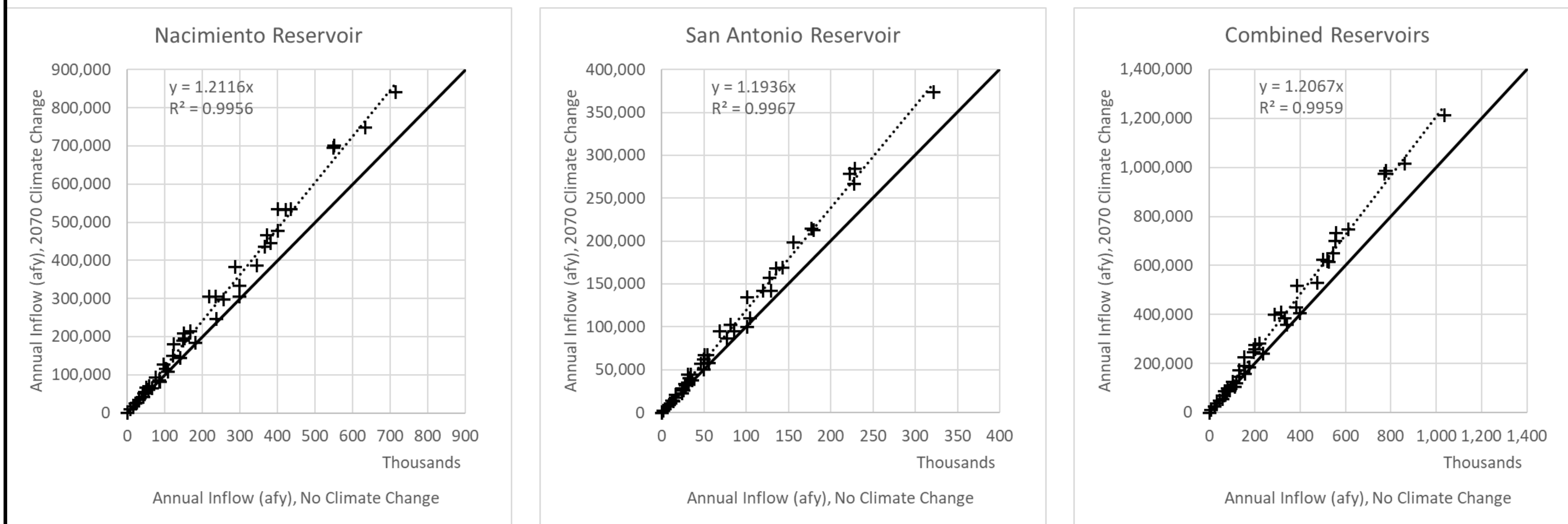
May 2022

Figure B6



Reservoir Inflow Comparison: 2070 Climate Change versus Non-Climate Change Conditions

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Figure B7

Provisional data subject to revision.

APPENDIX C

TM: 2-Dimensional Hydraulic Modeling for the Salinas River

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12/23/2021
Project # 8618191590

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Subject: 2-Dimensional Hydraulic Modeling for the Salinas River
Interlake Tunnel Analysis
Monterey and San Louis Obispo Counties, CA

Dear Amy,

This memorandum describes the 2-dimensional hydraulic modeling conducted for the Salinas River in support of the Interlake Tunnel project. The modeling used the US Army Corps of Engineers HEC-RAS version 5.0.7 computer program. Some changes were required to the input data to conform input data to the new version to pass input validation tests that were not in earlier versions. Other changes were made to make better use of output data from the Salinas Valley Operational Model (SVOM).

The model was provided to Wood by the Monterey County Water Resources Agency (Agency). The following changes were made by Wood to the model:

- The grid was viewed adjusted in many locations to better align cell boundaries with high ground. If a cell boundary crosses high ground then water can "leak" across the high ground. In addition, changes were made to some linear structures to conform their length to the grid cells as this program version now requires.
- Results from SVOM were reviewed, and seven additional tributaries were identified as providing a large enough flow that they were added as new inflow "boundaries" to the HEC-RAS model. These locations are described below.
- The Agency directed that Wood model the highest flow event from the SVOM, equivalent to the historical event of February 8, 1998
- Data downloaded from the US Geological Survey (USGS), including daily and peak gage flow and peak flows estimated at each 2D model boundary using the USGS "Stream Stats" online application were evaluated to identify a good way to estimate daily flows at each flow boundary. Daily flows at tributaries were modeled in proportion to the nearest tributary gage to their 2-year (50-percent annual exceedance probability) flow.
- In addition, an hourly time series was estimated for the inflow peak of the Salinas River at Bradley to conform its simulated peak to the observed (historical) peak while also conforming the mean daily flow to the observed historical value (which is less than the instantaneous peak because of averaging).

- The HEC-RAS model was run and data were extracted for the maximum extent of inundation, maximum velocity magnitude, maximum depth, and maximum water surface elevation at each computation point of the 2D model. These data were associated with GIS points and polygons.

HEC-RAS Model Overview

The 2D model extent is shown in **Figure 1** along with the locations of flow inputs and nearby USGS flow gages. The extent is unchanged from that provided by the Agency and extends from the mouth on Monterey Bay to river mile (RM) 94 about 0.5 mile downstream of the USGS gage for the Salinas River near Bradley. The model includes 201.85 square miles, of which 43.7 square miles were modeled as inundated up to an average depth of 5.2 feet during the simulated event. The model includes a "mesh" (almost a grid) of 565,034 cells, with almost all 100 by 100 feet square except for some irregularly shaped to conform to waterways or high ground.

The model includes a good match of river flow at Bradley. However, it does not include local flow from the floodplain or from tributaries other than those modeled, so river flows in the model were less than those observed at gages at Soledad, Chualar, and Spreckels.

The 2D model period used observed flows from February 5 through 11. The early peak (from February 1 to 4) was not modeled because it was not deemed to affect the maximum values of February 8 and added unnecessary computation time. The computation settings were retained as-is using a constant 1-minute step, as provided by the Agency. Model results were checked at many locations and flows and water elevations along the Salinas River varied smoothly showing that a shorter time step was not needed. Oscillations on small tributaries do not affect floodplain and river behavior and were attributed to wet/dry geometry of their small channels.

Observed Flows

Figure 2 shows historical daily mean flows from several USGS flow gages. These include four on the Salinas River (from up to downstream: Bradley, Soledad, Chualar, and Spreckels); two on Arroyo Seco (upstream "near Soledad" and downstream below Reliz Creek); and one each on El Toro and San Lorenzo Creeks. Also included is the calculated sum of the Salinas River plus Arroyo Seco downstream of their confluence. The data show that the river flows increase from up to downstream, and that the combination with Arroyo Seco about matches the river flow downstream at Chualar. Increases from Bradley to Soledad and from Chualar to Spreckels are likely from local inflow, much of which was not included in the 2D model. The data also show that flows are almost identical between the two Arroyo Seco gages, showing that no material infiltration out of the channel occurred between the two gages during this high-flow event.

The data show that the river peaked on February 8 while the tributary peaks were one day earlier. The tributaries had higher flows on the earlier February 3 peak. The lines show mean daily flows and the stand-alone (higher) points are instantaneous peak flows for the event. The peak flows for the tributaries were more than twice the mean daily flow, so the peaks were narrower than one day.

Model Flows

Figure 3 shows the model inflow for the Salinas River at Bradley. The gaged daily flows at Bradley matched the 2D model boundary so no adjustment was needed for location. The daily flows were interpolated to hourly flows for the model input, except that the one-day peak of February 8 was increased to match the instantaneous peak and its width was adjusted to match the observed mean daily value. The hourly data were shifted by 0.5 day so the peak day was all within February 8, and the first 12

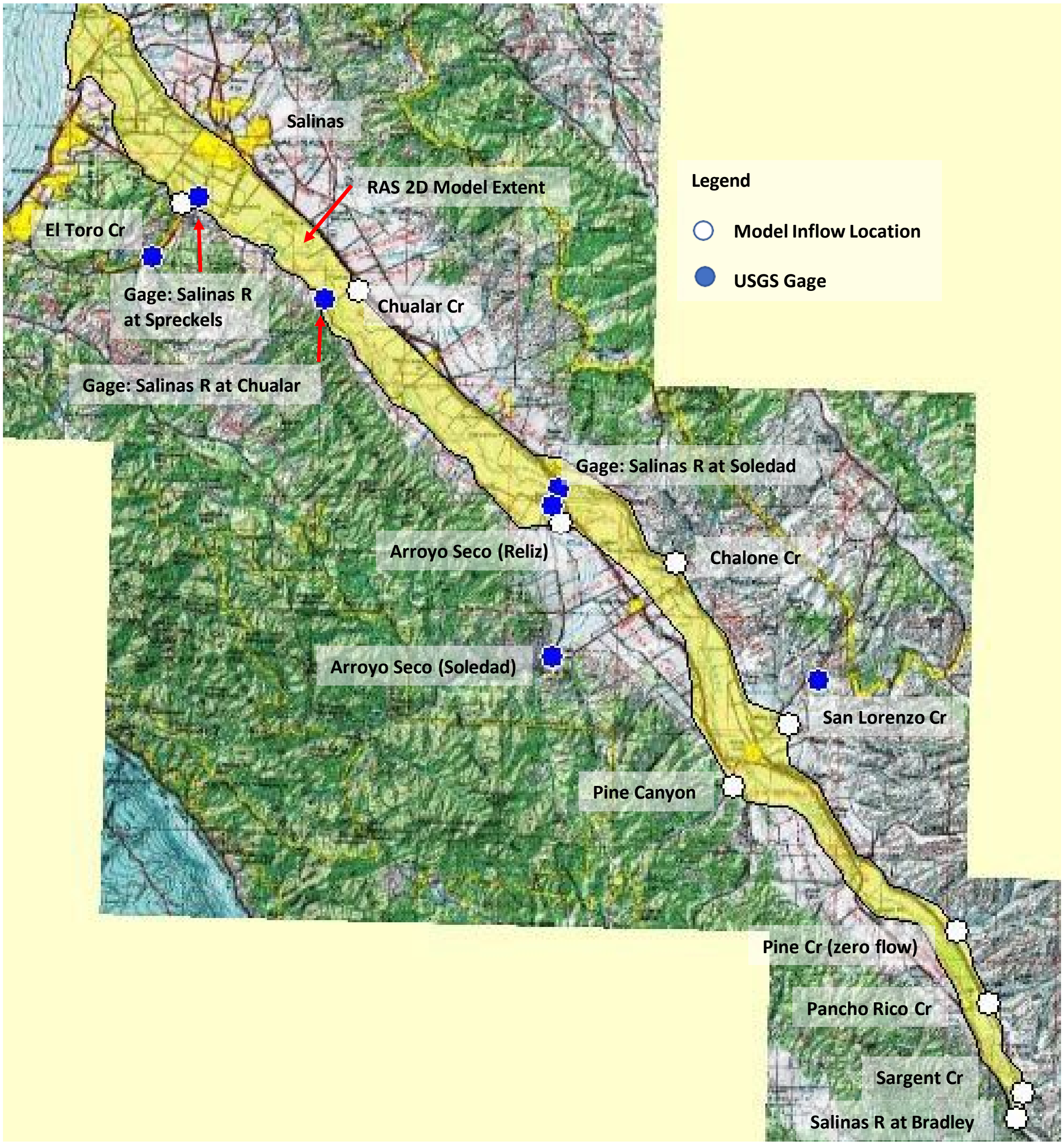

Figure 1. Salinas Valley 2D Model Extent, Inflow Locations, and USGS Flow Gages

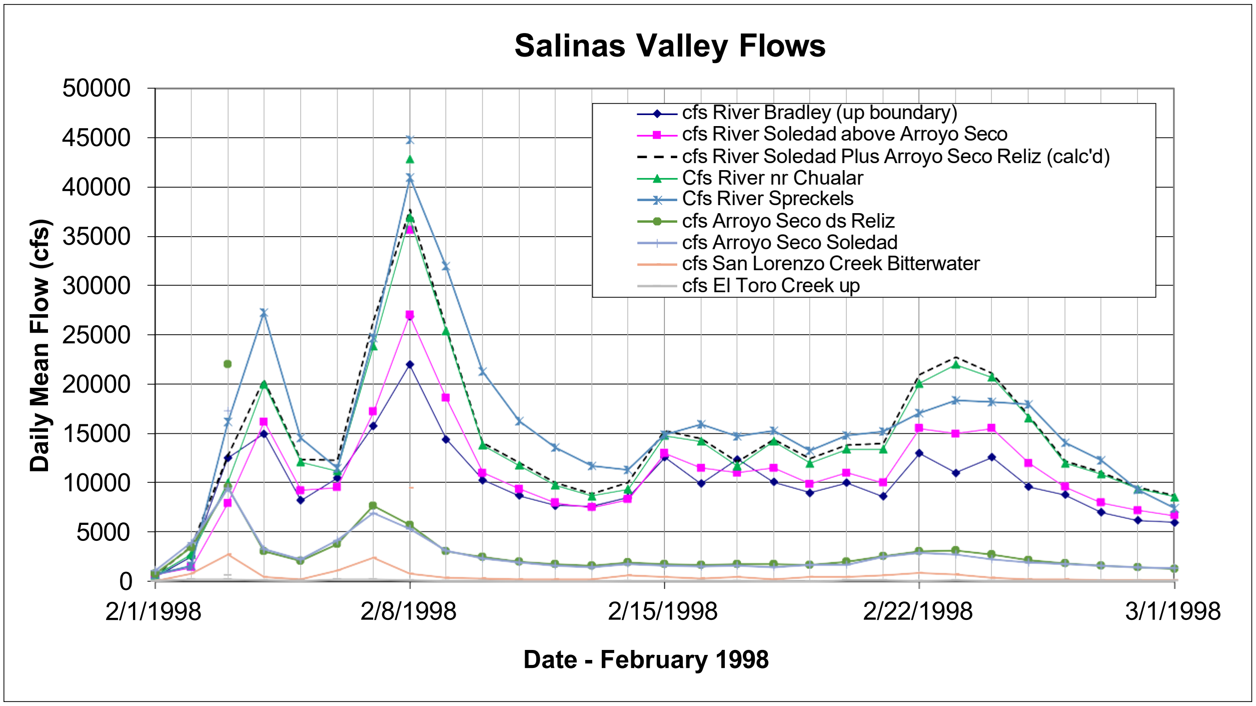

Figure 2. Observed Salinas Valley Flows

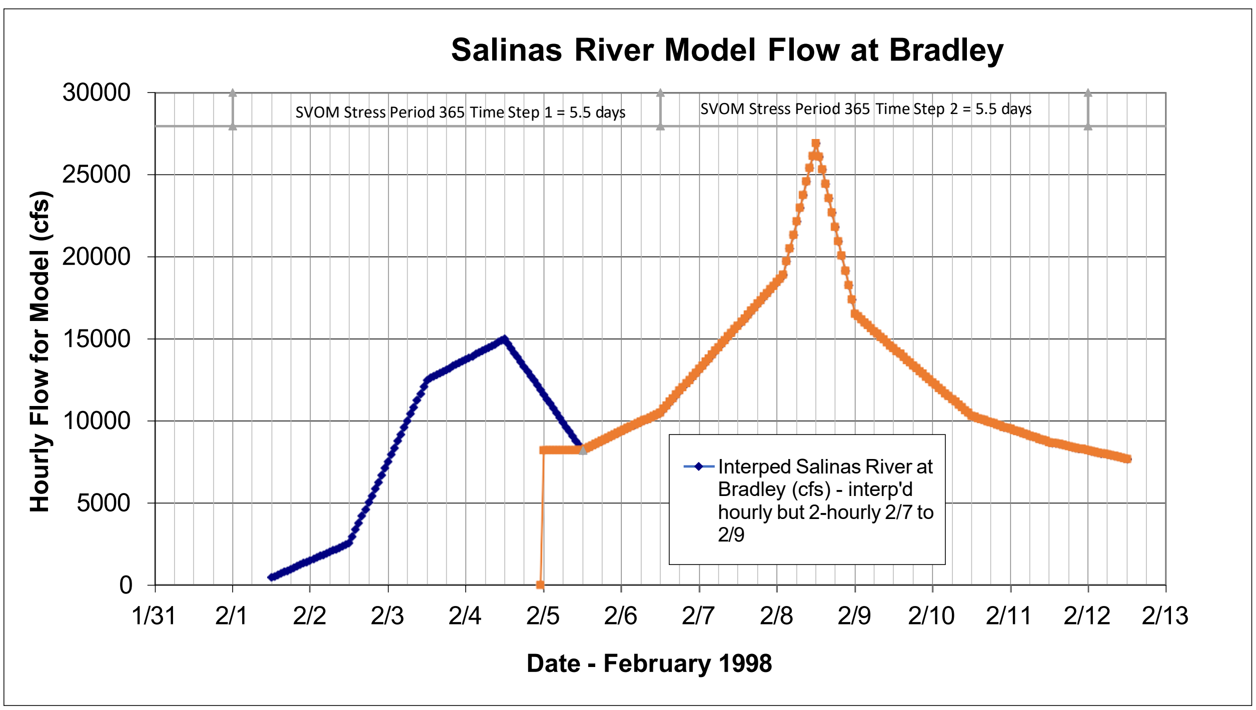

Figure 3. Model Inflow for Salinas River at Bradley for February 1998 Baseline

hours of February 5 were changed to a constant flow (not the lower February 4 flow) to match the starting "ramp-up" condition.

Model inflows for the two main tributaries – Arroyo Seco and San Lorenzo Creek – were assigned the mean daily gage flows. These were not adjusted for the peak-flow because they occurred earlier than the river peak. The gages were sufficiently close to the 2D model boundary that no adjustment was made for their location.

Other tributaries either were un-gaged or, for El Toro Creek, the gage was well upstream of the 2D model boundary, so flows were estimated. Multiple methods were tried; the chosen method adjusted the mean daily flow of a reference gage in proportion to the estimated 2-year peak flow. The three gages were most consistent (linear) for this method. Other methods using drainage area or area times mean annual precipitation were less linear and thus less suited for estimating tributary flows. **Table 1** lists parameters for each tributary with their reference gage parameters.

Table 1. Tributary Flow Model Parameters

Location	Area (mi2)	Mean Precip (in/year)	2-yr flow (cfs)	Mean-Daily Peak Feb 7, 1998 (cfs)
El Toro Creek used for itself:				
El Toro Cr at USGS Gage	31.9	22.7	280	235
El Toro Cr at 2D Boundary	42	21.9	323	271
Arroyo Seco used for west-side tributary:				
Arroyo Seco	297.9	29.1	3600	7700
Pine Canyon	15.5	20.4	115	246
San Lorenzo Cr used for east-side tributaries:				
San Lorenzo Cr	256.2	18.2	943	2450
Chualar Cr	35.3	15.8	120	312
Chalone Cr	141.3	15.5	374	972
Pine Cr (*)	39.9	15.4	125	325
Pancho Rico Cr	60.1	19.2	313	813
Sargent Cr	53.3	16.6	194	504

(*) Pine Cr was set to zero flow as a work-around for a ground geometry problem.

The predicted mean daily peaks for February 3 and 7 are compared to the observed gages in **Figures 4 and 5**. Each tributary has two points – a higher point for February 3 and a lower point for February 7. The two lines show the prediction using San Lorenzo Creek (which was used for all but one tributary). The estimation was higher than values for Arroyo Seco (used for Pine Canyon) and El Toro Creek (which used its own upstream gage as its reference). The two figures show the same information at different scales.

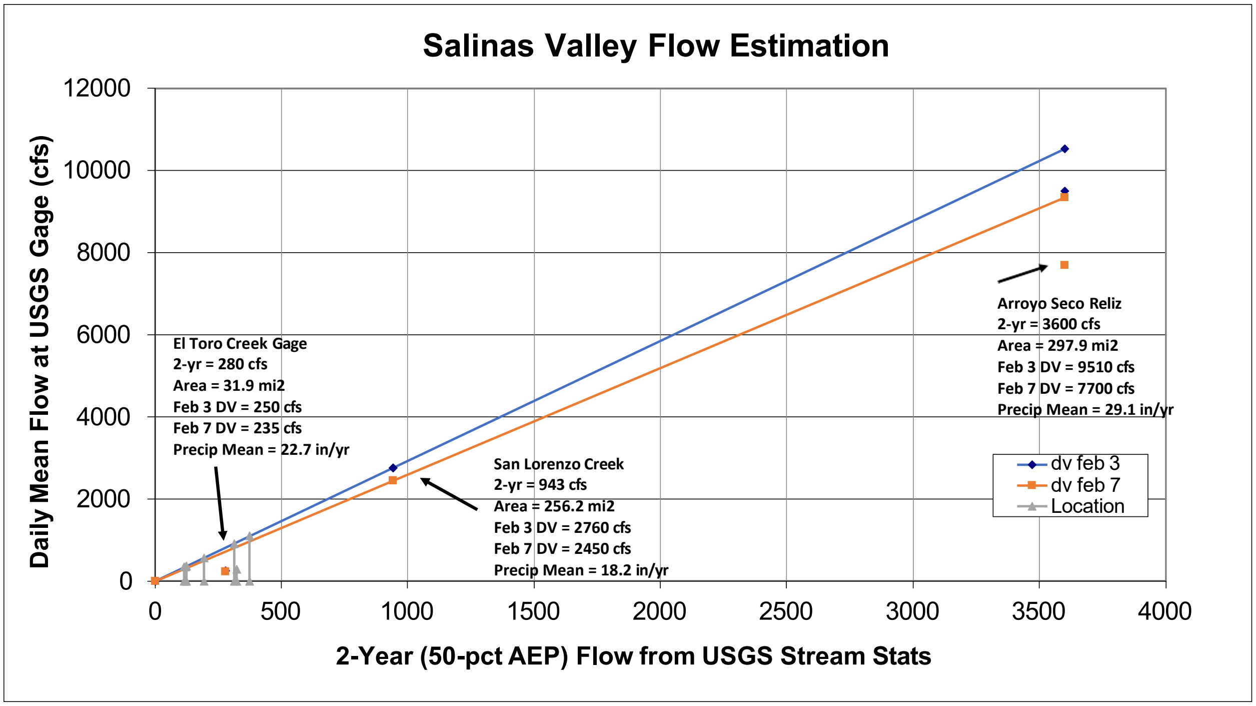

Figure 4. Salinas Valley Tributary Flow Estimates, Full Scale

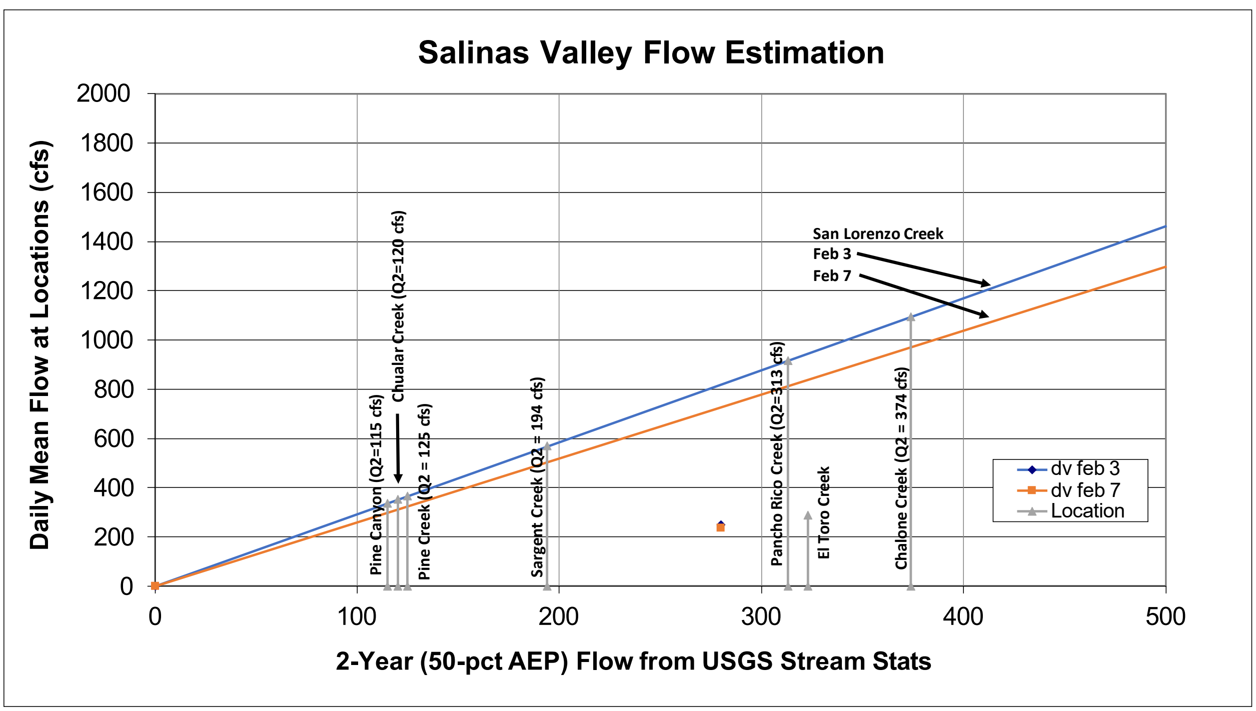

Figure 5. Salinas Valley Tributary Flow Estimates, Fine Scale

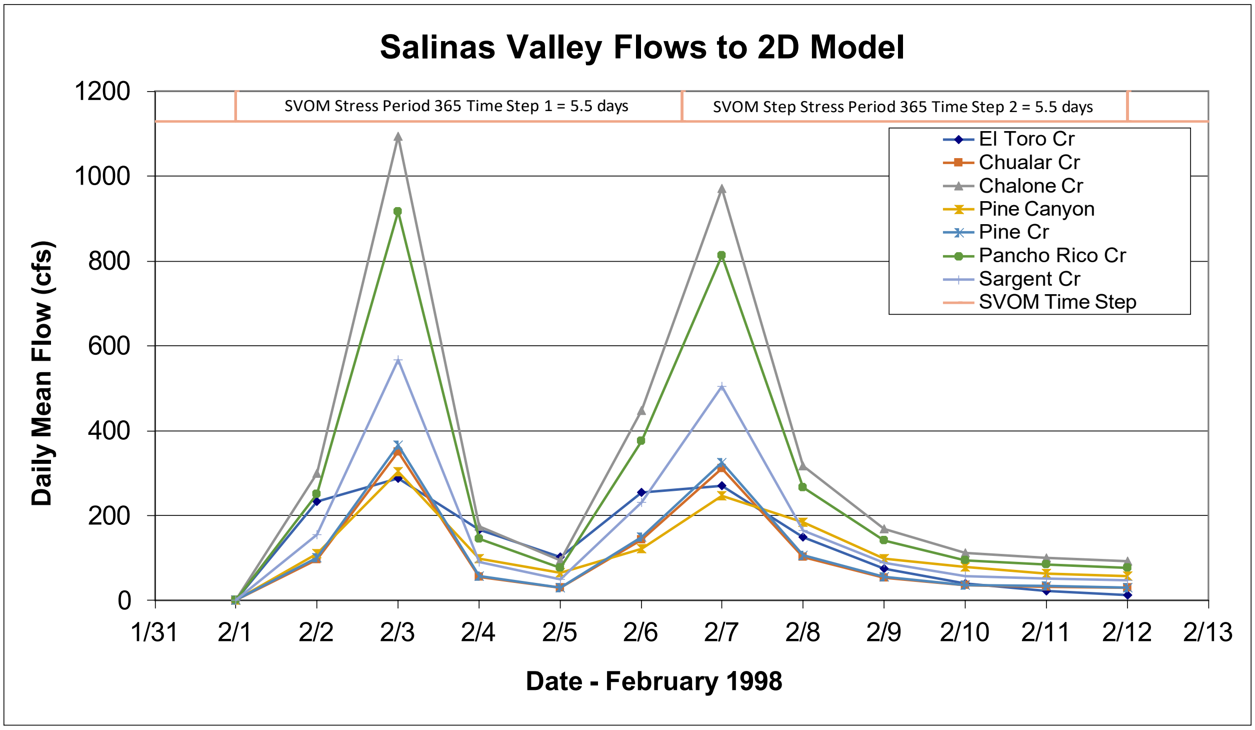

Figure 6. Model Inflow for Tributaries

Figure 6 shows the resulting hydrographs used for the 2D model boundaries. The model started on February 5 when the tributaries had relatively low flows.

Both **Figure 3 and 6** also show the two SVOM time steps (both are 5.5-day duration). Model inflows were averaged by these time steps and compared to those reported by the SVOM Baseline scenario. (The Bradley inflows used the interpolated series – not the data starting at constant flow on February 5.)

These comparisons are shown in **Figure 7, 8, and 9**. The figures show the same information at different scales. Differences in the two data sources result from an unknowable combination of uncertainties in the SVOM calibration plus differences in the SVOM Baseline scenario relative to the historical Salinas Valley Integrated Hydrologic Model (used for calibration). The 2D model used the historical peaks.

The 2-dimensional HEC-RAS model was run for the same event for three scenarios. Each scenario used a different boundary for the Salinas River at Bradley but used the same tributary inflow hydrographs (since the tributary flows are not impacted by changes to the reservoirs). The scenarios were as follows:

- Baseline
- Tunnel-Only
- Tunnel Plus Raise San Antonio Spillway 7 Feet

The hourly inflows at Bradley were calculated from the hydrograph developed for the Baseline scenario. The hourly inflow peak was adjusted up by the same proportion that the SVOM peak flow was relative to the Baseline scenario peak. The starting flow of 8220 cfs, and flows less than that, were kept the same as the Baseline scenario, and higher flows were increased in proportion to their excess above 8220 cfs. The resulting hydrographs and the SVOM hydrographs are compared in **Figure 10**.

The event hydrographs show two interesting effects. First, the SVOM-simulated peaks are delayed a time step from the inflow event in the input hydrology. This effect results from how SVOM models flood control releases based on starting storage in the reservoir and is an artifact within the SVOM.

The second effect is important to understand. The Tunnel-Only scenario hydrograph peak is higher than the Baseline scenario peak. The Tunnel Plus 7' Spillway Raise scenario hydrograph peak is also higher than the Baseline scenario peak, but is lower than the Tunnel-Only scenario peak, as expected because additional storage is provided in the San Antonio Reservoir. The with-Tunnel alternative peaks are higher for this (large) event peak because the Tunnel allowed more flow into San Antonio prior to the event and thereby displaced flood storage.

There will be instances where flood control releases are higher with the Tunnel than without because the Tunnel can increase the volume of water stored in San Antonio Reservoir, storing water that would otherwise have spilled from Nacimiento Reservoir, and thereby displace flood control volume from the Baseline scenario.

A single event like the simulated event might not be a representative view of the overall effects of the Tunnel on downstream inundation. There may be other times when flood releases are less with the Tunnel, even though flood releases are higher for this event.

Going into the simulated event, stage in Nacimiento Reservoir is about 15 feet lower under the Tunnel-Only scenario compared to the Baseline scenario. Within the first couple timesteps, that difference disappears because Nacimiento Reservoir is full during most of the event under all scenarios. Stage in San Antonio Reservoir, on the other hand, starts out more than 50 feet higher under the Tunnel-Only scenario compared to the Baseline scenario; that difference comes down over time because stage in San Antonio Reservoir increases quite a bit during this event under the Baseline scenario, whereas under the Tunnel-Only scenario the stage begins the event at or near the flood rule curve (elevation) above which flood control releases are required (so it cannot rise very far).

Under the Baseline scenario, Nacimiento Reservoir was making flood control releases throughout this event, and that does not change much under the with-Tunnel scenarios. San Antonio Reservoir, however, was not making flood control releases under the Baseline scenario, but with the with-Tunnel alternatives it makes a substantial amount.

The with-Tunnel alternatives reduce the flood control release volume overall compared to the Baseline scenario, but one should not be surprised that, during the very wettest events like that simulated here, the Tunnel might increase the amount of flood control release relative to the Baseline scenario, and thus increase the extent of downstream inundation. One of the main benefits of the Tunnel is that it collects more water in storage. If these extreme events begin with a larger amount of water in storage, then more flood control releases will be required because the amount of water coming into the reservoirs is the same for all scenarios.

This result may seem surprising, but it is perfectly reasonable once the trade-off of conservation pool storage and flood control storage for extreme events is understood. There may be a reduction in the severity of more frequent flooding events (like, the 1-year or 5-year flood), but the very wettest events may see an increase in flooding, as is the case for the event simulated. This would not be the case if, for example, this event followed a couple extremely dry years that left the reservoirs empty in all scenarios (for example, at the end of the early-1990s drought).

Model Results

Figure 11 compares the modeled peak flows on the Salinas River from up- to downstream for each of the three scenarios. The horizontal scale represents the "order" of the location but is not proportional to river-

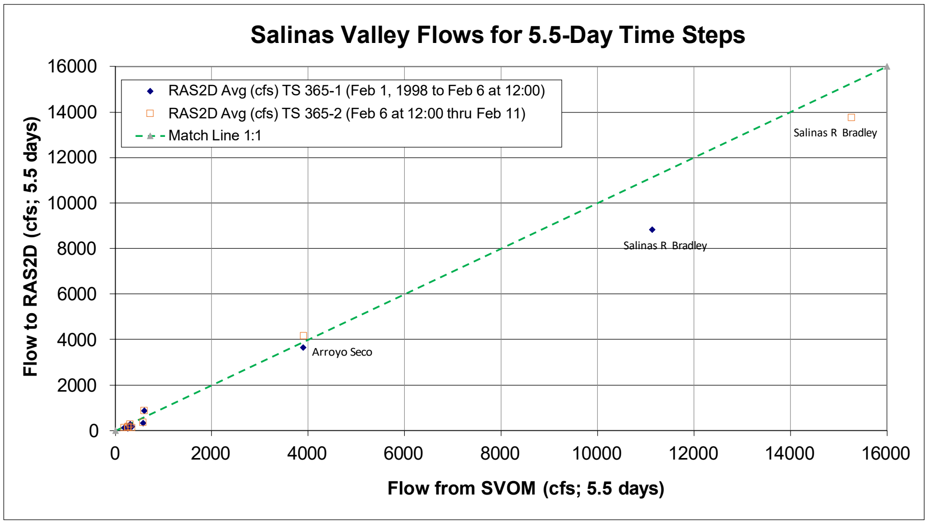

Figure 7. Average Time Step Flows for 2D and SVOM, Full Scale showing Salinas River at Bradley

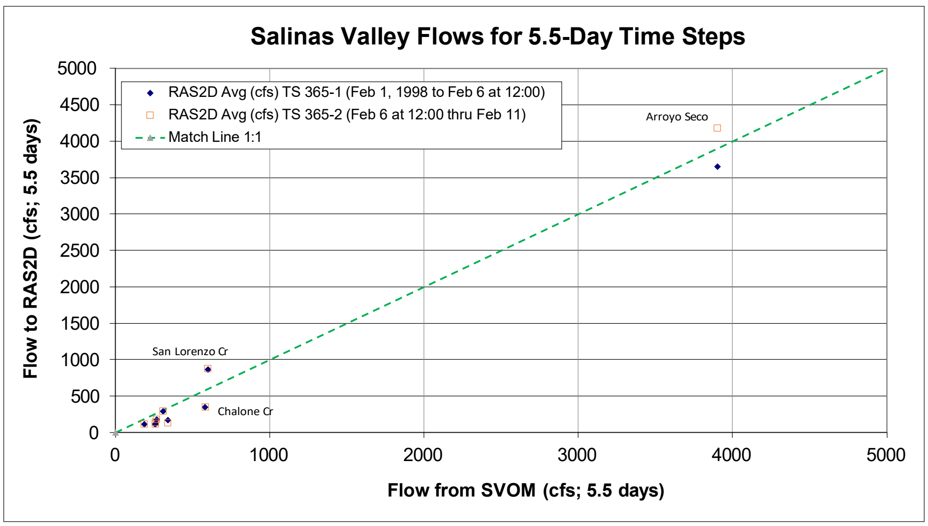

Figure 8. Average Time Step Flows for 2D and SVOM, Medium Scale

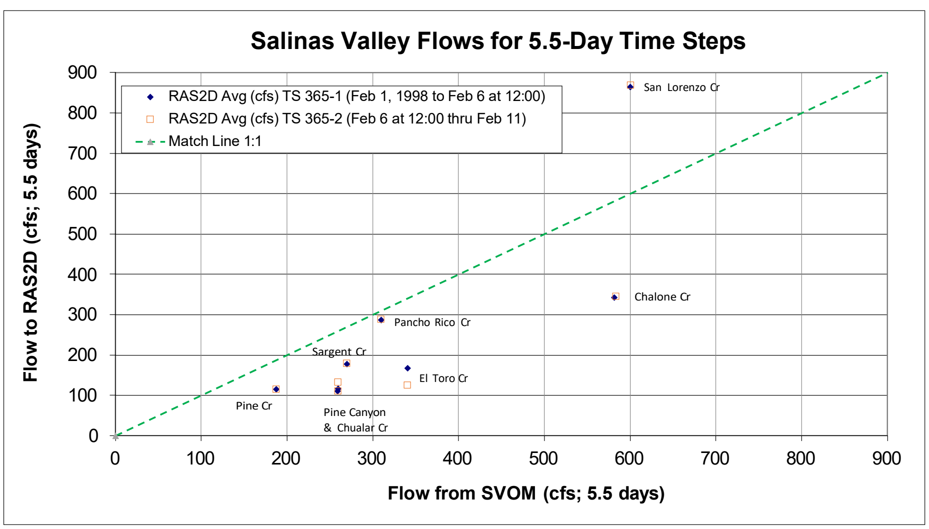

Figure 9. Average Time Step Flows for 2D and SVOM, Fine Scale

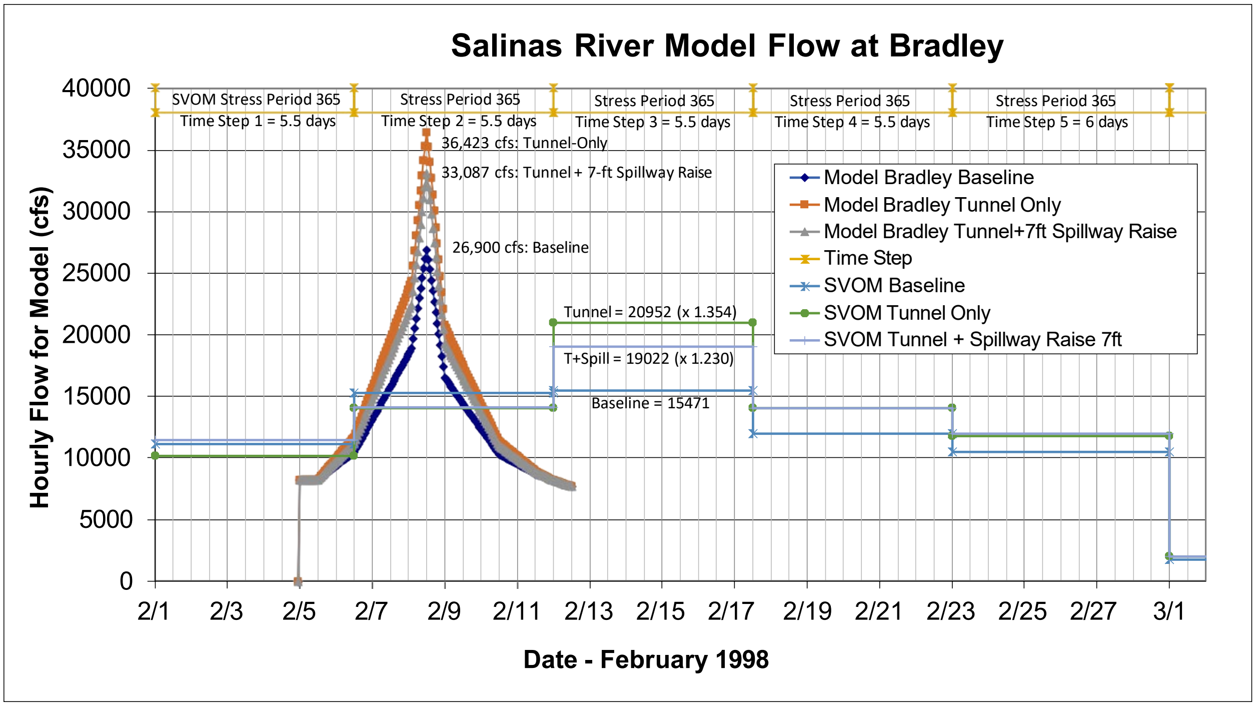

Figure 10. Salinas River at Bradley Alternative Inflow Hydrographs

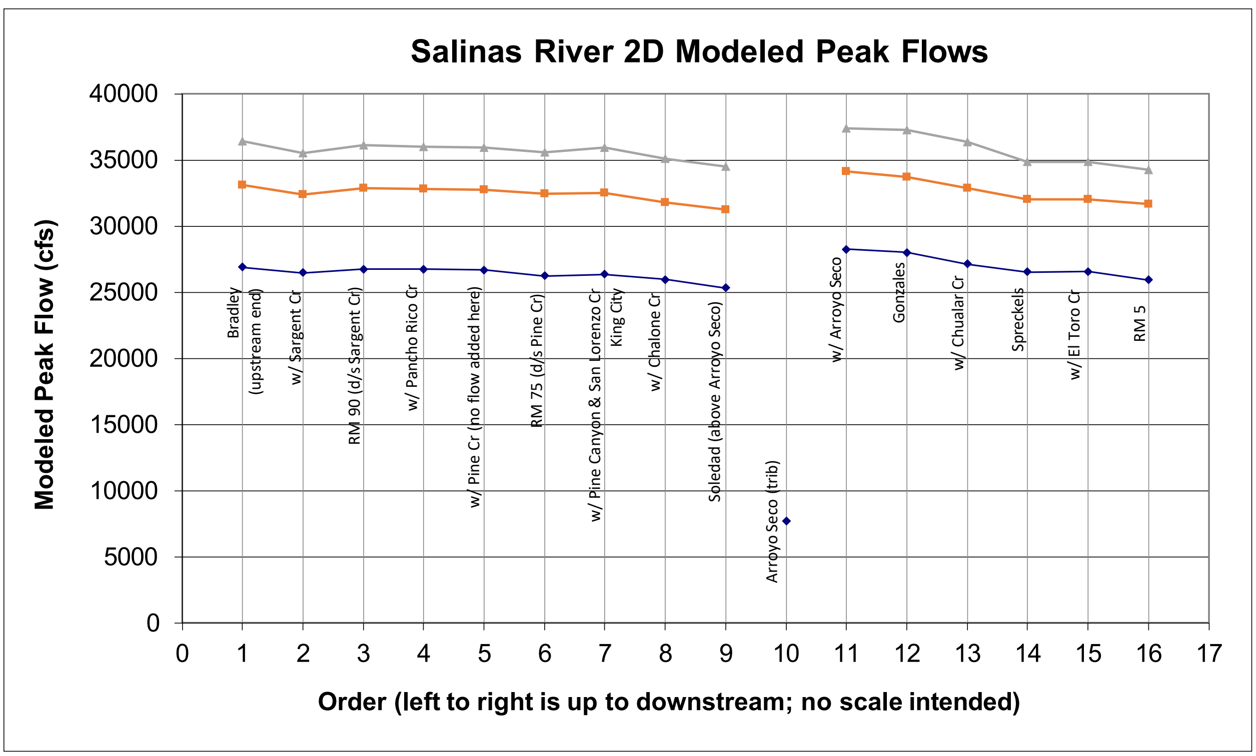

Figure 11. Maximum 2D Model Flows

mile distance. Except where a large inflow is added from Arroyo Seco, the data show a gradual reduction that results from attenuation of the flow peak by storage in the floodplain.

This is different from the observed increase in peak flows at the multiple gages, as discussed earlier. The reason for this difference is not known, but is likely a combination of not having included smaller tributaries and direct runoff from the floodplain. Exfiltration of groundwater to the river channel is not a likely reason because the variation should be slow, and because river flow was very low before the February peak started.

Model results provided digitally include the following:

- Model input files
- GIS shape file of inundation extent polygon
- GIS shape file of model "mesh" polygons including maximum values for depth, velocity magnitude, and water surface elevation corresponding to the cell computation points
- Images interpolating model results for depth, velocity magnitude, and water surface elevation

Project Alternative Modeling

Project alternatives will be modeled by adjusting the river peak in proportion to the change in SVOM flow relative to the SVOM Baseline scenario flow.

Limitations

This report was prepared exclusively for the Monterey County Water Resources Agency (Agency) by Wood Environment & Infrastructure Solutions, Inc. The quality of information, conclusions, and estimates contained herein is consistent with the level of effort involved in Wood services and based on: i) information available at the time of preparation, ii) data supplied by outside sources, and iii) the assumptions, conditions, and qualifications set forth in this report. This report is intended to be used by the Agency for the Interlake Tunnel project only, subject to the terms and conditions of its contract with Wood. Any other use of, or reliance on, this report by any third party is at that party's sole risk.

Closing

Wood appreciates the opportunity to serve the Agency for this portion of the Interlake Tunnel project and looks forward to serving the Agency further on work related to the Tunnel and to the Salinas Valley. If you have any questions, please contact the undersigned.

Sincerely,

Wood Environment & Infrastructure Solutions, Inc.

Seth Jelen, PE
Principal Engineer

Reviewed by:

Matt Baillie
Senior Hydrogeologist

Sj/--