County of Monterey

Saffron Room
1441 Schilling Place
Salinas, Ca 93901

Meeting Agenda

Wednesday, July 9, 2025

10:00 AM

SPECIAL BOARD OF DIRECTORS WORKSHOP

Join via Zoom: https://montereycty.zoom.us/j/91329464052 or Saffron Room 1441 Schilling Place, Salinas Ca 93901.

Water Resources Agency Board of Directors

Mike LeBarre, Chair
Matt Simis, Vice Chair
Mark Gonzalez
Deidre Sullivan
Ken Ekelund
Mike Scattini
Jason Smith
John Baillie
Jon Conatser

Participation in meetings:

You may attend the Board of Directors meeting through the following methods:

1. You may attend in person

2. Attend via Zoom (info below) or observe the live stream of the Board of Directors meetings at https://montereycty.zoom.us/j/91329464052?pwd=4uCLbT1XxkrvfUD17AOGxoA1WwluBY.1&from=addon

3. For ZOOM participation please join by computer audio at: https://montereycty.zoom.us/j/91329464052?pwd=4uCLbT1XxkrvfUD17AOGxoA1WwluBY.1&from=addon

OR to participate by phone call any of these numbers below:
+1 669 900 6833 US (San Jose)
+1 346 248 7799 US (Houston)
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+1 929 205 6099 US (New York)
+1 253 215 8782 US
+1 301 715 8592 US

Enter this Meeting ID number: 913 2946 4052 Password: 019092 when prompted.

You will be placed in the meeting as an attendee; when you are ready to make a public comment if joined by computer audio please Raise your Hand; and by phone please push *9 on your keypad.

PLEASE NOTE: IF ALL BOARD MEMBERS ARE PRESENT IN PERSON, PUBLIC PARTICIPATION BY ZOOM IS FOR CONVENIENCE ONLY AND IS NOT REQUIRED BY LAW. IF THE ZOOM FEED IS LOST FOR ANY REASON, THE BOARD OF DIRECTORS MEETING MAY BE PAUSED WHILE A FIX IS ATTEMPTED BUT THE MEETING MAY CONTINUE AT THE DISCRETION OF THE CHAIRPERSON.

4. If you choose not to attend the Board of Directors meeting but wish to make a comment on a specific agenda item, please submit your comment via email by 5:00 p.m. on the Friday before the meeting.. Please submit your comment to the Secretary of the Board at WRApubliccomment@countyofmonterey.gov mailto:WRApubliccomment@countyofmonterey.gov In an effort to assist the Secretary in identifying the agenda item relating to your public comment please indicate in the Subject Line, the meeting body (i.e. Board of Directors Agenda) and item number (i.e. Item No. 10). Your comment will be placed into the record at the Board meeting.

Participacion en Reuniones:

Puede asistir a la reunion de la Junta Directiva a traves de los siguientes metodos:

1. Podar asistir personalmente a la reunion; o,

2. Asistir por Zoom (informacion a continuacion), que observe la transmisión de la reunión de la Junta Directiva en vivo por https://montereycty.zoom.us/j/91329464052?pwd=4uCLbT1XxkrvfUD17AOGxoA1WwluBY.1 &from=addon

3. Para participar for ZOOM, por favor únase for audio de computadora por: https://montereycty.zoom.us/j/913 2946 4052

O para participar for teléfono, llame a culquiera de los números a continuación:
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+1 253 215 8782 US
+1 301 715 8592 US

Cuando se le solicite, ingrese este número de reunión: 913 2946 4052 contrasena: 019092

Se le colocará en la reunion como asistente; cuando deseé hacer un comentario público si esta unido por la computadora utilize la opción de levantar la mano en el chat de la pantalla; o por teléfono presione *9 en su teclado.

TENGA EN CUENTA: SI TODOS LOS MIEMBROS DE LA JUNTA ESTÁN PRESENTES EN PERSONA, LA PARTICIPACIÓN PÚBLICA DE ZOOM ES SOLO POR CONVENIENCIA Y NO ES REQUERIDA POR LA LEY. SI EL FEED DE ZOOM SE PIERDE POR CUALQUIER MOTIVO, LA REUNIÓN DE LA JUNTA DIRECTIVA PUEDE PAUSARSE MIENTRAS SE INTENTA UNA SOLUCIÓN, PERO LA REUNIÓN PUEDE CONTINUAR A DISCRECIÓN DEL PRESIDENTE.

4. Si prefiere no asistir a la reunión de la Junta Directiva pero desea hacer un comentario sobre algún tema específico de la agenda, por favor envie su comentario por correo electrónico antes de las 5:00 p.m. el Viernes antes de la reunion.. Envie su comentario al Secretario de la junta al correo electronico WRApubliccomment@countyofmonterey.gov mailto:WRApubliccomment@countyofmonterey.gov Para ayudar al Secretario a idenficar el artículo de la agenda relacionado con su comentario, por favor indique en la linea de asunto del correo electronico el cuerpo de la reunion (es decir, la Agenda de la Junta Directiva) y el número de artículo (es decir, el Artículo No. 10). Su comentario se colocará en el registro de la reunion de esta Junta.

Call to Order at 10:00 A.M.

Roll Call

Pledge of Allegiance

Scheduled Items

Hold a public workshop on Agency's Dam Safety and Operations Financial Strategy:

- Review update of future Dam Safety Projects
- Review status of current California Grant Funded Dam Safety Projects
- Review 2025-26 Fiscal-Year Dam Safety & Operations Budget (Fund 116)
- Review of the Agency's Existing Debt Obligations and updated Long-Range Financial Plan Model
- Review future Dam Safety & Operations funding strategy alternatives

Attachments: HBA Update Report Final April 2025
Economic Benefits MCWRA Investments Water Projects SV
Draft ILT and SA Spillway Modification Engineers Report (1)

Public Comment

Board of Directors Comments

Adjournment

County of Monterey

Board Report

Legistar File Number: WRAG 25-108

Item No.

Board of Supervisors
Chambers
168 W. Alisal St., 1st Floor
Salinas, CA 93901

July 09, 2025

Introduced: 7/2/2025
Version: 1

Current Status: Agenda Ready
Matter Type: WR General Agenda

Hold a public workshop on Agency's Dam Safety and Operations Financial Strategy:

- Review update of future Dam Safety Projects
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- Review future Dam Safety & Operations funding strategy alternatives

FINAL REPORT | APRIL 2025

Salinas Valley
Historical Benefits Analysis Update

PREPARED FOR

Monterey County Water Resources Agency

PREPARED BY

Salinas Valley
Historical Benefits Analysis Update

Prepared for

Monterey County Water Resources Agency

Project No. 867-60-23-02

Technical Lead: Matt Baillie, PG, CHg	May 30, 2024 Date
Project Manager: Les Chau, BCES	May 30, 2024 Date
QA/QC Review: Samantha Adams	May 30, 2024 Date

WEST YOST
Water. Engineered.

FINAL REPORT | APRIL 2025

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LIST OF ACRONYMS AND ABBREVIATIONS

AEP	Annual Exceedance Probability
af	Acre-Feet
afy	Acre-Feet Per Year
Basin	Salinas River Groundwater Basin
CDF	Cumulative Distribution Function
cfs	Cubic Feet Per Second
CSIP	Castroville Seawater Intrusion Project
DP	Deep Percolation
DWR	Department of Water Resources
ESU	Economic Study Unit
FMP	Farm Process
fps	Feet Per Second
GWP	Groundwater Pumping
HBA	Historical Benefits Analysis
HEC	Hydrologic Engineering Center
HEC-RAS	Hydrologic Engineering Center’s River Analysis System
IGSM	Integrated Groundwater-Surface Water Model
IWFM	Integrated Water Flow Model
MCWRA	Monterey County Water Resources Agency
msl	Mean Sea Level

MW	Montgomery Watson
NWP	Nacimiento Water Project
OWHM	One Water Hydrologic Model
SFR	Stream Flow Routing
SR	Stream Recharge
SRDF	Salinas River Diversion Facility
SVIGSM	Salinas Valley Integrated Ground and Surface Water Model
SVIHM	Salinas Valley Integrated Hydrologic Model
SVWM	Salinas Valley Watershed Model
SVWP	Salinas Valley Water Project
USGS	U.S. Geological Survey
West Yost	West Yost Associates
WY	Water Year

In 1998, Montgomery Watson (MW) prepared the Salinas Valley Historical Benefits Analysis (HBA; MW, 1998) for the Monterey County Water Resources Agency (MCWRA). This was the first time the benefits received by stakeholders in the Salinas Valley from the Nacimiento and San Antonio Reservoirs had been quantified. Since the original publication 25 years ago, MCWRA has constructed new water projects, additional data have been gathered, the understanding of the groundwater and surface water systems has evolved, and new tools for evaluating conditions in the Salinas Valley have been developed.

This HBA Update leverages these improvements to re-evaluate the water resources benefits provided by the Nacimiento and San Antonio Reservoirs to the Salinas River Groundwater Basin (Basin). It also incorporates projects implemented since Water Year (WY) 1994, which is the last WY covered by the 1998 HBA, including the Castroville Seawater Intrusion Project (CSIP), part of the Monterey County Water Recycling Projects, and the Salinas Valley Water Project (SVWP), which includes the Salinas River Diversion Facility (SRDF). These projects have been implemented to address the issues of seawater intrusion and groundwater overdraft observed in the study area since at least the late 1930s (DWR, 1946).

1998 HISTORICAL BENEFITS ANALYSIS

The 1998 HBA quantified the effects that the Nacimiento and San Antonio Reservoirs have had on the integrated groundwater-surface water system of the Salinas Valley. The analysis was completed using the Salinas Valley Integrated Ground and Surface Water Model (SVIGSM), a numerical model of the hydrologic system. The SVIGSM simulated conditions in the Basin from WY 1949 to 1994, both with and without the reservoirs. The difference between the two scenarios was considered to represent the benefits provided by the reservoirs to users in the Salinas Valley. The effects of flood events were simulated using a separate hydraulic model of the Salinas River and its floodplain, as the SVIGSM was not designed to simulate floodplain inundation.

The reservoirs store streamflow during wet periods and allow for release during drier periods. This has led to a reduction in the frequency and severity of flood events and an increase in groundwater storage, thereby retaining more water within the Basin. As stated in the 1998 HBA, the reservoirs have reduced the estimated magnitude of the 100-year flood in the Salinas River at Bradley from about 167,000 cubic feet per second (cfs) to 87,000 cfs. They have also increased the recharge to the groundwater system from the Salinas River and its tributaries by an average of 30,000 acre-feet per year (afy), and reduced seawater intrusion from about 18,000 afy to about 11,000 afy.

According to the 1998 HBA, the increased groundwater storage led to cost savings by reducing pumping costs, preventing the need for replacement or modification of pumping wells, and slowing the rate of seawater intrusion. This saved stakeholders in the Basin about $1.8 million per year. Additionally, the reduction in flooding prevented damage to buildings, structures, agricultural crops, and soil, saving stakeholders an additional $10.0 million per year. The total estimated benefit received from the reservoirs over the period of analysis was about $11.8 million per year.

PURPOSE AND APPROACH

This report updates the 1998 HBA using information and tools developed over the past 25 years. It also incorporates into the analysis projects that were implemented during that period (CSIP and SVWP, including SRDF). Nacimiento Reservoir, San Antonio Reservoir, CSIP, and SVWP (collectively, the Projects, which are shown in Figure ES-1) operate in tandem, so this analysis presents the benefits of the Projects as a whole. Benefits fall into three major categories:

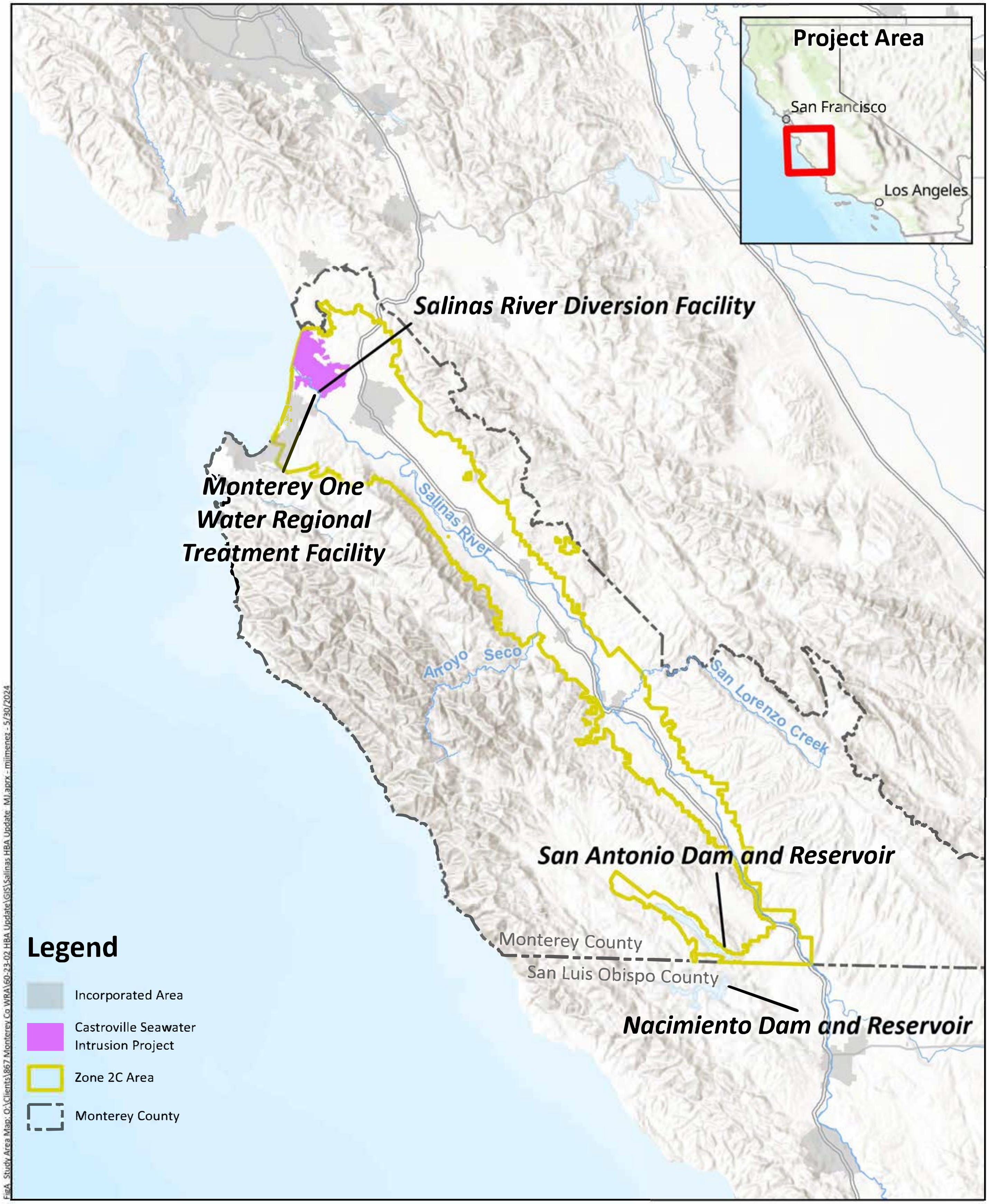
1. Hydrologic Benefits: those relating to groundwater levels and groundwater pumping
2. Flood Control Benefits: those relating to the frequency and severity of flood events
3. Economic Benefits: the monetary benefit realized by stakeholders stemming from the Hydrologic and Flood Control Benefits

For this HBA Update, the quantification of economic benefit is being prepared separately and is not included in this report.

The technical approach for quantifying the hydrologic and flood control benefits of the HBA Update follows that of the 1998 HBA wherever possible. It relies on the Salinas Valley Integrated Hydrologic Model (SVIHM), a numerical groundwater-surface water model developed by the U.S. Geological Survey (USGS). The model simulates conditions in the Basin both with and without the Projects from October 1967 to September 2018. The results from the SVIHM feed into a statistical analysis of annual peak flows for the Salinas River at Bradley. Selected peak flows are then used as inputs to a hydraulic model of the Salinas River and its floodplain. The study area for the HBA Update is MCWRA's Zone 2C, as shown in Figure ES-1. The differences between the SVIHM simulations with the Projects (Historical Scenario) and without the Projects (No Projects Scenario) represents the effects of the Projects.

The SVIHM is currently under development by the USGS and has not been released to the public, nor has its documentation report been published. Any presentation of results from the SVIHM prior to its release must be accompanied by the following disclaimer:

> *Historical SVIHM Model: Unoffical* [sic] *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 recieved* [sic] *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.*



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Prepared for:
Monterey County
Water Resources Agency
Historical Benefits
Analysis Update
April 2025

Salinas Valley
HBA Update
Study Area

Figure ES-1

STUDY SETTING

The distribution of the effects of the Projects within the Basin is influenced by the hydrogeologic context and developmental history of the Projects. Both factors are crucial for understanding the distribution of historical benefits.

The Basin sediments form aquifers, used for groundwater production, and aquitards, which restrict groundwater movement. The distribution of these aquifers and aquitards is a result of the Basin's complex depositional history. South of Greenfield, the Basin is filled with relatively coarse-grained alluvial and fluvial sediments without extensive fine-grained materials, forming a single aquifer without aquitards.

North of Greenfield, periodic marine transgressions deposited fine-grained materials alternately with terrestrial alluvial and fluvial sediments deposited during periods of lower sea level. In the Pressure Subarea, the sediments are divided into aquifers and aquitards based on the sequence of relatively coarse-grained and fine-grained materials. From the ground surface down, the named aquifers are the Shallow Aquifer, 180-Foot Aquifer, 400-Foot Aquifer, and Deep Aquifer. The 180-Foot and 400-Foot Aquifers have been the most heavily relied upon for groundwater production within the Basin. Further east, in the East Side Subarea, the aquifers and aquitards are less clearly defined. The sediments are typically divided into an East Side Shallow Aquifer and an East Side Deep Aquifer, with the degree of confinement increasing downward. The aquitards separating the aquifers are not continuous throughout the area north of Greenfield, with gaps in the aquitards representing areas where vertical groundwater movement between the aquifers can occur relatively easily.

In the Pressure Subarea, the shallowest aquitard, the Salinas Valley Aquitard, separates the Shallow Aquifer from the 180-Foot Aquifer. It generally restricts direct recharge from the Salinas River and its tributaries into the Basin aquifers. For groundwater to reach the main production aquifers of the northern part of the Basin, it must pass vertically through the aquitards or horizontally from areas further south.

Groundwater overdraft and seawater intrusion were recognized in the Basin during the first half of the 20th century. The California Department of Water Resources (DWR) conducted a detailed hydrogeologic study of the Basin (published as DWR Bulletin 52; DWR, 1946), which recommended storage and conveyance of surface water as a partial solution to the water issues facing the Basin. MCWRA built and operates the Nacimiento and San Antonio Reservoirs as a partial solution to address the issues of seawater intrusion and groundwater overdraft that have been affecting the Basin for decades. Construction of Nacimiento Dam was completed in 1957 and it began operating in WY 1958. Construction of San Antonio Dam was completed in 1967 and it began operating in WY 1968. MCWRA manages both reservoirs jointly for the purposes of flood control, water conservation, support of fish and wildlife habitat, dam safety, and recreation.

Since the construction of the reservoirs, two additional important projects, CSIP and SVWP, have been developed to help address groundwater overdraft and seawater intrusion. CSIP delivers alternative water sources to coastal growers affected by seawater intrusion, replacing locally pumped groundwater. CSIP consists of a conveyance pipeline network constructed beginning in 1995 that started delivering recycled water supplied by the Salinas Valley Reclamation Project at the Monterey One Water Regional Treatment Plant in 1998. SVWP included an increase in the spillway elevation at Nacimiento Dam (increasing the storage capacity of Nacimiento Reservoir) and the construction of the Salinas River Diversion Facility (SRDF), which rediverts stored reservoir water into the CSIP network, and resulted in re-operation of the reservoirs. The spillway raise was completed in 2009, and SRDF was completed in 2010.

HYDROLOGIC BENEFITS ANALYSIS

The Projects have effectively retained more water within the Basin through increased groundwater recharge from the Salinas River and its tributaries, and reduced groundwater demand. As a result, groundwater levels (or hydraulic heads) are higher, representing an increase in the amount of groundwater stored within the Basin. These higher groundwater levels have reduced the rate of seawater intrusion into the Basin's aquifers and decreased the pumping lift required to extract groundwater from wells. This demonstrates the significant effect the Projects have had on the Basin's water resources.

GROUNDWATER LEVELS

Over the analysis period for this HBA update (WY 1968 to 2018), groundwater levels have declined in much of the study area, particularly in the Pressure, East Side, and Arroyo Seco Subareas. Declines have averaged up to 3.0 feet per year in the area between Castroville and Salinas. Groundwater levels in the Forebay and Upper Valley Subareas have largely remained unchanged or have risen in some areas, increasing by as much as 0.5 feet per year along the Salinas River downstream of its confluence with Arroyo Seco. Figure ES-2 (the left side panel on Figure ES-2) shows the average annual simulated groundwater level change in the study area over the model period under the Historical Scenario with the projects in operation. Areas where groundwater levels increased are shown in shades of pink and areas where groundwater levels decreased are shown in shades of blue.

Without the Projects, the decline in groundwater levels would have been more severe and widespread. Figure ES-2b shows the average annual simulated groundwater level change in the study area over the model period under the No Projects Scenario. Figure ES-3 shows the difference in the average annual head change between the Historical and No Projects Scenarios, illustrating that across most of the study area, groundwater levels were higher with the projects. Thus, the Projects have mitigated the degree and extent of the observed groundwater level declines, especially in the northern part of the Basin, by as much as 0.9 feet per year (Figure ES-3a). As shown in Figure ES-3b, by the end of the model period (September 2018), the Projects had resulted in groundwater levels being as much as 67 feet higher than they would have been without the.

The average annual groundwater level changes described above were used to partition the Basin into thirteen Economic Study Units (ESUs). Each ESU includes an area that has experienced similar benefits from the Projects. The ESUs, delineated on Figure ES-3b, follow the established boundaries of the MCWRA Zone 2C subareas, with subdivisions based on the Projects' effects on groundwater levels as depicted in Figure ES-2a. Table ES-1 presents the average annual groundwater level change for each ESU with and without the Projects, as well as the difference between the with- and without-Project conditions. The largest annual differences in groundwater level change occur in ESUs 2 and 3 (0.14 and 0.21 feet per year), located in the East Side and Pressure Subareas, respectively, in the area between Castroville and Salinas.

Time series of average groundwater levels in individual ESUs show that the benefits of the Projects manifest differently in different parts of the Basin (see Figures 3-20a through 3-20m of the report for a time series of groundwater level in each ESU) and in relation to the start of operations of CSIP and the SRDF. Figure ES-4a shows the time series for ESUs 3 and 11 as examples. ESUs in the northwest part of the Basin (ESUs 1 through 4) experienced little effect from the Projects until 1998 when CSIP started operating. For instance, in ESU-3, the Projects resulted in less than a foot of groundwater level increase by the end of WY 1997, with substantial impact starting in WY 1998 when CSIP came online. By the end of the model period (WY 2018), the average groundwater level in ESU-3 was about 11 feet higher with the

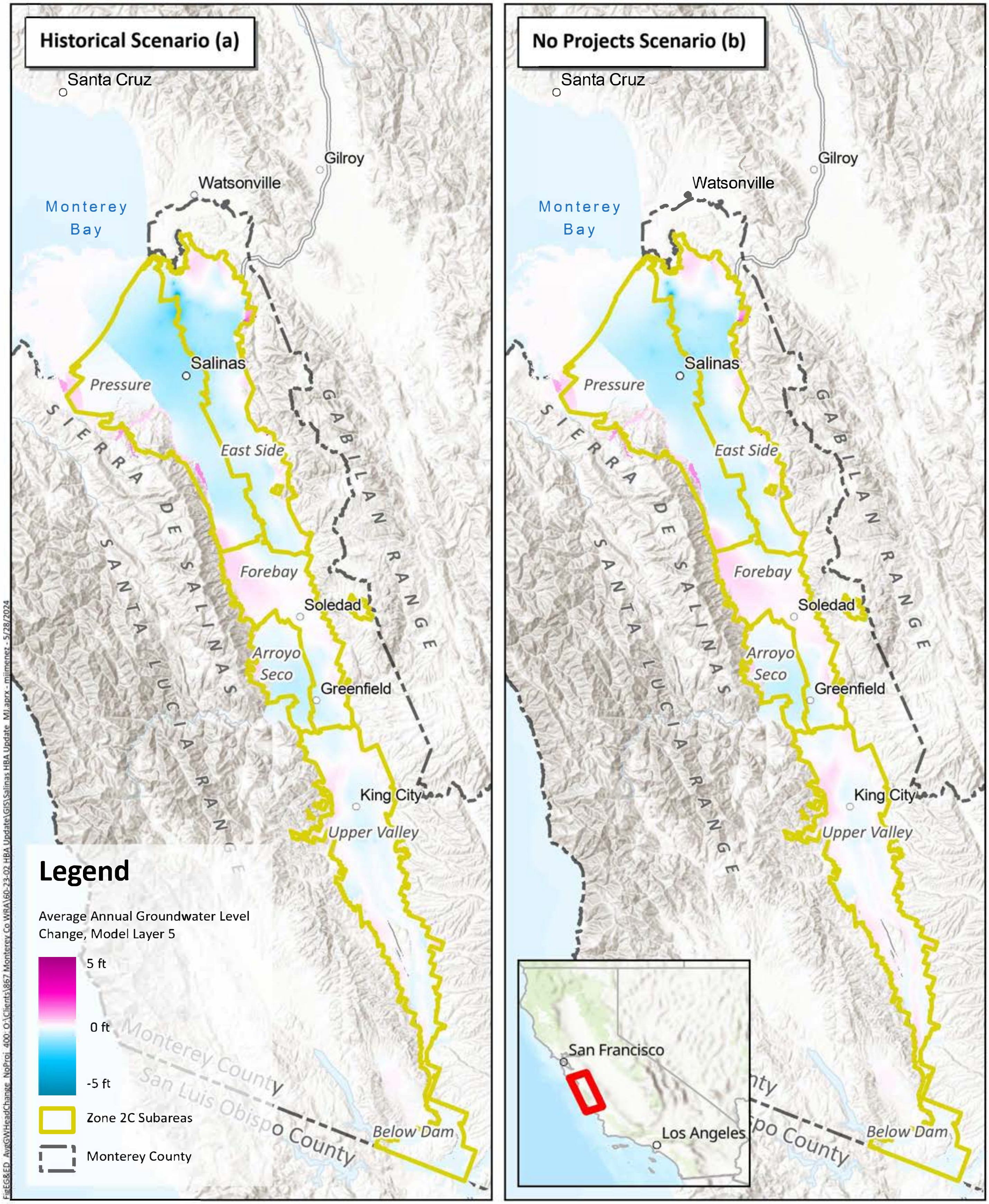
Projects than without. In other parts of the Basin (ESUs 5 through 13), the effects of the Projects are distributed more evenly over time, with fluctuations generally following climatic patterns. The effects of the Projects are felt most strongly during periods when groundwater levels decline because of dry conditions. ESU-11, which covers the northern portion of the Upper Valley Subarea, illustrates this behavior.

Table ES-1. Average Annual Groundwater Level Change (in ft) by ESU, Historical and No Projects Scenarios

ESU	Historical Scenario	No Projects Scenario	Difference Between Scenarios
1	0.08	0.08	0.00
2	-0.54	-0.68	0.14
3	-0.56	-0.78	0.21
4	-0.03	-0.05	0.02
5	-0.21	-0.23	0.02
6	-0.28	-0.31	0.03
7	-0.26	-0.30	0.04
8	0.13	0.09	0.04
9	-0.07	-0.14	0.06
10	-0.26	-0.29	0.03
11	-0.02	-0.10	0.08
12	0.00	-0.07	0.06
13	-0.17	-0.19	0.03

Notes:

Simulated groundwater level changes in this table are for Model Layer 3, which represents the 180-Foot Aquifer in the Pressure Subarea, the East Side Shallow Aquifer in the East Side Subarea, and the undifferentiated aquifer elsewhere.



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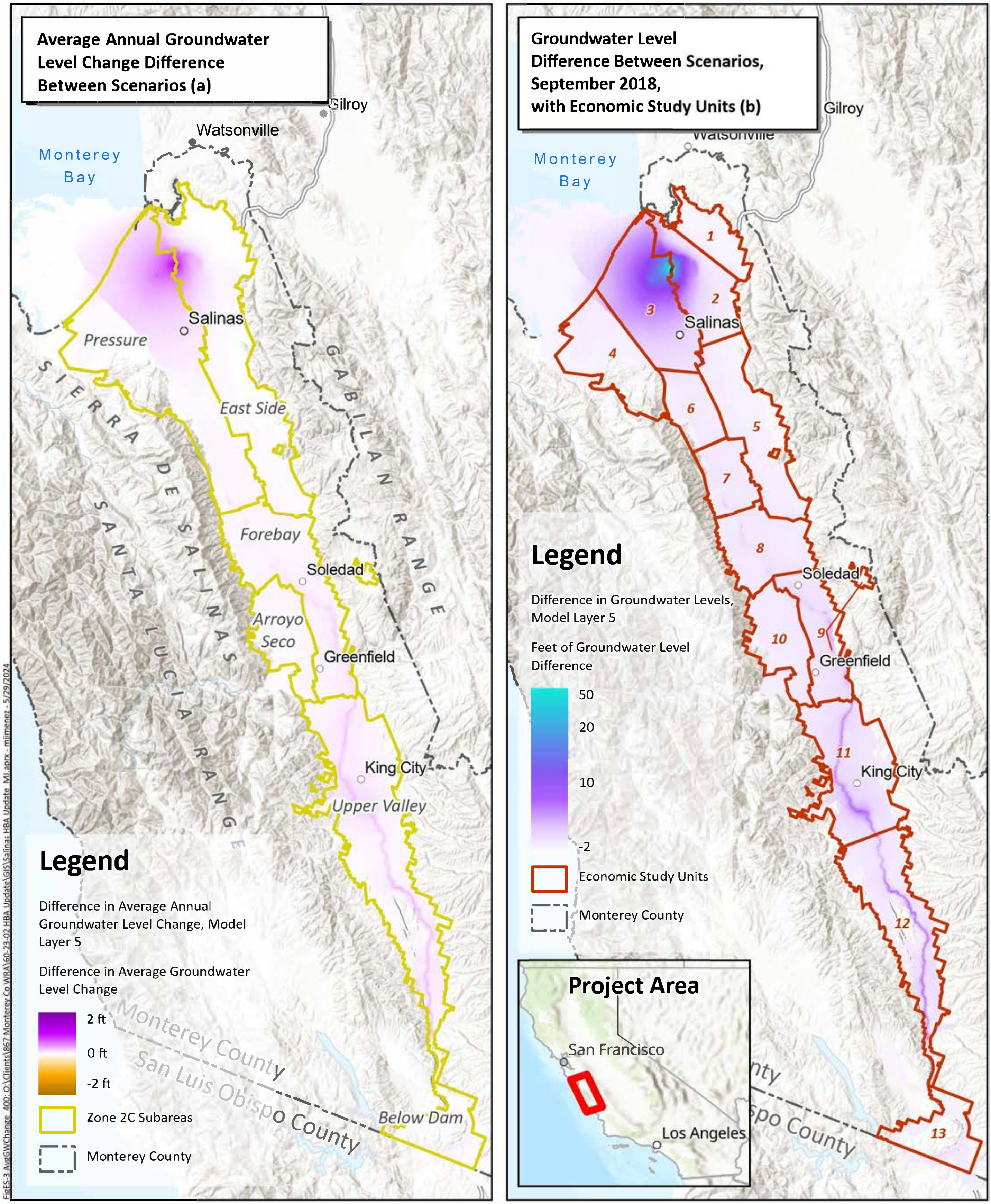
Prepared for:
Monterey County Water Resources Agency
Historical Benefits Analysis Update
April 2025

Average Annual Groundwater Level Change
400-Foot Aquifer & Equivalent

Figure ES-2



FigES-3 AvgGWChange 400: O:\Clients\867 Monterey Co WRA\60-23-02 HBA Update\GIS\Salinas HBA Update_MJ.aprx - mjimenez - 5/29/2024

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April 2025

Groundwater Level Change (a) and Groundwater Level (b) Differences Between Scenarios
400-Foot Aquifer & Equivalent

Figure ES-3

These results demonstrate that the reservoirs have provided substantial benefits to the portions of the Basin where the Salinas River is directly connected to the Basin aquifers (especially ESUs 6 through 12), while having more limited effect in the ESUs where confining layers limit the river-aquifer connection or where the Salinas River does not run through the ESU (especially ESUs 1 through 4). CSIP, through its delivery of recycled water from the Monterey One Water Regional Treatment Plant and diverted surface water from the SRDF, has provided major benefits to groundwater levels in the coastal portion of the Basin (especially ESUs 2 and 3).

Time series of average groundwater levels in individual ESUs show that the benefit of the Projects manifests differently in the different parts of the Basin (see Figures 3-20a through 3-20m in the main report for a time series of groundwater level in each ESU). ESUs in the northwest part of the Basin (ESUs 1 through 4) experienced little effect from the Projects until 1998 when CSIP came online. For instance, in ESU-3, the Projects resulted in less than a foot of groundwater level increase by the end of WY 1997, with substantial impact starting in WY 1998 when CSIP came online (Figure ES-4a). By the end of the model (WY 2018), the average groundwater level in ESU-3 was about 11 feet higher with the Projects than without.

In other parts of the Basin (ESUs 5 through 13), the effects of the Projects are distributed more evenly over time, with fluctuations generally following climatic patterns. The effects of the Projects are felt most strongly during periods when groundwater levels fall because of dry conditions. ESU-11, which covers the northern portion of the Upper Valley Subarea, illustrates this behavior (Figure ES-4b).

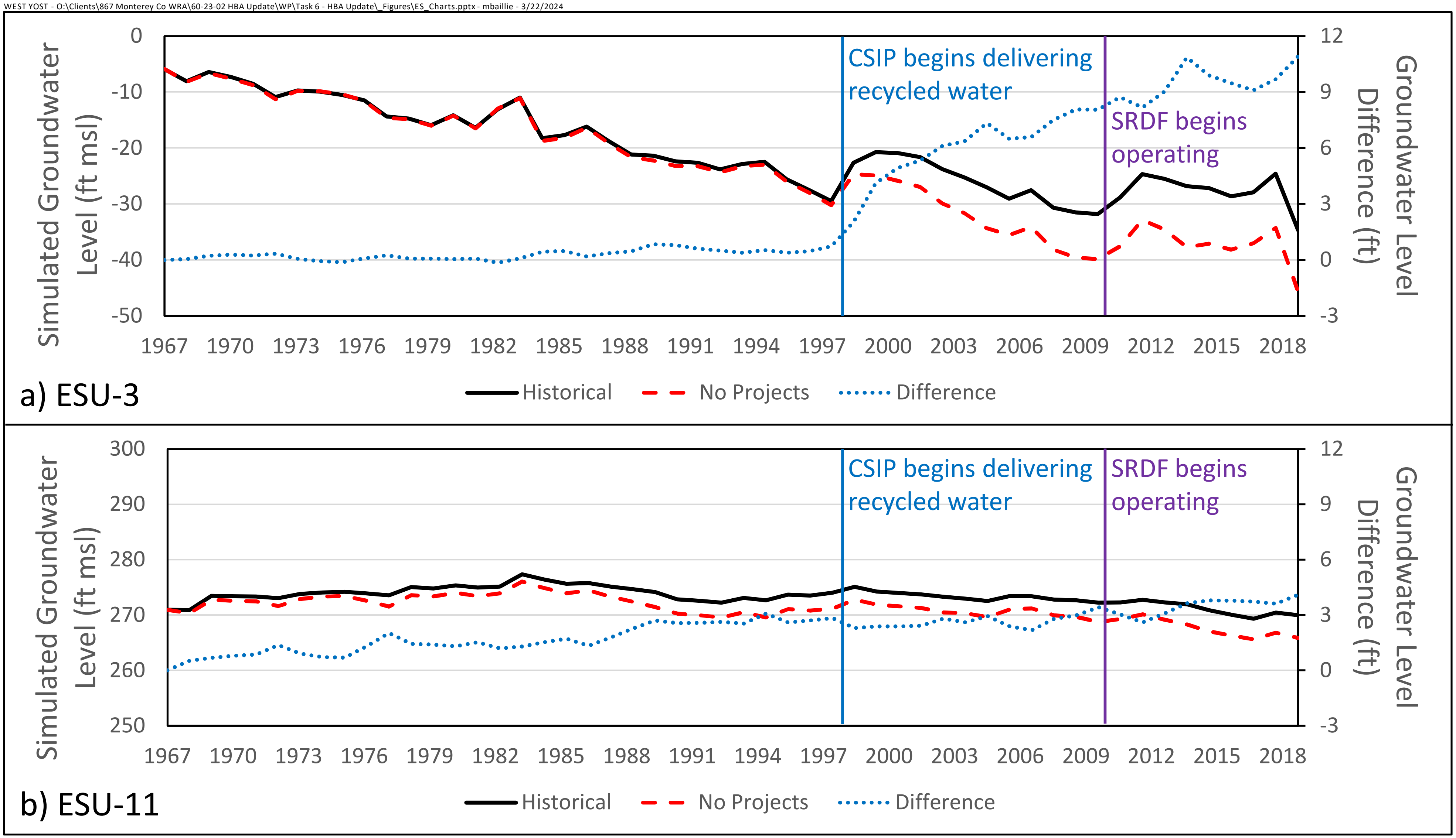


Figure ES-4

Average End-of-Year Groundwater Level in ESUs 3 and 11, Historical and No Projects Scenarios

These results demonstrate that the reservoirs have provided substantial benefits since their construction to those portions of the Basin where the Salinas River is directly connected to the Basin aquifers (especially ESUs 6 through 12), while having more limited effect in the ESUs where confining layers limit the river-aquifer connection (especially ESUs 1 through 4). CSIP, through its delivery of recycled water from the Monterey One Water Regional Treatment Plant and diverted Salinas River water from the SRDF, has provided major benefits to groundwater levels in the coastal portion of the Basin that has not been felt elsewhere.

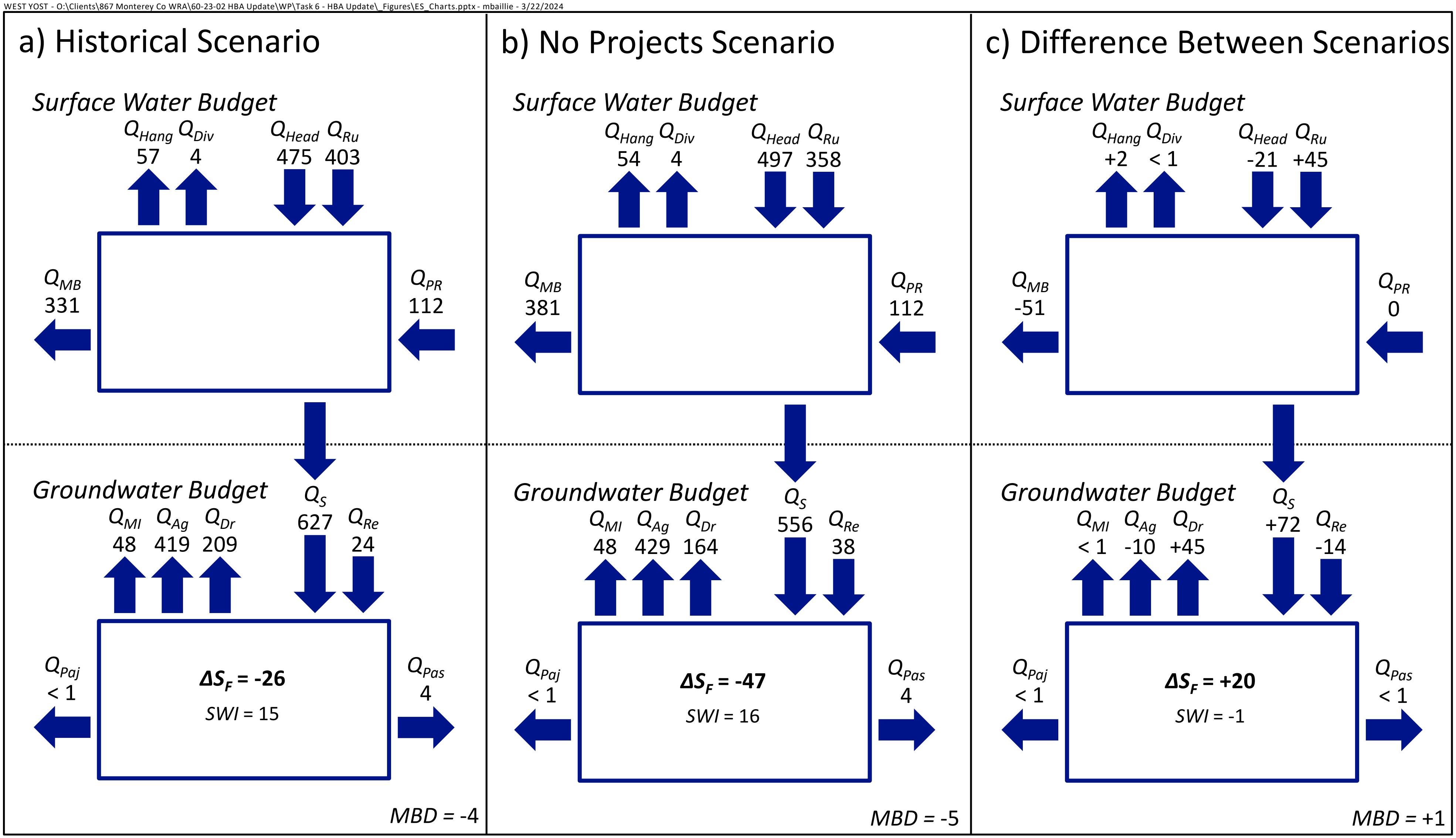
GROUNDWATER AND SURFACE WATER BUDGETS

The benefits of groundwater level rise attributed to the Projects reflect changes to the amount and timing of water moving through the groundwater-surface water system of the Basin. These effects can be represented as changes to groundwater and surface water budgets of the Basin. A water budget quantifies the volume of water entering or exiting a system and is a crucial means for understanding water movement and storage. A water budget can include any number of different components depending on the system being studied and the purpose for which the budget is prepared. The difference between inflow and outflow components of a water budget typically signifies the change in storage within the system.

For this HBA Update, water budgets were prepared for both the groundwater system and the stream network. The groundwater-surface water exchange is the major hydrologic connection between groundwater and the stream network. The average annual water budgets for the Historical and No Project Scenarios are graphically depicted in Figure ES-5. For each scenario, the budget depicts the annual average volume of each inflow and outflow to the surface water and groundwater systems (in thousands of afy). Figure ES-5 also shows the water budget differences between the scenarios.

The average annual groundwater budget for the Historical Scenario is represented in the lower half of Figure ES-5a. The largest component of the simulated groundwater budget over the historical period is recharge to the aquifers from the stream network (Q_S), averaging about 627,000 afy. Other significant inflows to the groundwater system are net recharge[1] (Q_{Re}, 24,000 afy) and seawater intrusion (SWI,15,000 afy). Most of the inflow is balanced by the two largest outflow components: agricultural pumping (Q_{Ag}, 419,000 afy) and discharge from shallow groundwater to agricultural drains (Q_{Dr}, 209,000 afy). Other outflow components include municipal and industrial pumping (Q_{MI}, 48,000 afy) and groundwater outflow to the neighboring Pajaro and Paso Robles Basins (combined, less than 5,000 afy). The total of all outflow components is greater than the total of all inflow components, indicating a loss of fresh groundwater in storage (ΔS_F), averaging about 26,000 afy. The same information for the No Projects scenario is illustrated in Figure ES-5b.

[1] Net recharge is the sum of deep percolation of water past the root zone (positive "recharge") and evapotranspiration of shallow groundwater within the root zone (negative "recharge").



Abbreviations:

- Q_S = Groundwater-Surface Water Exchange
- Q_{MI} = Municipal & Industrial Pumping
- Q_{Ag} = Agricultural Pumping
- Q_{Dr} = Discharge to Drains
- Q_{Re} = Net Recharge
- Q_{Pas} = Groundwater Exchange with Paso Robles Basin
- Q_{Paj} = Groundwater Exchange with Pajaro Basin
- ΔS_F = Change in Fresh Groundwater Storage
- *SWI* = Seawater Intrusion
- *MBD* = Mass Balance Difference
- Q_{Head} = Inflow at Stream Headwaters
- Q_{Ru} = Land Surface Runoff
- Q_{Hang} = Outflow from Hanging Streams
- Q_{Div} = Streamflow Diversion
- Q_{PR} = Salinas River Inflow from Paso Robles Basin
- Q_{MB} = Outflow to Monterey Bay

Notes:

1. All components are displayed in thousands of acre-feet per year; totals may not sum due to rounding.
2. Arrow orientation denotes direction of flow.
3. Difference between scenarios is Historical Scenario minus No Projects Scenario

Figure ES-5

Average Annual Groundwater and Surface Water Budgets, Historical and No Projects Scenarios and Difference Between Scenarios

Monterey County Water Resources Agency

Historical Benefits Analysis Update

April 2024

WELL IMPACTS

As described in the 1998 HBA, changes in groundwater levels can affect the operation of pumping wells. This can occur when the groundwater level in a well drops to within the perforated interval of the well or below the pump intake, potentially necessitating the modification or replacement of the well. For this HBA Update, an analysis was conducted on 292 pumping wells for which construction information was available. The aim was to determine the extent to which the Projects have prevented negative impacts to pumping wells in the Basin. The analysis found that only two of the pumping wells analyzed (one in ESU 3 and one in ESU 11) would have been impacted had the Projects not been implemented.

As stated in the discussion about groundwater budgets, the Projects have reduced the amount of agricultural pumping by about 10,000 afy, totaling about 500,000 af over the model duration. Figure ES-6 illustrates the cumulative difference in agricultural pumping between the Historical and No Projects conditions (by aquifer area) over the simulation period, demonstrating the effect of the Projects. About 60% of the decrease in pumping occurred in the Pressure Subarea, 21% in the Upper Valley Subarea, 15% in the Forebay Subarea, 2% in the Arroyo Seco Subarea, 1% in the East Side Subarea, and less than 1% in areas of the model domain outside Zone 2C.

The decrease in agricultural pumping in the Pressure Subarea has largely occurred since CSIP came online in 1998. The provision of recycled and surface water to the CSIP network has reduced the need for agricultural pumping in this area to satisfy crop demand. The decrease in other subareas has been relatively uniform over the model duration, likely due to the generally higher groundwater levels resulting from the Projects. During the portion of the model period with CSIP operating (WY 1998 to 2018), the Projects reduced pumping by about 19,000 afy over the entire study area.

SEAWATER INTRUSION

Seawater intrusion is a key issue in the Basin. It results from depressed groundwater levels within Basin aquifers that are directly connected to the Pacific Ocean, or vertical leakage from an overlying intruded aquifer. Explicitly simulating seawater intrusion into freshwater aquifers requires accounting for the movement and mixing of waters of two different densities (i.e., seawater and freshwater) within a porous medium. The SVIHM does not employ such an approach to simulating seawater intrusion; where the Basin's freshwater aquifers intersect Monterey Bay, groundwater levels represent observed sea level values multiplied by a factor accounting for the higher density of seawater. As currently configured, the SVIHM can only simulate seawater intrusion as a flux across the location of the coast and cannot predict the extent of onshore seawater intrusion.

As stated in the groundwater budget discussion, simulated seawater intrusion was about 15,000 afy with the Projects and about 16,000 afy without, indicating that the Projects (mostly CSIP) have prevented about 1,000 afy of seawater intrusion. Figure ES-7 presents the time series of average annual seawater intrusion flux entering the Basin under the Historical and No Projects Scenarios, along with the difference between them. Very little difference in seawater intrusion existed until 1998 when CSIP came online, indicating that the recycled and surface water delivery has significantly and positively influenced the occurrence of seawater intrusion into the Basin.

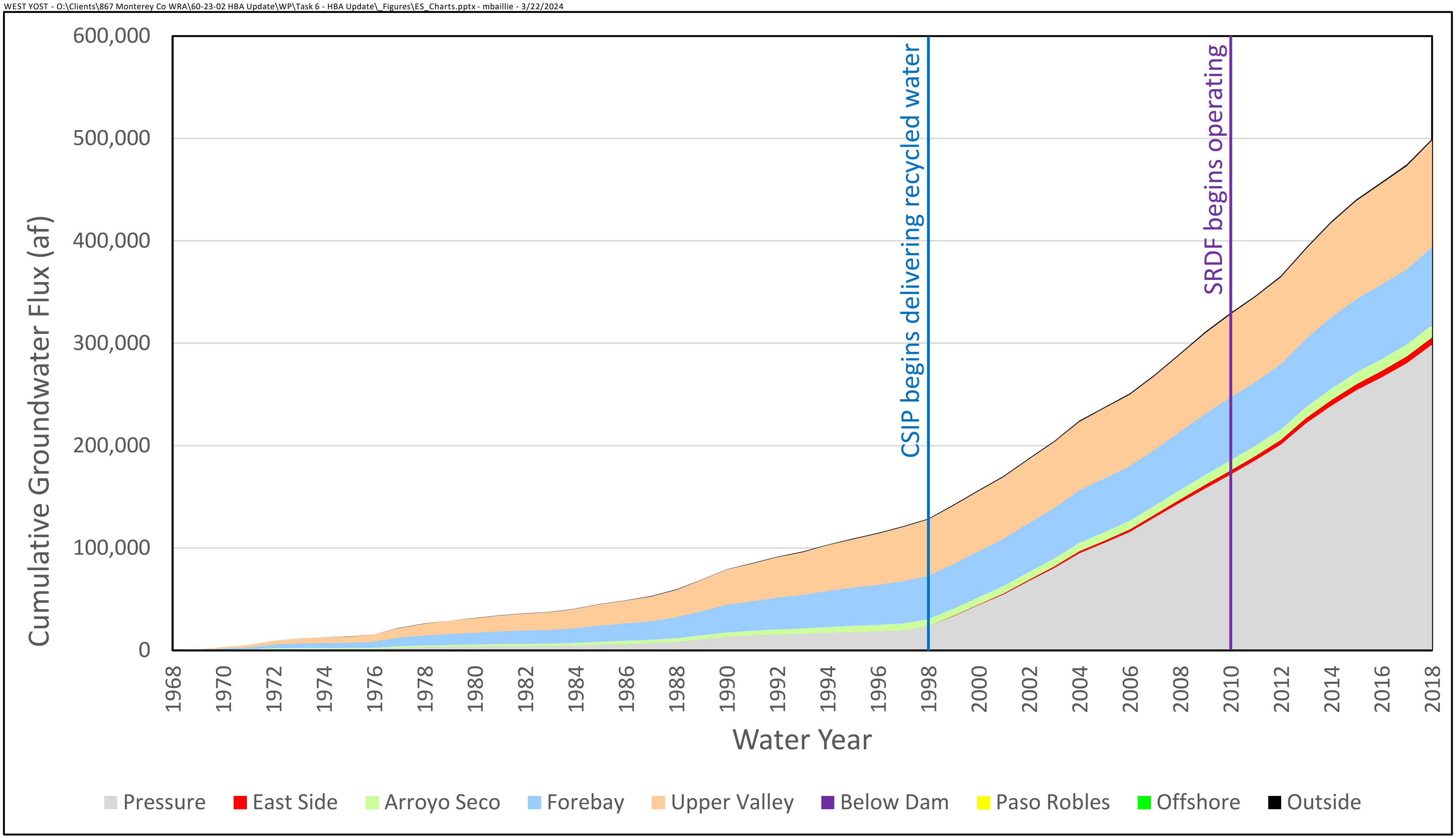


Figure ES-6

Cumulative Difference in Agricultural Pumping by Subarea

Monterey County Water Resources Agency

Historical Benefits Analysis Update

April 202!

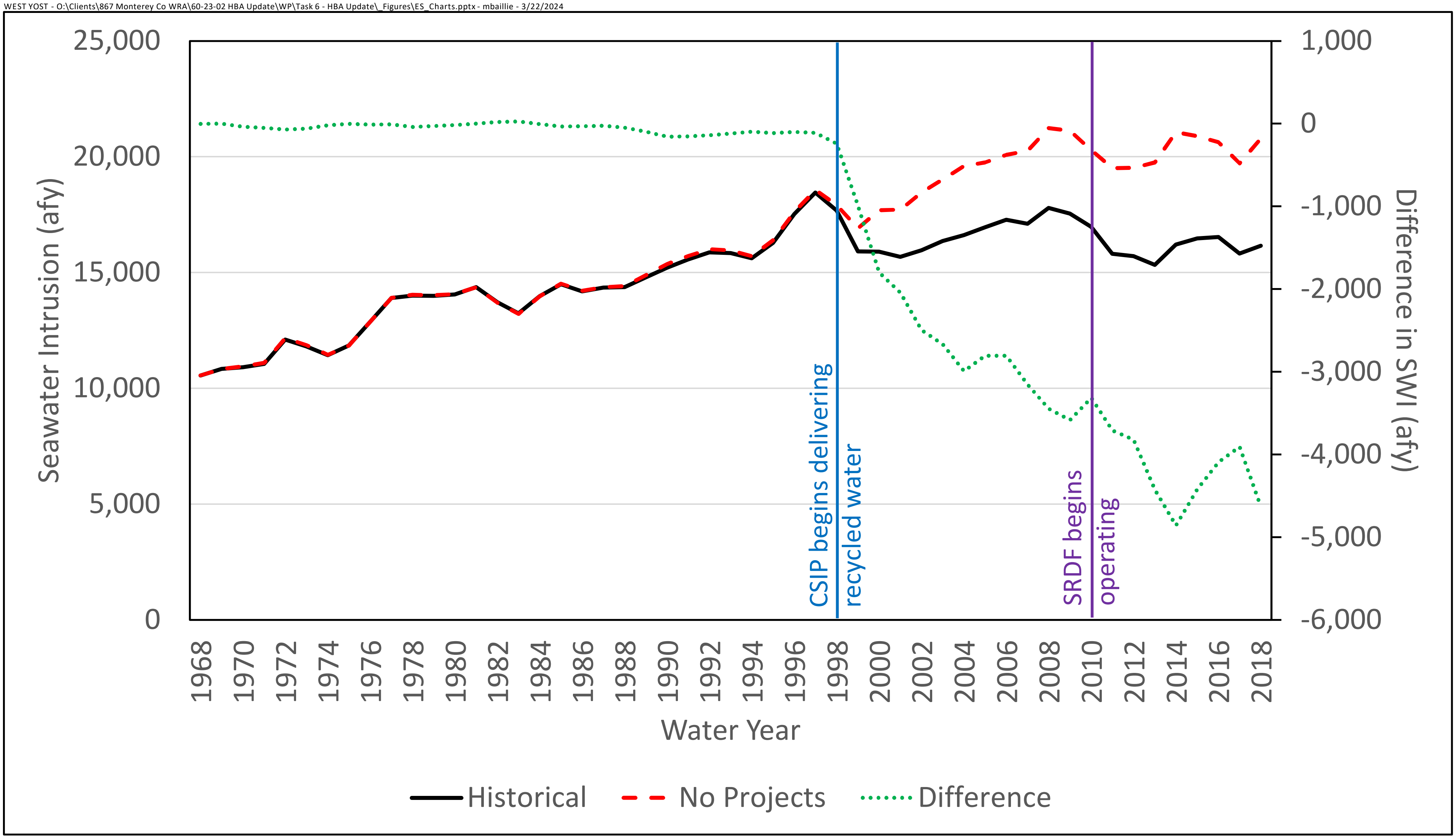


Figure ES-7

Annual Seawater Intrusion into Study Area

Over the period of the analysis, the Projects have reduced the amount of seawater intrusion in the Basin by about 68,000 af. Most of this reduction occurred in the 180-Foot Aquifer (35%) and the 400-Foot Aquifer (56%). The remaining difference occurred in the Shallow and Deep Aquifers; however, this does not imply that seawater intrusion is directly occurring in the Deep Aquifer, as the nature of the connection between the Deep Aquifer and the Pacific Ocean is currently unknown.

FLOOD CONTROL BENEFITS ANALYSIS

Another major benefit provided by the Projects has been a reduction in the frequency and magnitude of peak flows in the system. This is achieved through the storage in the reservoirs of peak flows generated within the watersheds upstream of the Nacimiento and San Antonio Reservoirs. This attenuates the peak flows, thereby reducing their effect on streamflow in the Salinas River.

For this HBA Update, streamflow data were used to develop a statistical distribution of peak annual streamflow in the Salinas River at Bradley with and without the Projects. The effects of selected peak flows in the Salinas River and its floodplain were then simulated using a 2-dimensional hydraulic model. This provides a quantitative demonstration of the effect the Projects have had on flood risk in the Basin.

FLOOD FLOW FREQUENCIES

For this HBA Update, flood flow magnitudes in the Salinas River at Bradley were estimated using 1) the results of the Historical and No Projects Scenarios, 2) measured streamflow data, 3) measured releases from and estimated inflow to Nacimiento and San Antonio Reservoirs, and 4) simulated streamflow in the Salinas River upstream of the reservoirs. The difference in flood flow magnitudes between the Historical and No Projects conditions represents the effect of the Projects.

Table ES-2 summarizes the peak flow magnitudes for selected annual exceedance probabilities (e.g. a 10-year flood). With the Projects, the 100-year flood at Bradley was estimated to be about 114,600 cfs, which is close to the largest actual observed streamflow at Bradley of 120,000 cfs (on March 11th, 1995). Without the Projects, the 100-year flood would have been about 159,000 cfs. This means that the Projects have reduced the 100-year flood magnitude by about 44,000 cfs, a 28% decrease. Without the Projects, the model suggests that the with-Projects 100-year flood magnitude of about 114,600 cfs would have occurred on average once every 34 years, which is about three times as frequently.

The Projects have had a proportionately larger impact on floods with more frequent recurrence intervals, such as the 25-year flood, which was decreased by 47%. This demonstrates that the reservoirs are more likely to have sufficient storage capacity to absorb the entirety of smaller peak flows generated in the reservoirs' watersheds.

Table ES-2. Peak Flow Magnitudes for Selected Return Probabilities, Observed and Estimated Streamflow Datasets			
Return Period (Years)	10	25	100
Annual Exceedance Probability	0.1	0.04	0.01
Observed Streamflow (WY 1968-2018)	35,700	65,900	132,900
Historical Scenario	28,500	53,400	114,600
No Projects Scenario	67,600	100,900	158,700
Difference Between Scenarios	+39,100	+47,500	+44,100
Percent Decrease Due to Projects	58%	47%	28%

Notes:

All peak flows are in cubic feet per second (cfs)

Difference between scenarios is calculated as No Projects Scenario peak flow minus Historical Scenario peak flow; this is the opposite of the calculation used in Hydrologic Benefits Analysis, and is used here to avoid plotting negative differences on logarithmic charts.

PEAK FLOW INUNDATION

Selected peak flows were used as input to a hydraulic model of the Salinas River and its floodplain to simulate the extent of inundation under the influence of the peak flow at Bradley. Simulations were conducted for 5-, 10-, 25-, and 100-year flows, with and without the Projects. Table ES-3 summarizes the flood inundated area (in acres) for selected return periods. Figures ES-8 and ES-9 shows the inundation areas and depth for the Historical and No Projects Scenarios, respectively, for the 100-year flood. Figure ES-10 shows the difference in the inundation depth between scenarios. The simulation results indicate that the Projects have effectively reduced the extent of inundation during flood events. For instance, the 100-year flood with the Projects resulted in about 60,000 acres of inundation, compared to about 65,000 acres without the Projects. This suggests that the Projects have decreased the 100-year flood inundation by about 5,000 acres.

Table ES-3. Inundated Area (in acres) for Selected Return Periods, Historical and No Projects Scenarios			
Return Period (Years)	10	25	100
Historical Scenario	31,700	45,400	60,000
No Projects Scenario	48,100	56,500	65,000
Difference Between Scenarios	-16,500	-11,100	-4,900

Notes:

Areas are rounded to the nearest 100 acres; totals may not sum due to rounding

Difference between scenarios is calculated as Historical Scenario minus No Projects Scenario.

Just as for the peak flow magnitudes, the Projects have decreased the extent of inundation resulting from more frequent flood events (e.g., the 25-year flood) to a greater degree than less frequent events (e.g., the 100-year flood;). For example, the 25-year flood inundated about 45,000 acres in the Historical Scenario, while the No Projects Scenario inundated about 57,000 acres. This difference equates to about 17 fewer square miles of floodplain inundated.

As shown in Figure ES-10, the Projects have also reduced the depth of flooding during peak flow events. Inundation under the 100-year flood was simulated to be as much as 10 feet lower with the Projects than without, and much of the floodplain experienced several feet less inundation depth due to the Projects.

Lastly, along with the decreased magnitude of peak flows and extent of flooding, the Projects have also reduced the velocity of flows within the inundated area, mitigating the risk of agricultural soil erosion and damage to structures in the floodplain. The linear flow velocity of water within the inundated area for the 100-year floods with and without the Projects is shown in Figure ES-11. The flow velocity with the Projects is mostly about 5 feet per second (fps) or less, with lower velocities in the northern part of the Basin and higher velocities in the southern part, where the floodplain is more constrained laterally. Without the Projects, the flow velocities would have been higher, between 5 and 10 fps across much of the floodplain.

These results demonstrate that the Projects have prevented the inundation of thousands of acres of land by decreasing peak flow magnitudes over the period since the reservoirs began operating.

Just as the Projects have reduced the magnitude of more frequent flood events (e.g., the 25-year flood) to a greater degree than the 100-year flood, the extent of inundation for these more frequent events is decreased more due to the Projects (Table ES-3). For example, the with-Projects 25-year flood inundated about 45,000 acres, while the without-Projects 25-year flood inundated about 57,000 acres.

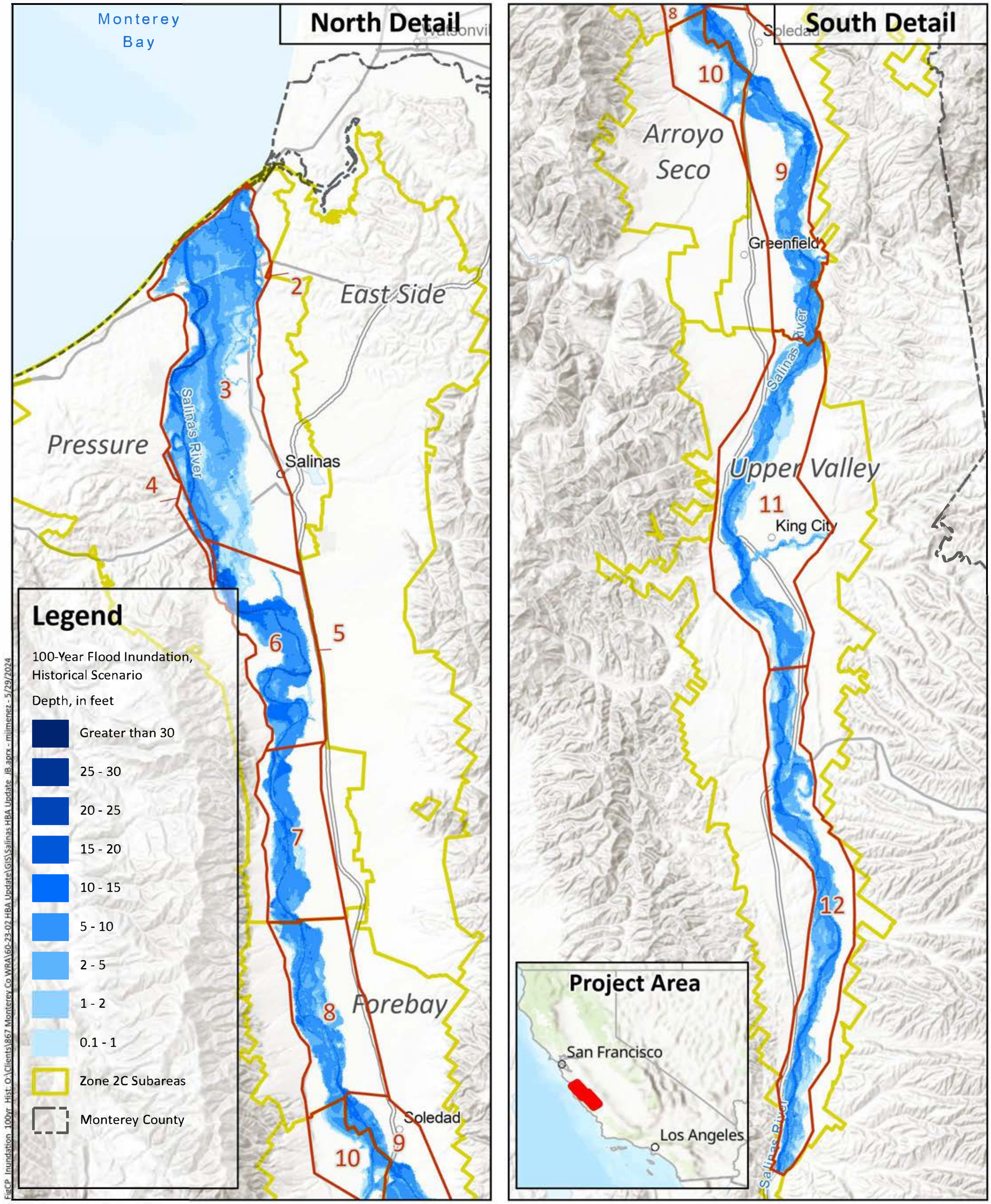
The Projects have also reduced the depth of flooding during peak flow events (compare Figures ES-8 and ES-9). Inundation under the 100-year flood was simulated to be as much as 10 feet lower with the Projects than without, and much of the floodplain experienced several feet less inundation depth due to the Projects.

Along with the decreased magnitude of peak flows and extent of flooding, the Projects have also reduced the velocity of flows within the inundated area. Figure ES-10 shows the linear flow velocity of water within the inundated area for the 100-year floods with and without the Projects. The flow velocity with the Projects is mostly about 5 feet per second (fps) or less, with lower velocities in the northern part of the Basin and higher velocities in the southern part, where the floodplain is more constrained laterally. Without the Projects, the flow velocities would have been higher, between 5 and 10 fps across much of the floodplain.

These results demonstrate that the Projects have prevented the inundation of thousands of acres of land by decreasing peak flow magnitudes over the period since the reservoirs began operating.

SOIL EROSION SUSCEPTIBILITY

The susceptibility of agricultural soils to erosion during inundation is a significant concern. The 1998 HBA categorized inundated soils into high, medium, or low susceptibility to erosion based on the flow velocity of the floodwater and the erodibility of the soil. This HBA Update follows the same approach to determine the Erosion Potential Index (EPI) throughout the inundated area. Table ES-4 summarizes the area, in acres, classified as low, medium, and high EPI for each scenario under selected return periods. The Projects have resulted in about 6,000 fewer acres being classified as high EPI for the 100-year flood event. This reduction in high EPI areas indicates that the Projects have substantially reduced the susceptibility of soil to erosion during flood events.



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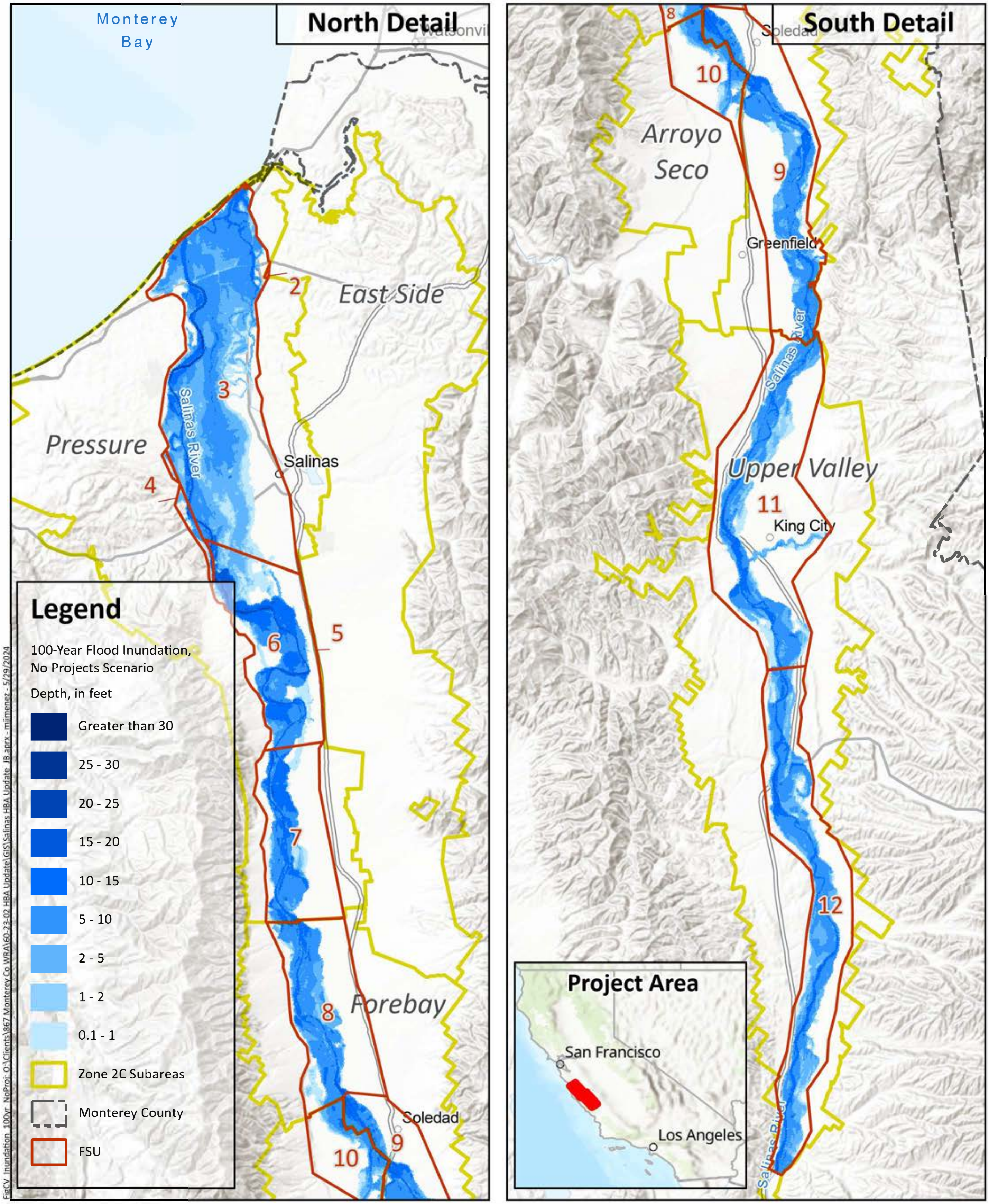
Inundation Area and Depth for 100-Year Flood
Historical Scenario

Figure ES-8



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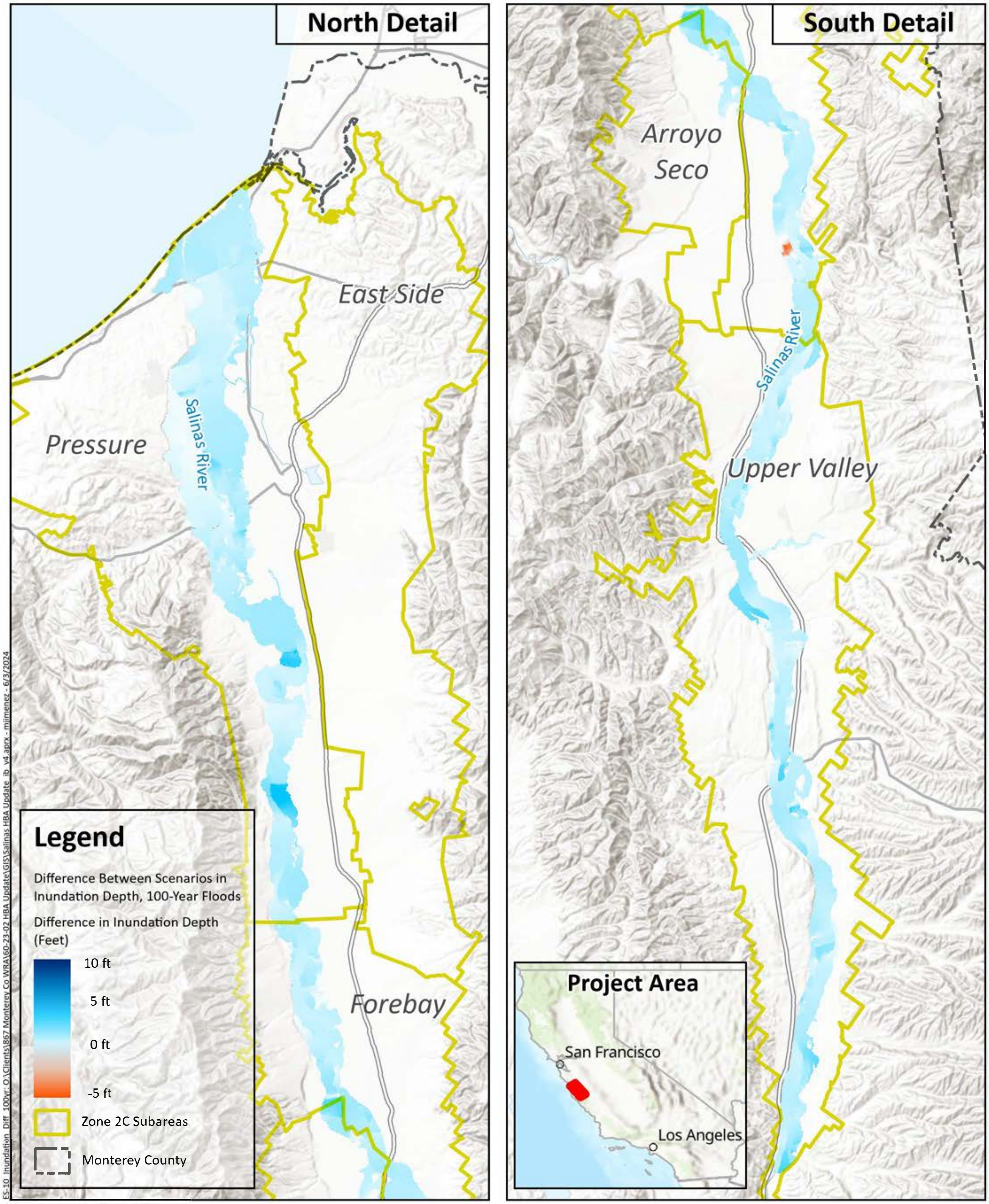
Inundation Area and Depth for 100-Year Flood
No Projects Scenario

Figure ES-9



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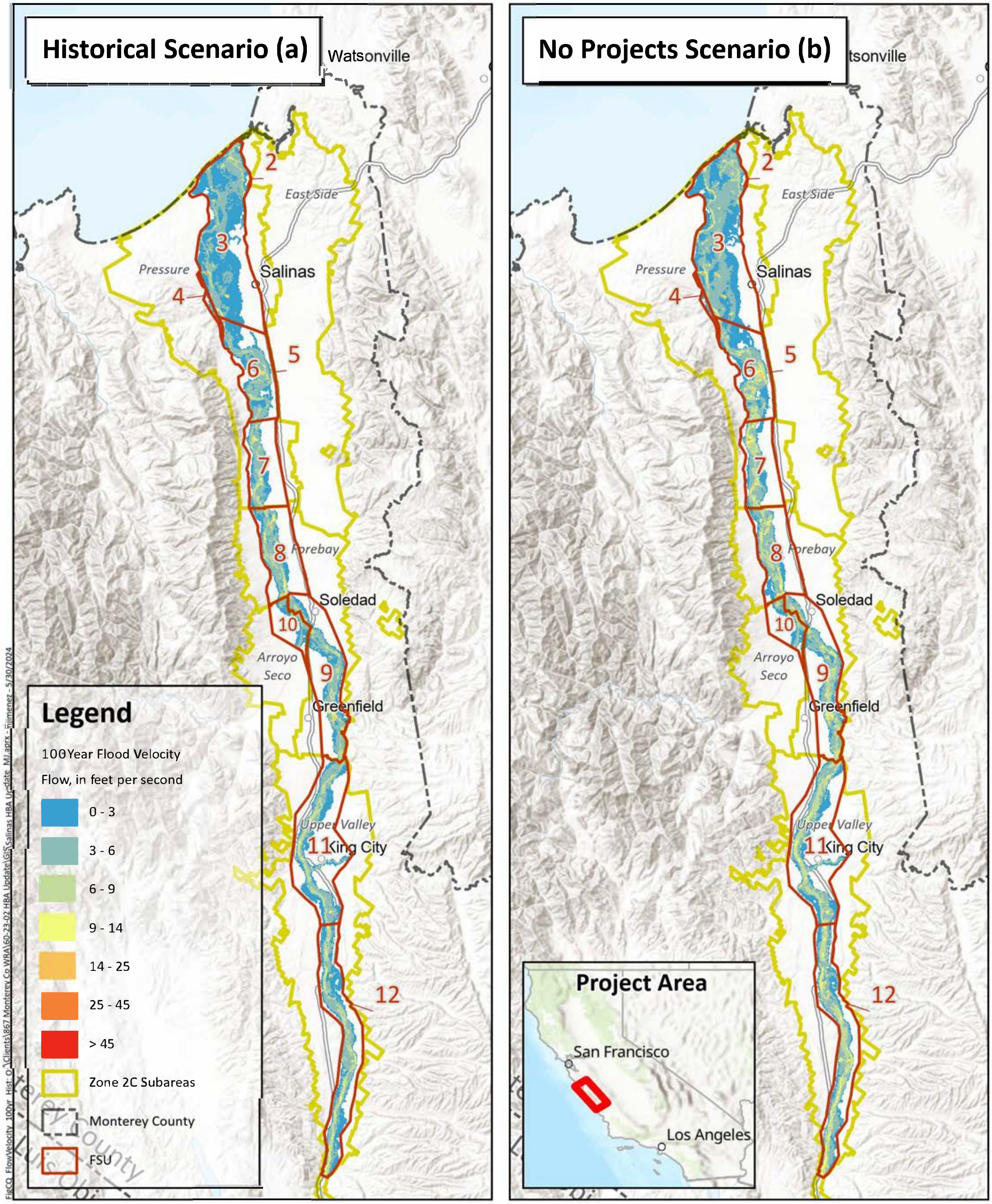
Water Resources Agency
Salinas Valley HBA
April 2025

Difference Between Scenarios in Inundation Depth for 100-Year Flood

Figure ES-10



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April 2025

Flow Velocity for 100-Year Flood

Figure ES-11

Table ES-4. Area in Each Erosion Potential Index Category for 100-Year Event in the Historical and No Projects Scenarios, in acres			
Erosion Potential Index Category	Low	Medium	High
Historical Scenario	22,300	23,200	11,000
No Projects Scenario	17,800	30,100	16,900
Difference Between Scenarios	+4,500	-6,900	-5,900

ECONOMIC BENEFITS ANALYSIS

The 1998 HBA provided an economic estimate of the benefit that stakeholders in the Basin have received from the reservoirs since their construction For this HBA Update, the quantification of economic benefit is being prepared separately and is not included in this report (One Water Econ, In Preparation).

OTHER BENEFITS

The Projects provide a range of benefits beyond the hydrologic and flood control benefits. While these additional benefits are not quantified, they are important. The Projects, particularly the reservoirs, have supported recreation and tourism, including camping, hiking, and fishing. Recreational benefits are evaluated and quantified in further detail in the Economic Benefits Analysis prepared by One Water Econ.

The Projects have contributed environmental benefits by supporting fish and wildlife habitat and the migration of endangered Steelhead trout between the Pacific Ocean and their spawning grounds in the Salinas River and its tributaries. The Projects provide peace of mind to Basin stakeholders by enhancing the predictability of streamflow in the Salinas River through peak flow magnitude reduction and the occurrence of years with little streamflow. Finally, the Projects serve as a safeguard against increased uncertainty in future conditions; with climate change potentially leading to greater climatic variability, the importance of the Projects' ability to store and redistribute flow captured during wet periods is likely to increase.

SUMMARY AND CONCLUSIONS

The Projects provide a range of benefits beyond the hydrologic and flood control benefits. While these additional benefits are not quantified, they are important. The Projects, particularly the reservoirs, have supported recreation and tourism, including camping, hiking, and fishing. Recreational benefits are evaluated and quantified in further detail in the Economic Benefits Analysis prepared by One Water Econ (One Water Econ, In Preparation).

The Projects have also contributed environmental benefits by supporting fish and wildlife habitat below the dams and the migration of endangered Steelhead trout between the Pacific Ocean and their spawning grounds in the Salinas River and its tributaries. The provision of recycled water to the CSIP area has also provided environmental benefits by reducing the discharge of treated wastewater into the Monterey Bay National Marine Sanctuary.

Finally, the Projects serve as a safeguard against increased uncertainty in future conditions; with climate change potentially leading to greater climatic variability, the importance of the Projects' ability to store and redistribute flow captured during wet periods is likely to increase. The Projects provide peace of mind to Basin stakeholders by enhancing the predictability of streamflow in the Salinas River through reduction in both peak flow magnitudes and the occurrence of years with little streamflow.

REFERENCES

California Department of Water Resources (DWR). 1946. Salinas Basin Investigation Summary Report. Bulletin 52-B. 68p.

Montgomery Watson (MW). 1998. Salinas Valley Historical Benefits Analysis (HBA). Prepared for Monterey County Water Resources Agency in association with CH2MHILL and Schaaf and Wheeler Associates. 297p. April 1998.

One Water Econ. In Preparation. Economic Benefits of MCWRA's Investments in Water Infrastructure Projects for Salinas Valley. Prepared for Monterey County Water Resources Agency.

CHAPTER 1
Introduction and Background

This report represents an update to the existing Salinas Valley Historical Benefits Analysis (HBA) prepared by Montgomery Watson (MW) in 1998, which quantified the benefits that the Salinas River Groundwater Basin (Basin) has accrued due to the construction of the Nacimiento and San Antonio Reservoirs. The goal of the work presented in this report is to update the analyses presented in the 1998 HBA to take advantage of an improved understanding of the Basin, improved tools, and additional data collection, and to address important changes in the approach to water resources management in the Basin since 1998. These changes include: production of recycled water at the Salinas Valley Reclamation Plant and distribution of that water for irrigation through the Castroville Seawater Intrusion Project (CSIP) system; development of the Salinas Valley Water Project (SVWP) and construction of the Salinas River Diversion Facility (SRDF); implementation of the Flow Prescription for setting streamflow targets to aid migration of Steelhead trout; construction of the Nacimiento Water Project (NWP); and additional changes to the operation of the Nacimiento and San Antonio Reservoirs. This report presents quantified benefits that have accrued to the Basin stakeholders over the 51-year period from Water Year (WY) 1968 to 2018 due to the presence of the Nacimiento and San Antonio Reservoirs and related projects and programs (referred to collectively in this report as “the Projects”). This quantification of benefit is used by the Monterey County Water Resources Agency (MCWRA) to demonstrate the continued effects these projects and programs have on the system and as part of the determination of assessments on stakeholders in the Basin.

This HBA Update was completed in fulfillment of the scope of services submitted by West Yost to the MCWRA on April 7, 2023. The scope of services was approved by the MCWRA Board of Directors on April 17, 2023 by Board Order No. 23-32.

1.1 ORGANIZATION OF REPORT

This HBA Update is organized into chapters that broadly follow the structure of the 1998 HBA. The nine chapters are:

- Chapter 1. Introduction and Background
- Chapter 2. Tools and Approach
- Chapter 3. Hydrologic Benefits Analysis
- Chapter 4. Flood Control Benefits Analysis
- Chapter 5. Economic Benefits Analysis
- Chapter 6. Other Benefits
- Chapter 7. Discussion of Uncertainty
- Chapter 8. Summary and Conclusions
- Chapter 9. References

1.2 STUDY AREA

The study area for this HBA Update is equivalent to the MCWRA assessment Zone 2C (Zone 2C), which falls within the Salinas Valley in coastal central California between the San Joaquin Valley and the Pacific Ocean, as shown on Figure 1-1. This section describes the context of water resources in the study area, including the hydrogeologic setting in which the study area resides, the history of water resources development in the study area, and the particular water-related issues that are of greatest concern.

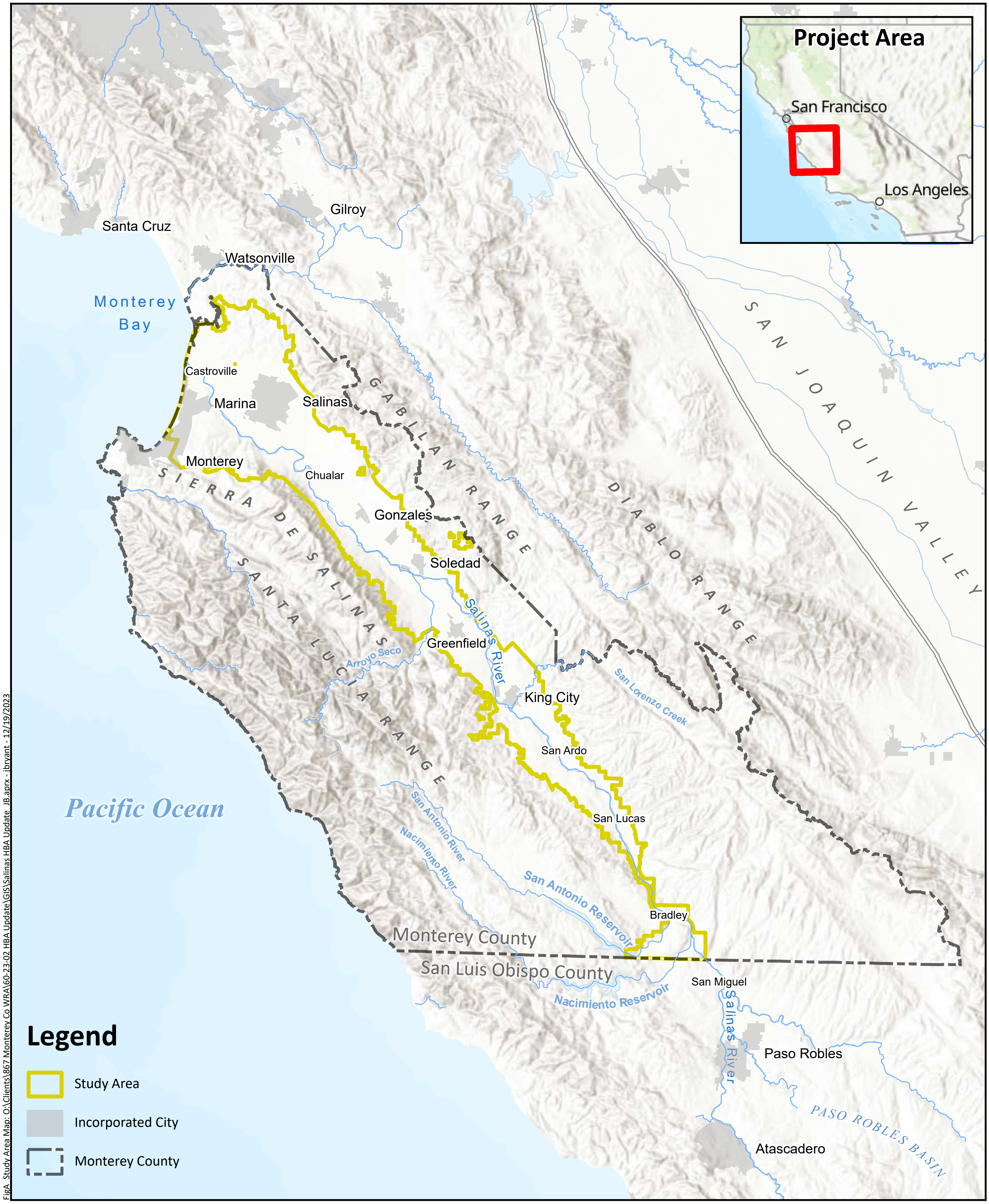
1.2.1 Study Area Overview

The Salinas Valley stretches along the Salinas River from its headwaters in San Luis Obispo County about 170 miles north to its outlet to the Pacific Ocean at Monterey Bay. The Salinas River watershed covers an area of more than 4,000 square miles, or more than 2.5 million acres. This study concentrates on the portion of the Salinas River watershed north of San Miguel, where the Salinas Valley narrows after passing through the Paso Robles Basin. Major tributaries to the Salinas River within the study area include the Nacimiento River (on which Nacimiento Reservoir lies), the San Antonio River (on which San Antonio Reservoir lies), San Lorenzo Creek, Arroyo Seco, Alisal Creek, and El Toro Creek. The study area also includes some areas outside of the Salinas River watershed that are tributary to Elkhorn Slough and Monterey Bay.

The study area is bounded on the east and west by mountain ranges. The eastern boundary comprises the Gabilan and Diablo Ranges, while the western boundary comprises the Sierra de Salinas and the Santa Lucia Range. The northern boundary lies along Elkhorn Slough and the hills to its east. The southern extent of the study area is defined based on a lateral constriction of the alluvial valley as the eastern and western bounding ranges approach the Salinas River.

The Salinas Valley is bounded on either side by normal faults that accommodate the uplift of the bounding mountain ranges. The geologic history and current geologic context of the Salinas Valley are described in detail in Rosenberg (2001); this history has resulted in low-permeability bedrock mountain ranges bounding an alluvial basin in which the sediment thickness is as great as 12,000 feet. The depositional environment has varied from fluvial to marine over time, depending on the location, tectonic history, and sea level fluctuations (Kennedy/Jenks, 2004). The structural and depositional history of the Basin have resulted in a deep, productive alluvial basin that can be broadly broken into two regions: a southern region where groundwater is unconfined and resides in undifferentiated aquifers made up of largely fluvial and alluvial sediments, and a northern region where groundwater is contained in a series of confined to semi-confined aquifers made up of fluvial, alluvial, and marine sediments, including extensive but discontinuous fine-grained confining layers. This hydrostratigraphic context has been critical to the past and present of water resources development in the Basin.

The study area land use is heavily agricultural, but also includes a number of urban areas and rural, unincorporated communities. The total value of agricultural production in Monterey County in 2021 was over $4 billion from about 300,000 irrigated acres (County of Monterey Agricultural Commissioner, 2022), most of it within the Salinas Valley. Cities and unincorporated communities within the study area include Bradley, Castroville, Chualar, Gonzales, Greenfield, King City, Marina, Salinas, San Ardo, San Lucas, and Soledad. Both the agricultural users and the population place heavy demands on groundwater in the Basin, which represents by far the largest source of water to users. Of this, agricultural use is by far the dominant use of groundwater in the Basin, representing about 90 percent of total metered pumping (e.g., Brown and Caldwell, 2015a).



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Salinas Valley
HBA Update
Study Area

Figure 1-1

1.2.2 Relevant Research

Since the 1998 HBA was prepared, numerous studies have contributed to advancing the understanding of the geology and hydrology of the study area. Some of these studies are listed below:

- Seafloor Rocks and Sediments of the Continental Shelf from Monterey Bay to Point Sur, California (Eittreim et al., 2000)
- Hydrogeologic Investigation of the Salinas Valley Basin in the Vicinity of Fort Ord and Marina (Harding ESE, 2001)
- Geologic Resources and Constraints, Monterey County, California (Rosenberg, 2001)
- Geohydrology of a Deep-Aquifer System Monitoring-Well Site at Marina, Monterey County, California (Hanson et al., 2002)
- North Monterey County Comprehensive Water Resources Management Plan (MCWRA and EDAW, 2002)
- Deep Aquifer Investigation – Hydrogeologic Data Inventory, Review, Interpretation and Implications (Feeney and Rosenberg, 2003)
- Geohydrologic Framework of Recharge and Seawater Intrusion in the Pajaro Valley, Santa Cruz and Monterey Counties, California (Hanson, 2003)
- Hydrostratigraphic Analysis of the Northern Salinas Valley (Kennedy/Jenks, 2004)
- Installation of Deep Aquifer Monitoring Wells – DMW-2 (MACTEC, 2005)
- Seaside Groundwater Basin Watermaster Seawater Sentinel Wells Project Summary of Operations (Feeney, 2007)
- El Toro Groundwater Study (Geosyntec, 2007)
- Protective Elevations to Control Sea Water Intrusion in the Salinas Valley (Geoscience, 2013)
- State of the Salinas River Groundwater Basin (Brown and Caldwell, 2015a)
- Recommendations to Address the Expansion of Seawater Intrusion in the Salinas Valley Groundwater Basin (MCWRA, 2017)
- Recommendations to Address the Expansion of Seawater Intrusion in the Salinas Valley Groundwater Basin – 2020 Update (MCWRA, 2020)
- California's Groundwater – Update 2020 (DWR, 2021)
- Eastside Aquifer Subbasin Groundwater Sustainability Plan (SVBGSA, 2022a)
- Forebay Aquifer Subbasin Groundwater Sustainability Plan (SVBGSA, 2022b)
- Langley Area Subbasin Groundwater Sustainability Plan (SVBGSA, 2022c)
- Upper Valley Aquifer Subbasin Groundwater Sustainability Plan (SVBGSA, 2022d)
- 180/400-Foot Aquifer Subbasin Groundwater Sustainability Plan 2022 Update (SVBGSA, 2022e)
- Groundwater Sustainability Plan, Monterey Subbasin (MCWDGSA and SVBGSA, 2022)

These studies have contributed to an increased understanding of Basin characteristics, and their results have been used to develop the tools and analyses that allow for in-depth, holistic representation of the

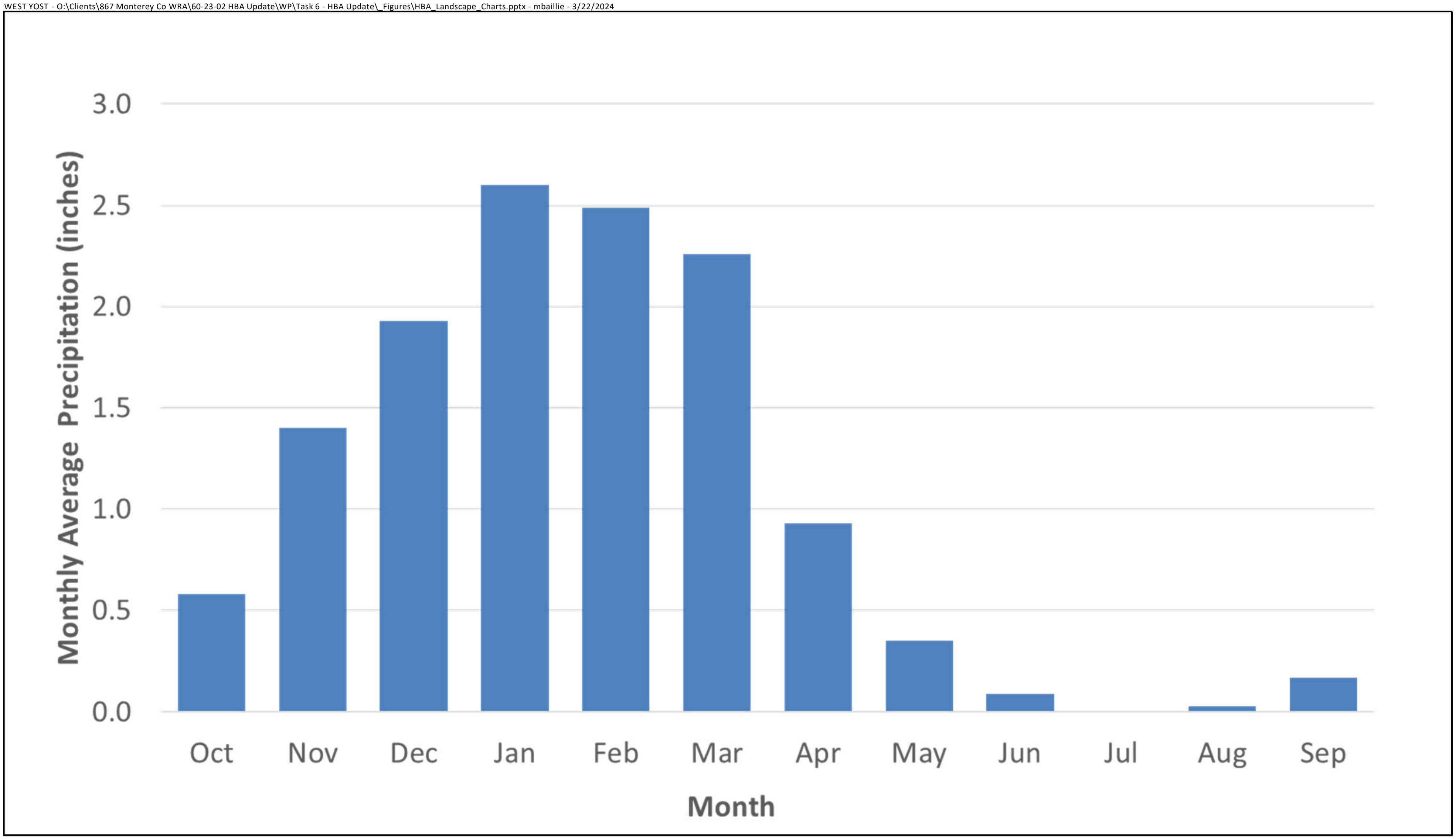
Basin. Of particular importance are the models under development by the U.S. Geological Survey (USGS) that were used to assist with preparation of this report (as described in Chapter 2 of this report).

1.2.3 Hydrologic Setting

The study area lies within coastal Central California, an area with a Mediterranean climate typified by mild, dry summers and cool, wet winters. As shown on Figure 1-2, about 90 percent of the annual rainfall occurs during the period from November to April. The seasonal rainfall pattern results in highly seasonal natural streamflow distribution in the study area. Figure 1-3 shows the monthly average streamflow at the USGS Arroyo Seco near Soledad stream gauge (#11152000), which was chosen because it represents a location of relatively high, unregulated streamflow in the study area. Figure 1-4 illustrates the spatial distribution of rainfall in the study area, which is highly impacted by topography, with the highest average annual rainfall occurring on the mountain ranges that bound the study area, especially on the coastal Santa Lucia Range to the west.

As a result of its complex depositional history, the Basin contains a heterogeneous mix of alluvial, fluvial, and marine sediments. For analytical and documentational purposes, this complexity has been simplified into a hydrostratigraphy with defined aquifers and aquitards in parts of the Basin, based on the presence of extensive connected sediments that respond in similar ways to regional stresses, as detailed in hydrogeologic cross-sections present in Kennedy/Jenks, 2004 and Brown and Caldwell, 2015a. As noted above, the Basin can generally be divided into two broad hydrostratigraphic regions, with the northern region hosting a series of confined to semi-confined aquifers interspersed with aquitards, and the southern region hosting a generally continuous sequence of unconfined fluvial and alluvial sediments (e.g., Kennedy/Jenks, 2004).

The sediments of the basin are generally interconnected in various ways, although hydrostratigraphic units (such as aquifers and aquitards) have been defined based on the long experience of hydrogeologists and groundwater users. Although there are no structural barriers within the Basin that compartmentalize groundwater in the system, differences in the generalized hydrostratigraphic context in different parts of the Basin have led to its division into subbasins. Figure 1-5 shows groundwater subbasins that make up the study area as defined by the California Department of Water Resources (DWR). The study area includes part or all of the 180/400 Foot Aquifer (DWR 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), and Monterey (3-004.10) Subbasins. MCWRA subdivides the Basin somewhat differently. Figure 1-6 shows the MCWRA-defined groundwater subareas that make up Zone 2C; this approach divides the study area into the Pressure, East Side, Forebay, Arroyo Seco, Upper Valley, and Below Dam Subareas. This HBA Update presents results based on the Zone 2C Subarea definitions.

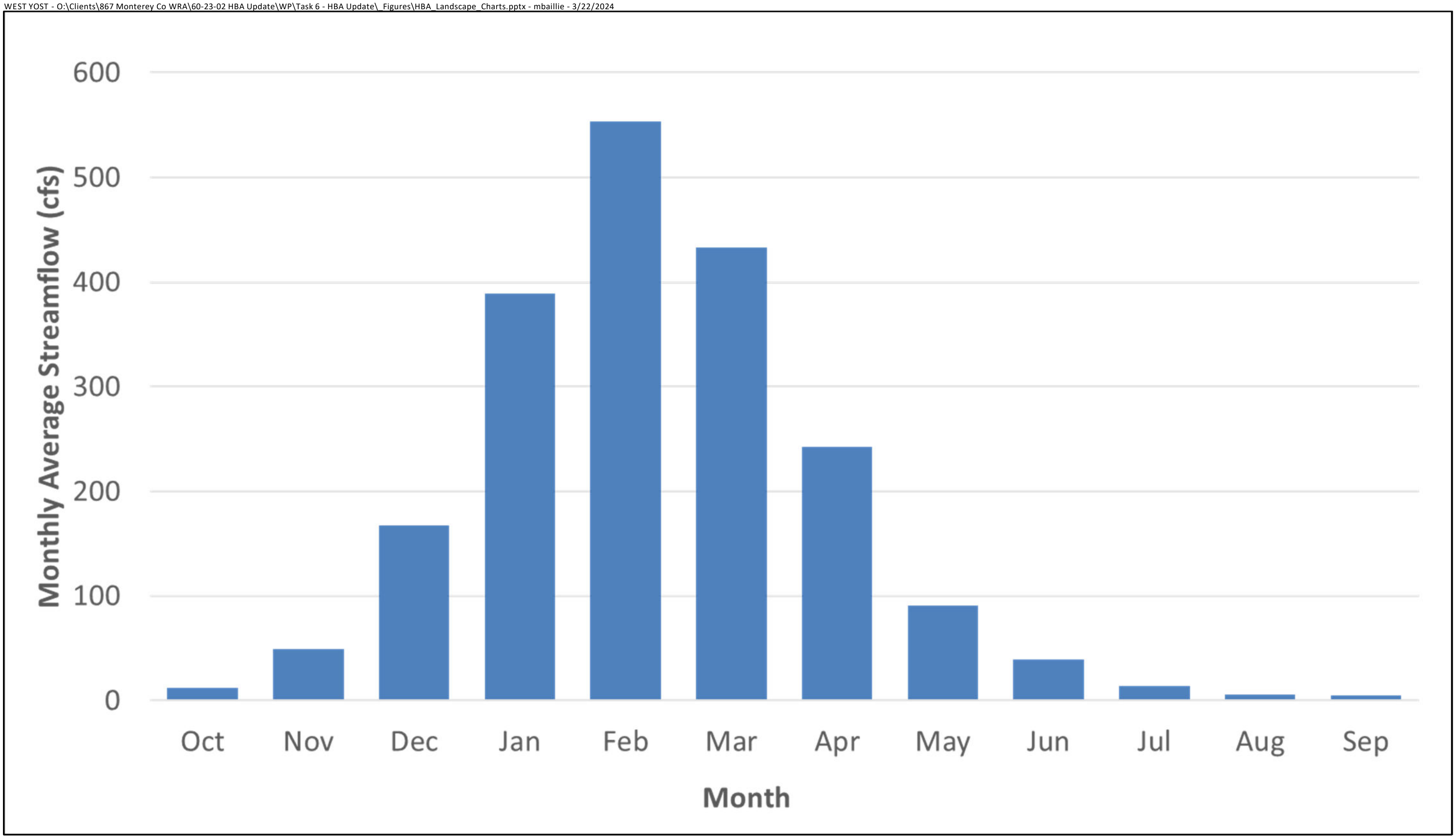


Notes:

1. Source: PRISM Climate Group, Oregon State University, https://prism.oregonstate.edu, data created 12 Sep 2013, accessed 20 Aug 2015.
2. Data represent monthly average rainfall values over period from Water Years 1981 to 2010

Figure 1-2

Monthly Average Rainfall, Salinas Municipal Airport



Notes:

1. Source: USGS
2. Average monthly streamflows for the period from Oct 1901 to Sep 2022

Figure 1-3

Monthly Average Streamflow, Arroyo Seco near Soledad Gauge

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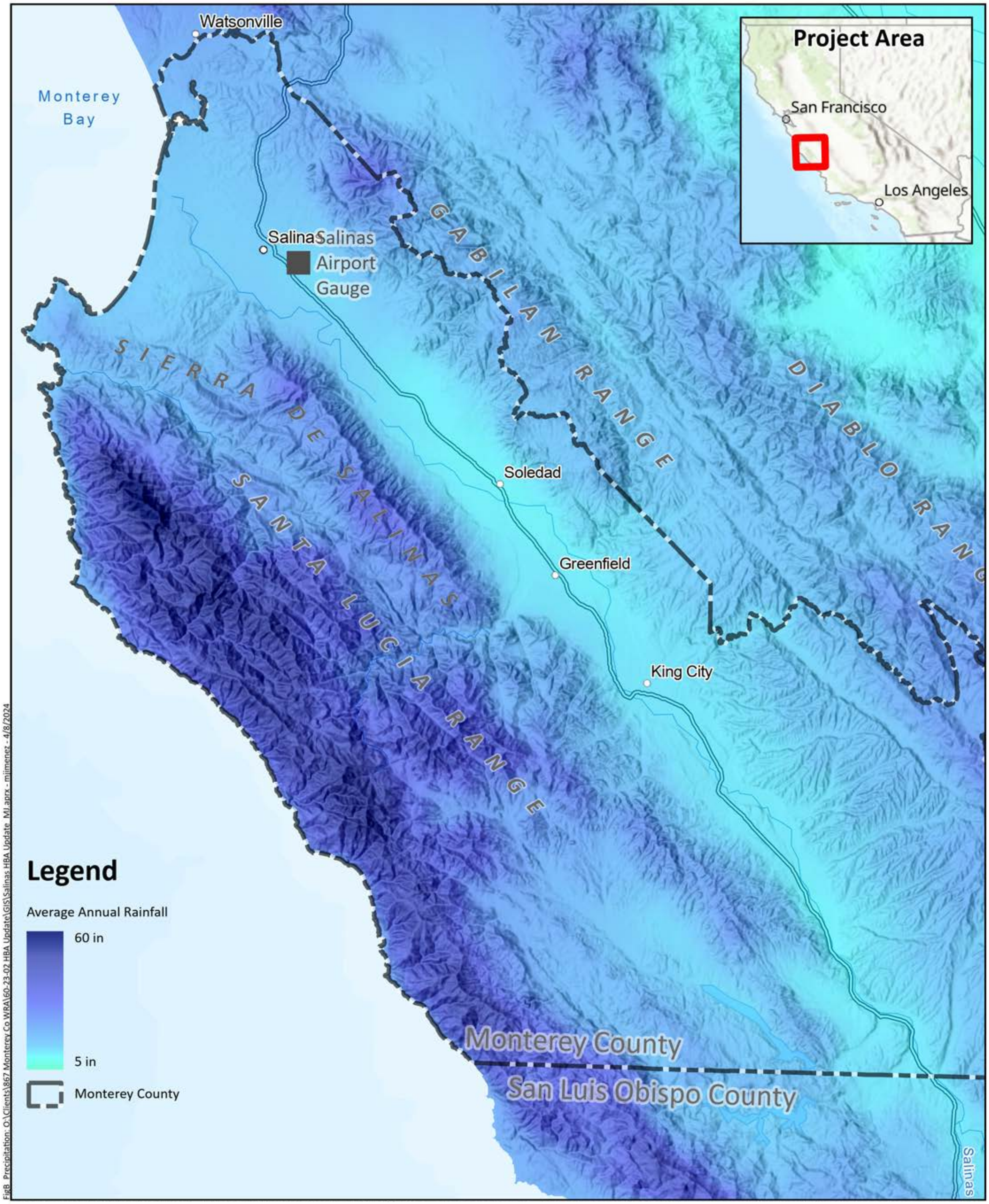

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Source: PRISM Climate Group, Oregon State University, https://prism.oregonstate.edu, data created 12 Sep 2013, accessed 20 Aug 2015. Data represent monthly average rainfall values over the period from Water Year 1981 to 2010.

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Salinas Valley HBA Update
May 2024

Regional Distribution of Annual Rainfall

Figure 1-4

Source: DWR, 2021

Prepared by:

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0 5 10 Miles

0 8 16 Km

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Monterey County Water Resources Agency
Salinas Valley HBA Update
April 2025

DWR-Defined Groundwater Subbasins

Figure 1-5

Source: MCWRA

Prepared by:

WEST YOST

Miles 0 5 10

Km 0 8 16

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Monterey County Water Resources Agency
Salinas Valley HBA Update
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MCWRA Zone 2C Subareas

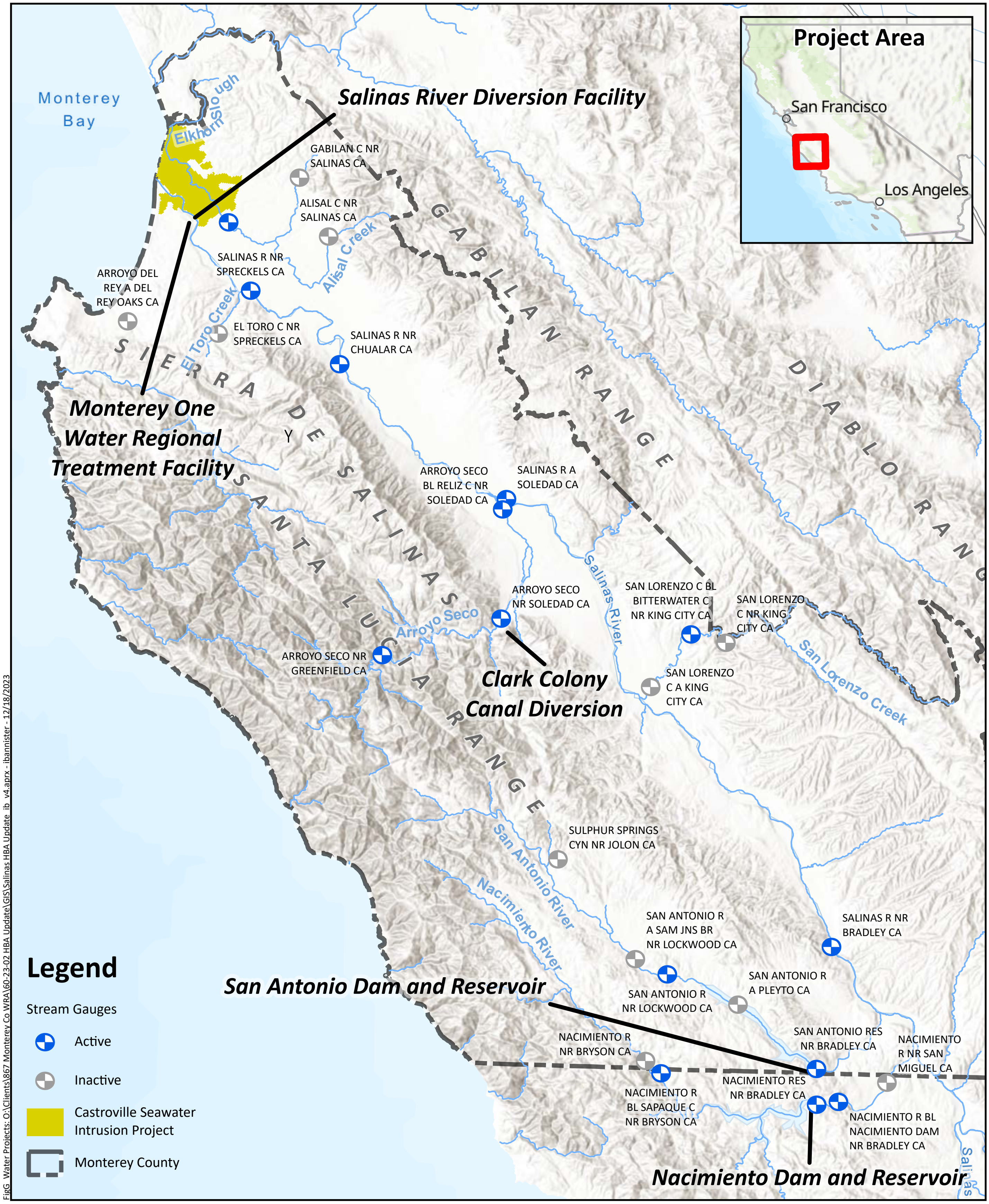
Figure 1-6

Detailed hydrogeologic studies have revealed that the aquifers and aquitards of the northern region are discontinuous, particularly approaching the foothills of the Gabilan Range. The coastal area contains three major freshwater supply aquifers – termed the 180-Foot, 400-Foot, and Deep Aquifers – separated from each other by aquitards made up of fine-grained sediments. There is also a thin aquifer made up of surficial sediments overlying the uppermost aquitard, but it is not generally used for water supply. On the eastern side of the northern region, the defined layering present in the coastal area breaks down into a sequence of thin, discontinuous coarse- and fine-grained layers in which groundwater exists in semi-confined conditions; in this area, the sediments are typically broken into a Shallow Aquifer and a Deep Aquifer, generally mapped (e.g., by MCWRA) as hydrologically equivalent of the 180-Foot and 400-Foot Aquifers, respectively. A transition zone lies between the confined and semi-confined portions of the northern region (Kennedy/Jenks, 2004). The aquitards present in the northern region pinch out to the south around Chualar; south of this point, the aquifers are in an unconfined state (Brown and Caldwell, 2015a).

The Salinas River is the dominant hydrologic feature in the study area, running from south to north through the Salinas Valley and gathering tributary flow from the watersheds that drain the surrounding mountain ranges (Figure 1-7). The Salinas River enters the study area from the Paso Robles Basin to the south, ultimately discharging into Monterey Bay near the town of Marina. Beyond about San Ardo, the Salinas River is a low-gradient, meandering river that runs more or less down the center of the Salinas Valley except where major tributaries, such as Arroyo Seco, have delivered sediments that have pushed the course of the Salinas River to one side or the other of the Valley.

In general, the Salinas River loses water to the Basin aquifers throughout the study area. Communication between the river and the aquifers is limited where fine-grained sediments underlie the river, acting as a barrier to exchange between the groundwater and surface water systems. As described above, extensive, continuous fine-grained sediments are present in the northern region of the Basin, especially the coastal area. The uppermost aquitard, the Salinas Valley Aquitard, limits the amount of recharge that the Salinas River is able to provide to the freshwater aquifers.

There are a few significant manmade structures and projects that impact groundwater and surface water flow in the study area (Figure 1-7) and discussed in more detail in Section 1.2.4. The two large surface water reservoirs present at the southern end of the study area, the Nacimiento and San Antonio Reservoirs, store streamflow generated in the watersheds of the Nacimiento and San Antonio Rivers, which are tributary to the Salinas River. These reservoirs are owned and operated by MCWRA for the purposes of flood control, water conservation, support of fish migration and fish and wildlife habitat, and recreation. Two diversions exist to provide surface water to agricultural users in the study area. The Clark Colony Canal diverts water from Arroyo Seco and delivers it to users in an area to the southwest of Greenfield. The SRDF diverts water from the Salinas River and delivers it to agricultural users in the CSIP area near Castroville. Finally, the Monterey One Water Recycled Water Facility treats wastewater generated in the northern region of the study area and delivers it to agricultural uses in the CSIP area.



Prepared by:

WEST YOST

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Salinas Valley HBA Update
April 2025

Salinas Valley Surface Water Network and Water Projects

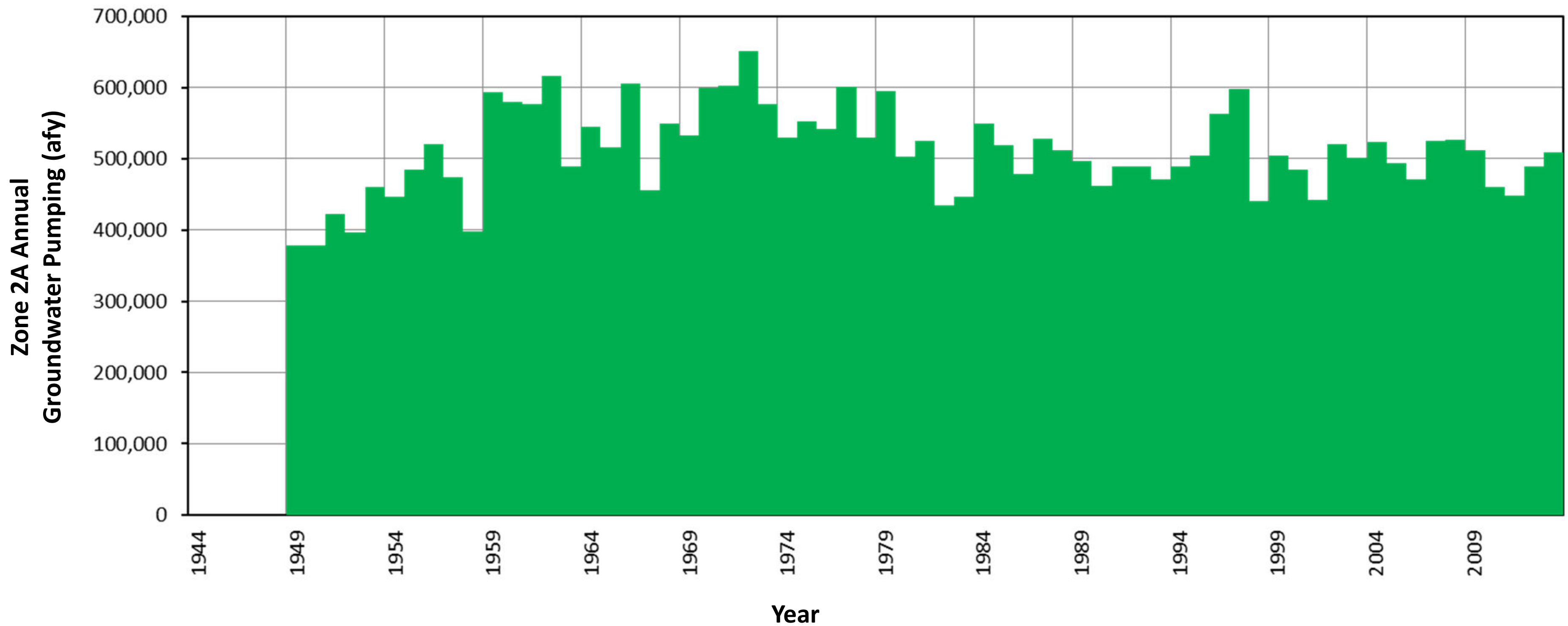
Figure 1-7

1.2.4 Water Resources Development in the Basin

Groundwater resources of the study area have been utilized to supply agricultural users since the late 19th century (DWR, 1946). The development of water resources in the Basin has been driven largely by agricultural demand, which grew over the course of the 20th century as the amount of irrigated acreage increased (MW, 1998). Total groundwater pumping reported to MCWRA for Zone 2A (which is a slightly smaller area than Zone 2C) increased from about 400,000 acre-feet per year (afy) in 1949 to about 600,000 afy by 1959, and has decreased slightly since then, generally falling between 400,000 and 500,000 afy over the past several decades (Figure 1-8).

Declining groundwater head in the middle part of the 20th century, especially in the northern part of the Basin, demonstrated that groundwater pumping was increasing beyond the capability of the natural system to replenish the aquifers. The projects and programs that have been constructed in the study area have sought to address this imbalance. Nacimiento Reservoir became operational in WY 1958, followed by San Antonio Reservoir in WY 1968. The reservoirs retain more water within the Basin by holding high flows back behind the dams in the winter when they would otherwise largely flow out to the ocean and releasing them in the summertime when the recharge potential along the Salinas River is at its highest. The presence of the reservoirs reversed groundwater storage losses in the southern region of the study area (the Forebay and Upper Valley Subareas; Brown and Caldwell, 2015a), but not in the northern region (the Pressure and East Side Subareas). This result can be attributed to the spatial variability in the connection between the Salinas River and the underlying aquifers described in Section 1.2.1; increasing recharge through the Salinas River has the most direct impact on aquifers that are hydraulically connected to the river.

To help address seawater intrusion in the 180- and 400-Foot Aquifers, MCWRA constructed the CSIP, a pipeline system that distributes recycled wastewater from the Monterey One Water Regional Treatment Plant to agricultural users in the area around the town of Castroville (Figure 1-7). The intention of the CSIP is to reduce pumping in the coastal areas of the main production aquifers by providing an alternative supply, increasing freshwater storage through in-lieu recharge, and slowing the occurrence of seawater intrusion in this area. Construction of CSIP started in 1995 and recycled water deliveries started in 1998.



Notes:
1. Source: Brown and Caldwell, 2015a

Figure 1-8

Annual Zone 2A Groundwater Pumping

To help provide additional flexibility and introduce more tools to manage seawater intrusion, MCWRA developed the SVWP, which consists of two major components: modification of the spillway at Nacimiento Dam to increase the reservoir storage capacity; and construction of the SRDF near Blanco (Figure 1-7). The spillway modification, completed in 2009, consisted of the installation of an Obermeyer gate on top of the existing Nacimiento Dam spillway, which increases the spillway crest elevation. The gate allows Nacimiento Reservoir to store additional water, especially during the winter wet season, which allows for the reservoir stage to increase while retaining the ability to pass the Probable Maximum Flood. The SRDF, completed in 2010, consists of an inflatable rubber dam that stretches across the Salinas River, impounding streamflow in the Salinas River, diverting and treating it at the Salinas Valley Reclamation Plant, and delivering it to the CSIP distribution pipeline system.

As conditions and infrastructure in the basin have changed, the approach to operating the Nacimiento and San Antonio Reservoirs has been modified. A detailed discussion of the current and prior operational approaches for the reservoirs is beyond the scope of this report. Important alterations have resulted from the infrastructure projects described above and the development of the Flow Prescription that focused on modifying operations to support the migration of endangered Steelhead trout in the Salinas River and its tributaries, and critical fish and wildlife habitat below the Nacimiento and San Antonio Dams (MCWRA, 2005). MCWRA has published documentation of their current operational approach for Nacimiento Reservoir (MCWRA, 2018). Wood (2023) provides a discussion of the current operational approach as it was implemented in the groundwater-surface water modeling performed to support the Environmental Impact Report for the proposed Nacimiento-San Antonio Interlake Tunnel and Spillway Modification Project.

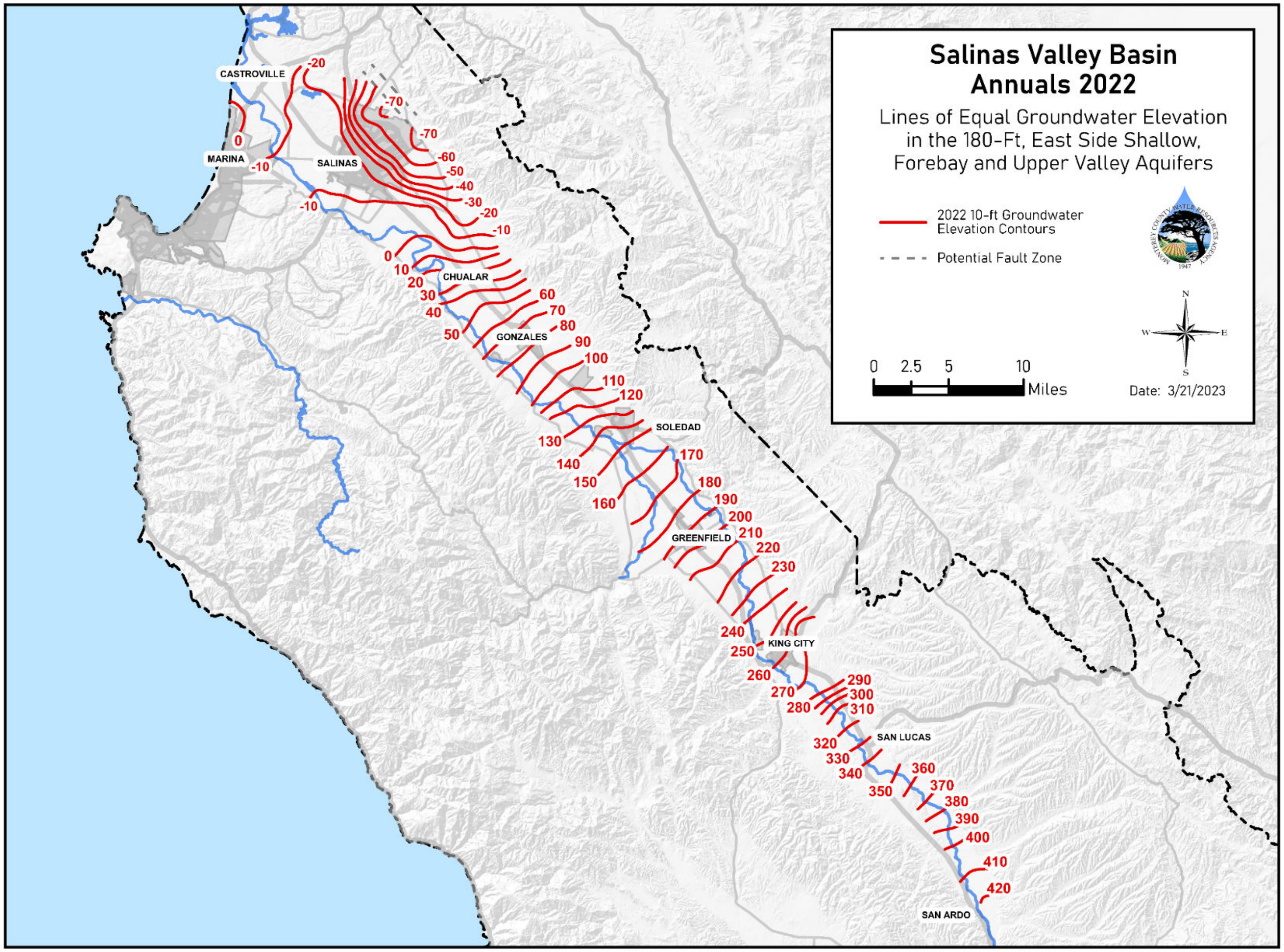
1.2.5 Groundwater Issues in the Basin

The Basin has been in an overall condition of overdraft for decades due to its long history of intense irrigated agriculture, a near-total reliance on groundwater, and its complex hydrogeology. This overdraft has resulted in reductions in groundwater in storage, depressed groundwater head in all major water supply aquifers, and seawater intrusion into the Basin. The severity of these issues led to all of the non-adjudicated portions of the Basin being categorized as Medium or High Priority by DWR, and the Pressure Subbasin categorized as critically overdrafted (DWR, 2021). Manifestations of these issues occur most prominently in the northern part of the Basin, specifically the Pressure and East Side Subareas, where fine-grained units prevent substantial replenishment of depleted aquifers from the Salinas River.

MCWRA has monitored groundwater head conditions throughout the Basin since the 1940s, and has prepared annual to biannual groundwater head maps since 1994 (available on https://www.co.monterey.ca.us/government/government-links/water-resources-agency/documents/groundwater-elevation-contours, accessed September 15, 2023). These maps demonstrate the groundwater head decline that has continued since at least the 1980s, with the lowest observed groundwater heads occurring in the East Side subarea and seasonal lows occurring near the end of the summer irrigation season. Figure 1-9 shows contours of groundwater elevation (referred to throughout this report as groundwater head) in the 180-Foot Aquifer, East Side Shallow, Forebay, and Upper Valley Aquifers in Fall 2022 (i.e., after the irrigation season and before seasonal rainfall). Figure 1-10 shows groundwater head contours in the 400-Foot Aquifer and East Side Deep Aquifers in Fall 2022. Figure 1-11 shows groundwater head contours in the 180-Foot and East Side Shallow Aquifers in August 2022 (i.e., near the end of the irrigation season). Figure 1-12 shows groundwater head contours in the 400-Foot and East Side Deep Aquifers in August 2022. These maps show groundwater heads well below sea level in much of the northern part of the Basin, both during and after the main part of the irrigation season. Near the end of the irrigation season, in August 2022, groundwater head was as much as 130 feet below sea level in the East Side Deep Aquifer (Figure 1-12).

Depressed groundwater heads equate to a loss of total storage in the aquifers of the Basin. The 2015 State of the Basin Report (Brown and Caldwell, 2015a) presented an analysis of storage changes by subarea since the mid-1940s, based on annual subarea-average groundwater head changes provided by MCWRA (Figure 1-13). This analysis showed that groundwater storage in the Basin decreased by nearly 800,000 acre-feet (af) by the peak of the mid-1990s drought, rebounding to a decrease of around 500,000 af by 2014. The largest proportion of the storage loss happened in the East Side Subarea (about 300,000 af by 2014). The Pressure Subarea also saw substantial declines in storage (about 100,000 af by 2014) that resisted replenishment during wet periods. The Forebay and Upper Valley Subareas have also experienced extensive declines in storage during very dry periods, but these tended to recover during wet periods. The completion of the Nacimiento and San Antonio Reservoirs in 1957 and 1967, respectively, led to a reversal of the storage loss in the Forebay and Upper Valley Subareas (except during extended dry periods), but not in the Pressure and East Side Subareas.

Seawater intrusion was recognized in the Basin as early as the 1930s (DWR, 1946). MCWRA has monitored chloride levels in the northern part of the Basin since then, and sporadically publishes updated maps of the extent of seawater intrusion in the 180-Foot and 400-Foot Aquifers in the Pressure Subarea – these maps have been reproduced as Figures 1-14 and 1-15, respectively. The extent of seawater intrusion has continued to migrate inland over the past 80 years, progressing to the outskirts of Salinas in recent years, about 8 miles from the coast. The extent of seawater intrusion in the 400-Foot Aquifer (Figure 1-15) shows the importance of cross-aquifer communication (through wells screened across both aquifers, poorly constructed wells, or discontinuities in the aquitard separating them), with a large area experiencing elevated chloride concentrations well east of the main body of the seawater intrusion front.



Notes:

1. Source: MCWRA

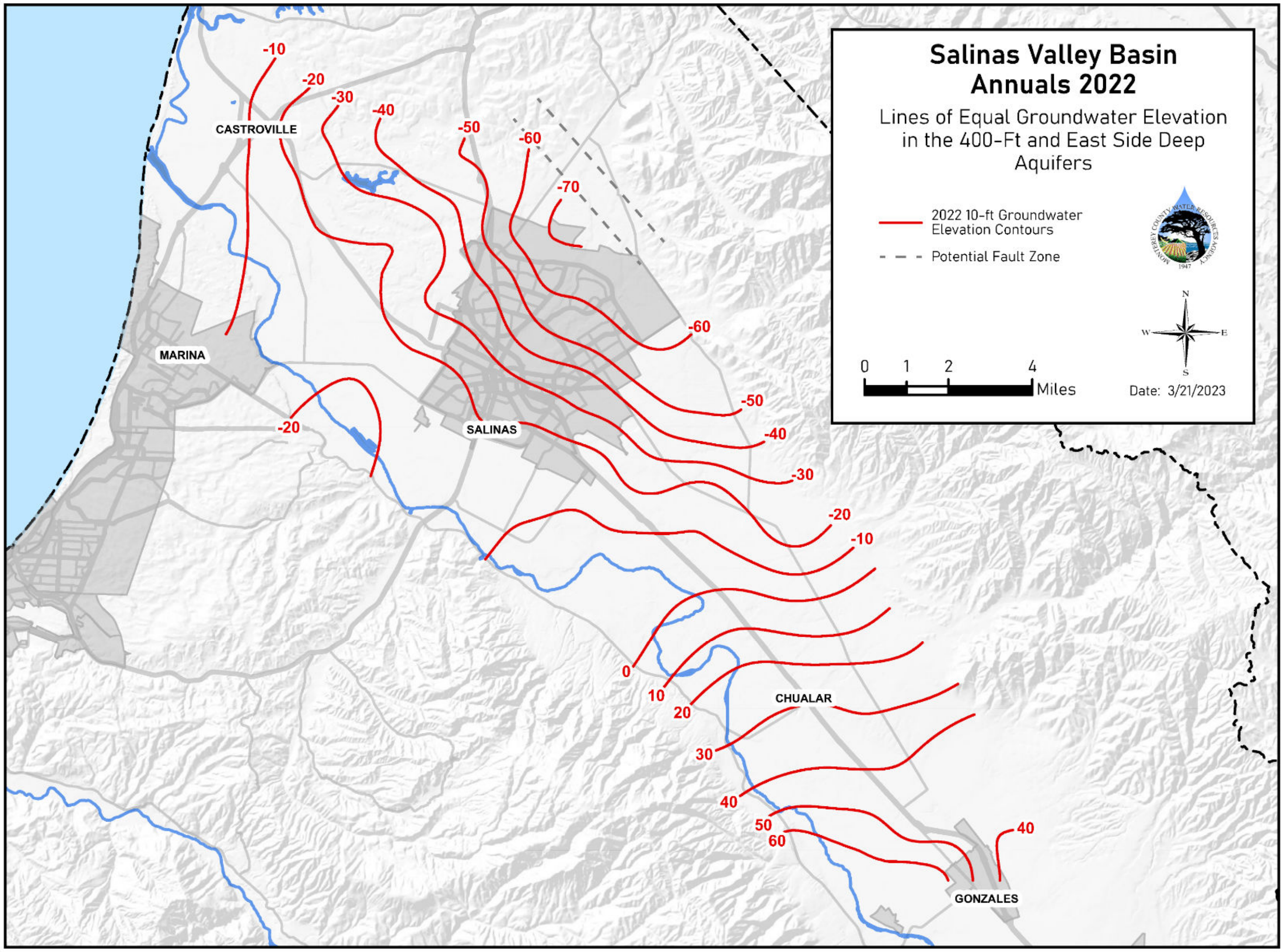
Figure 1-9

Groundwater Head in 180-Foot Aquifer (and Equivalent), Fall 2022

Monterey County Water Resources Agency

Historical Benefits Analysis Update

April 2025

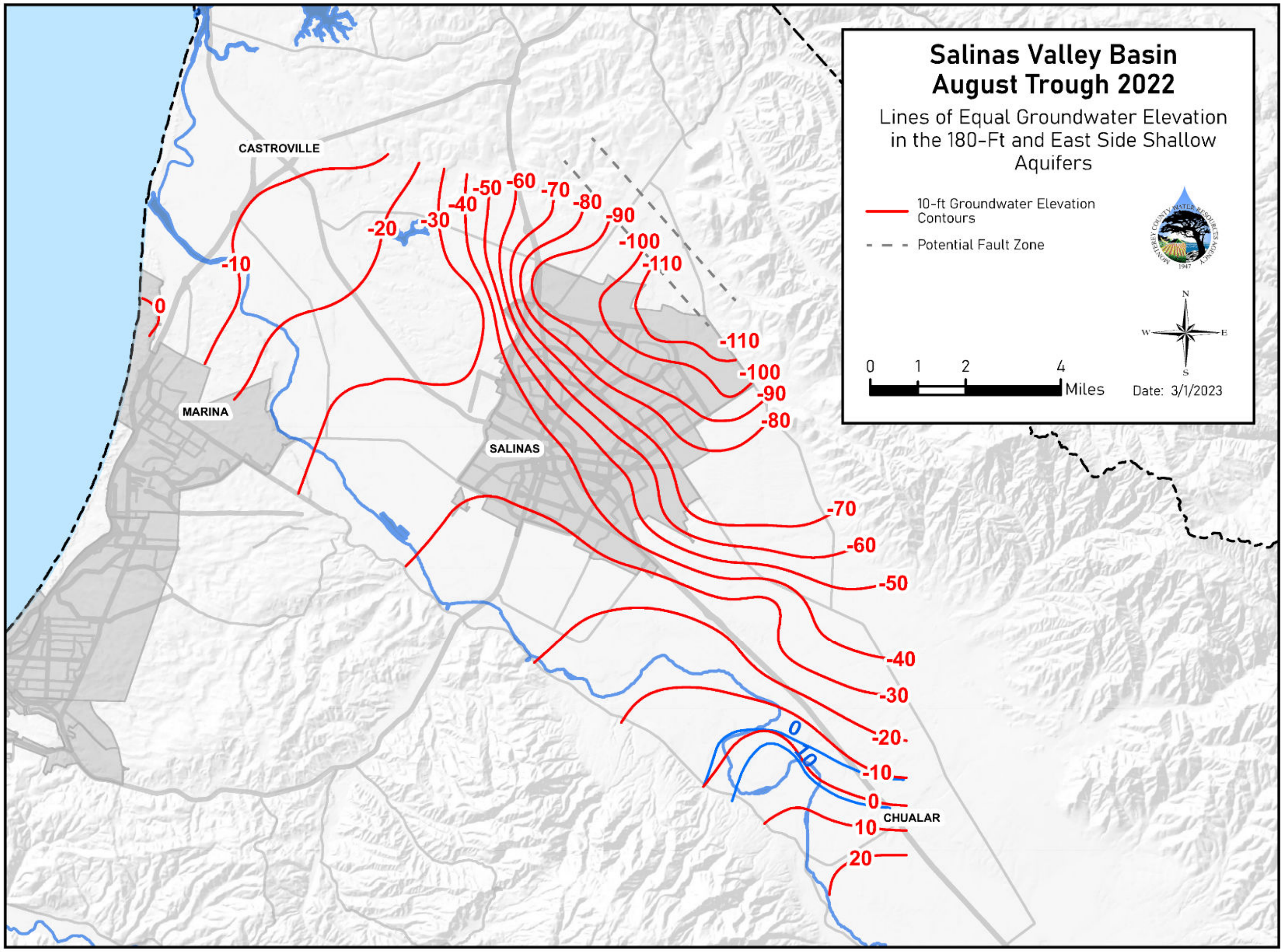


Notes:
1. Source: MCWRA

Figure 1-10

Groundwater Head in 400-Foot Aquifer (and Equivalent), Fall 2022

Monterey County Water Resources Agency
Historical Benefits Analysis Update
April 2025



Notes:
1. Source: MCWRA

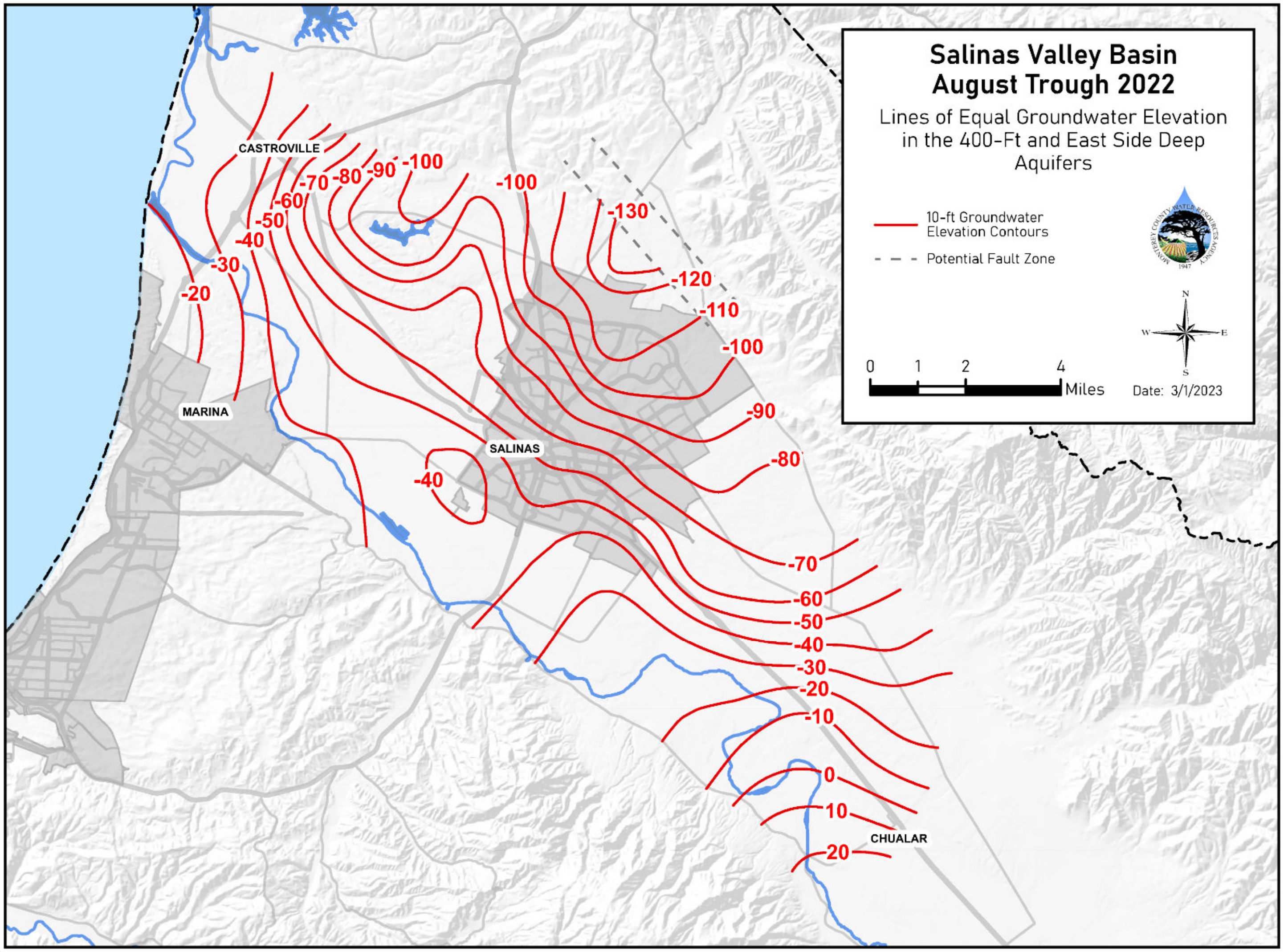
Figure 1-11

Groundwater Head in 180-Foot Aquifer (and Equivalent), August 2022

Monterey County Water Resources Agency

Historical Benefits Analysis Update

April 2025

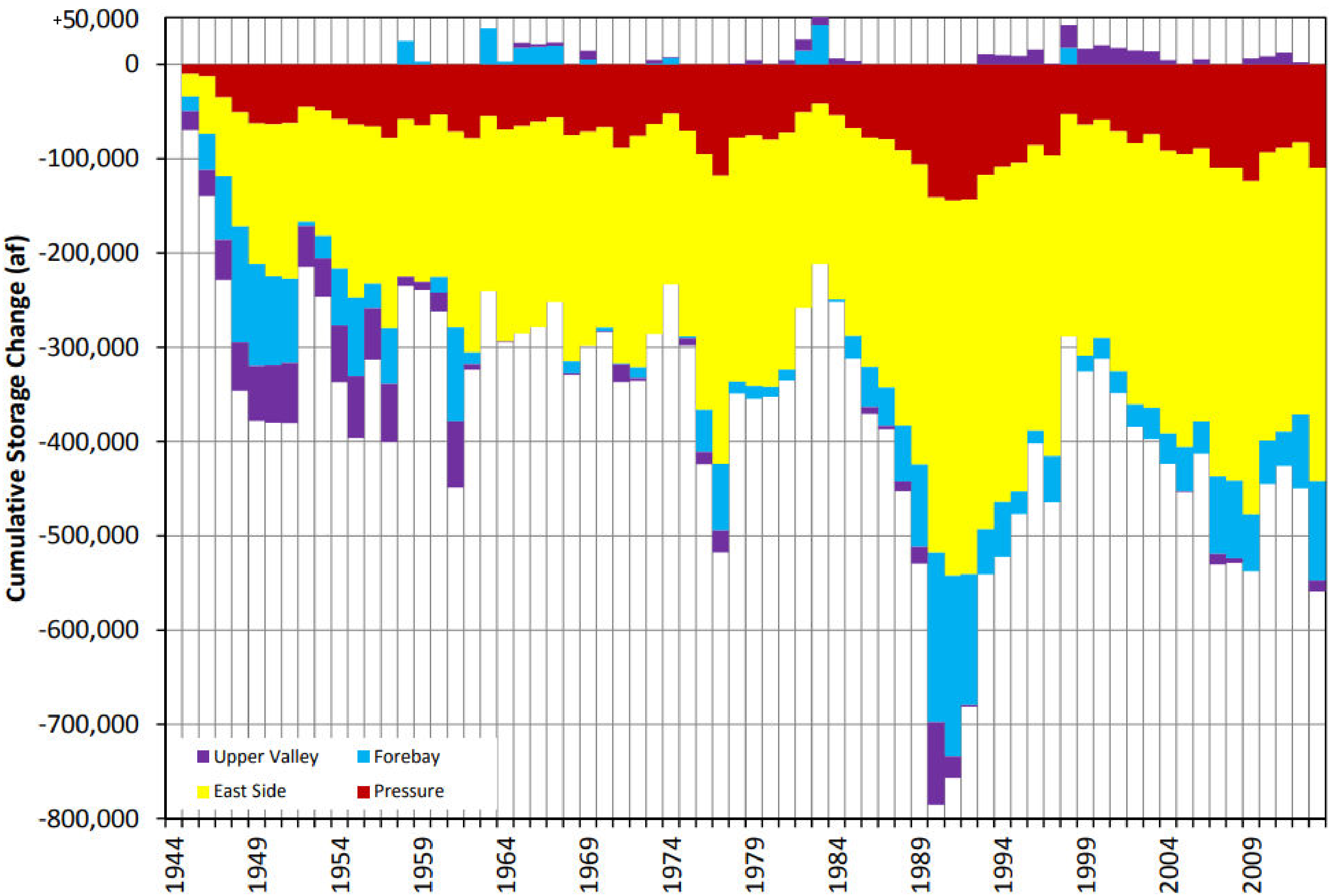


Notes:
1. Source: MCWRA

Figure 1-12

Groundwater Head in 400-Foot Aquifer (and Equivalent), August 2022

Monterey County Water Resources Agency
Historical Benefits Analysis Update
April 2025

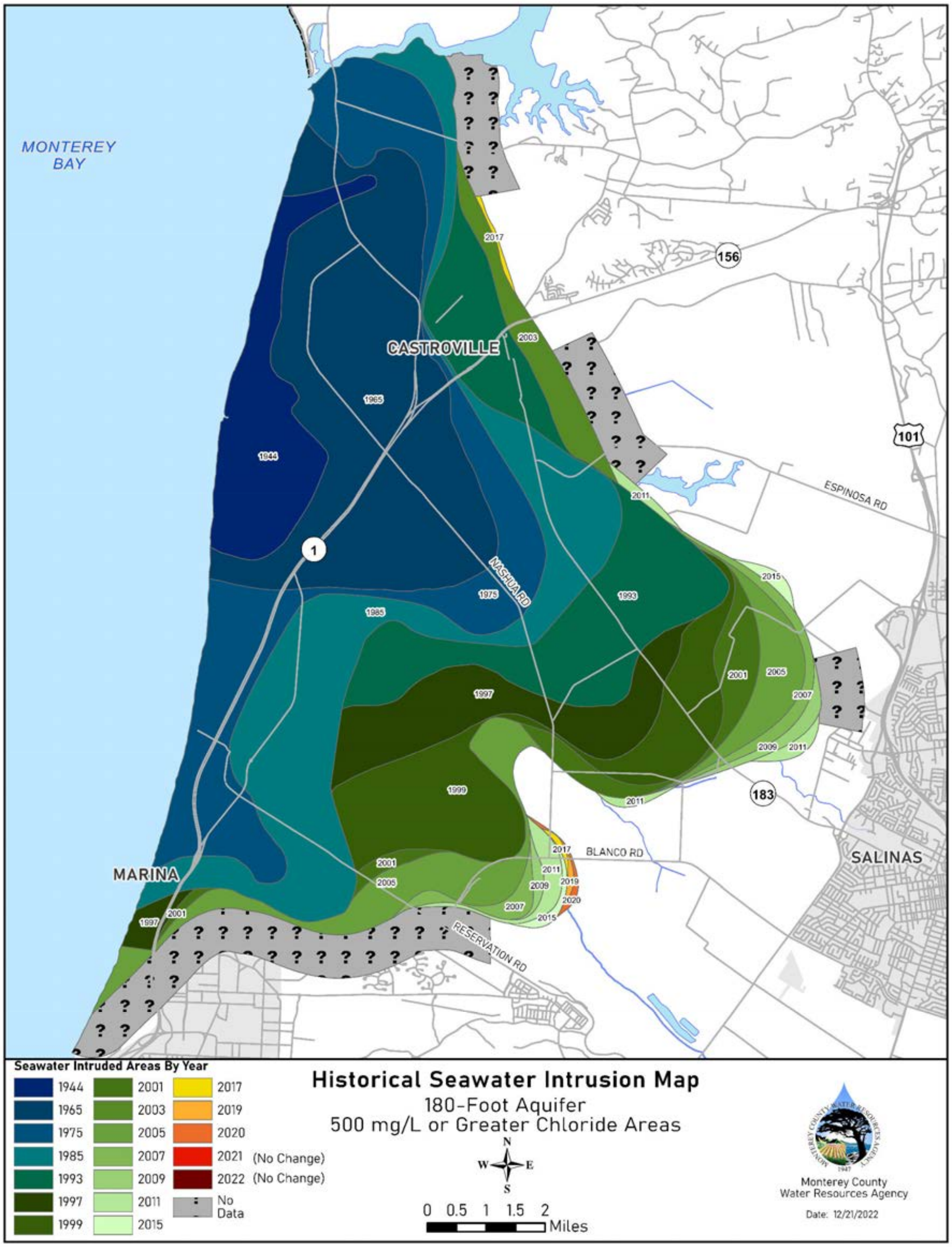


Notes:
1. Source: Brown and Caldwell, 2015a

Figure 1-13

Cumulative Storage Change by Zone 2C Subarea

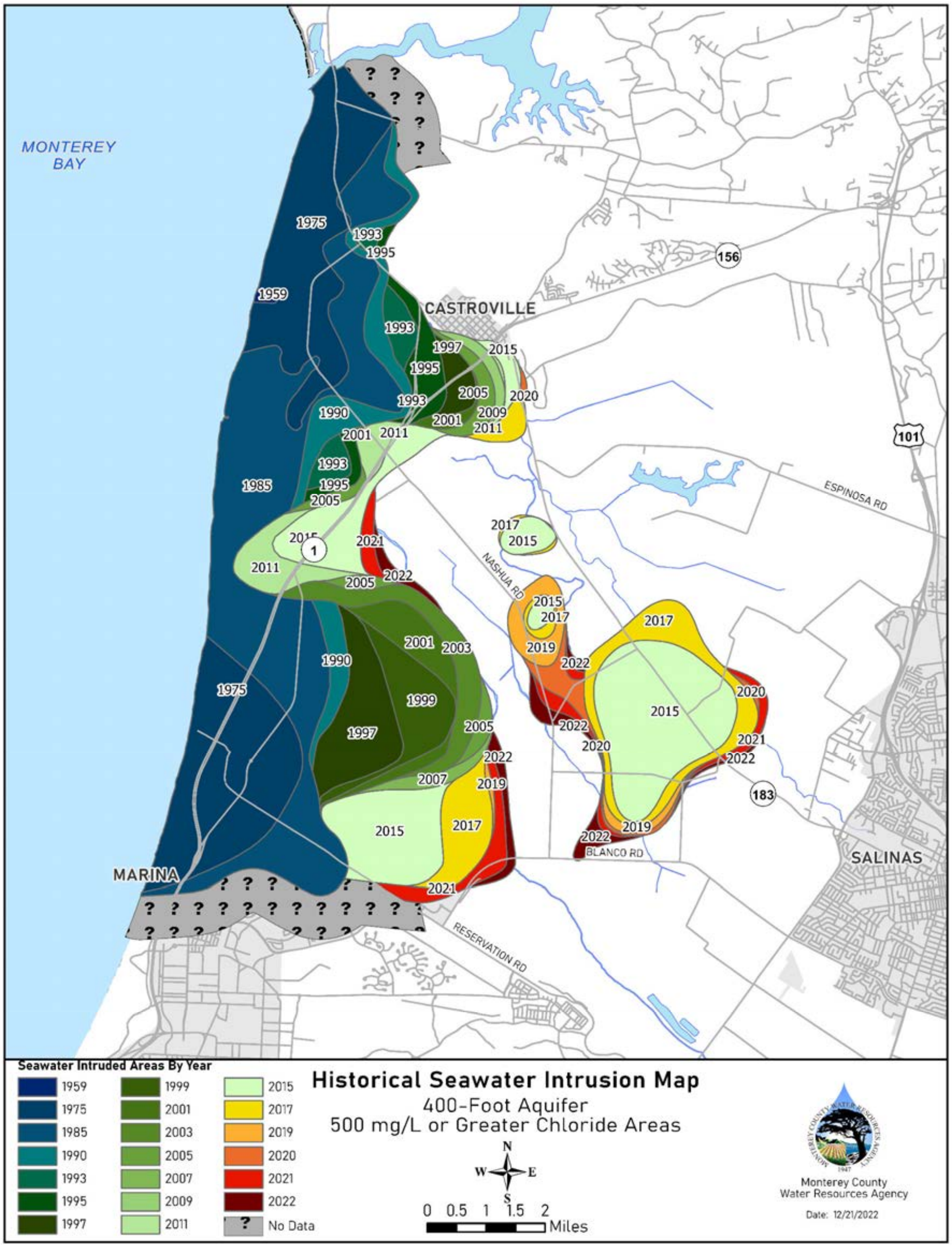
Monterey County Water Resources Agency
Historical Benefits Analysis Update
April 2025



Notes:
1. Source: MCWRA

Figure 1-14

Seawater Intrusion Extent in 180-Foot Aquifer, 2022



Notes:
1. Source: MCWRA

Figure 1-15

Seawater Intrusion Extent in 400-Foot Aquifer, 2022

Monterey County Water Resources Agency
Historical Benefits Analysis Update
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1.3 1998 HBA

The 1998 HBA investigated the benefits to the Basin stakeholders from the construction and operation of Nacimiento and San Antonio Reservoirs over the period since Nacimiento Reservoir was completed in 1957. The quantification of benefits was achieved by simulation of conditions in the Basin with and without the reservoirs using then-current tools, with the difference between the with- and without-reservoir conditions representing the influence of the reservoirs. The 1998 HBA used economic analyses to express the benefits in monetary terms to illustrate the value that the Basin stakeholders have received from the presence of the reservoirs.

In general, the quantified benefits of the reservoirs have resulted from their ability to impound water during the winter wet period and release it during drier periods. The existence of the reservoirs has resulted in more water being kept within the Basin, increased groundwater recharge, more water in groundwater storage, higher groundwater heads, reduced seawater intrusion, and reduced flooding.

1.3.1 Hydrologic Benefits

According to the 1998 HBA, from 1958 to 1994 the reservoirs resulted in an average of 30,000 afy of additional fresh groundwater entering storage in the Basin. This led to a decrease of seawater intrusion of about 7,000 afy. The higher groundwater heads resulting from the increased freshwater storage have also lessened the need for the replacement or modification (e.g., deepening) of extraction wells in the Basin, particularly in the Upper Valley Subarea. The decreased extent of seawater intrusion has prevented the salinization of dozens of extraction wells in the coastal area, which otherwise would likely have needed to be replaced with wells pumping from the Deep Aquifers.

1.3.2 Flood Control Benefits

The 1998 HBA analysis of flooding quantified the degree by which flood flows in the Salinas River have been reduced as a result of the effective management of the reservoirs. The 100-year flood in the Salinas River at Bradley was estimated to be about 87,000 cubic feet per second (cfs) with the reservoirs in place, as compared to an about 167,000 cfs without the reservoirs. This resulted in substantially reduced inundation of the Salinas River floodplain and the land and structures found there. In the Salinas River at Spreckels, the 100-year flood with the reservoirs was estimated to be about 86,000 cfs, and about 149,000 cfs without the reservoirs. The analysis also found that the with-reservoir 100-year flow of 87,000 afy at Bradley would have occurred about once every 8 years without the reservoirs, while the with-reservoir 100-year flow of 86,000 cfs at Spreckels would have occurred about once every 22 years without the reservoirs.

1.3.3 Economic Benefits

The 1998 HBA estimated the monetary benefits that the Basin has realized because of the increased storage, reduced seawater intrusion, and reduced frequency and extent of inundation. Overall, the reservoirs resulted in about $1.5 million per year in reduced pumping costs, $89,000 per year in reduced well costs (deepening and other modifications to wells), and $241,000 per year in avoided costs to replace wells impacted by seawater intrusion (totaling just over $1.8 million per year in benefit due to the increased fresh groundwater in storage). In addition, the reduced frequency and extent of inundation caused by the presence of the reservoirs has increased crop income, reduced repair costs, and reduced damage to structures and buildings in the floodplain. The 1998 HBA estimated that the reservoirs resulted in about $5.5 million per year of increased crop income and reduced repair costs, and about $4.5 million per year of reduced damage to structures and buildings in the floodplain. In total, the 1998 HBA estimated that the reservoirs resulted in $11.8 million per year of benefit to the stakeholders in the Basin.

1.3.4 Other Benefits

The 1998 HBA listed a number of other benefits that stakeholders in the Basin have received from the reservoirs that cannot necessarily be quantified. These benefits included groundwater quality improvements outside of the area of seawater intrusion, the future utility of fresh groundwater currently in storage, avoided costs for developing a surface water distribution system for addressing seawater intrusion, reduction of risk due to rainfall variation, recreational and environmental benefits, and other indirect benefits such as employment and tourism. The 1998 HBA did not quantify these other benefits because they would occur outside the period of the analysis, or the uncertainties in accounting were too high, or their quantification would result in the double counting of benefit.

1.3.5 Need for an Updated HBA

The 1998 HBA covered the 46-year period from 1949 to 1994 using the Salinas Valley Integrated Ground and Surface Water Model (SVIGSM), which was developed for MCWRA over the previous several years and was updated for the 1998 HBA. Since the publication of the 1998 HBA, 25 years have passed that have seen substantial improvements in the understanding of the Basin, collection of additional data, changes to how MCWRA operates the reservoirs, and improvements to the computational tools suited to the kind of analysis undertaken for the 1998 HBA. These factors all justify an update to the 1998 HBA. Accordingly, this HBA Update relies on the improvements of knowledge and tools over the past 25 years to provide a revised characterization of the benefit accrued by stakeholders in the Basin from the presence of the Nacimiento and San Antonio Reservoirs.

CHAPTER 2
Tools and Approach

This chapter describes the tools and approaches used to perform the analyses presented in this HBA Update. This study relies on various numerical, analytical, and qualitative assessments of conditions in the Basin to arrive at a characterization of the effect of the Projects on the groundwater-surface water system.

2.1 1998 HBA APPROACH

The 1998 HBA used then-current tools to estimate the benefit accrued to the Basin stakeholders from the existence of the Nacimiento and San Antonio Reservoirs. The 1998 HBA largely relied on model simulations using the SVIGSM, which was built using the finite element Integrated Groundwater-Surface Water Model (IGSM) software, the development of which was later taken over by DWR and transitioned into the Integrated Water Flow Model (IWFM), which is currently in use for studies in many basins throughout California.

IGSM was designed to simulate groundwater and surface water conditions, groundwater-surface water interaction, and agricultural supply and demand processes, with the goal of investigating basin-wide conditions in heavily agricultural settings such as the Salinas Valley. The SVIGSM relied on some important customizations to simulate reservoir operations and seawater intrusion, both critical to the understanding of the Basin. The SVIGSM was developed by MW in the mid-1990s based on earlier models (MW, 1997) and used to prepare the 1998 HBA. The SVIGSM was used to simulate groundwater head, groundwater flow, streamflow, groundwater-surface water interaction, land surface processes, agricultural demand, groundwater extraction, reservoir operations, and seawater intrusion. It was calibrated to measured groundwater head at wells, streamflow at gauging stations on the Salinas River, mapped extents of seawater intrusion, and trends in groundwater chloride concentrations over time. For the 1998 HBA, the SVIGSM simulation covered WY 1949 to 1994, a period which included years prior to and after the construction of the reservoirs.

The estimated effect of the reservoirs over the historical period was assessed by simulating two configurations of the Basin with the SVIGSM: a historical simulation and a “without reservoirs” simulation (MW, 1998). The historical simulation represented the calibrated historical scenario developed by MW, the intention of which was to match as closely as possible the historical observations of Basin conditions included in the calibration dataset. The “without reservoirs” simulation was similarly configured to the historical simulation, but without the reservoirs present, i.e., the Nacimiento and San Antonio Rivers were allowed to flow uncontrolled. The difference between the historical and “without reservoirs” simulations represented the effect of the reservoirs.

The SVIGSM was not well-suited to simulating certain aspects of the effect of the reservoirs, particularly the Flood Control and Economic Benefits Analyses. For the Flood Control Benefits Analysis, the SVIGSM results were supplemented by an analytical approach to quantifying the magnitude of peak flow events (flood frequency analysis) based on simulated streamflows. The effect of these peak flows on the extent and depth of inundation, streamflow velocities, and soil erosion were investigated using a separate Hydrologic Engineering Center (HEC) model known as HEC-2.

The Economic Benefits Analysis relied on the results of the Hydrologic and Flood Control Benefits Analyses, equating the differences between the historical and “without reservoirs” simulations to monetary benefits using estimates of well construction costs, power costs, flood damage to structures, and other factors. These calculations were based on calculations of economic benefits (such as the difference in groundwater head at a pumping well multiplied by cost per foot of pumping lift equaling the additional cost of power to extract groundwater). Altogether, the 1998 HBA estimated that the reservoirs resulted in a total benefit of about $11.8 million per year over the historical period, as discussed in Chapter 1 of this report.

2.2 HBA UPDATE MODELING TOOLS

This section briefly describes the tools that were utilized to prepare this HBA Update. This discussion does not provide an exhaustive explanation of these modeling tools, but instead provides a brief overview and references to documentation for the individual models and modeling software. The Salinas Valley Integrated Hydrologic Model (SVIHM) is a preliminary product that is currently under review by the USGS, and no documentation of this tool is available at the time of publication of this report.

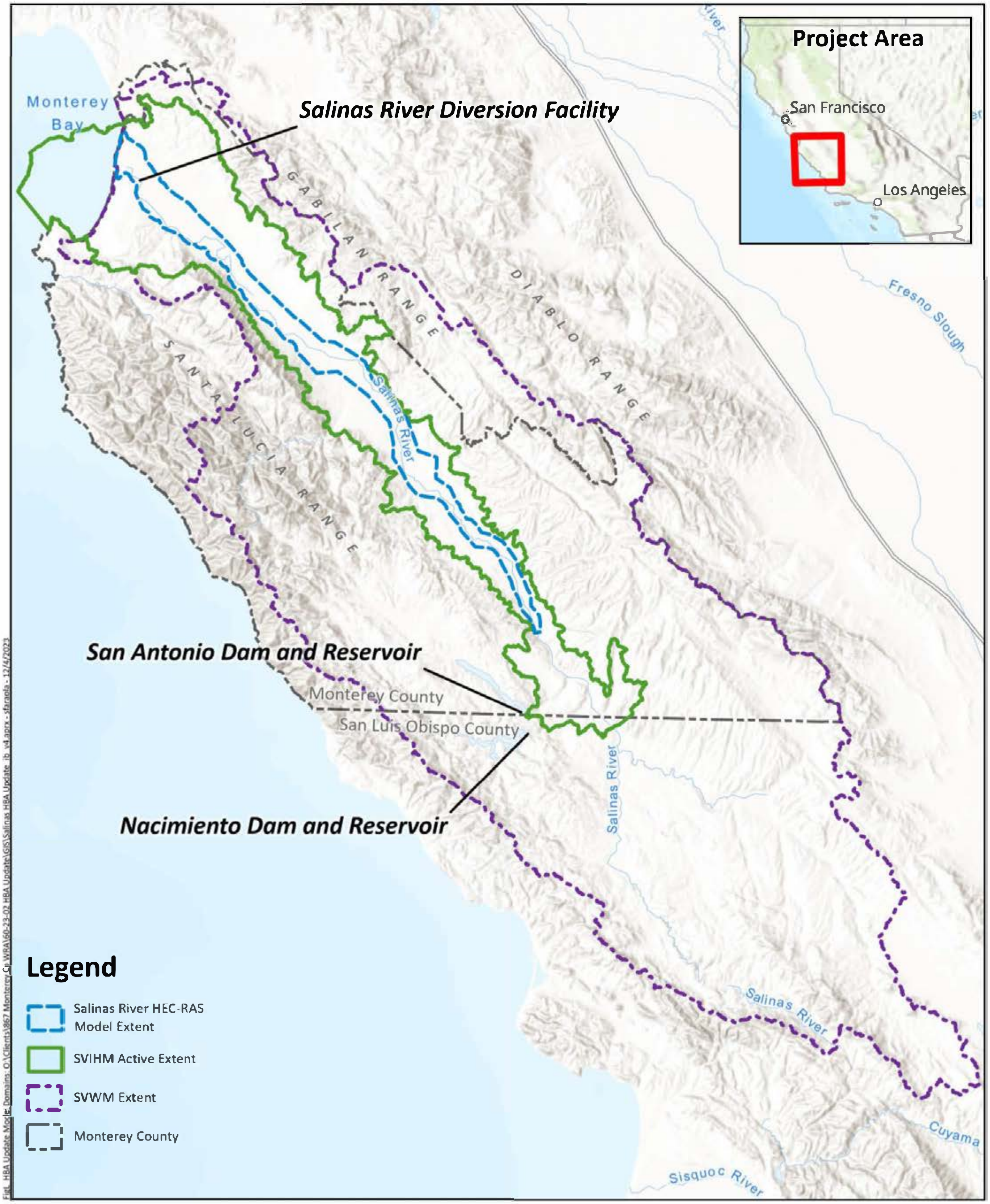
2.2.1 Salinas Valley Integrated Hydrologic Model

The SVIHM is a complex, three-dimensional groundwater and surface water flow model of the Salinas Basin developed by the USGS. This model is built using the MODFLOW One Water Hydrologic Model (OWHM) code, which is focused on coupled groundwater-surface water systems in which agricultural supply and demand are key components of the overall water budget (Boyce et al., 2020). OWHM simulates three-dimensional groundwater flow, streamflow routing, land surface processes, water demand based on crop type, and other processes impacting the groundwater and surface water systems.

The SVIHM is designed to simulate groundwater and surface water flow over the historical period from October 1967 to September 2018. The model is discretized into 612 monthly stress periods[1]. The model domain consists of 976 rows, 272 columns, and 9 layers. The horizontal spacing is 529 feet by 529 feet; layer thicknesses vary throughout the model domain to represent the hydrostratigraphy described in Chapter 1 of this report. The active model domain is shown on Figure 2-1. The Salinas Valley Watershed Model (SVWM), a USGS rainfall-runoff routing model, provides streamflow inputs along the edges of the SVIHM. The domain of the SVWM and the Salinas River HEC River Analysis System (HEC-RAS) model are also shown in Figure 2-1.

The SVIHM includes capabilities for simulating: groundwater flow through the permeable aquifers of the Basin; streamflow routing through the defined stream system; groundwater-surface water interaction; groundwater exchange with adjacent basins and the ocean; estimation of crop water demand; satisfaction of crop water demand by precipitation, surface water deliveries, and groundwater pumping; the diversion and delivery of surface water; municipal and industrial well pumping; agricultural drains; and internal structural barriers (e.g., faults). The SVIHM incorporates historical estimates of climate variables (precipitation and potential evapotranspiration), land use data, sea level variation, groundwater heads in adjacent basins, reservoir releases, stream flow inputs, and recycled and surface water deliveries to the CSIP area. The model receives along its edges streamflow inputs simulated by the SVWM.

[1] The stress period is the basic unit of time discretization in a MODFLOW model and represents a period of the model during which all stresses on the model (e.g., groundwater pumping) are uniform. Each stress period can be divided into multiple timesteps.



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Salinas Valley HBA Update
April 2025

HBA Update Model Domains

Figure 2-1

The USGS has calibrated the SVIHM to long-term records of groundwater, surface water, and agricultural pumping data. Because of the preliminary nature of the SVIHM, details on the calibration are not currently available. Accordingly, the USGS requires that any presentation of results from the SVIHM before it is published publicly must be accompanied by the following disclaimer:

> *Historical SVIHM Model: Unoffical* [sic] *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 recieved* [sic] *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.*

2.2.2 Salinas River HEC-RAS Model

A streamflow model for the Salinas River was developed by FlowWest based on earlier models by Newfields and others (FlowWest, 2015) using the HEC-RAS 2D software. The model simulates two-dimensional flow in the Salinas River and its floodplain from about Bradley to the mouth of the river at Monterey Bay (Figure 2-1). In addition to inflow at the south end of the system, the Salinas River is fed by tributary inflow from Arroyo Seco and San Lorenzo Creek. HEC-RAS 2D is not capable of simulating groundwater-surface water interaction, which is an important process in the study area.

The Salinas River HEC-RAS model has been used in previous studies to investigate the impacts of various projects and management actions on 5- and 10-year peak flow events in the system, focusing on the extent and depth of flooding and the velocity of flow (FlowWest, 2015). It has been used to study the effect of peak streamflows on the system in a quasi-steady state mode, with input flow in the Salinas River consisting of a ramp-up period followed by an extended period of the peak flow rate. The simulations do not include any subsequent ramp-down period, and the model does not simulate the movement of a realistic hydrograph through the system.

2.2.3 Differences from 1998 HBA Modeling Approach

The most fundamental difference between the 1998 HBA and this HBA Update is that this update addresses the effects of key water projects that have been implemented or changed operationally since 1994; these effects were not captured in the 1998 HBA. This HBA Update covers most of the intervening period, with the analysis ending with WY 2018 (the end of the period simulated by the SVIHM). The SVIGSM used to prepare the 1998 HBA covered the period of WY 1949 through WY 1994, a 46-year period, including nine years before either reservoir became operational (WY 1949 to 1957), 10 years between Nacimiento Reservoir beginning operations and San Antonio Reservoir beginning operations (WY 1958 to 1967), and 27 years with both reservoirs operational (WY 1968 to 1994). The first 9 years of the SVIGSM modeling period were not included in the analysis of benefit, such that the benefit analysis covered the 37-year period from WY 1958 to 1994.

The SVIHM covers the period from WY 1968 (when San Antonio Reservoir came online) to WY 2018. Because the SVIHM is a preliminary model, it cannot be modified to cover the earlier period included in the 1998 HBA analysis (WY 1958 to 1967), when only Nacimiento Reservoir was operational, or the years before that (WY 1949 to 1957) simulated by the SVIGSM.

One consequence of extending the analytical period to WY 2018 is that the SVIHM simulates projects and programs in the Basin that were not included in the SVIGSM. These include the recycled water and treated Salinas River water deliveries to the CSIP area and the increased spillway elevation at Nacimiento Dam (see Chapter 1). The latter is implemented within the historical record of Nacimiento Reservoir releases, which is used as the upstream boundary condition for the Nacimiento River. Deliveries to the CSIP area are included as non-routed deliveries (for the recycled water) and semi-routed deliveries (for the Salinas River water) supplied to agricultural users in the CSIP area using historical records provided to the USGS. It would be extremely difficult to determine the benefit of each aspect of the Projects individually (e.g., the benefit of just the SRDF), since it would require estimating historical reservoir releases in its absence, which would be highly speculative. Therefore, this HBA Update analyzes the benefit of the various Projects collectively.

Based on the analyses presented in the 1998 HBA, the SVIGSM did not simulate the effect of reductions in groundwater head on the ability of pumping wells to supply the demands placed on them. The model showed no difference in the average annual pumping between the historical and "without reservoir" conditions, despite substantial differences in the fresh groundwater storage. Impacts of the removal of the reservoirs on pumping wells was quantified based on the simulated head at each well, known details of the well construction, and assumptions about how a reduction in groundwater head would necessitate changes to the well design or replacement of the well. In contrast, the SVIHM may modify pumping due to differences in the availability of other water sources to satisfy crop demand. Therefore, for the HBA Update, well impacts are considered in terms of changes both to groundwater head and groundwater pumping between scenarios.

The SVIHM does not currently include the capability to directly simulate the intrusion of seawater into freshwater aquifers. While the model does simulate the flux of water across the interfaces between the aquifer units and the ocean (where they outcrop on the floor of Monterey Bay), it uses an approximation to convert the head along those outcrops from a depth below sea level to an equivalent freshwater head. Characterization of groundwater within the model does not account for the differences in density between seawater and freshwater that drive seawater intrusion or the mixing of seawater and fresh groundwater. There are packages available for MODFLOW that can approximate the amount and extent of seawater intrusion in a more sophisticated way (e.g., SWI2; Bakker et al., 2013), but they have not been utilized in the SVIHM to date. The rate of seawater intrusion can be quantified using the SVIHM from the rate of groundwater flow across the coast, but it ignores the impact of density differences between seawater and freshwater. The SVIHM, as configured, cannot therefore be used to simulate the extent of seawater intrusion or how it changes over time.

Other than the above differences, the approach used in this HBA Update to quantifying benefits largely follows that of the 1998 HBA in order to allow for a direct comparison to the extent possible. There are additional differences between the SVIGSM and SVIHM that result from differences in the hydrologic conceptual models and the software tools being used. These differences are assumed to be of relatively low significance compared to those discussed above and are not considered in detail here. Comparisons between the capabilities of the SVIGSM and MODFLOW-OWHM were discussed in Brown and Caldwell (2015b).

2.3 BENEFITS QUANTIFICATION APPROACH

As noted above, the benefits quantification approach follows that of the 1998 HBA as closely as possible considering the differences between the modeling tools used. This section briefly describes how the analysis of model results was translated into a quantified benefit provided by the reservoirs. The benefits are categorized into hydrologic (groundwater head and storage and impacts on wells), flood control (frequency and severity of flood events), economic (monetary equivalent of the hydrologic and flood control benefits), and other benefits.

2.3.1 Hydrologic Benefits Analysis

The 1998 HBA included a Hydrologic Benefits Analysis based on an evaluation of the reservoirs' effects on groundwater levels, seawater intrusion, well construction and/or rehabilitation, and regional groundwater quality. For this HBA Update, the Hydrologic Benefits Analysis (Chapter 3 of this report) similarly assesses the benefits that the Projects have supplied to the groundwater system, with a focus on groundwater quantity and quality.

Changes in groundwater head, and therefore the amount of groundwater storage, represent the fundamental manifestation of impacts on the groundwater system. Changes to groundwater head and storage are tracked throughout the model and are presented in this report as: maps of groundwater head (and groundwater head differences between scenarios); storage change as a component of groundwater budgets (including differences between scenarios); and groundwater head changes aggregated into spatial subdivisions of the Basin, following the concept of Economic Study Units (ESUs) in the 1998 HBA.

Seawater intrusion was quantified in the 1998 HBA as a flux of groundwater across the coast, as well as delineation of the onshore area underlain by aquifers intruded by seawater (i.e., the extent of the seawater intrusion front). As noted above, the SVIHM does not have the capability to directly simulate the intrusion of seawater into a groundwater system, or to track its movement within the aquifers. Instead, the volume of seawater crossing the coast can be calculated from the simulated groundwater flux from the model.

Changes to groundwater head and storage have the potential to have negative effects on the ability of groundwater wells to operate. In the 1998 HBA, impacts on wells were approached either by evaluating increases to pumping lift necessitated by lower groundwater heads at well locations, or by identifying wells needing modifications or replacement to operate under depleted aquifer conditions. For this HBA Update, the well impacts analysis includes: estimates of increased pumping lift due to reduced groundwater head at wells; simulated reductions in pumping due to reduced groundwater head at wells; and the proportion of wells requiring modification or replacement as suggested by the model results. As noted in the 1998 HBA, well replacement can be assumed to involve installation of wells in deeper aquifers than those in which the existing well is already screened, especially the Deep Aquifers; however, the effect of this replacement is not simulated in the model. The connection between the Deep Aquifers and the ocean remains poorly understood, so the long-term effect on seawater intrusion of shifting pumping downward into the Deep Aquifers remains difficult to assess.

The analysis of regional groundwater quality impacts in the 1998 HBA was somewhat qualitative, and considered whether the reservoirs would be likely to lead to impacts on groundwater quality. That analysis concluded that the reservoirs could be expected to have positive effects on groundwater quality in the Basin, due to the increased recharge that takes place in the riparian area. This HBA Update does not include a discussion of impacts on regional groundwater quality.

2.3.2 Flood Control Benefits Analysis

The Flood Control Benefits Analysis in the 1998 HBA focused on the impacts of flooding in the system by quantifying benefits from reductions in frequency of flooding, severity of flooding, impacts to agricultural soil, and impacts to buildings and structures in the floodplain. That analysis estimated the magnitude of flood events of different return intervals (e.g., the 100-year flood) with and without the reservoirs, then simulated the propagation of inundation under the calculated peak flows using a separate HEC-2 model. The results of those simulations were used to estimate the impact of the reservoirs on agriculture and structures in the floodplain.

For this HBA Update, the impacts of the Projects on the system follows much the same approach. The results of the SVIHM are used to develop time series of peak annual streamflow with and without the Projects. These time series are then converted into a statistical distribution of peak flows for different return periods using a Flood Frequency Analysis. These statistical distributions provide information on both the magnitude of peak flows and the frequency of significant flood events.

Selected peak flow events from the Flood Frequency Analysis are simulated using the Salinas River HEC-RAS Model to demonstrate the extent and depth of inundation and the flow velocity under each event. The model results are then combined with published information on the spatial distribution of soil types to understand the potential for flood events to cause agricultural soil erosion. The effect on buildings and structures is assessed as part of the Economic Benefits Analysis discussed in the next section.

2.3.3 Economic Benefits Analysis

The Economic Benefits Analysis in the 1998 HBA translated the impacts quantified under the Hydrologic and Flood Control Benefits Analyses into monetary benefits to the stakeholders of the Basin due to the effects that the reservoirs have had on the groundwater and surface water systems. These benefits were expressed in numerous ways, including reduced power costs to pump groundwater, reduced well maintenance and replacement costs, reduced crop damage due to flooding, and reduced damage to buildings and structures in the floodplain.

For the HBA Update, the Economic Benefits Analysis is currently being performed by One Water Econ. Their analysis is based on the results of the Hydrologic and Flood Control Benefits Analyses presented in this report. The methodology and results of the Economic Benefits Analysis will be presented in a separate report.

2.3.4 Other Benefits

The 1998 HBA included a brief discussion of other benefits that have been derived from the reservoirs over time, including: improved groundwater quality outside of the area of seawater intrusion; storage of high-quality groundwater for future use; preservation of freshwater storage for future use; reduced risk from rainfall variability; and increased land values, employment opportunities, and tourism.

This HBA Update similarly discusses in a qualitative manner other benefits that the Projects have provided to the stakeholders of the Basin. Like the 1998 HBA, no attempt is made in this analysis to quantify these benefits.

2.4 MODEL SCENARIOS

The analyses supporting this HBA Update rely on two model scenarios run using the SVIHM: a Historical Scenario and a No Projects Scenario. The key model outputs of note include groundwater head (h) and water flux (Q). The latter may refer to groundwater/surface water interaction across the streambed, groundwater pumping, recharge , and other such processes. The difference between the two scenarios is used to demonstrate the benefits accrued from the Projects over the course of the model simulation period, and is based on the following calculations:

$$h_{diff} = h_{hist} - h_{noproj} \quad (1)$$

$$Q_{diff} = Q_{hist} - Q_{noproj} \quad (2)$$

where h_{diff} is the head difference between the scenarios, h_{hist} is a groundwater head under the Historical Scenario, h_{noproj} is the head at the same location and time under the No Projects Scenario, Q_{diff} is the water flux difference between the scenarios, Q_{hist} is a water flux under the Historical Scenario, and Q_{noproj} is the water flux at the same location and time under the No Projects Scenario. Values of h_{diff} and Q_{diff} are assumed to represent the effects of the Projects. This approach follows that of the 1998 HBA. Unless stated otherwise, the difference between the scenarios is expressed as the Historical Scenario minus the No Projects Scenario.

2.4.1 Historical Scenario

The Historical Scenario (analogous to the historical case of the 1998 HBA) simulates historical conditions within the Salinas Valley over the period from October 1967 to September 2018 (i.e., WY 1968 to 2018). It was designed by the USGS to reproduce, as closely as possible, observed conditions in the study area over the historical period.

The spatial extent of the SVIHM does not include Nacimiento and San Antonio Reservoirs (Figure 2-1). The effect of the reservoirs on the system is simulated using the historical measurements of reservoir releases from each reservoir, which are provided as streamflow inputs to the Nacimiento and San Antonio Reservoirs. The Nacimiento River enters the SVIHM about 5 miles below the outlet of the Nacimiento Dam; the USGS assumes no groundwater-surface water interaction or surface runoff occurs above this point in the Nacimiento River.

The Historical Scenario incorporates projects and programs related to the reservoirs (as described in Chapter 1) during the period of their operation. Both reservoirs are present throughout the time period simulated by the model. The effect of raising of the Nacimiento Dam spillway elevation is included in the time series of reservoir releases beginning in 2009 when the spillway modifications were completed. Recycled water deliveries from the Monterey One Water Regional Treatment Plant begin in 1998, while SRDF deliveries of Salinas River water begin in 2010.

2.4.2 No Projects Scenario

The No Projects Scenario fulfills the same purpose for the HBA Update as did the “without reservoirs” case used for the 1998 HBA analysis. It is similar to the Historical Scenario except that it removes the Projects by making the following modifications to the Historical Scenario:

- **Removal of the reservoirs:** The Historical Scenario uses historical reservoir releases (as reported by MCWRA) as the streamflow inputs for the Nacimiento and San Antonio Rivers. For the No Projects Scenario, the streamflow inputs at these locations are replaced by estimated historical reservoir inflows provided by MCWRA. The use of the reservoir inflow ignores any potential interaction with the surrounding environment that would have occurred between where MCWRA estimates reservoir inflow and where each stream intersects the active domain of the SVIHM. Because the stream inflow into the SVIHM represents a monthly average, this study assumes that the travel time between the reservoir inflow and the SVIHM boundary is negligible.
- **Raising of Nacimiento Dam spillway elevation (part of SVWP):** The modification of the Nacimiento Dam spillway was completed in 2009. The impact of raising the spillway crest elevation is incorporated into the reservoir release time series for the Historical Scenario input. The use of reservoir inflows as the stream inflow inputs to the SVIHM in the No Projects Scenario removes the effect of the spillway raise.
- **Removal of recycled water deliveries to CSIP area:** The Monterey One Water Regional Treatment Plant began delivering recycled water to growers in the CSIP area via a pipeline network in 1998, as described in Chapter 1. The SVIHM simulates recycled water deliveries to the CSIP area as non-routed deliveries (meaning that they do not move through the stream network) available to satisfy crop demands in the area. The volume of delivery is based on historical records provided by MCWRA. The No Projects Scenario sets these deliveries to zero.
- **Removal of Salinas River diversions to CSIP area (part of SVWP):** The SRDF began diverting water from the Salinas River to deliver to growers in the CSIP area in 2010. As with the recycled water deliveries, the SVIHM makes diverted water available to satisfy crop demands in the CSIP area; SRDF diversions are delivered to CSIP as semi-routed deliveries (meaning that they move through the stream network prior to delivery). The volume of delivery is based on historical records provided by MCWRA. The No Projects Scenario sets these deliveries to zero.

As noted in Section 2.3, the difference between the Historical and No Projects Scenarios is taken to represent the effect (benefits) on the study area of the construction and operation of the Projects. Throughout this report (unless stated otherwise), the difference represents the Historical Scenario minus the No Projects Scenario; for example, if head is higher under the Historical Scenario than the No Projects Scenario, the head difference is reported as positive.

CHAPTER 3
Hydrologic Benefits Analysis

This chapter describes the effects that the Nacimiento and San Antonio Reservoirs, and related projects and programs, have had on groundwater conditions in the study area. The storage of flows in the Nacimiento and San Antonio River watersheds during the wet winter season, and subsequent release during dry parts of the year (and in dry years) has resulted in the retention of more water in the Basin through recharge of reservoir releases. This increased recharge has resulted in higher groundwater heads in the Basin.

The spatial distribution of these effects must take place in context of the hydrogeologic conceptual model described in Chapter 1. The connection between the surface water and groundwater systems is strongest in the Upper Valley and Forebay Subareas and in the southern part of the Pressure and East Side Subareas, where no extensive confining units exist to separate the Salinas River from important water supply aquifers. Further north, through the majority of the Pressure and East Side Subareas, the Salinas Valley Aquitard largely separates the Salinas River from the major production aquifers.

3.1 BENEFIT QUANTIFICATION APPROACH

The Hydrologic Benefits of the Projects were determined by quantifying the differences between the Historical (with projects) and No Projects Scenarios (see Chapter 2). The effects on the groundwater system manifest as regional groundwater head differences, changes to groundwater-surface water flux, changes to well pumping, and seawater intrusion rates. In each case, the sections below quantify the head and water flux values under each scenario, as well as the difference between them.

To the extent possible, differences in the simulated state of the system between the Historical and No Projects Scenarios are ascribed to one or more of the projects and programs simulated under the Historical Scenario but removed for the No Projects Scenario, based on understanding of the hydrogeologic conceptual model and the timing and location of the projects and programs.

3.2 GROUNDWATER HEAD

The groundwater level at a given location is defined in terms of piezometric head (or simply head), which is a measurement of the pressure that the water stored in an aquifer is under, referenced to a vertical datum. It is commonly thought of as the elevation to which water would rise in a well or piezometer installed in an aquifer. MODFLOW calculates the head in each active model cell for each model timestep, producing a three-dimensional distribution of head within the Basin.

Changes in groundwater head are a proxy for changes in aquifer storage. As storage in aquifers declines, groundwater head declines, while increasing groundwater storage is represented by an increase in groundwater head. Accordingly, the groundwater head results in the model can be used to understand how aquifer storage changes over time.

As described in Chapter 1, decades of overdraft in the Basin have resulted in decreased groundwater heads, largely in the northern part of the Basin, where aquitards restrict the downward movement of water (including from the Salinas River) to recharge the main production aquifers. This situation has resulted in groundwater heads that are below sea level through much of the Pressure and East Side Subareas (as shown in Figures 1-9 through 1-12). This section describes the effects that the Projects have had on simulated groundwater head through the historical period from WY 1968 to 2018. These effects were quantified as the difference between the Historical and No Projects Scenarios, as described in Chapter 2.

This discussion focuses on differences between scenarios in Model Layer 3 (representing the 180-Foot Aquifer, East Side Shallow Aquifer, and undifferentiated aquifers of the other Subareas), Model Layer 5 (representing the 400-Foot Aquifer, East Side Deep Aquifer, and undifferentiated aquifers of the other Subareas), and Model Layer 7 (taken to represent the Deep Aquifer in the Pressure Subarea). Outside of the Pressure Subarea, where extensive aquitards separate the sediments into relatively well-defined aquifers, and the East Side Subarea, where groundwater exists in a semi-confined to confined state (with confinement increasing with depth) due to many fine-grained interbeds within the aquifer sediments, the sediments in the study area are not separable into different aquifer units, and groundwater head varies little from layer to layer.

3.2.1 September 2018 Simulated Groundwater Head

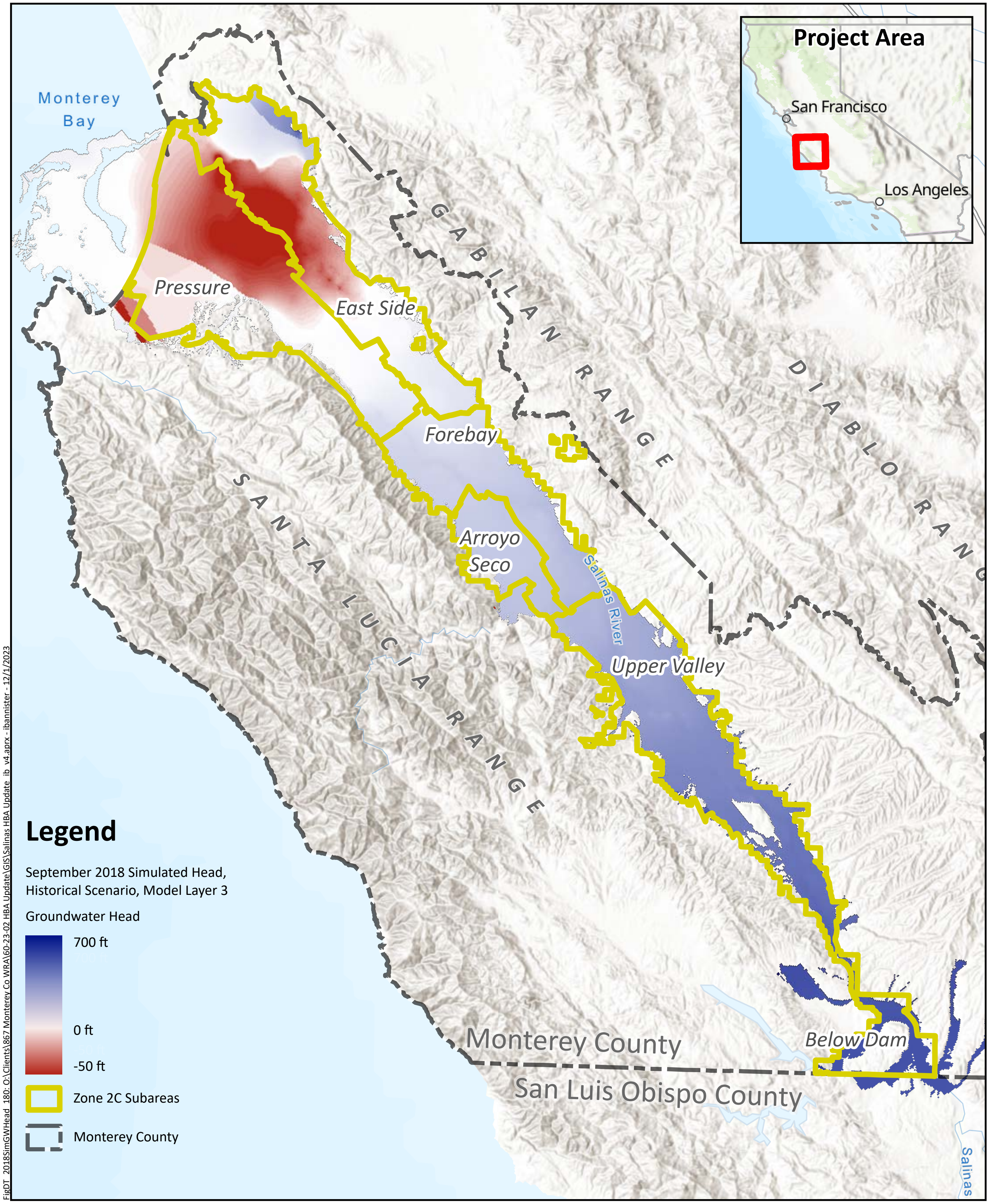
Modeled groundwater head values at the end of the model simulation period (i.e., September 2018) aggregate the effects of the Projects on the groundwater head conditions in the Basin. Figures 3-1 through 3-3 provide the groundwater head values simulated for September 2018 under the Historical Scenario for Model Layers 3, 5, and 7. Figures 3-4 through 3-6 show the groundwater head values simulated for September 2018 under the No Projects Scenario for the same model layers. Figures 3-7 through 3-9 show the differences between the Historical and No Projects Scenarios simulated for September 2018 for the same model layers.

Figures 3-1 through 3-6 show the expected decline in head from the higher-elevation parts of the Basin at its southern end to the coastal area to the north. On these figures, blue colors represent groundwater head values above mean sea level (msl) and red colors represent groundwater head values below msl. The large area of groundwater heads below sea level in the Pressure and East Side Subareas is notable on these figures.

Figure 3-7 shows the head difference in Model Layer 3 between the Historical and No Projects Scenarios simulated for the end of the model, September 2018. The head difference is largest in two areas: along the Salinas River from about Bradley to about Gonzales, and in the area between Castroville and Salinas (see Figure 1-1 for referenced locations). The head difference along the Salinas River is up to about 15 feet, with the largest differences occurring upstream of King City. Most differences along the River are about 10 feet or less. The difference vanishes around Gonzales. In the area between Castroville and Salinas, the difference is as much as about 48 feet between scenarios.

Figure 3-8 shows the head difference in Model Layer 5 between the Historical and No Projects Scenarios simulated for the end of the model, September 2018. The pattern of the head differences is very similar to that of Model Layer 3. Head differences along the Salinas River in Model Layer 5 are very similar in magnitude to those of Model Layer 3 up to about Greenfield, and then are smaller north of this point. Head differences in the area between Castroville and Salinas are slightly larger in Model Layer 5, reaching as much as about 67 feet.

Figure 3-9 shows the head difference in Model Layer 7 between the Historical and No Projects Scenarios simulated for the end of the model simulation period in September 2018. The overall pattern of head differences is similar to those of Model Layers 3 and 5. Head differences along the Salinas River are generally similar in magnitude, reaching up to about 15 feet south of King City. Head differences in the area between Castroville and Salinas are smaller compared to those in Model Layers 3 and 5, reaching a maximum of about 12 feet.



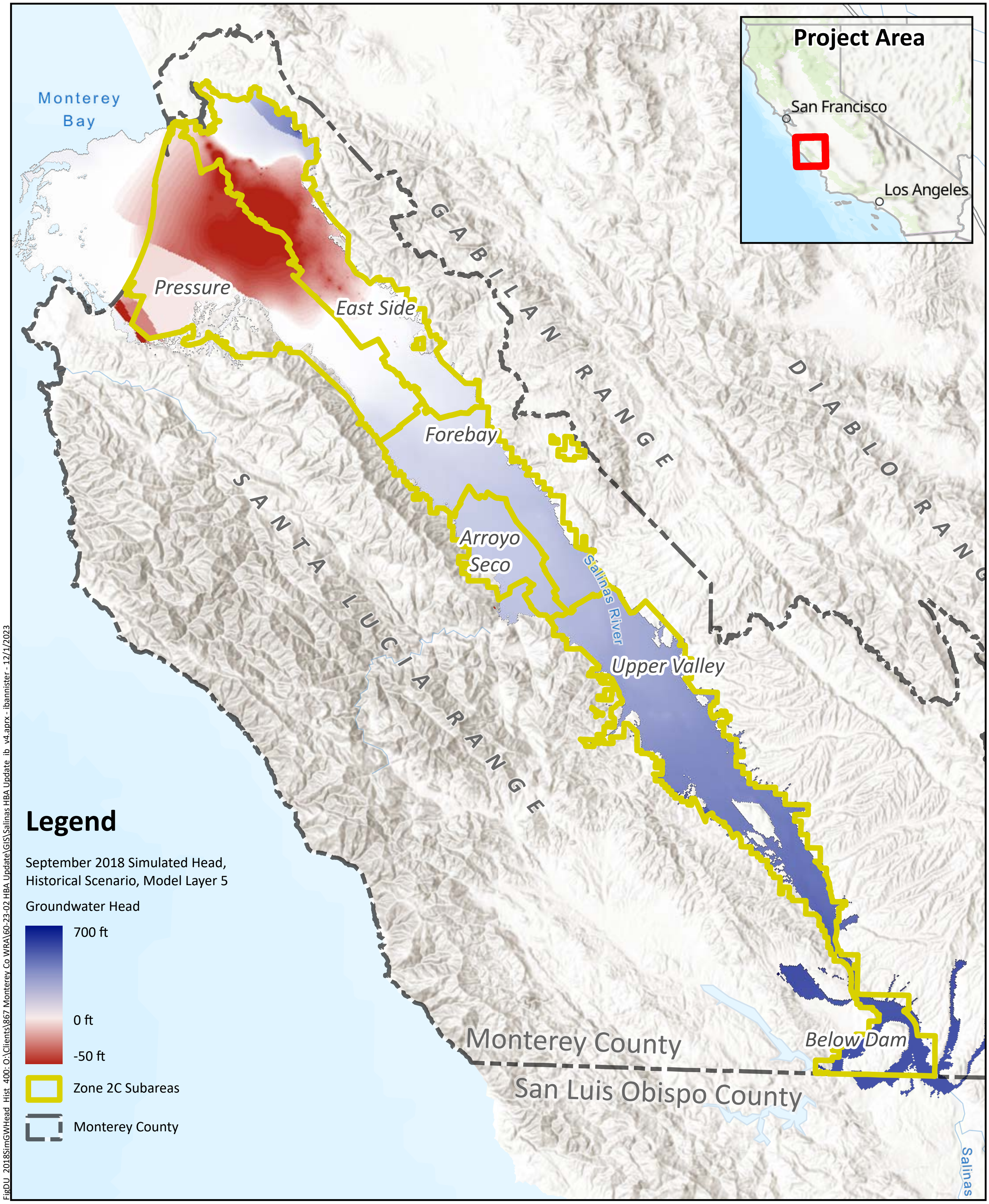
September 2018
Simulated Groundwater Head
Historical Scenario
180-Foot Aquifer & Equivalent

Prepared by:
WEST YOST

0 5 10 Miles
0 8 16 Km

Prepared for:
Monterey County Water Resources Agency
Salinas Valley HBA Update
April 2025

Figure 3-1



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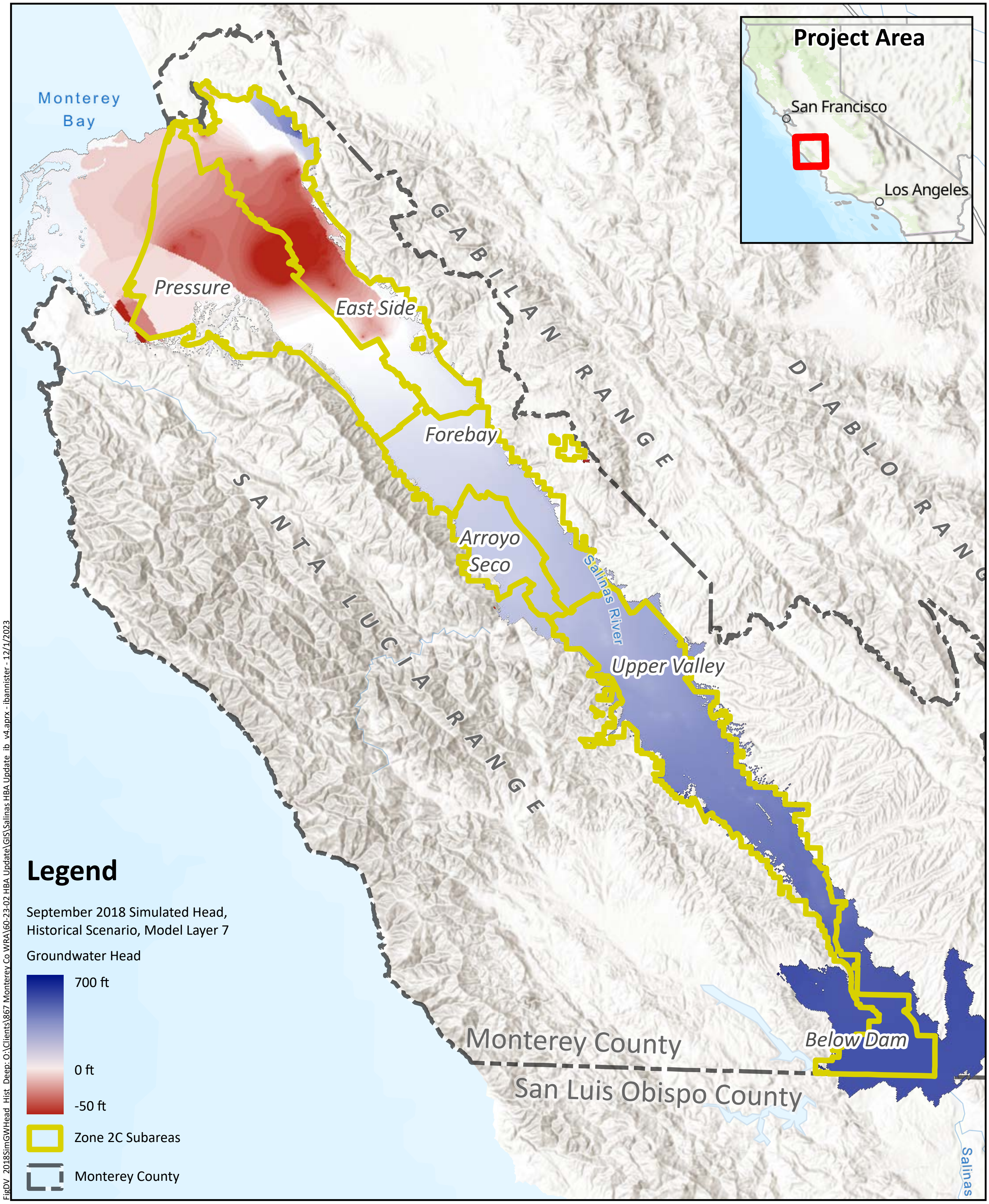
April 2025

September 2018
Simulated Groundwater Head
Historical Scenario
400-Foot Aquifer & Equivalent

Figure 3-2



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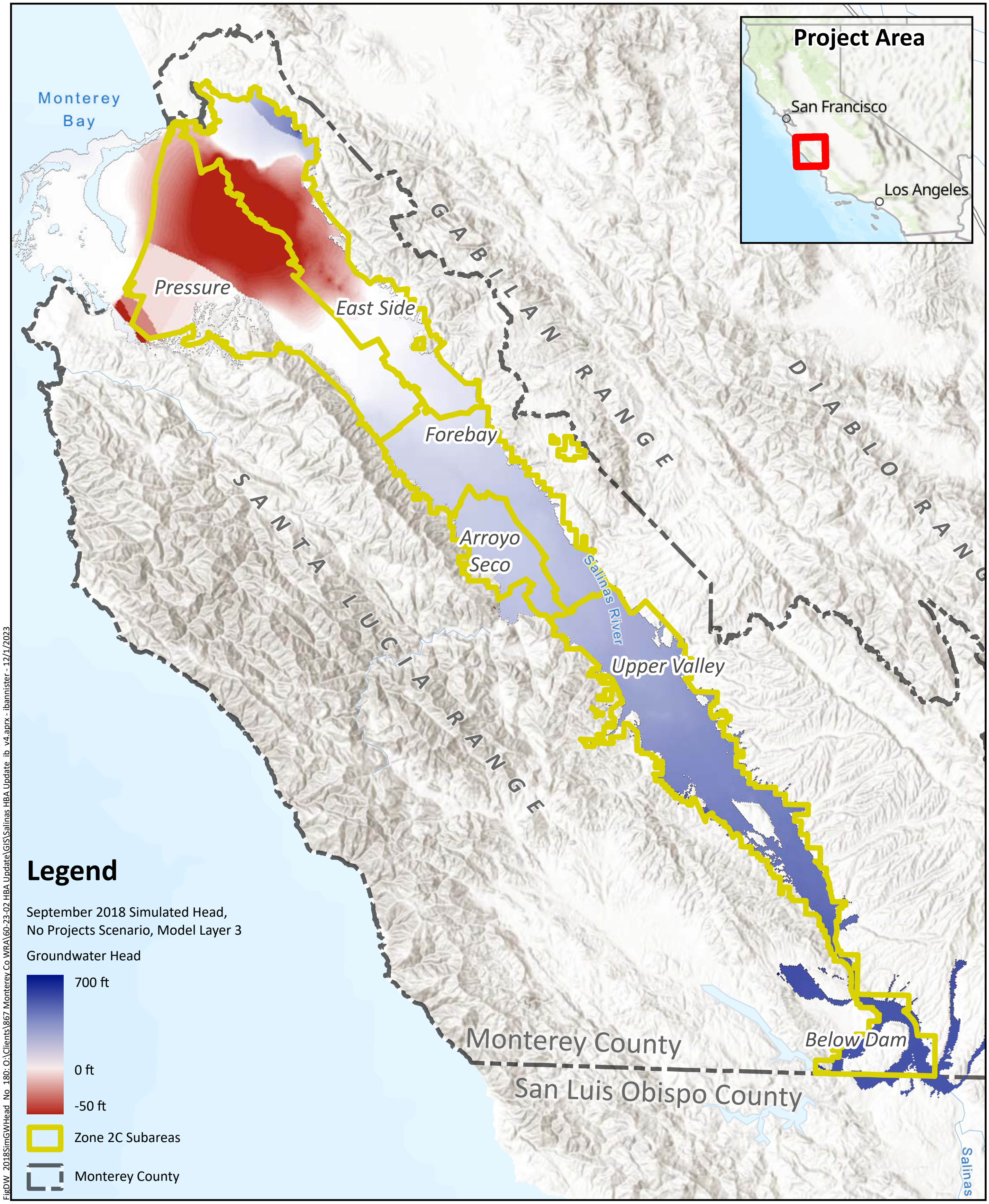
April 2025

September 2018
Simulated Groundwater Head
Historical Scenario
Deep Aquifer

Figure 3-3



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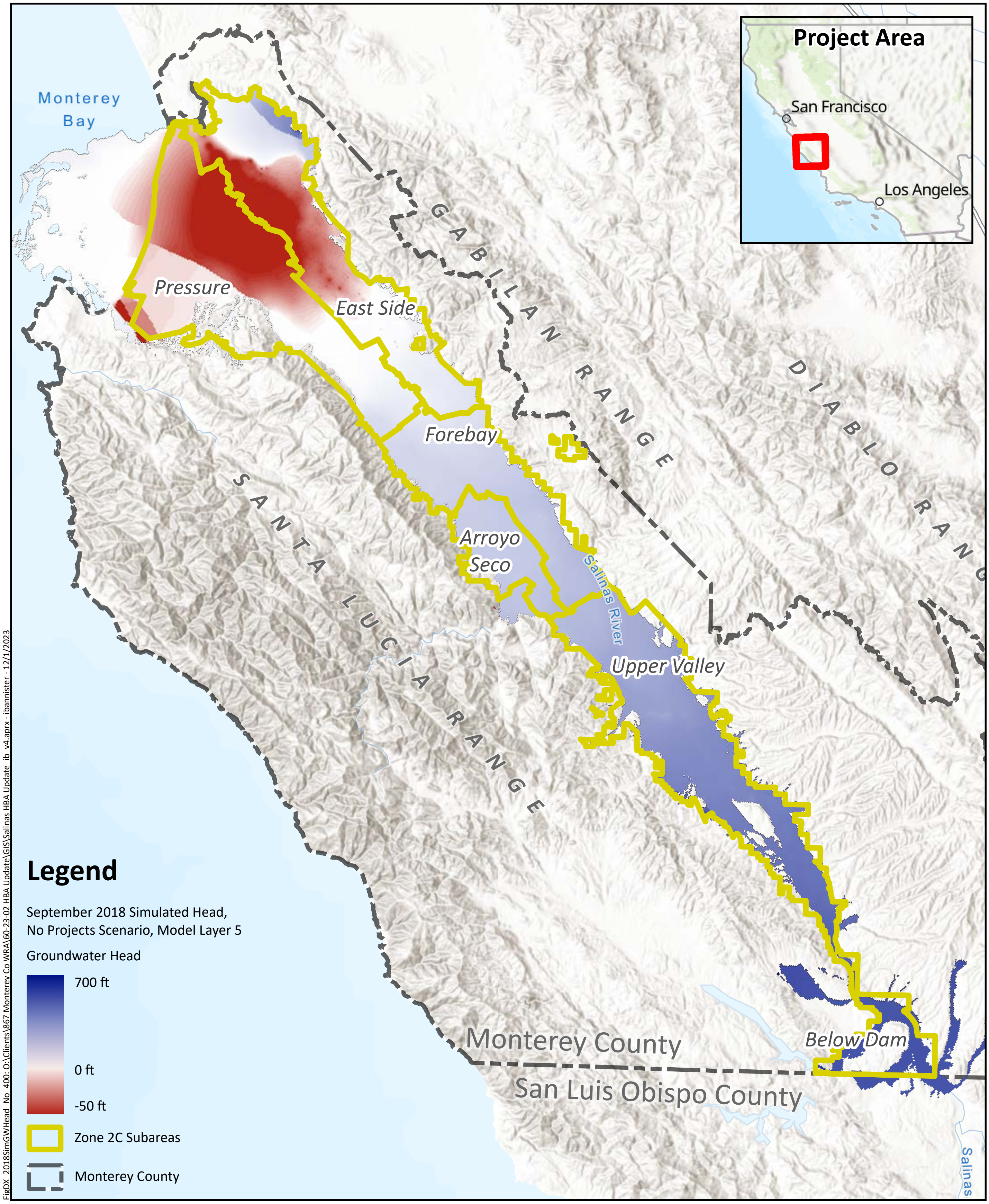
September 2018
Simulated Groundwater Head
No Projects Scenario
180-Foot Aquifer & Equivalent

Figure 3-4



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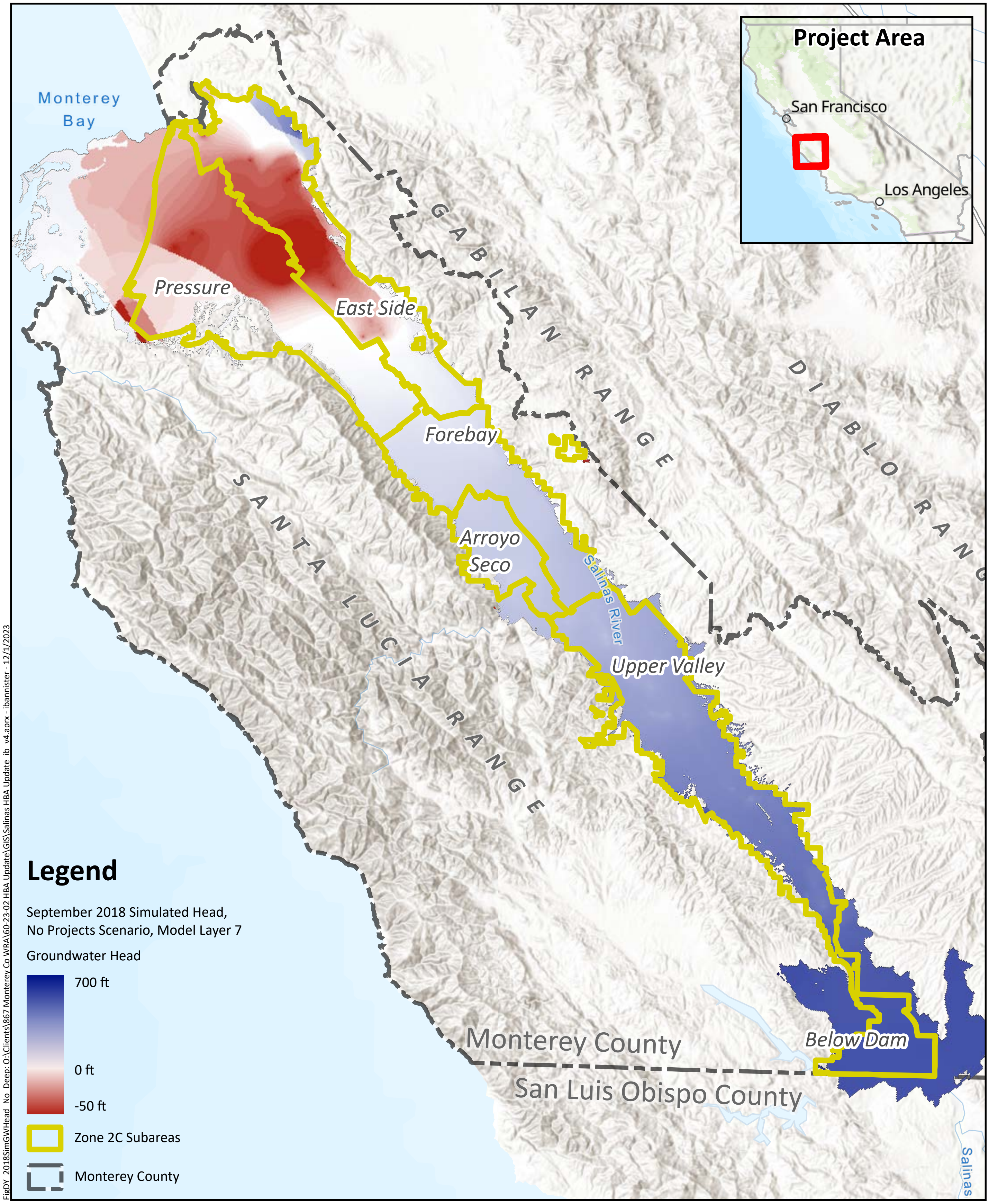
September 2018
Simulated Groundwater Head
No Projects Scenario
400-Foot Aquifer & Equivalent

Figure 3-5



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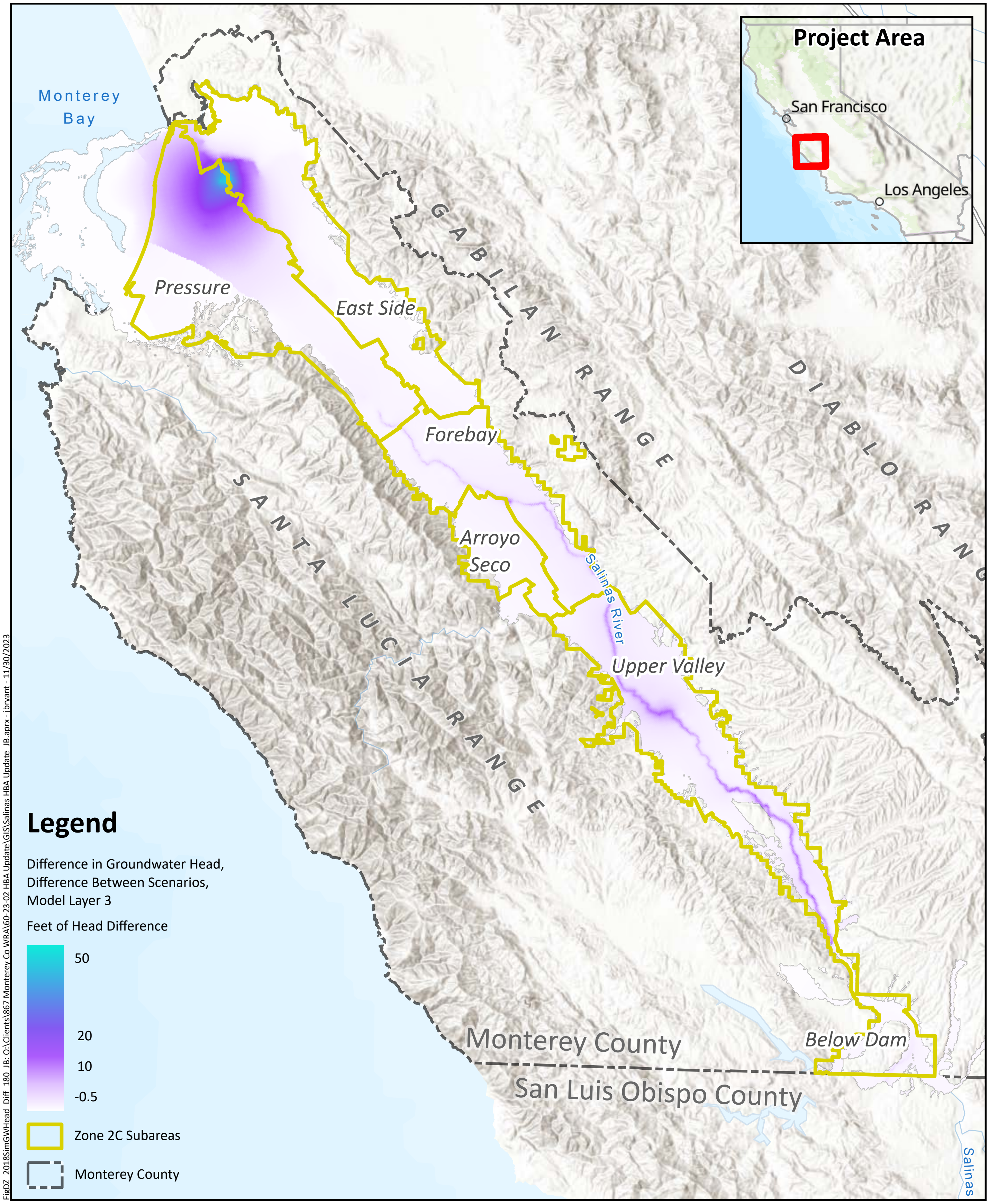
April 2025

September 2018
Simulated Groundwater Head
No Projects Scenario
Deep Aquifer

Figure 3-6



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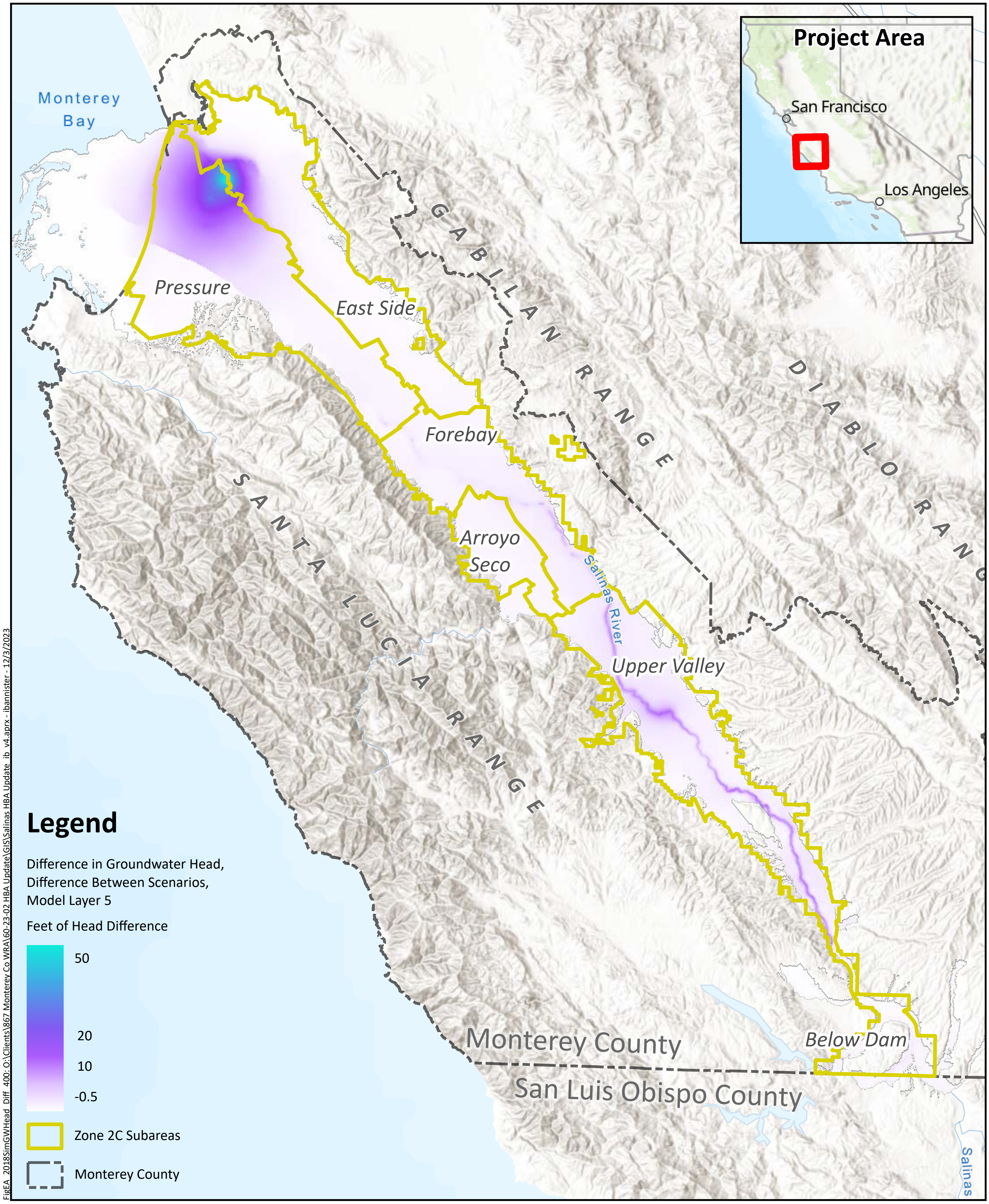
April 2025

September 2018
Simulated Groundwater Head
Difference Between Scenarios
180-Foot Aquifer & Equivalent

Figure 3-7



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Prepared by:

WEST YOST

0 5 10 Miles

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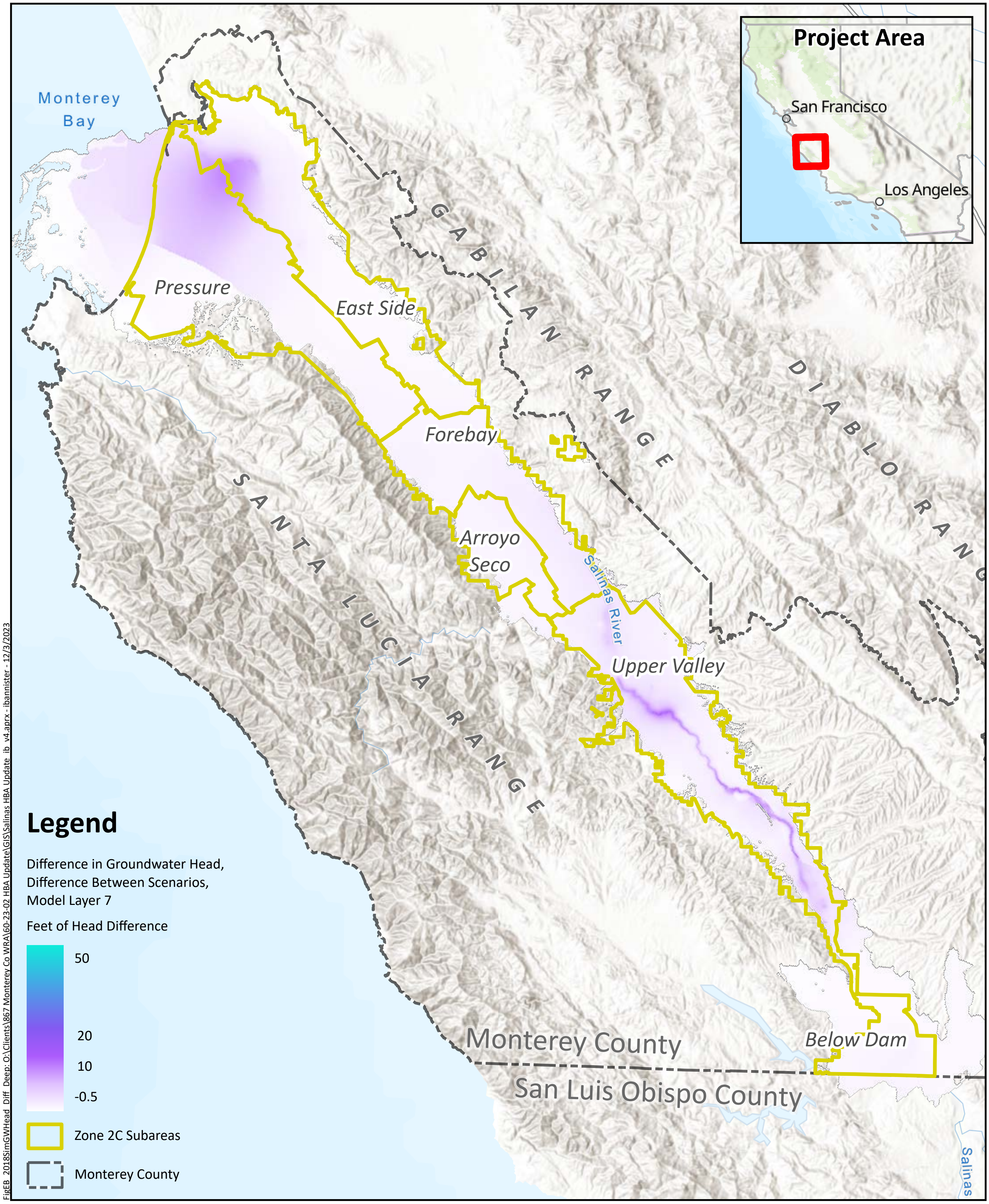
April 2025

September 2018
Simulated Groundwater Head Difference Between Scenarios
400-Foot Aquifer & Equivalent

Figure 3-8



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Prepared by:

WEST YOST

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0 8 16 Km

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Salinas Valley HBA Update

April 2025

September 2018
Simulated Groundwater Head
Difference Between Scenarios
Deep Aquifer

Figure 3-9

The head differences that occur along the Salinas River can be understood to result from the operations of the reservoirs, which store high flows during wet periods for later release during drier periods. This results in increased recharge along the Salinas River, maintaining higher groundwater head values in the riparian area and adjacent aquifers. Head differences between Castroville and Salinas can likely be ascribed to the operation of CSIP, which delivers recycled and surface water to agricultural users in the coastal area to reduce agricultural demand on the main production aquifers in the Pressure Subarea (the 180-Foot and 400-Foot Aquifers). The head difference is much smaller in the Deep Aquifers of the Pressure Subarea because the effects of the CSIP are more significant in the shallower aquifers.

3.2.2 Average Annual Groundwater Head Change

Another approach to understanding the effects of the Projects on groundwater head is to analyze the head change that occurs over the course of each year (annual groundwater head change). This is done by calculating the simple difference between the end-of-water-year head and the head simulated for the end of the previous water year.

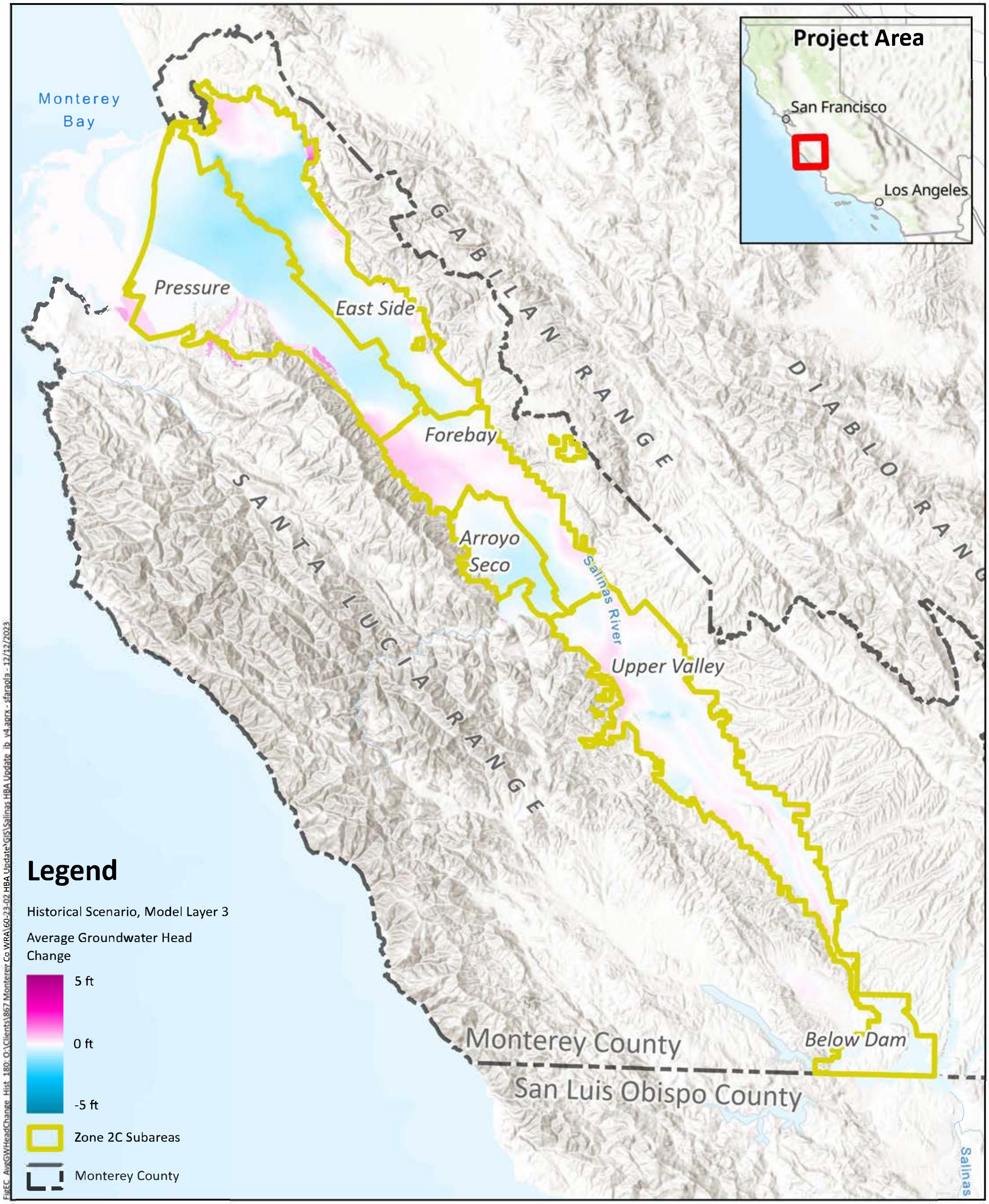
Figures 3-10 through 3-12 present the average annual groundwater head change under the Historical Scenario for Model Layers 3, 5, and 7. Figures 3-13 through 3-15 show the average annual groundwater head change under the No Projects Scenario for the same model layers. Figures 3-16 through 3-18 present the differences in the average annual groundwater head change between the two scenarios for the same model layers.

On average, head in Model Layer 3 simulated under the Historical Scenario (Figure 3-10) declined by about half a foot to a foot per year in much of the northern part of the study area, from about Gonzales north; the largest decline in head in this area was about 1.5 feet per year in the area between Castroville and Salinas (see Figure 1-1 for locations). Head also declined by up to about half a foot per year in the Arroyo Seco area, and by up to about 0.2 feet per year in the area between the dams and Bradley. Increases in head were mostly limited to the vicinity of the Salinas River (up to around Gonzales), reaching as much as about 0.5 feet per year downstream of the confluence with Arroyo Seco.

Average annual head change in Model Layer 5 under the Historical Scenario (Figure 3-11) followed the same pattern as in Model Layer 3, but with a slightly larger average annual head decrease in the northern part of the study area, reaching a maximum of about 3 feet per year in the area between Castroville and Salinas.

Average annual head change in Model Layer 7 under the Historical Scenario (Figure 3-12) followed the same general pattern as in Model Layers 3 and 5. South of about Gonzales, the aquifers are generally undifferentiated, so head changes in this area would be expected to be very similar between model layers. Model Layer 7 average annual head change in the northern part of the study area was around 1 foot per year through much of the area, reaching up to about 2 feet per year in the northeastern corner of the model domain.

The overall pattern of average annual head change in Model Layer 3 simulated under the No Projects Scenario (Figure 3-13) is similar to that for the Historical Scenario (Figure 3-10), except that the average annual head change was generally more negative, with larger head declines in the northern part of the study area (large area of at least 0.7 feet per year, with a maximum head decline of about 2.2 feet per year). Head increases along the Salinas River are mostly limited to the area downstream of Soledad, the area around King City, and the area downstream of San Ardo.



Prepared by:

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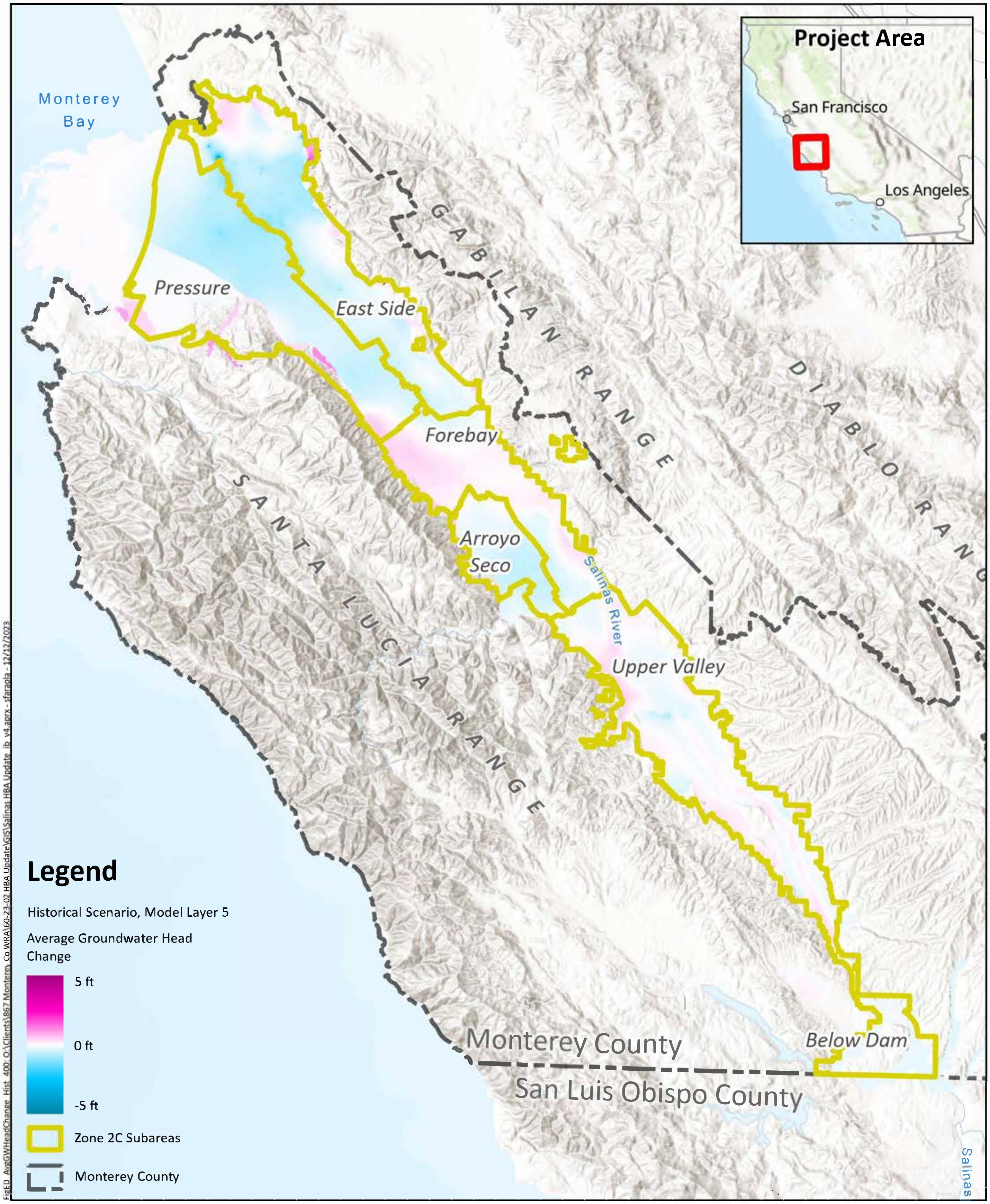
Average Annual Groundwater Head Change, Historical Scenario
180-Foot Aquifer & Equivalent

Figure 3-10



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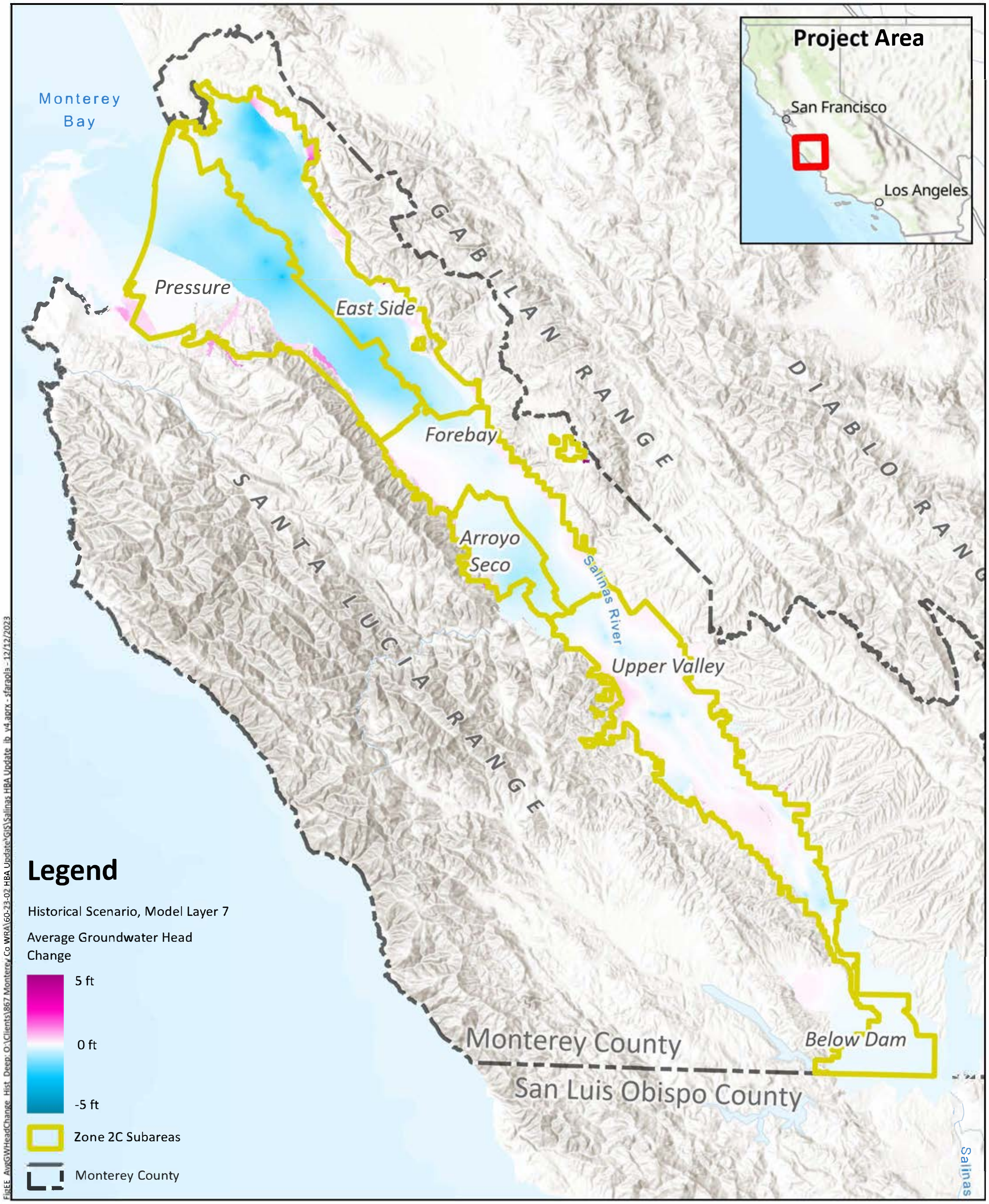
April 2025

Average Annual Groundwater Head Change, Historical Scenario
400-Foot Aquifer & Equivalent

Figure 3-11



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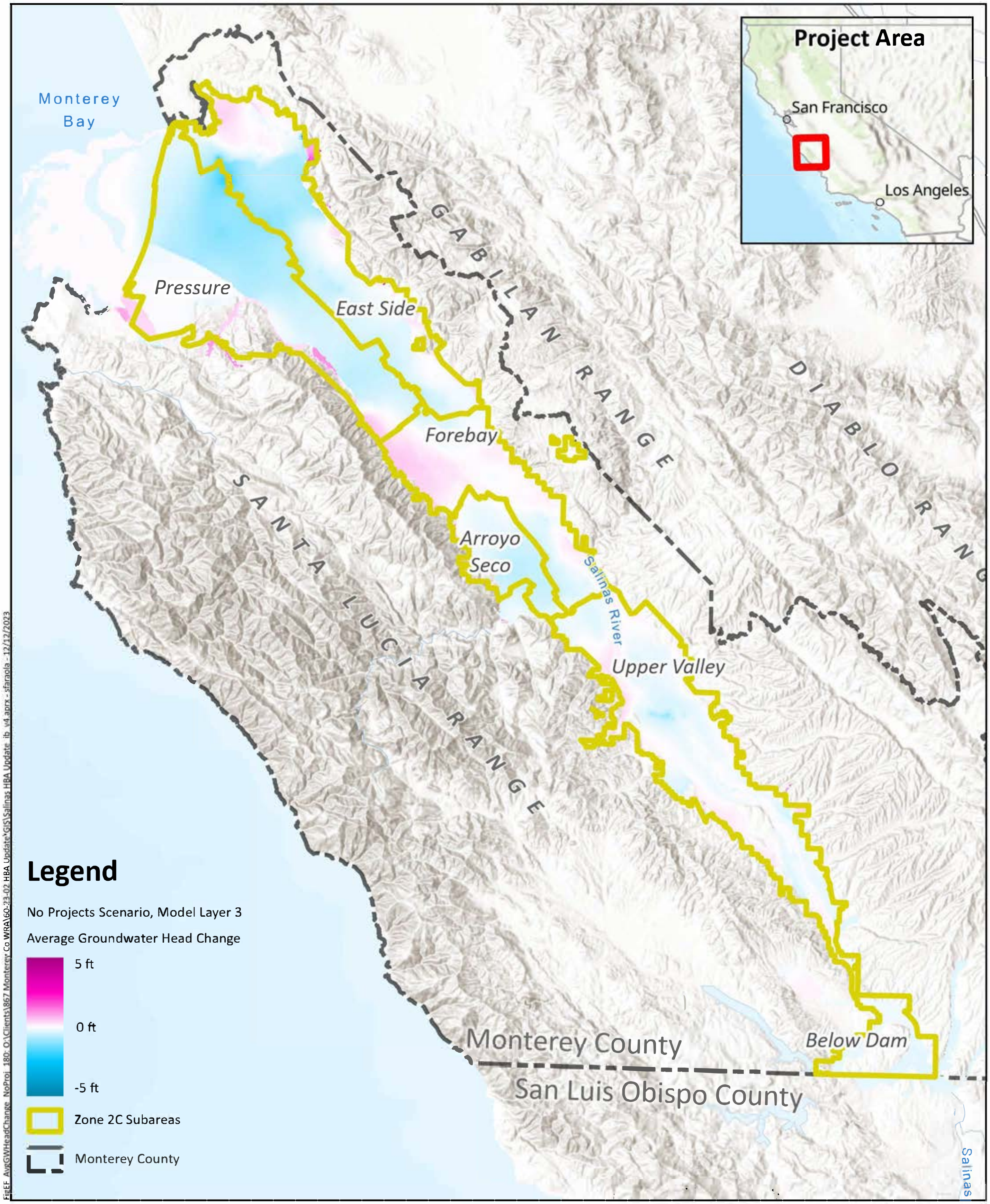
Salinas Valley HBA Update

April 2025

Average Annual Groundwater Head Change, Historical Scenario

Deep Aquifer

Figure 3-12



Prepared by:

WEST YOST

0 5 10 Miles
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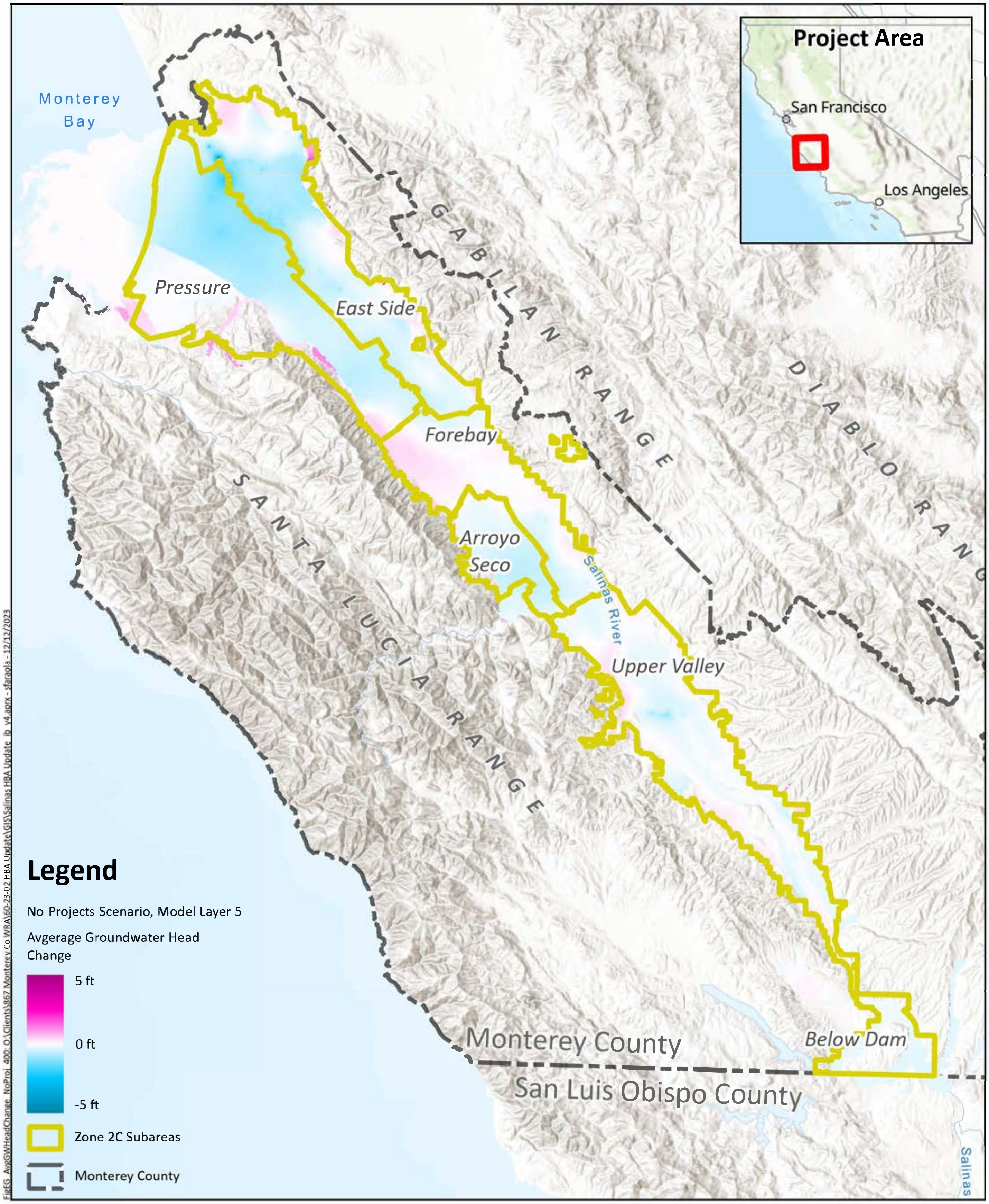
April 2025

Average Annual Groundwater Head Change, No Projects Scenario
180-Foot Aquifer & Equivalent

Figure 3-13



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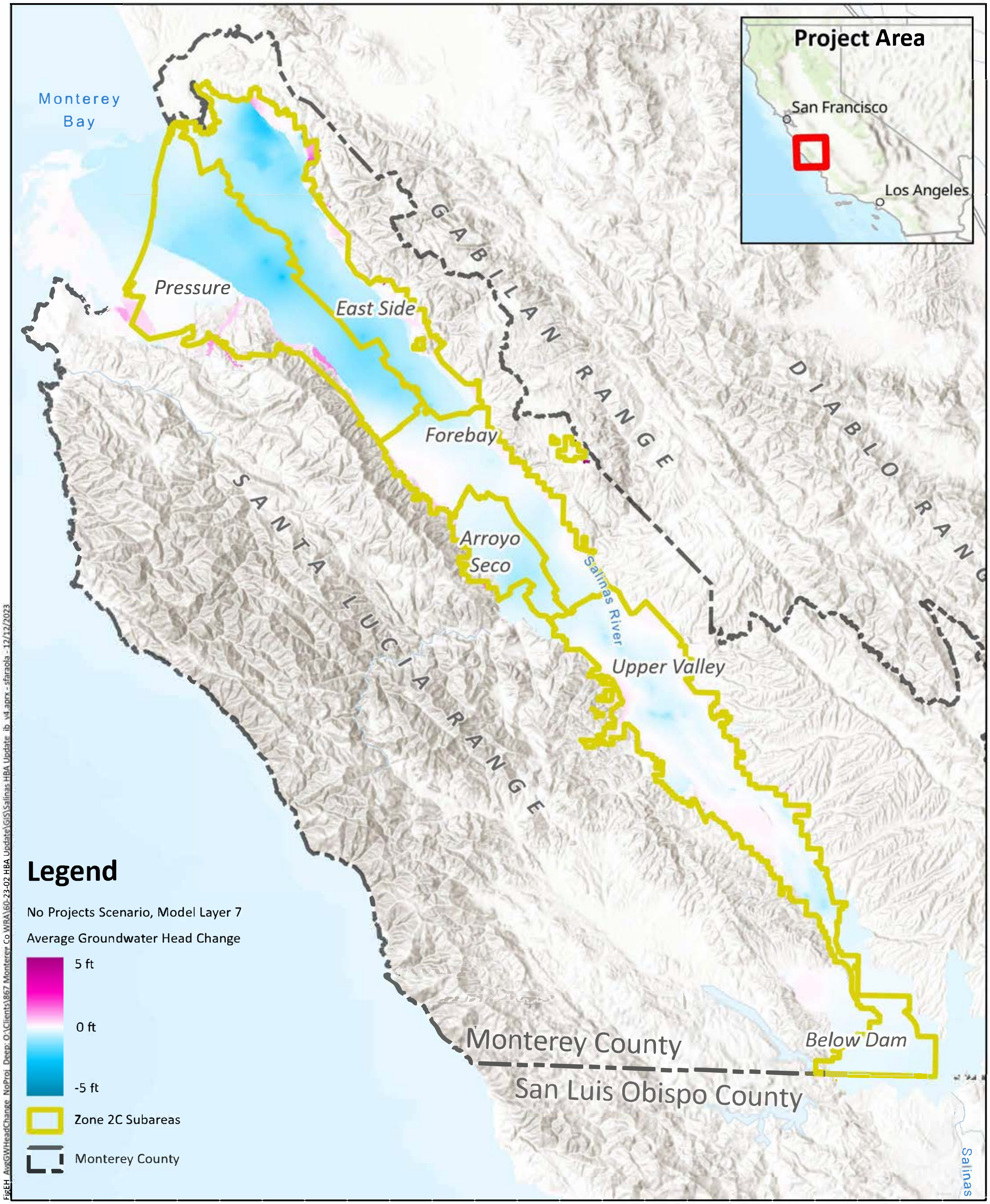
April 2025

Average Annual Groundwater Head Change, No Projects Scenario
400-Foot Aquifer & Equivalent

Figure 3-14



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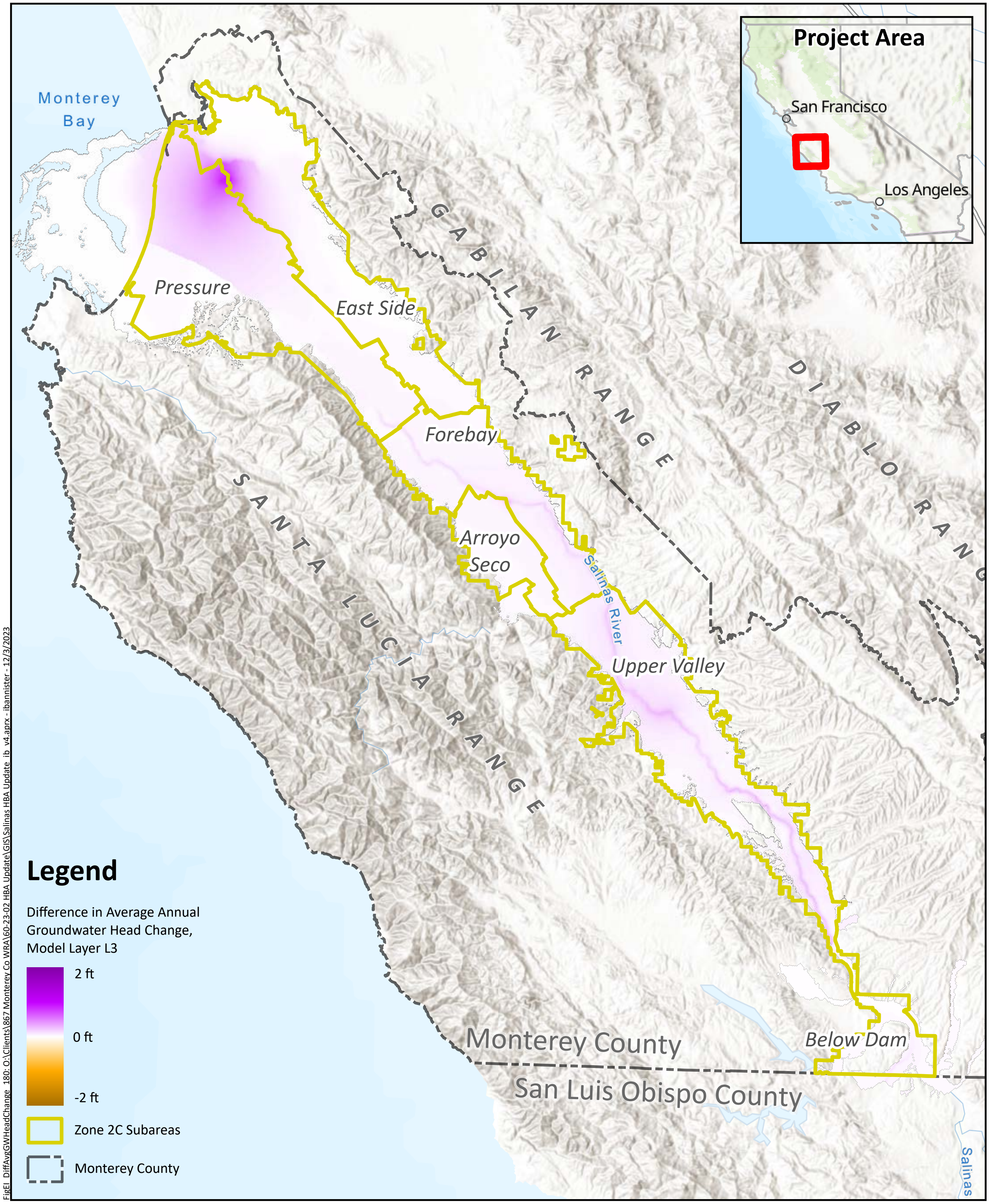
Average Annual Groundwater Head Change, No Projects Scenario
Deep Aquifer

Figure 3-15



FigEI_DiffAvgGWHeadChange_180: O:\Clients\867 Monterey Co WRA\60-23-02 HBA Update\GIS\Salinas HBA Update_ib_v4.aprx - ibannister - 12/3/2023

Prepared by:

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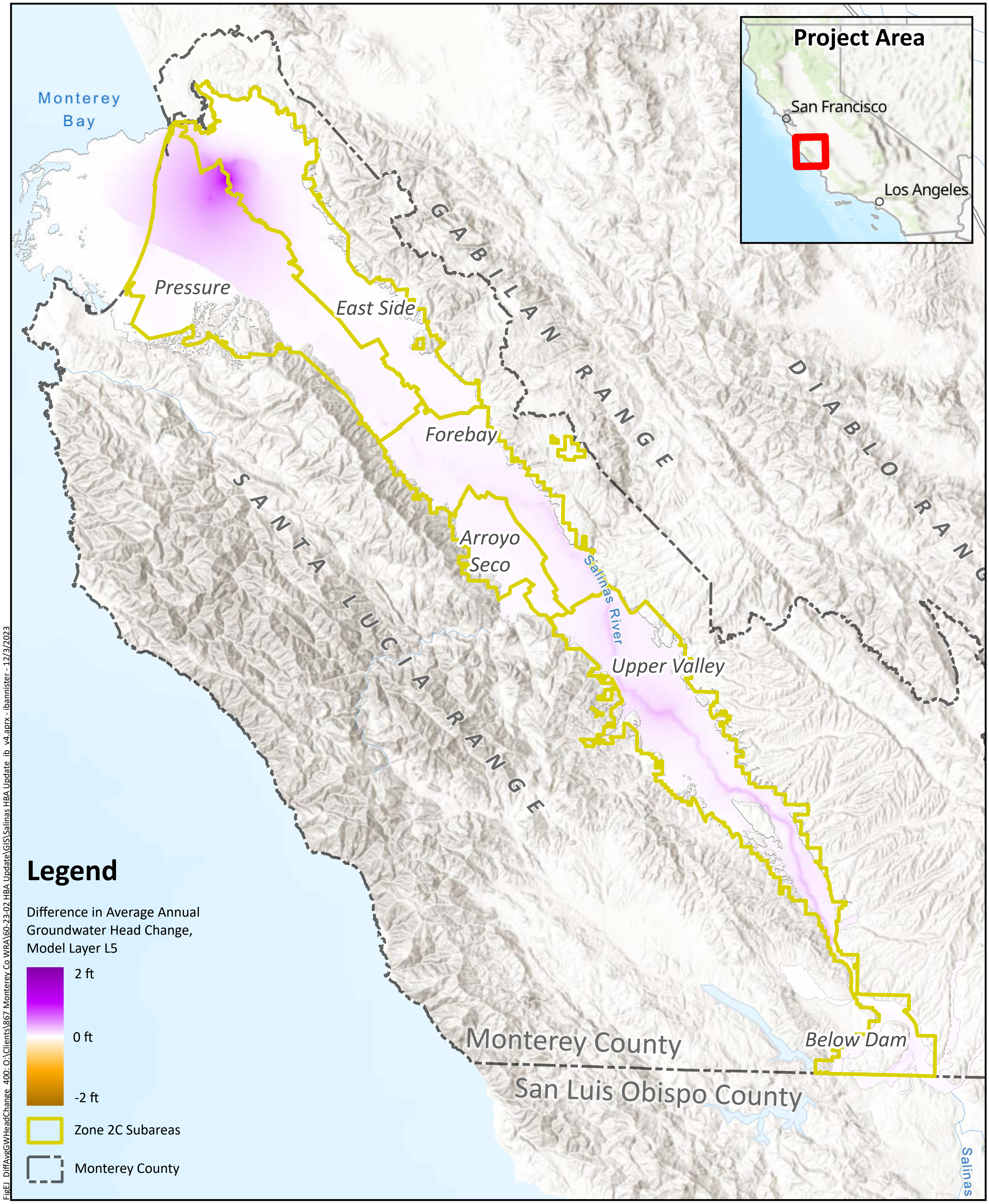
April 2025

Difference in Average Annual Groundwater Head Change
180-Foot Aquifer & Equivalent

Figure 3-16



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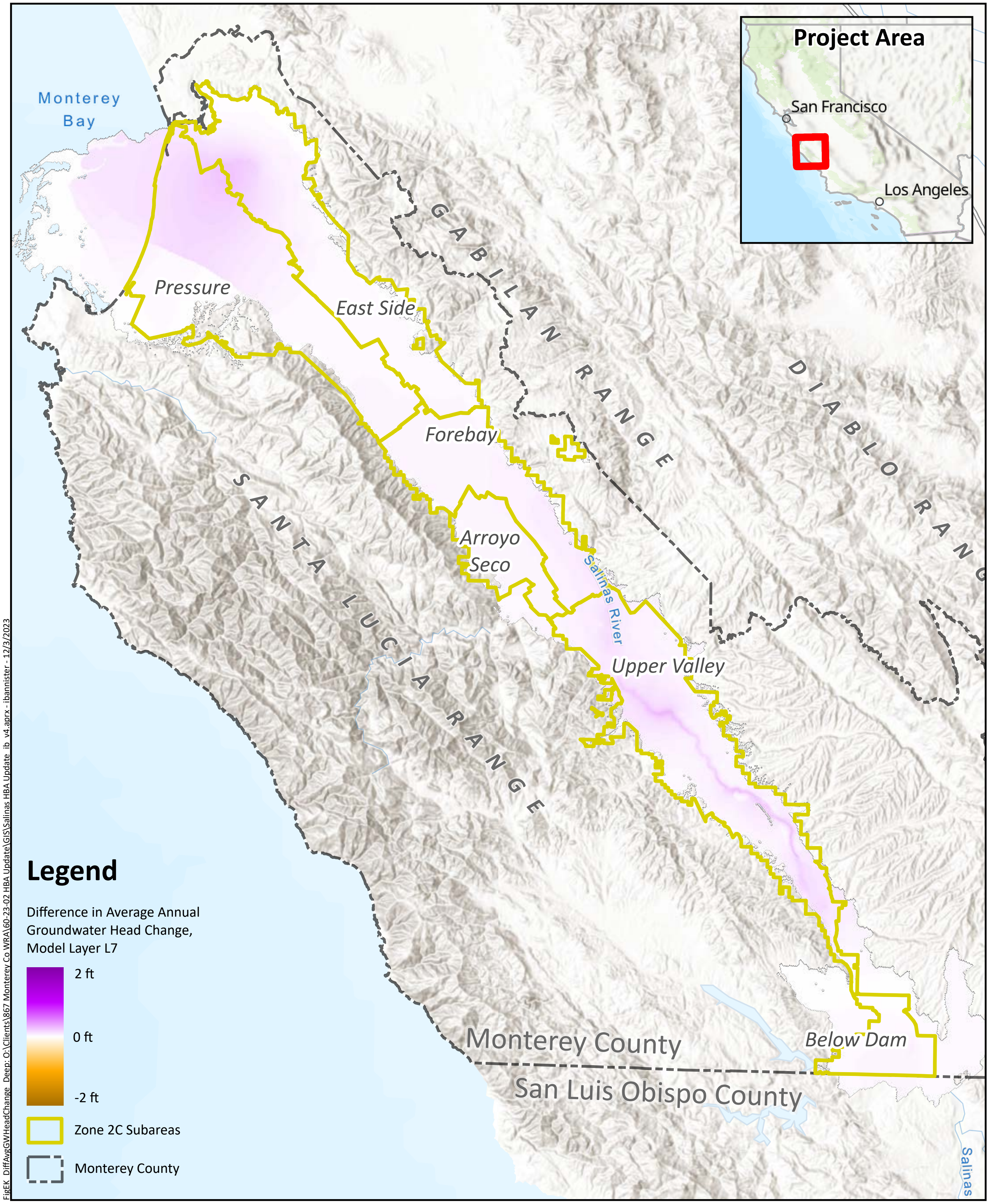
April 2025

Difference in Average Annual Groundwater Head Change
400-Foot Aquifer & Equivalent

Figure 3-17



FigEK_DiffAvgGWHeadChange_Deep: O:\Clients\867 Monterey Co WRA\60-23-02 HBA Update\GIS\Salinas HBA Update_ib_v4.aprx - ibannister - 12/3/2023

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April 2025

Difference in Average Annual Groundwater Head Change
Deep Aquifer

Figure 3-18

Similarly, the overall pattern of average annual groundwater head change in Model Layer 5 for the No Projects Scenario (Figure 3-14) is similar to that for the Historical Scenario (Figure 3-11), except that head changes are generally more negative along the Salinas River and in the area between Castroville and Salinas. In the northern part of the study area, groundwater head declined by more than a foot per year in much of the area between Castroville and Salinas, with a maximum decline of about 3.3 feet per year.

The average annual head change pattern in Model Layer 7 under the No Projects Scenario (Figure 3-15) looks similar to that for the Historical Scenario (Figure 3-12). In the northern part of the study area, where the Deep Aquifer is a separate defined unit, head declined by about a foot to 1.2 feet per year in much of the area between Castroville and Salinas.

The differences between scenarios are illustrated on Figures 3-16 to 3-18, which show the difference in the Historical Scenario and No Projects Scenario average annual head changes. As noted in previous sections, these differences are calculated as the Historical Scenario results minus the No Projects Scenario results; a positive number indicates higher head conditions simulated for the Historical Scenario. Figure 3-16 shows the difference between the scenarios in Model Layer 3. Notable differences between scenarios were largely in the vicinity of the Salinas River south of about Gonzales, and the region between Castroville and Salinas. The average annual head change was about 0.1 to 0.3 feet per year more positive in the vicinity of the Salinas River under the Historical Scenario. In the northern part of the study area, the average annual head change was up to about 0.9 feet per year less negative under the Historical Scenario.

The difference in average annual head change in Model Layer 5 (Figure 3-17) looks very similar to the differences simulated in Model Layer 3. The head change in the area between Castroville and Salinas was as much as about 1.3 feet per year less negative under the Historical Scenario compared to the No Projects Scenario.

The differences in average annual head change in Model Layer 7 (Figure 3-18) are smaller than those simulated in Model Layers 3 and 5. The average annual head change in the area between Castroville and Salinas was up to about 0.2 feet per year less negative under the Historical Scenario than under the No Projects Scenario.

The average annual head change maps presented in this section provide another indication of the effect of the Projects. As described in Section 3.2.1 above, the most significant effects occur in the vicinity of the Salinas River and in the area between Castroville and Salinas. Along the Salinas River, the average annual head change was positive along much of the Salinas River south of Gonzales under the Historical Scenario, whereas the No Projects Scenario simulated positive head changes over a much more constrained portion of the riparian area. This difference can be ascribed to the presence and operation of the Nacimiento and San Antonio Reservoirs. The average annual head change was also less negative in the area between Castroville and Salinas under the Historical Scenario compared to the No Projects Scenario. Differences in this area indicate the effect of the presence and operation of the CSIP system.

Further understanding of the effect of the Projects can be gained by considering the average annual head change maps for wet, normal, and dry years. The maps representing average annual head changes for both scenarios by water year type for Model Layers 3, 5, and 7 are presented in Appendix A. The difference between scenarios is largely insensitive to year type in the northern part of the study area, where the differences are likely to be largely due to the operation of the CSIP system, which can provide water to agricultural users during any year type.

Along the Salinas River, the reservoirs (and related projects and programs) result in smaller average annual head increases during wet years compared to the No Projects Scenario because the storage of high winter wet flows within the reservoirs results in less streamflow and less recharge during the winters of wet years. During normal and dry years, the average annual head change along the Salinas River is less negative under the Historical Scenario than the No Projects Scenario, reflecting the effect of the reservoirs releasing water during dry years. The overall effect of the reservoirs on the area around the Salinas River is to provide additional recharge during normal and dry years at the expense of recharge during wet years. Sections 3.3 and 3.4 below describe the differences in the fluxes entering and leaving the groundwater system, including recharge along the Salinas River.

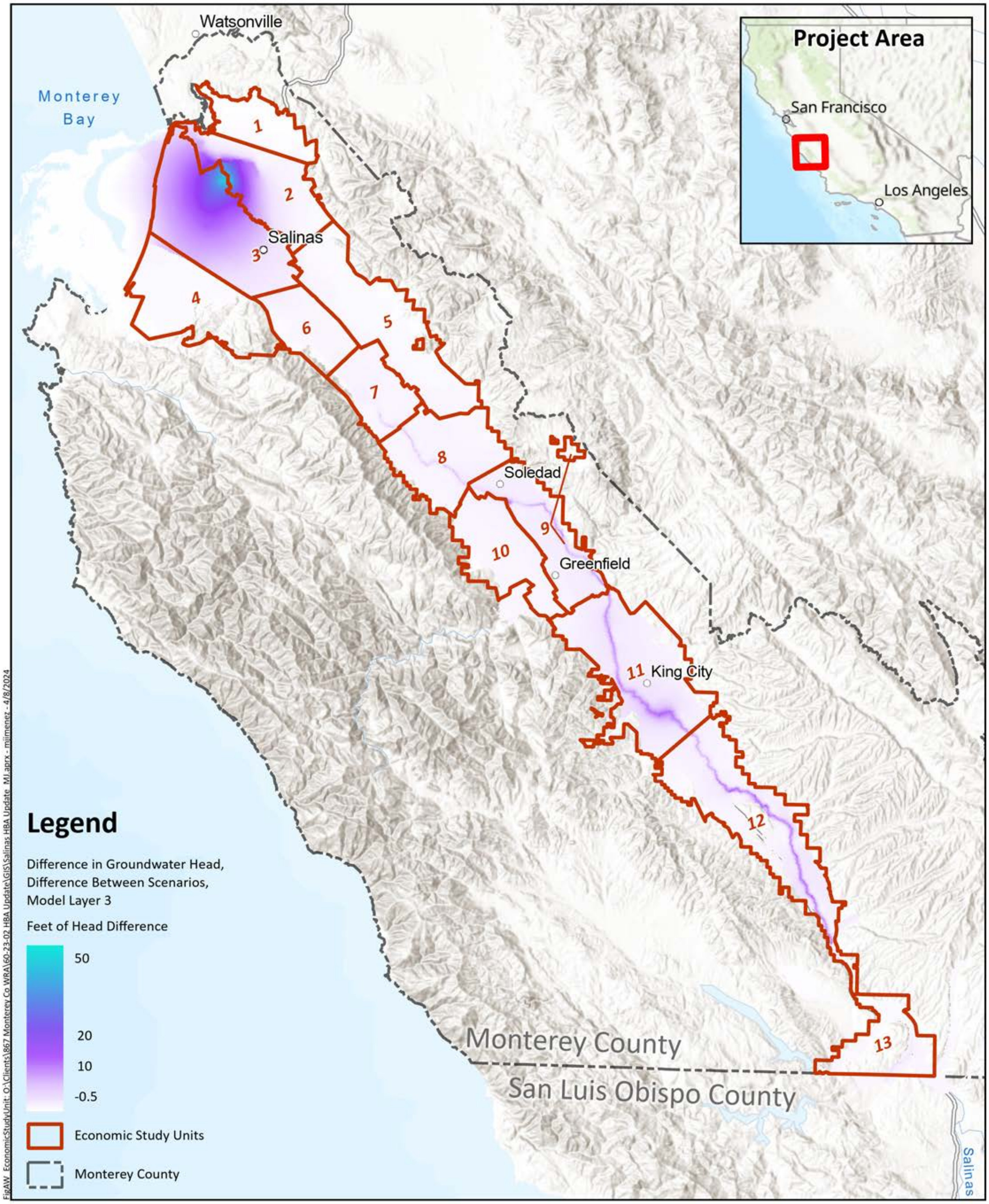
3.2.3 Economic Study Unit Delineation

The 1998 HBA summarized the benefits provided by the Nacimiento and San Antonio Reservoirs on a spatial basis using subdivisions of the model domain referred to as Economic Study Units (ESUs). These units provided a way to group together portions of the study area that experienced similar benefits (as quantified by the average annual groundwater head change). The 1998 HBA divided the SVIGSM model domain into 12 ESUs, two of which were not included in the benefit quantification.

Because this HBA Update utilizes a different set of tools for the quantification of the benefits of the Projects, a new ESU map is used to group portions of the study area together. As with the 1998 HBA, the ESU map is based on the groundwater head difference between the Historical and No Projects Scenarios, in this case demonstrated using the September 2018 model results (shown previously on Figure 3-7). The September 2018 results represent the cumulative difference between scenarios over the entirety of the 51-year simulation period, providing the most detailed understanding of the spatial variation in the benefit of the Projects.

Figure 3-19 shows the ESUs used for this study, along with the September 2018 head difference. This study uses 13 ESUs covering all of Zone 2C. The ESUs follow the Zone 2C Subarea boundaries (see Figure 1-6), with subareas subdivided into multiple ESUs as dictated by the head differences between scenarios. The East Side Subarea is divided into 3 ESUs (1, 2, and 5); the Pressure Subarea is divided into 4 ESUs (3, 4, 6, and 7); the Forebay Subarea is divided into 2 ESUs (8 and 9); the Arroyo Seco Subarea is a single ESU (10); the Upper Valley Subarea is divided into 2 ESUs (11 and 12); and the Below Dam Subarea is a single ESU (13). Other areas within the model domain but outside of Zone 2C are not included in any ESU, including the portion of the model domain within San Luis Obispo County.

The 1998 HBA presented (as Figures 1-14 through 1-23) time series of average annual groundwater head for the individual ESUs. The averaging relied on a temporal and spatial weighting approach that emphasized the times and places of the greatest magnitude of pumping. For this HBA Update, heads were not weighted either spatially or temporally. Instead, the analysis of head values by ESU concentrates on the end-of-water-year (i.e., end of September) simulated groundwater heads output by the SVIHM, averaged across each ESU. Figure 3-20 presents the average end-of-water-year groundwater heads for ESUs 1 through 13, showing the results for the Historical and No Projects Scenarios as well as the difference between the two (note that the scale of the left-hand vertical axis is the same on each of these figures, but the upper and lower bounds change to suit the results for each ESU). Table 3-1 provides the average annual head change averaged across each ESU for the Historical and No Projects Scenarios.



Prepared by:

WEST YOST

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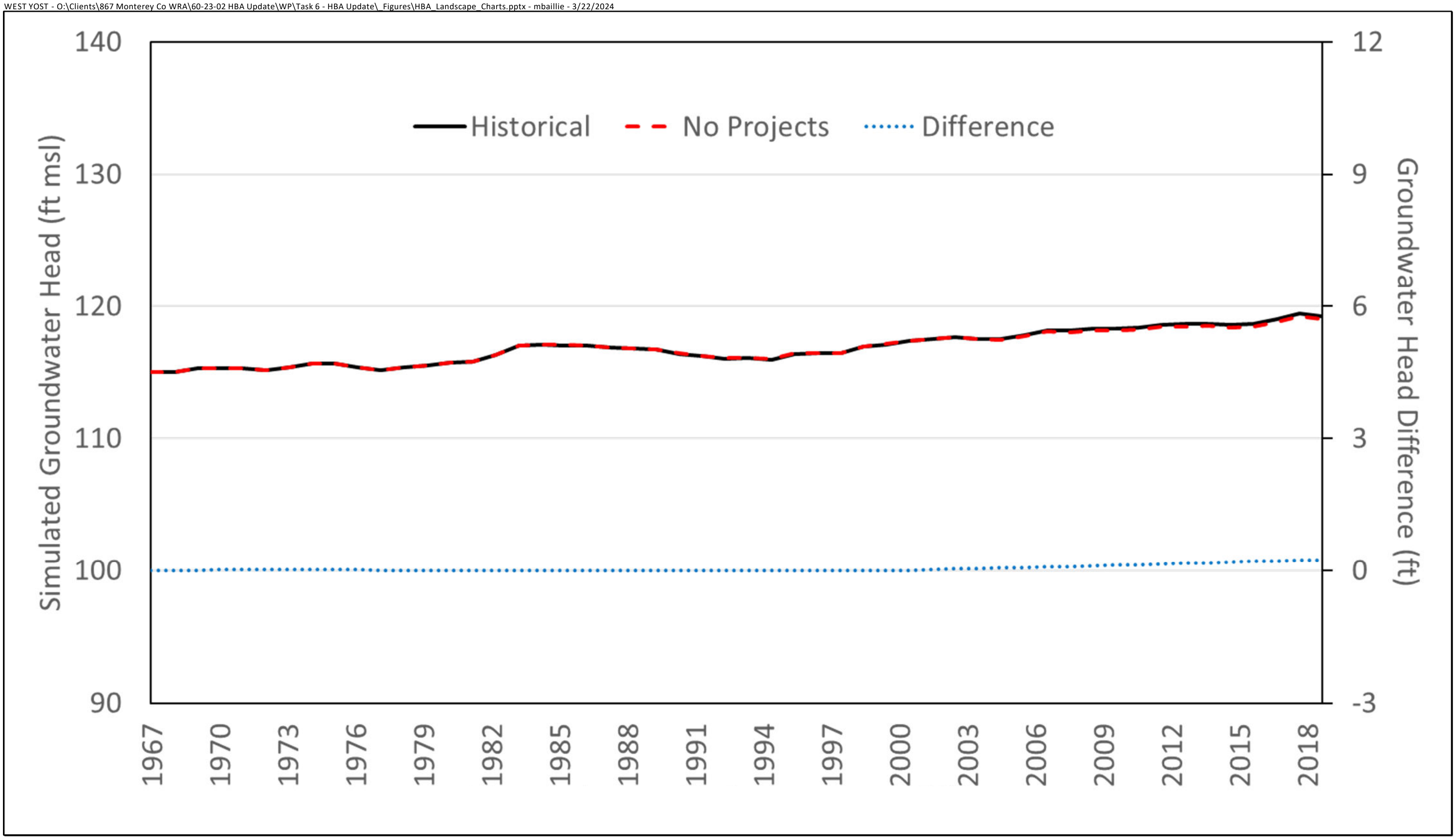
Salinas Valley HBA Update

April 2025

Economic Study Units

Figure 3-19



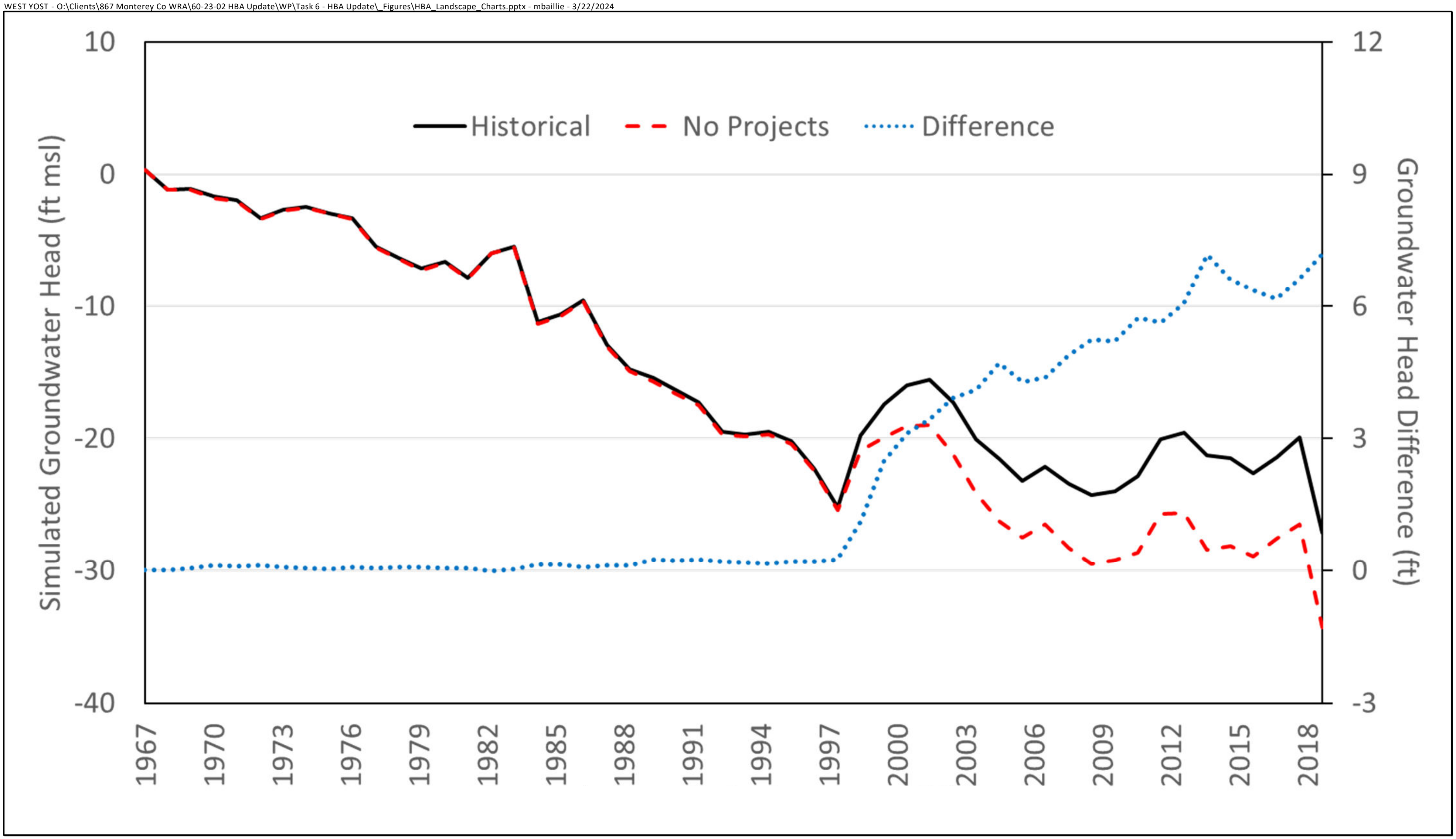
Notes:

1. Average annual head changes are presented for Model Layer 3 only, which represents the 180-Foot Aquifer in the Pressure Subarea, the East Side Shallow Aquifer in the East Side Subarea, and the undifferentiated aquifer in other Subareas
2. ft = feet; ft msl = feet above mean sea level

Figure 3-20a

Average End-of-Year Groundwater Head in ESU-1, Historical and No Projects Scenarios

Monterey County Water Resources Agency
Historical Benefits Analysis Update
April 2025



Notes:

1. Average annual head changes are presented for Model Layer 3 only, which represents the 180-Foot Aquifer in the Pressure Subarea, the East Side Shallow Aquifer in the East Side Subarea, and the undifferentiated aquifer in other Subareas
2. ft = feet; ft msl = feet above mean sea level

Figure 3-20b

Average End-of-Year Groundwater Head in ESU-2, Historical and No Projects Scenarios

Monterey County Water Resources Agency

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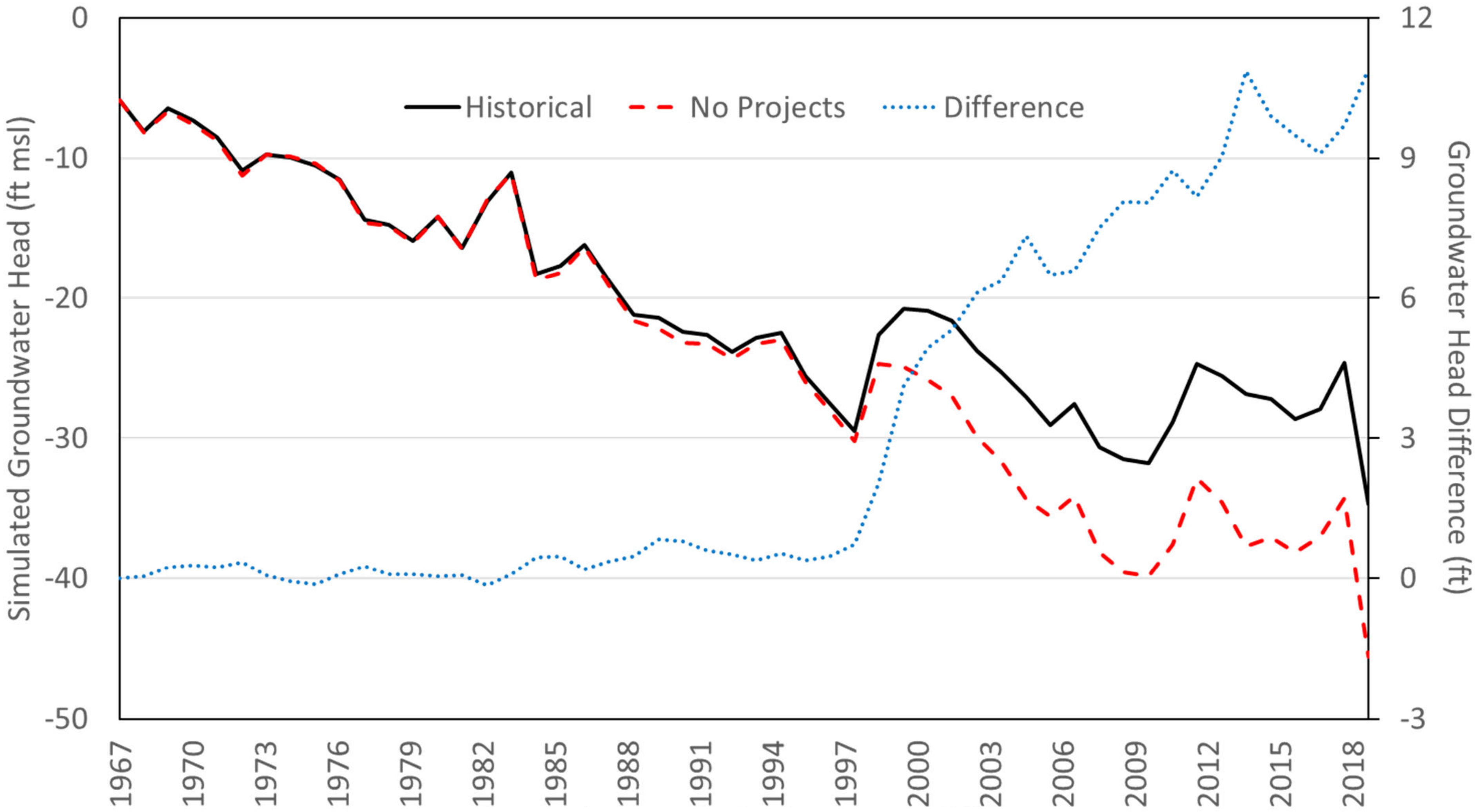
April 2025



Notes:

1. Average annual head changes are presented for Model Layer 3 only, which represents the 180-Foot Aquifer in the Pressure Subarea, the East Side Shallow Aquifer in the East Side Subarea, and the undifferentiated aquifer in other Subareas
2. ft = feet; ft msl = feet above mean sea level

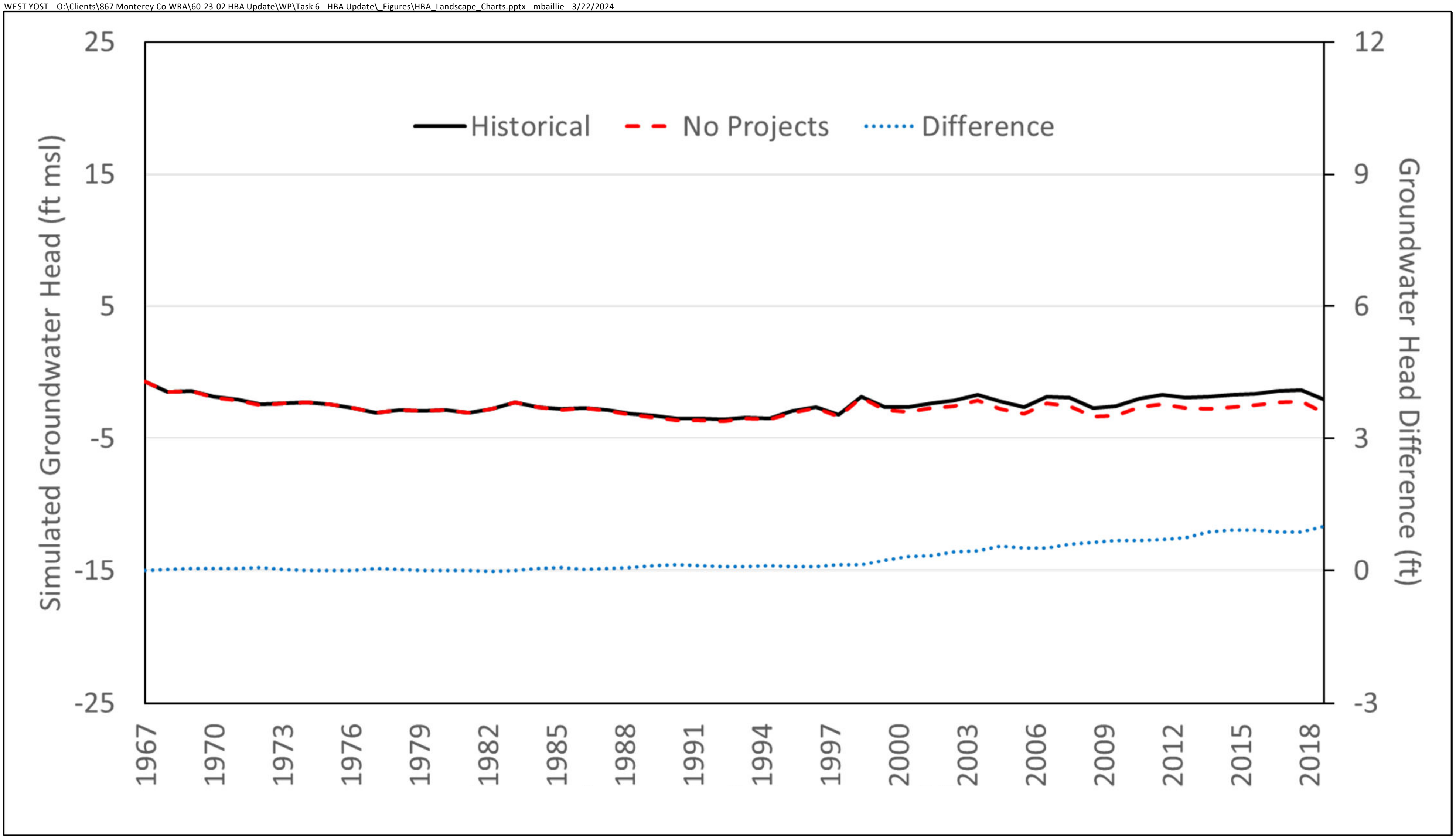
Figure 3-20c

Average End-of-Year Groundwater Head in ESU-3, Historical and No Projects Scenarios

Monterey County Water Resources Agency

Historical Benefits Analysis Update

April 2025



Notes:

1. Average annual head changes are presented for Model Layer 3 only, which represents the 180-Foot Aquifer in the Pressure Subarea, the East Side Shallow Aquifer in the East Side Subarea, and the undifferentiated aquifer in other Subareas
2. ft = feet; ft msl = feet above mean sea level

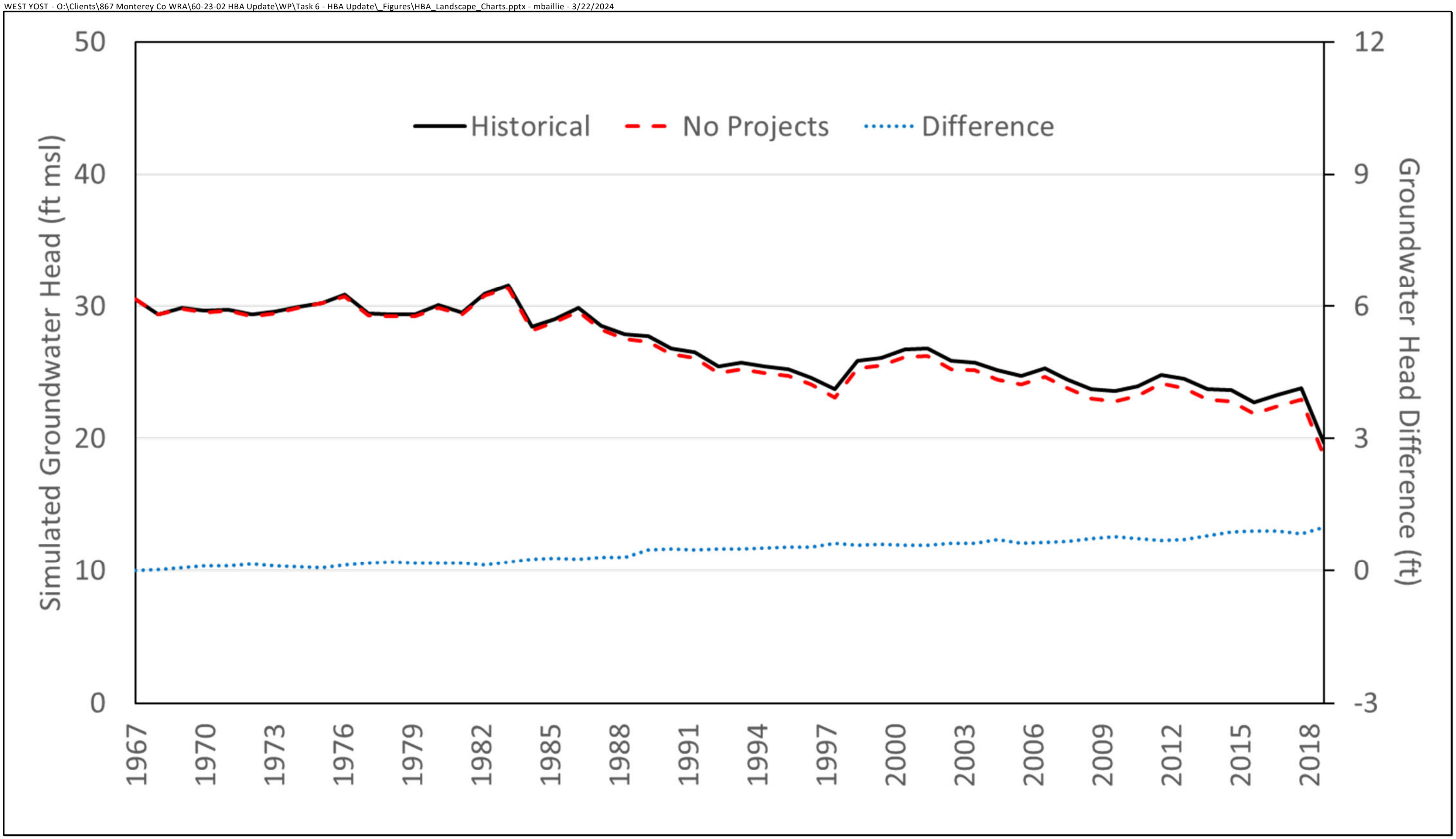
Figure 3-20d

Average End-of-Year Groundwater Head in ESU-4, Historical and No Projects Scenarios

Monterey County Water Resources Agency

Historical Benefits Analysis Update

April 2025



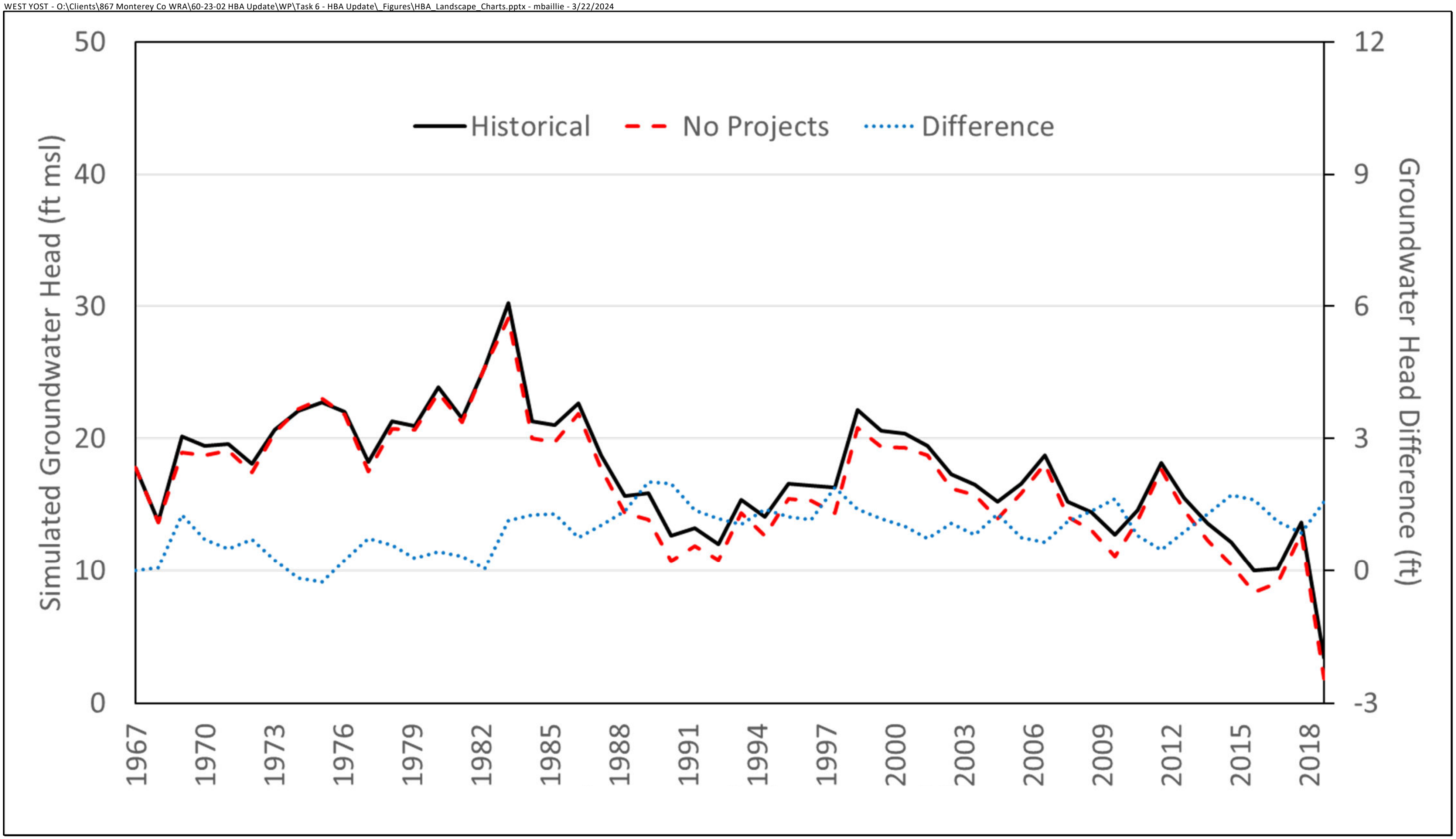
Notes:

1. Average annual head changes are presented for Model Layer 3 only, which represents the 180-Foot Aquifer in the Pressure Subarea, the East Side Shallow Aquifer in the East Side Subarea, and the undifferentiated aquifer in other Subareas
2. ft = feet; ft msl = feet above mean sea level

Figure 3-20e

Average End-of-Year Groundwater Head in ESU-5, Historical and No Projects Scenarios

Monterey County Water Resources Agency
Historical Benefits Analysis Update
April 2025



Notes:

1. Average annual head changes are presented for Model Layer 3 only, which represents the 180-Foot Aquifer in the Pressure Subarea, the East Side Shallow Aquifer in the East Side Subarea, and the undifferentiated aquifer in other Subareas
2. ft = feet; ft msl = feet above mean sea level

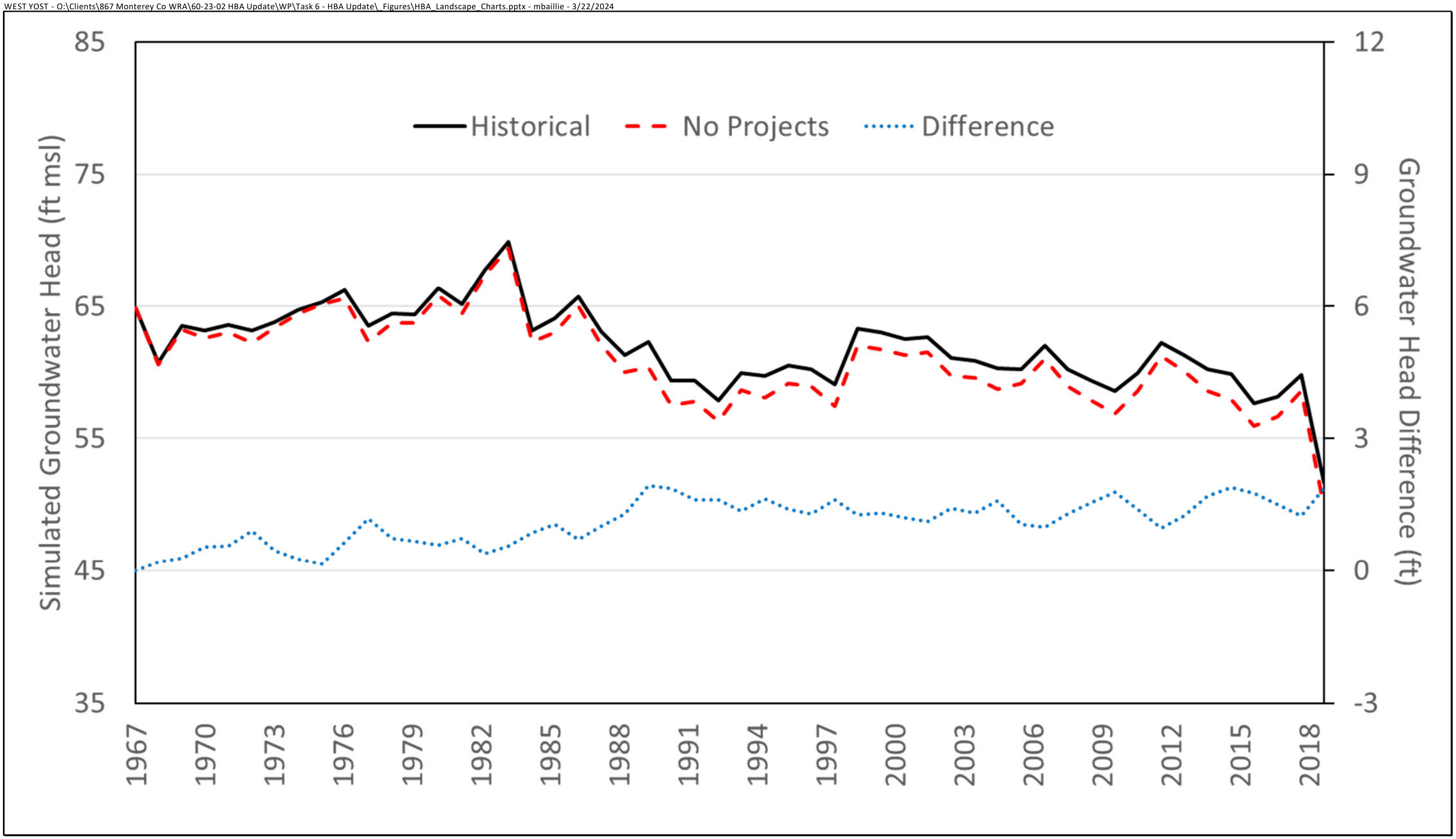
Figure 3-20f

Average End-of-Year Groundwater Head in ESU-6, Historical and No Projects Scenarios

Monterey County Water Resources Agency

Historical Benefits Analysis Update

April 2025



Notes:

1. Average annual head changes are presented for Model Layer 3 only, which represents the 180-Foot Aquifer in the Pressure Subarea, the East Side Shallow Aquifer in the East Side Subarea, and the undifferentiated aquifer in other Subareas
2. ft = feet; ft msl = feet above mean sea level

Figure 3-20g

Average End-of-Year Groundwater Head in ESU-7, Historical and No Projects Scenarios

Monterey County Water Resources Agency
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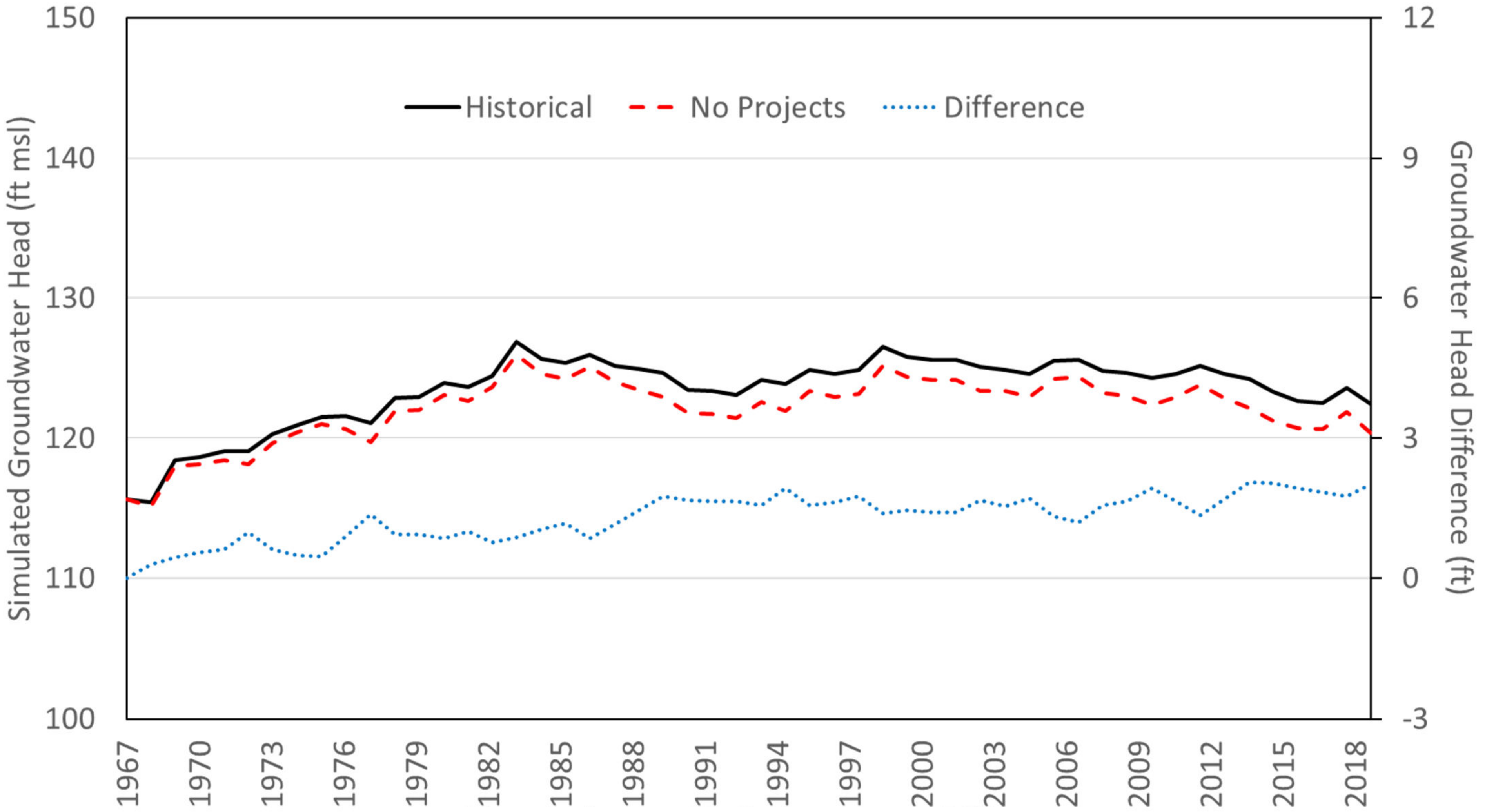
April 2025



Notes:

1. Average annual head changes are presented for Model Layer 3 only, which represents the 180-Foot Aquifer in the Pressure Subarea, the East Side Shallow Aquifer in the East Side Subarea, and the undifferentiated aquifer in other Subareas
2. ft = feet; ft msl = feet above mean sea level

Figure 3-20h

Average End-of-Year Groundwater Head in ESU-8, Historical and No Projects Scenarios

Monterey County Water Resources Agency

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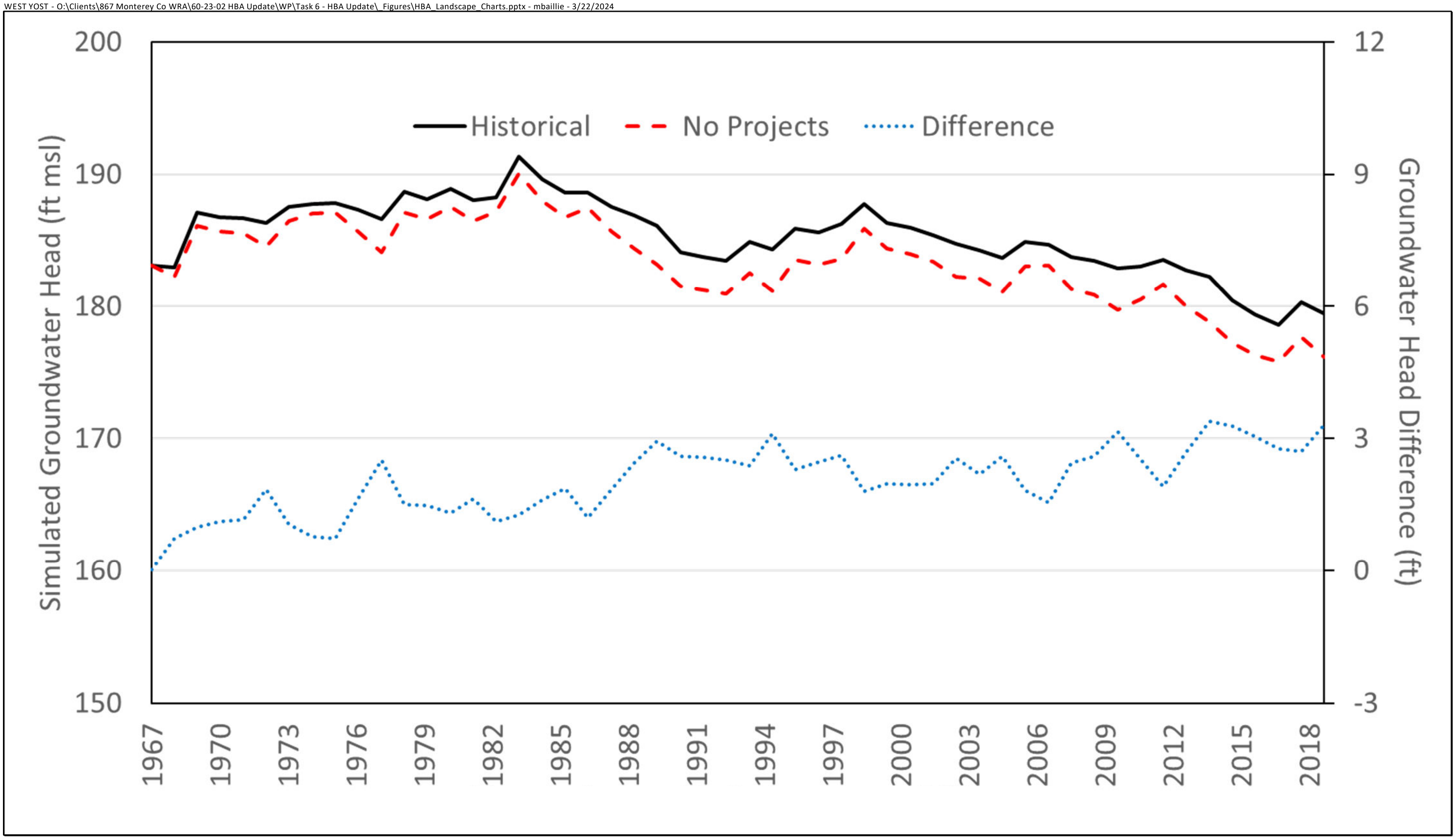
April 2025



Notes:

1. Average annual head changes are presented for Model Layer 3 only, which represents the 180-Foot Aquifer in the Pressure Subarea, the East Side Shallow Aquifer in the East Side Subarea, and the undifferentiated aquifer in other Subareas
2. ft = feet; ft msl = feet above mean sea level

Figure 3-20i

Average End-of-Year Groundwater Head in ESU-9, Historical and No Projects Scenarios

Monterey County Water Resources Agency

Historical Benefits Analysis Update

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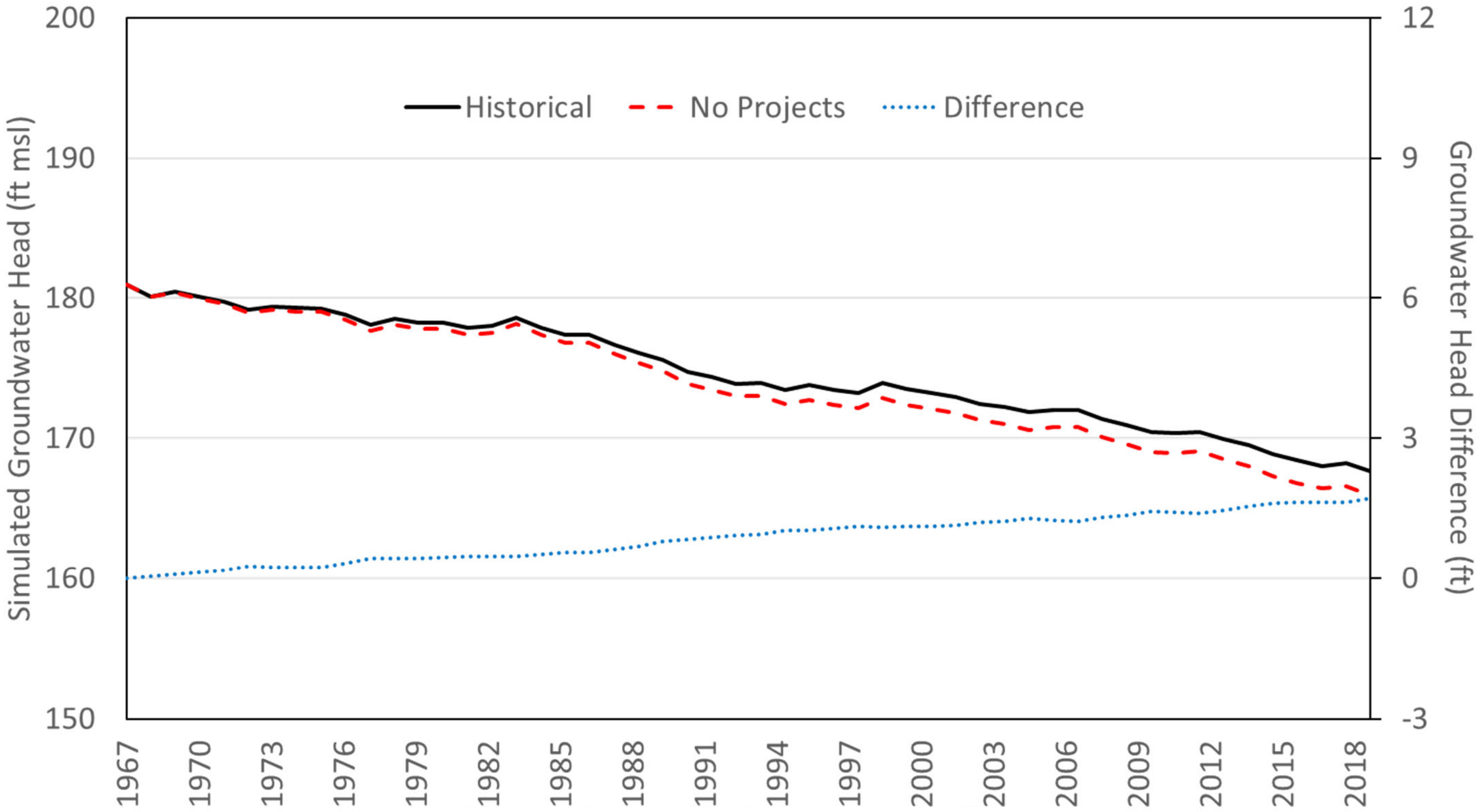

Notes:

1. Average annual head changes are presented for Model Layer 3 only, which represents the 180-Foot Aquifer in the Pressure Subarea, the East Side Shallow Aquifer in the East Side Subarea, and the undifferentiated aquifer in other Subareas
2. ft = feet; ft msl = feet above mean sea level

Figure 3-20j

Average End-of-Year Groundwater Head in ESU-10, Historical and No Projects Scenarios

Monterey County Water Resources Agency

Historical Benefits Analysis Update

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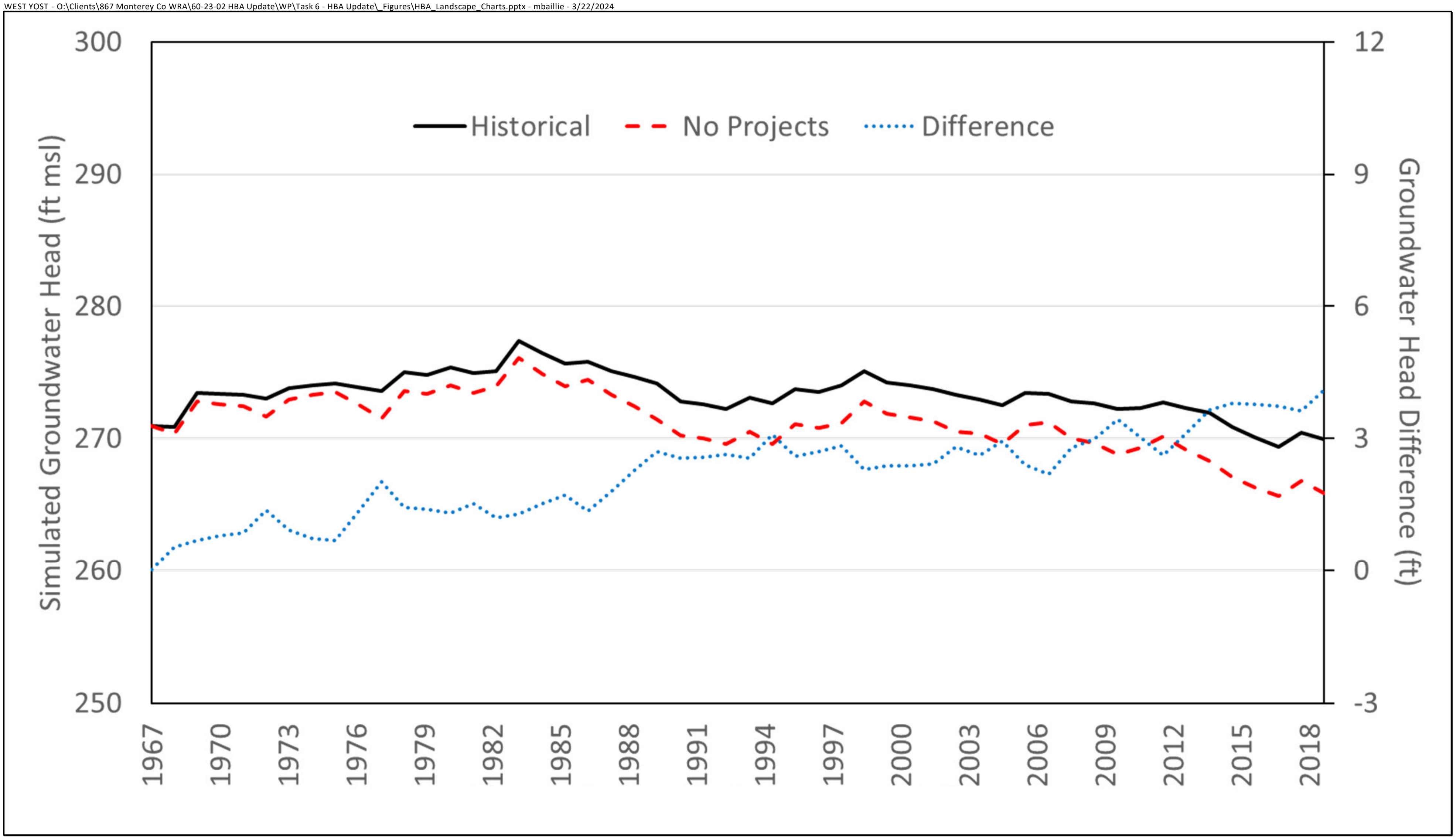


Notes:

1. Average annual head changes are presented for Model Layer 3 only, which represents the 180-Foot Aquifer in the Pressure Subarea, the East Side Shallow Aquifer in the East Side Subarea, and the undifferentiated aquifer in other Subareas
2. ft = feet; ft msl = feet above mean sea level

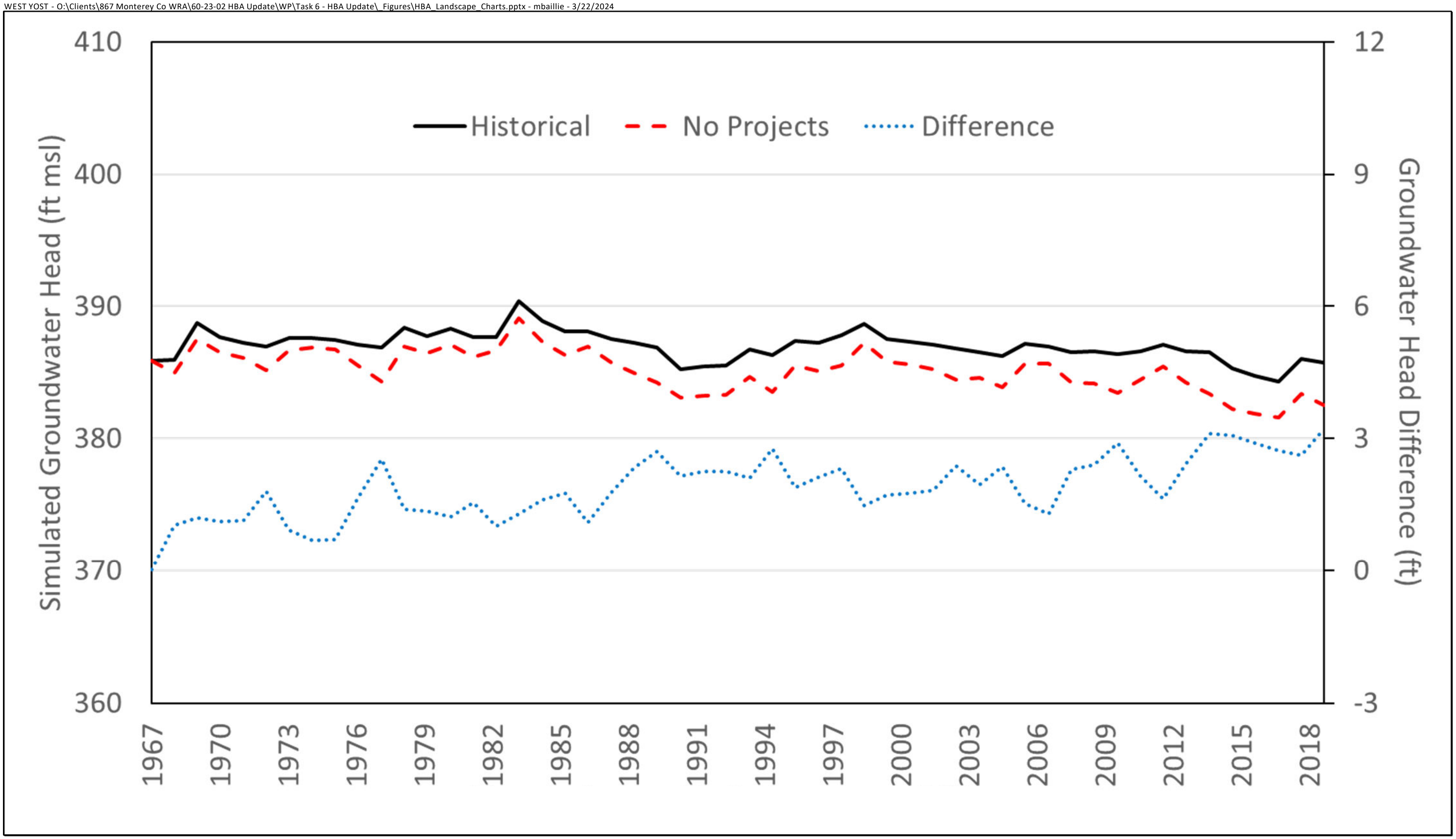
Figure 3-20k

Average End-of-Year Groundwater Head in ESU-11, Historical and No Projects Scenarios

Monterey County Water Resources Agency

Historical Benefits Analysis Update

April 2025



Notes:

1. Average annual head changes are presented for Model Layer 3 only, which represents the 180-Foot Aquifer in the Pressure Subarea, the East Side Shallow Aquifer in the East Side Subarea, and the undifferentiated aquifer in other Subareas
2. ft = feet; ft msl = feet above mean sea level

Figure 3-20l

Average End-of-Year Groundwater Head in ESU-12, Historical and No Projects Scenarios

Monterey County Water Resources Agency
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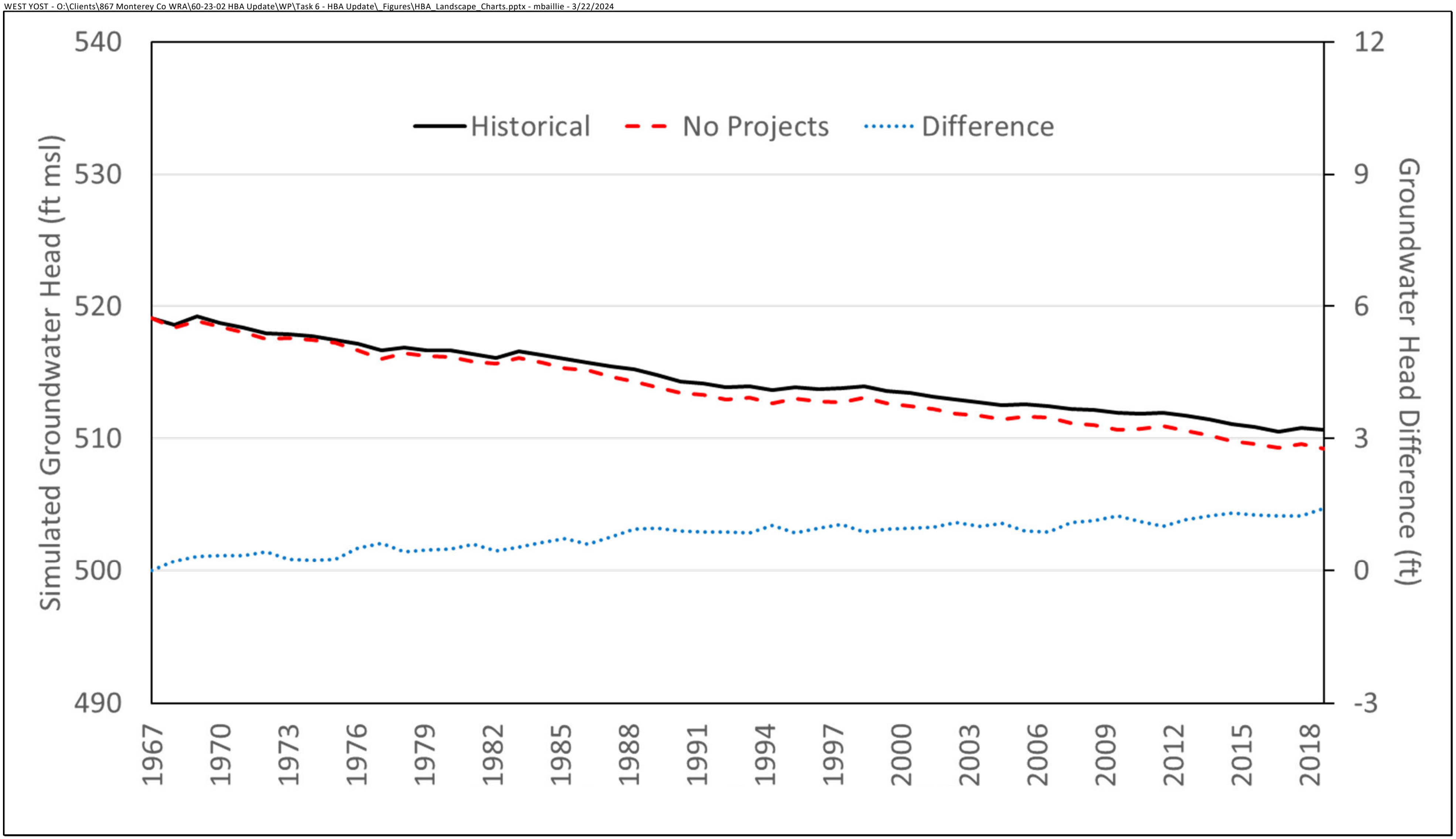
April 2025



Notes:

1. Average annual head changes are presented for Model Layer 3 only, which represents the 180-Foot Aquifer in the Pressure Subarea, the East Side Shallow Aquifer in the East Side Subarea, and the undifferentiated aquifer in other Subareas
2. ft = feet; ft msl = feet above mean sea level

Figure 3-20m

Average End-of-Year Groundwater Head in ESU-13, Historical and No Projects Scenarios

Table 3-1. Annual Average Head Change (in ft) by ESU, Historical and No Projects Scenarios

ESU	Historical Scenario				No Projects Scenario				Difference Between Scenarios			
	All Years	Wet Years	Normal Years	Dry Years	All Years	Wet Years	Normal Years	Dry Years	All Years	Wet Years	Normal Years	Dry Years
1	+0.08	+0.25	+0.08	-0.05	+0.08	+0.25	+0.08	-0.06	0.00	0.00	+0.01	+0.01
2	-0.54	+0.44	-0.66	-1.17	-0.68	+0.38	-0.90	-1.24	+0.14	+0.07	+0.24	+0.07
3	-0.56	+1.21	-0.84	-1.63	-0.78	+1.19	-1.18	-1.82	+0.21	+0.02	+0.34	+0.19
4	-0.03	+0.23	-0.06	-0.20	-0.05	+0.24	-0.08	-0.22	+0.02	-0.01	+0.03	+0.03
5	-0.21	+0.38	-0.23	-0.68	-0.23	+0.38	-0.24	-0.72	+0.02	0.00	+0.02	+0.04
6	-0.28	+3.08	-0.76	-2.36	-0.31	+3.12	-0.67	-2.60	+0.03	-0.03	-0.09	+0.25
7	-0.26	+1.52	-0.39	-1.52	-0.30	+1.74	-0.44	-1.75	+0.04	-0.22	+0.04	+0.23
8	+0.13	+1.21	-0.11	-0.40	+0.09	+1.41	-0.17	-0.62	+0.04	-0.20	+0.06	+0.21
9	-0.07	+1.40	-0.48	-0.71	-0.14	+1.85	-0.58	-1.14	+0.06	-0.45	+0.10	+0.43
10	-0.26	+0.19	-0.33	-0.54	-0.29	+0.19	-0.36	-0.60	+0.03	0.00	+0.03	+0.06
11	-0.02	+0.97	-0.28	-0.46	-0.10	+1.25	-0.37	-0.82	+0.08	-0.28	+0.09	+0.36
12	0.00	+1.05	-0.36	-0.36	-0.07	+1.52	-0.47	-0.81	+0.06	-0.47	+0.10	+0.44
13	-0.17	+0.12	-0.24	-0.29	-0.19	+0.19	-0.27	-0.39	+0.03	-0.07	+0.03	+0.10

Note:

- Simulated head changes in this table are for Model Layer 3, which represents the 180-Foot Aquifer in the Pressure Subarea, the East Side Shallow Aquifer in the East Side Subarea, and the undifferentiated aquifer elsewhere.

These figures show the effect of the Projects on groundwater head in the different parts of the study area. For all 13 ESUs, the Projects result in higher head throughout the model duration, with the largest head differences mostly occurring at the end of the modeling period. (Negative head differences, indicating higher head without the Projects, are present, but they are small in magnitude and very isolated in time.) In general, the ESUs can be grouped into broad categories based on their responses to the Projects. The northernmost ESUs (1 through 4) show little to no response to the Projects until the CSIP system comes online in 1998, then a steady increase in the head difference between scenarios is seen over the remainder of the model period. By the end of the simulation period, this area shows the largest overall difference between the Scenarios, with an average difference of about 11 feet in ESU 3. The response in the remaining ESUs (5 through 13) is largely governed by conditions in the Salinas River. The difference between the scenarios is smaller in these ESUs (about 4 feet or less) compared to the northernmost ESUs, and increases over the entire model duration, indicating that the reservoirs are most important to head conditions in these ESUs.

3.3 GROUNDWATER BUDGETS

The groundwater budget is the basic accounting tool for the movement of water into and out of a groundwater basin. It quantifies groundwater inflows and outflows and changes in groundwater storage. This section discusses groundwater budgets for the study area, detailing various portions of it for the Historical and No Projects Scenarios, as well as the difference between the scenarios. This discussion focuses on changes in storage, recharge, streamflow losses, and seawater intrusion.

3.3.1 Development of Groundwater Budget Equation

A groundwater budget can be formulated in various ways, depending on the goal of the analysis and the data available. A very basic groundwater budget may be written as:

$$\Delta S = Q_{in} - Q_{out} \tag{3}$$

where ΔS is the change in groundwater storage, Q_{in} is the sum of all inflow components, and Q_{out} is the sum of all outflow components. If the various inflow and outflow components can be quantified separately, the groundwater budget equation can be expanded. For example:

$$\Delta S = Q_{in1} + Q_{in2} + Q_{in3} - Q_{out1} - Q_{out2} - Q_{out3} \tag{4}$$

where Q_{in1}, Q_{in2}, Q_{in3}, Q_{out1}, Q_{out2}, and Q_{out3} are various different inflow and outflow components. The detail included in a groundwater budget is a function of the amount of data available and the goal of the analysis.

The 1998 HBA categorized groundwater budget inflows and outflows as follows. Groundwater inflows were deep percolation of recharge (*DP*), stream recharge (*SR*), and groundwater inflow from adjacent basins (*BF*). The sole groundwater outflow was groundwater pumping (*GWP*). Groundwater exchange with adjacent parts of the model domain (*SF*) if a groundwater budget applied for a portion of the model (e.g., a subarea) could be either an inflow or an outflow. The 1998 HBA groundwater budget equation was represented as:

$$DFGW = DP + SR + BF \pm SF - GWP \tag{5}$$

where *DFGW* is the change in fresh groundwater storage. Seawater intrusion was not included in this equation because the equation only deals with fresh groundwater inflows and outflows, not the aquifer as a whole. A calculation of total storage change would need to incorporate the amount of seawater intrusion.

For this HBA Update, we follow the approach of the 1998 HBA, but with an increased number of groundwater budget components. The groundwater budget equation for the HBA Update is represented as:

$$\Delta S_F = Q_R + Q_S - Q_{MI} - Q_{Ag} - Q_{Dr} + Q_{Pas} + Q_{Paj} \quad (6)$$

where ΔS_F is the change in fresh groundwater storage, Q_R is net recharge, Q_S is net groundwater-surface water flux, Q_{MI} is municipal and industrial groundwater pumping, Q_{Ag} is agricultural pumping, Q_{Dr} is net discharge to drains, Q_{Pas} is net groundwater inflow from the Paso Robles Basin, and Q_{Paj} is net groundwater inflow from the Pajaro Basin. As with the groundwater budget formulation used in the 1998 HBA, this equation implicitly incorporates the effect of seawater intrusion. To explicitly incorporate seawater intrusion, the above equation can be modified as follows:

$$\Delta S = Q_R + Q_S - Q_{MI} - Q_{Ag} - Q_{Dr} + Q_{Pas} + Q_{Paj} + SWI \quad (7)$$

where ΔS is the change in overall groundwater storage and SWI is seawater intrusion. Combining these two equations:

$$\Delta S_F = \Delta S - SWI \quad (8)$$

ΔS can be thought of as the change in overall groundwater storage that is reflected by changes to groundwater head. In settings where seawater intrusion is a concern, seawater entering freshwater aquifers maintains higher head values in the aquifer as compared to a situation where the coast is a no-flow boundary. *SWI* then represents a loss of fresh groundwater storage (hence minus *SWI* in Equation 8) because it replaces fresh groundwater in storage with seawater. Therefore, the change in fresh groundwater is equal to the change in storage reflected in changes to groundwater head plus the amount of seawater intrusion.

The groundwater budgets presented in this report are derived from the results of a MODFLOW-OWHM model. The general MODFLOW approach for reporting groundwater budget results groups all of the inflows together and all outflows together; any given groundwater budget component (e.g., well pumping) can have both inflow and outflow. The default groundwater budget is reported by MODFLOW as a mass balance check to demonstrate the model is conserving mass. This approach to the groundwater budget equation can be depicted as:

$$MBD = \sum Q_{in} - \sum Q_{out} \quad (9)$$

where $\sum Q_{in}$ is the sum of all groundwater inflow components, $\sum Q_{out}$ is the sum of all groundwater outflow components, and *MBD* is the mass balance difference (i.e., a quantification of the degree to which mass is conserved in the model). In this equation, the change in storage is incorporated into the sums of groundwater inflows and outflows. This means that, contrary to general hydrogeologic convention, a loss in storage is represented in the model groundwater budget as a positive number (a net inflow *from* storage). This is because the MODFLOW groundwater budget is calculated from the perspective of the groundwater flow system, and groundwater in storage is considered separate from the flow system; water entering storage is considered to be leaving the groundwater flow system and is therefore expressed as an outflow.

Expressed in the same terms as Equation 7 above, the MODFLOW groundwater budget can be expanded to:

$$MBD = Q_R + Q_S - Q_{MI} - Q_{Ag} - Q_{Dr} + Q_{Pas} + Q_{Paj} + SWI - \Delta S \quad (10)$$

In terms of the change in fresh groundwater storage,

$$\Delta S_F = Q_R + Q_S - Q_{MI} - Q_{Ag} - Q_{Dr} + Q_{Pas} + Q_{Paj} - MBD \quad (11)$$

This groundwater budget equation is the basis for discussions of groundwater inflows, outflows, and changes in storage in this report.

One other important matter to understand regarding the groundwater budgets presented in this report is the expression of recharge. MODFLOW-OWHM relies on a specialized module for MODFLOW called the Farm Process (FMP). FMP simulates dynamic crop demand based on climate data inputs, and the satisfaction of that demand by various sources of available water (Schmid et al., 2006). One source is groundwater in situations where the crop root zone intersects the water table. This use of groundwater by crops is quantified in the water budget as *negative recharge*. If this use is larger than the flux of groundwater downward past the root zone, the net recharge can be less than zero. This situation is not the norm throughout the Basin, but can occur in certain places at certain times.

3.3.2 Model Domain Groundwater Budget

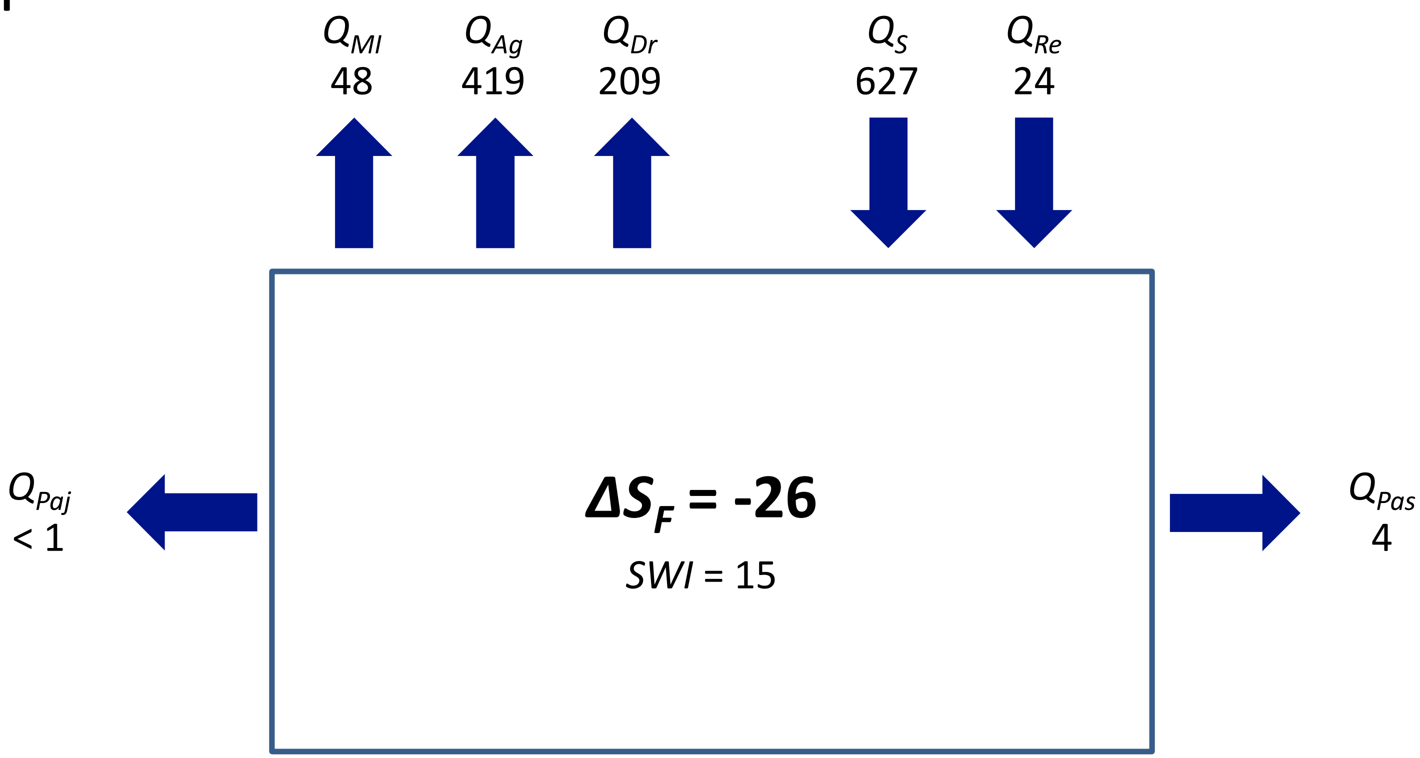
The average annual groundwater budget for the entire model domain for the Historical Scenario is shown as Figure 3-21; the budget for the No Projects Scenario is shown as Figure 3-22. The difference in groundwater budget components is shown as Figure 3-23. The tabulated groundwater budget is presented in Table 3- 2. Groundwater budget components depicted in these and other figures are rounded to the nearest 1,000 afy; depicted averages may not sum exactly due to this rounding. As noted in Chapter 2, the difference shown is equal to the Historical Scenario groundwater budget component minus the No Projects Scenario groundwater budget component. A positive difference indicates that the magnitude of the groundwater flux was greater under the Historical Scenario.

The model results indicate that the Basin experienced under the Historical Scenario (as compared to the No Projects Scenario) about 72,000 afy more groundwater-surface flux, about 45,000 afy more discharge to drains, about 14,000 afy less net recharge, about 10,000 afy less agricultural pumping, and about 20,000 afy less storage loss. Seawater intrusion is simulated to be about 1,000 afy less (seawater intrusion is discussed in more detail in Section 3.6). Changes to other groundwater budget components are not significant in magnitude.

Historical Scenario

Area: **Entire Model Domain**

Year Type: **All**



MBD = -4

Abbreviations:

- Q_S = Groundwater-Surface Water Exchange
- Q_{MI} = Municipal & Industrial Pumping
- Q_{Ag} = Agricultural Pumping
- Q_{Dr} = Discharge to Drains
- Q_{Re} = Net Recharge
- Q_{Pas} = Groundwater Exchange with Paso Robles Basin
- Q_{Paj} = Groundwater Exchange with Pajaro Basin
- ΔS_F = Change in Fresh Groundwater Storage
- *SWI* = Seawater Intrusion
- *MBD* = Mass Balance Difference

Notes:

1. Water budget components are rounded to nearest 1,000 acre-feet per year and displayed in thousands of acre-feet per year; totals may not sum due to rounding and imperfect closure of the model mass balance (denoted by *MBD*).
2. Arrow orientation denotes direction of groundwater flow. Arrows pointing away from the box show groundwater leaving the aquifer volume under consideration. Arrows pointing toward the box show groundwater entering the aquifer volume.
3. See Section 3.3 of the text for the development of the SVIHM groundwater budget equation.

Figure 3-21

Average Annual Groundwater Budget, Historical Scenario

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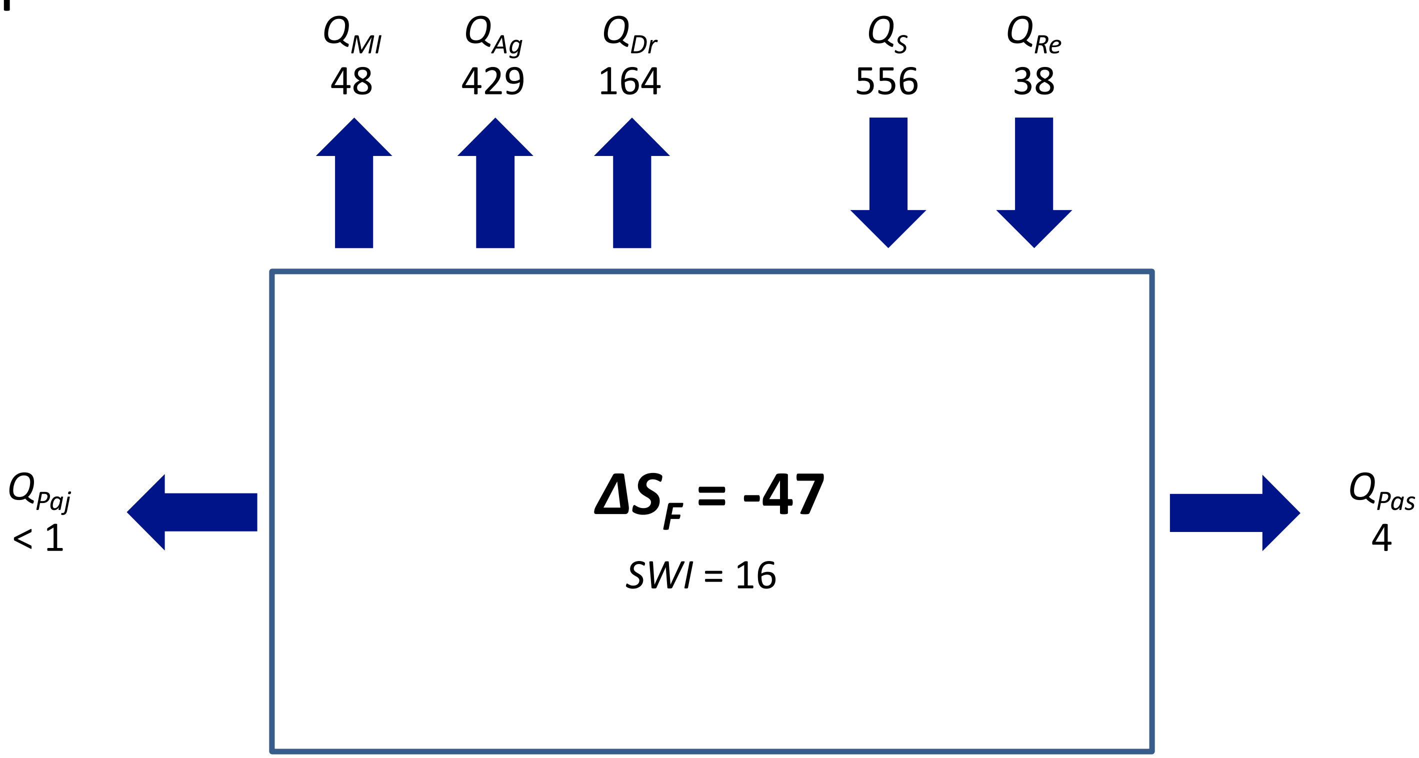
No Projects Scenario

Area: **Entire Model Domain**

Year Type: **All**



MBD = -5

Abbreviations:

- Q_S = Groundwater-Surface Water Exchange
- Q_{MI} = Municipal & Industrial Pumping
- Q_{Ag} = Agricultural Pumping
- Q_{Dr} = Discharge to Drains
- Q_{Re} = Net Recharge
- Q_{Pas} = Groundwater Exchange with Paso Robles Basin
- Q_{Paj} = Groundwater Exchange with Pajaro Basin
- ΔS_F = Change in Fresh Groundwater Storage
- *SWI* = Seawater Intrusion
- *MBD* = Mass Balance Difference

Notes:

1. Water budget components are rounded to nearest 1,000 acre-feet per year and displayed in thousands of acre-feet per year; totals may not sum due to rounding and imperfect closure of the model mass balance (denoted by *MBD*).
2. Arrow orientation denotes direction of groundwater flow. Arrows pointing away from the box show groundwater leaving the aquifer volume under consideration. Arrows pointing toward the box show groundwater entering the aquifer volume.
3. See Section 3.3 of the text for the development of the SVIHM groundwater budget equation.

Figure 3-22

Average Annual Groundwater Budget, No Projects Scenario

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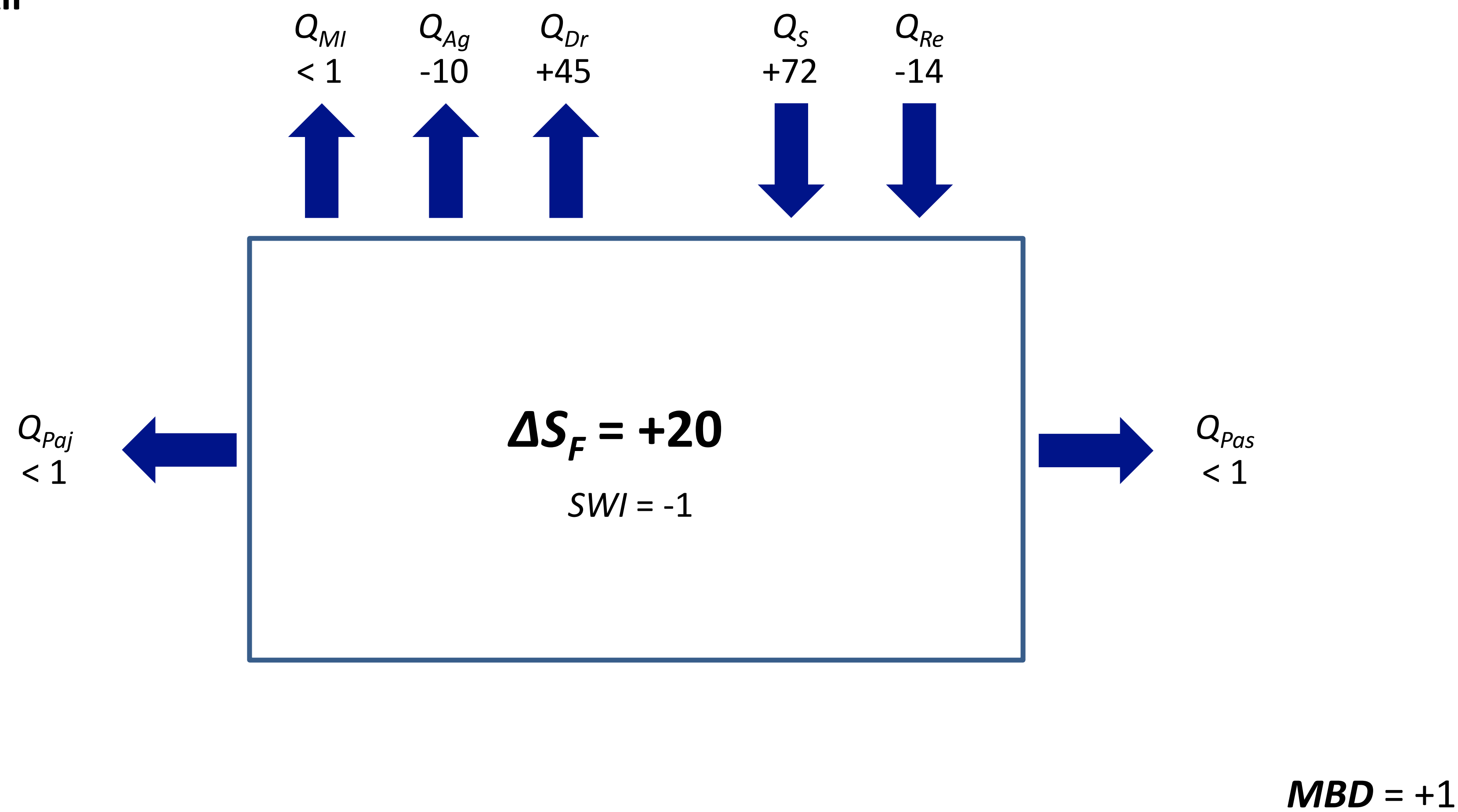
Difference Between Scenarios

Area: **Entire Model Domain**

Year Type: **All**



Abbreviations:

- Q_S = Groundwater-Surface Water Exchange
- Q_{MI} = Municipal & Industrial Pumping
- Q_{Ag} = Agricultural Pumping
- Q_{Dr} = Discharge to Drains
- Q_{Re} = Net Recharge
- Q_{Pas} = Groundwater Exchange with Paso Robles Basin
- Q_{Paj} = Groundwater Exchange with Pajaro Basin
- ΔS_F = Change in Fresh Groundwater Storage
- *SWI* = Seawater Intrusion
- *MBD* = Mass Balance Difference

Notes:

1. Water budget components are rounded to nearest 1,000 acre-feet per year and displayed in thousands of acre-feet per year; totals may not sum due to rounding and imperfect closure of the model mass balance (denoted by *MBD*).
2. Arrow orientation denotes direction of groundwater flow. Arrows pointing away from the box show groundwater leaving the aquifer volume under consideration. Arrows pointing toward the box show groundwater entering the aquifer volume.
3. See Section 3.3 of the text for the development of the SVIHM groundwater budget equation.
4. Difference between scenarios is calculated as Historical Scenario minus No Projects Scenario

Figure 3-23

Average Annual Groundwater Budget, Difference Between Scenarios

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Table 3-2. Average Annual Groundwater Budget for Historical and No Projects Scenario, and Difference Between Scenarios (in afy)

Groundwater Budget Component		Historical Scenario	No Projects Scenario	Difference
Inflows	Net Recharge	24,000	38,000	-14,000
	GW/SW Flux	627,000	556,000	+72,000
	GW Exchange with Ocean	15,000	16,000	-1,000
	Total In	**666,000**	**610,000**	**+56,000**
Outflows	M&I Pumping	48,000	48,000	< 1,000
	Ag Pumping	419,000	429,000	-10,000
	Drains	209,000	164,000	+45,000
	GW Exchange with Pajaro Basin	< 1,000	< 1,000	< 1,000
	GW Exchange with Paso Robles Basin	4,000	4,000	< 1,000
	Total Out	**680,000**	**645,000**	**+35,000**
Change in Storage		**-11,000**	**-31,000**	**+20,000**
Mass Balance Difference		**-4,000**	**-5,000**	**+1,000**

Notes:
- Groundwater budget components are rounded to the nearest 1,000 acre-feet per year; totals may not sum due to rounding
- Difference between scenarios is calculated as Historical Scenario minus No Projects Scenario

The increase in groundwater-surface water flux mostly results from increased normal- and dry-year stream losses in the southern portion of the study area. Increased drain discharge and reduced net recharge result from higher groundwater head values in this same southern area. Reduced agricultural pumping occurs in various parts of the study area. The reduced storage loss is also distributed across the study area, although it is most substantial in the south. The reduced seawater intrusion is focused in the coastal area. The spatial and temporal distribution of changes between the scenarios is discussed more fully in Section 3.3.4.

Additional insight can be gained by considering average annual groundwater budgets for different year types. The categorization of year types is discussed briefly in Section 3.2.1; water year type categories used here are wet, normal, and dry.

Figures 3-24, 3-25, and 3-26 provide the average annual wet-year groundwater budgets for the Historical Scenario, No Projects Scenario, and difference between scenarios, respectively. Table 3-3 presents this groundwater budget information in a tabular format. During wet years, substantially more water moves through the system compared to the average for all years. This includes increased streamflow losses, more recharge, and more discharge to drains. Agricultural pumping is smaller in wet years because of increased availability of precipitation to supply crop demands. Overall, the average wet year sees a substantial increase in fresh groundwater storage. The difference between scenarios during the average wet year is generally similar (less net recharge, less agricultural pumping, and more drain discharge under the Historical Scenario compared to the No Projects Scenario), but there is about 37,000 afy less streamflow loss and about 75,000 afy less increase in storage under the Historical Scenario than in the No Projects Scenario. This reflects the fact the reservoirs capture high flows during wet years that otherwise would have flowed down the Salinas River; some amount of this flow would have contributed to recharging the aquifers during wet years.

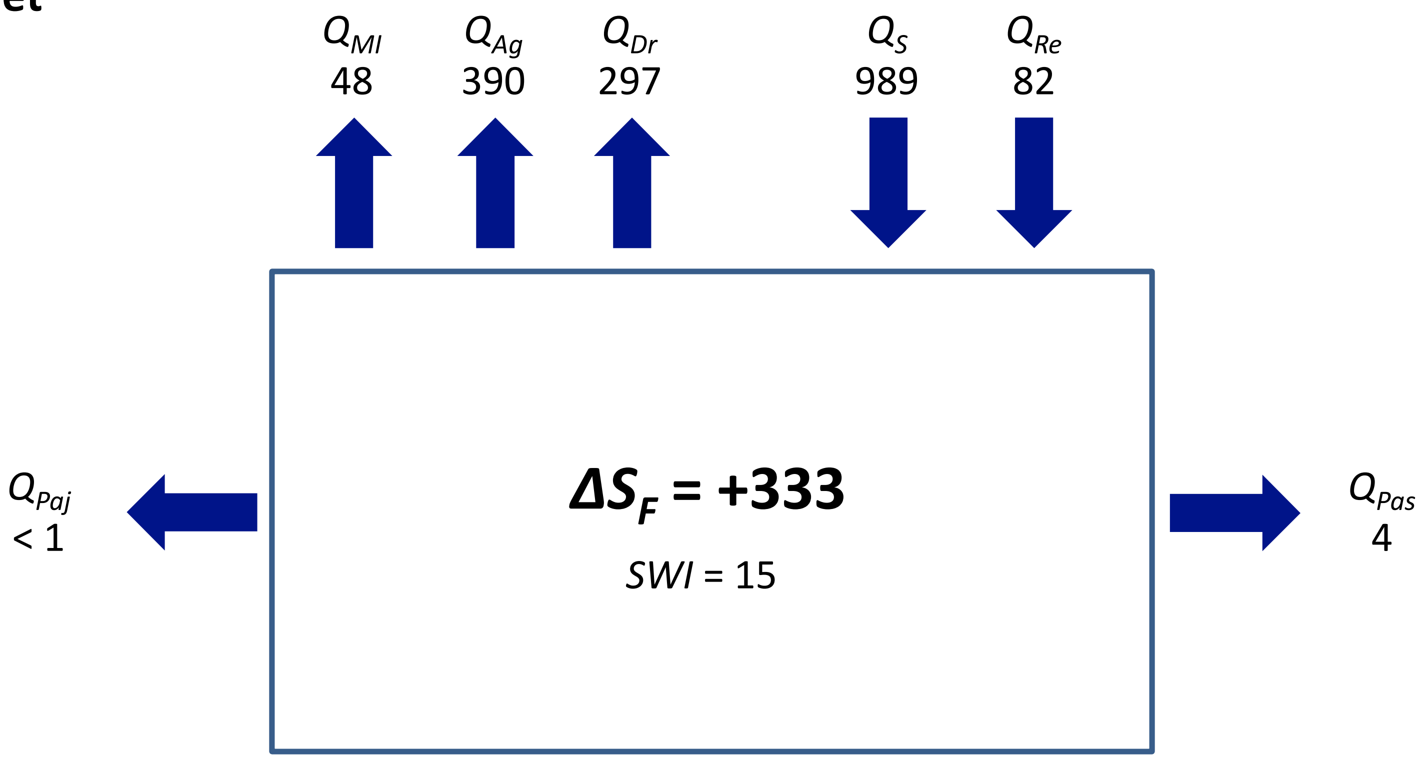
Figures 3-27, 3-28, and 3-29 provide the average annual normal-year groundwater budgets for the Historical Scenario, No Projects Scenario, and difference between scenarios, respectively. Table 3-4 presents this groundwater budget information in a tabular format. Overall, the average normal-year groundwater budget is similar to the average groundwater budget for all years, except that the loss of fresh groundwater storage is much higher. This reflects the fact that the average annual groundwater storage loss for all years is biased by very large storage gains during wet years.

Figures 3-30, 3-31, and 3-32 provide the average annual dry-year groundwater budgets for the Historical Scenario, No Projects Scenario, and difference between scenarios, respectively. Table 3-5 presents this groundwater budget information in a tabular format. During dry years, there is less water moving through the system compared to other year types. Stream loss, recharge, and discharge to drains are all smaller. The differences between the Historical and No Projects Scenarios demonstrate that the effect of the Projects is greatest during dry years. Stream losses are about 159,000 afy higher under the Historical Scenario compared to the No Projects Scenario. Although some amount of this increased stream leakage ends up discharging to drains (about 57,000 afy higher under the Historical Scenario), much of it contributes to replenishment of fresh groundwater storage (about 90,000 afy higher under the Historical Scenario). This demonstrates the ability of the reservoirs to continue supporting flow in the Salinas River and recharge of hydraulicly connected aquifers during dry years.

Historical Scenario

Area: **Entire Model Domain**

Year Type: **Wet**



MBD = -2

Abbreviations:

- Q_S = Groundwater-Surface Water Exchange
- Q_{MI} = Municipal & Industrial Pumping
- Q_{Ag} = Agricultural Pumping
- Q_{Dr} = Discharge to Drains
- Q_{Re} = Net Recharge
- Q_{Pas} = Groundwater Exchange with Paso Robles Basin
- Q_{Paj} = Groundwater Exchange with Pajaro Basin
- ΔS_F = Change in Fresh Groundwater Storage
- *SWI* = Seawater Intrusion
- *MBD* = Mass Balance Difference

Notes:

1. Water budget components are rounded to nearest 1,000 acre-feet per year and displayed in thousands of acre-feet per year; totals may not sum due to rounding and imperfect closure of the model mass balance (denoted by *MBD*).
2. Arrow orientation denotes direction of groundwater flow. Arrows pointing away from the box show groundwater leaving the aquifer volume under consideration. Arrows pointing toward the box show groundwater entering the aquifer volume.
3. See Section 3.3 of the text for the development of the SVIHM groundwater budget equation.

Figure 3-24

Average Annual Wet-Year Groundwater Budget, Historical Scenario

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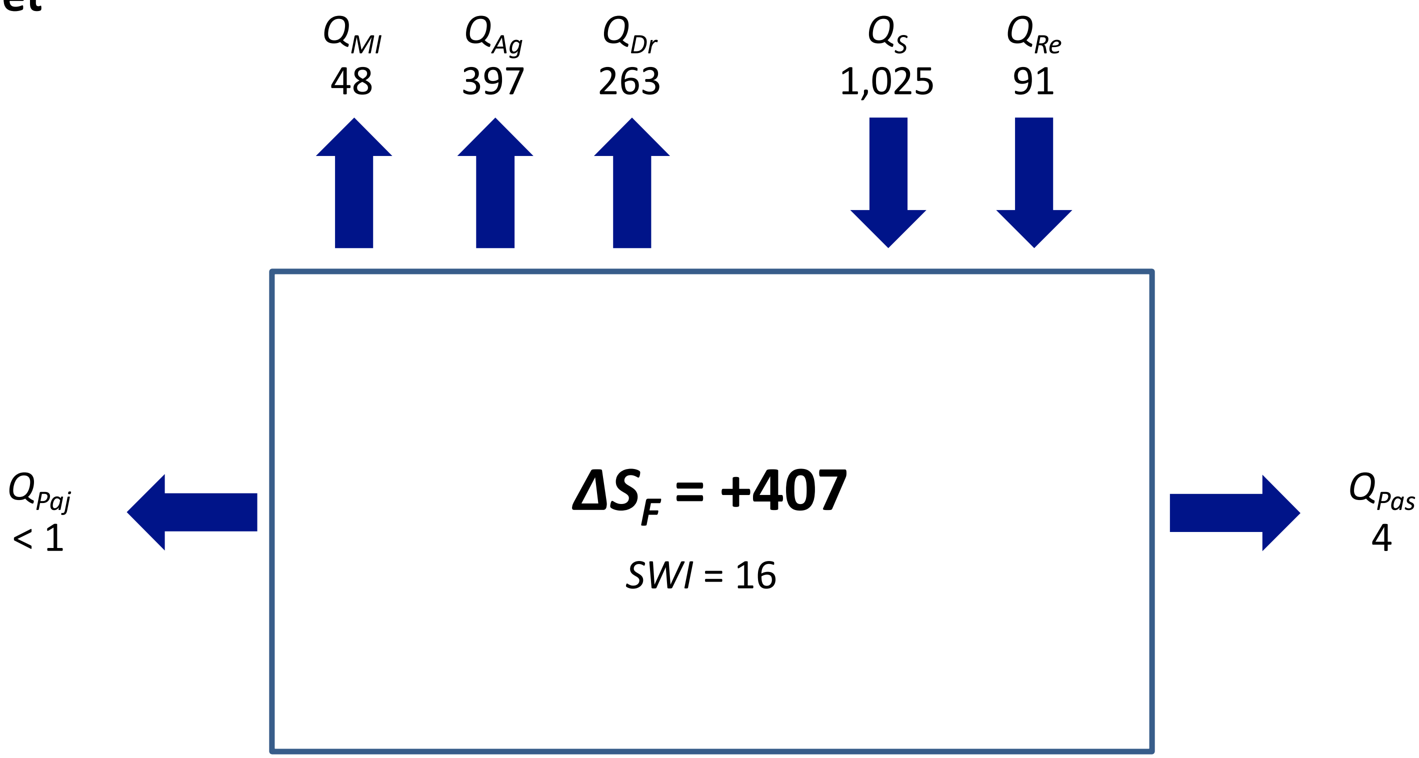
No Projects Scenario

Area: **Entire Model Domain**

Year Type: **Wet**



MBD = -2

Abbreviations:

- Q_S = Groundwater-Surface Water Exchange
- Q_{MI} = Municipal & Industrial Pumping
- Q_{Ag} = Agricultural Pumping
- Q_{Dr} = Discharge to Drains
- Q_{Re} = Net Recharge
- Q_{Pas} = Groundwater Exchange with Paso Robles Basin
- Q_{Paj} = Groundwater Exchange with Pajaro Basin
- ΔS_F = Change in Fresh Groundwater Storage
- *SWI* = Seawater Intrusion
- *MBD* = Mass Balance Difference

Notes:

1. Water budget components are rounded to nearest 1,000 acre-feet per year and displayed in thousands of acre-feet per year; totals may not sum due to rounding and imperfect closure of the model mass balance (denoted by *MBD*).
2. Arrow orientation denotes direction of groundwater flow. Arrows pointing away from the box show groundwater leaving the aquifer volume under consideration. Arrows pointing toward the box show groundwater entering the aquifer volume.
3. See Section 3.3 of the text for the development of the SVIHM groundwater budget equation.

Figure 3-25

Average Annual Wet-Year Groundwater Budget, No Projects Scenario

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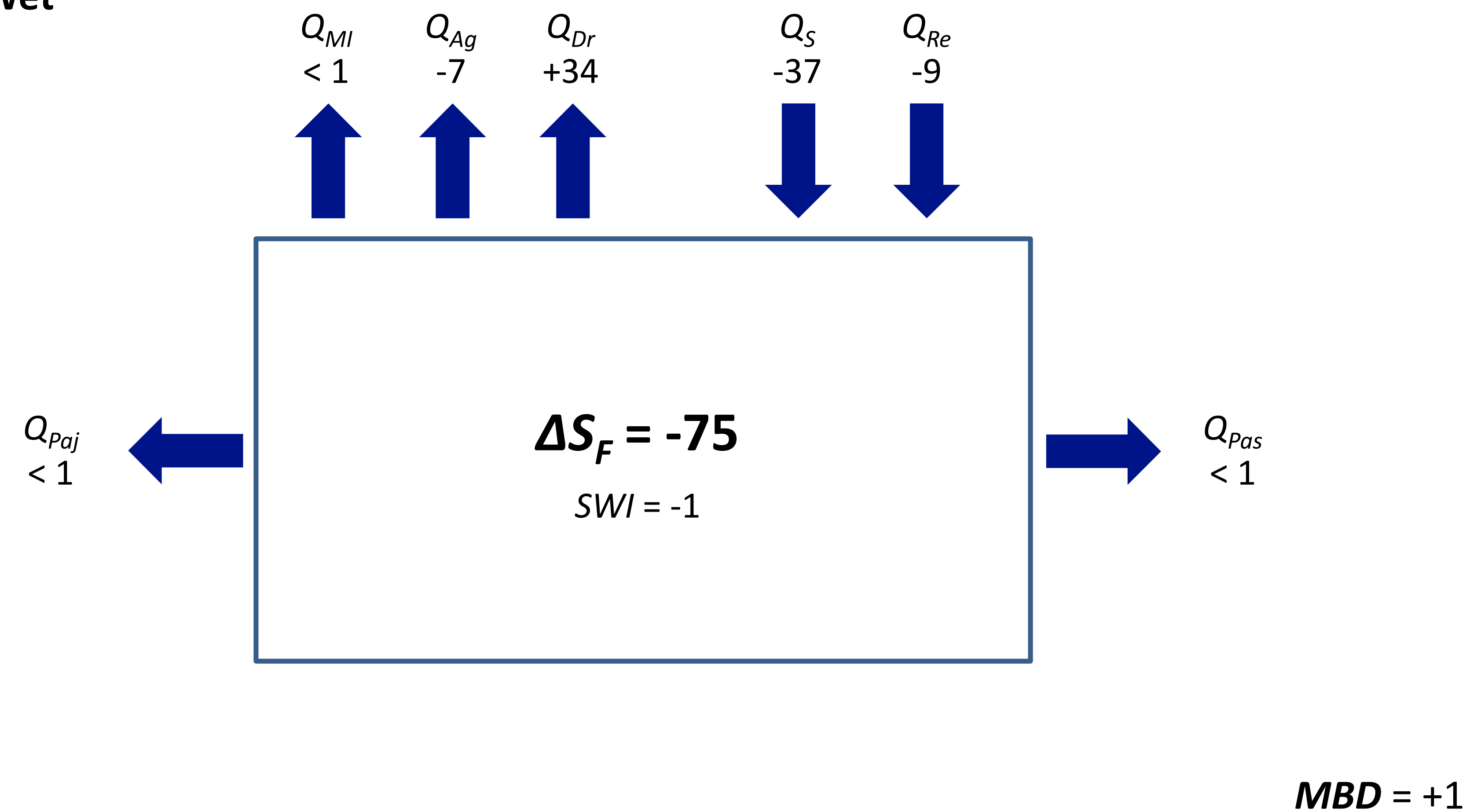
Difference Between Scenarios

Area: **Entire Model Domain**

Year Type: **Wet**



Abbreviations:

- Q_S = Groundwater-Surface Water Exchange
- Q_{MI} = Municipal & Industrial Pumping
- Q_{Ag} = Agricultural Pumping
- Q_{Dr} = Discharge to Drains
- Q_{Re} = Net Recharge
- Q_{Pas} = Groundwater Exchange with Paso Robles Basin
- Q_{Paj} = Groundwater Exchange with Pajaro Basin
- ΔS_F = Change in Fresh Groundwater Storage
- *SWI* = Seawater Intrusion
- *MBD* = Mass Balance Difference

Notes:

1. Water budget components are rounded to nearest 1,000 acre-feet per year and displayed in thousands of acre-feet per year; totals may not sum due to rounding and imperfect closure of the model mass balance (denoted by *MBD*).
2. Arrow orientation denotes direction of groundwater flow. Arrows pointing away from the box show groundwater leaving the aquifer volume under consideration. Arrows pointing toward the box show groundwater entering the aquifer volume.
3. See Section 3.3 of the text for the development of the SVIHM groundwater budget equation.
4. Difference between scenarios is calculated as Historical Scenario minus No Projects Scenario

Figure 3-26

Average Annual Wet-Year Groundwater Budget, Difference Between Scenarios

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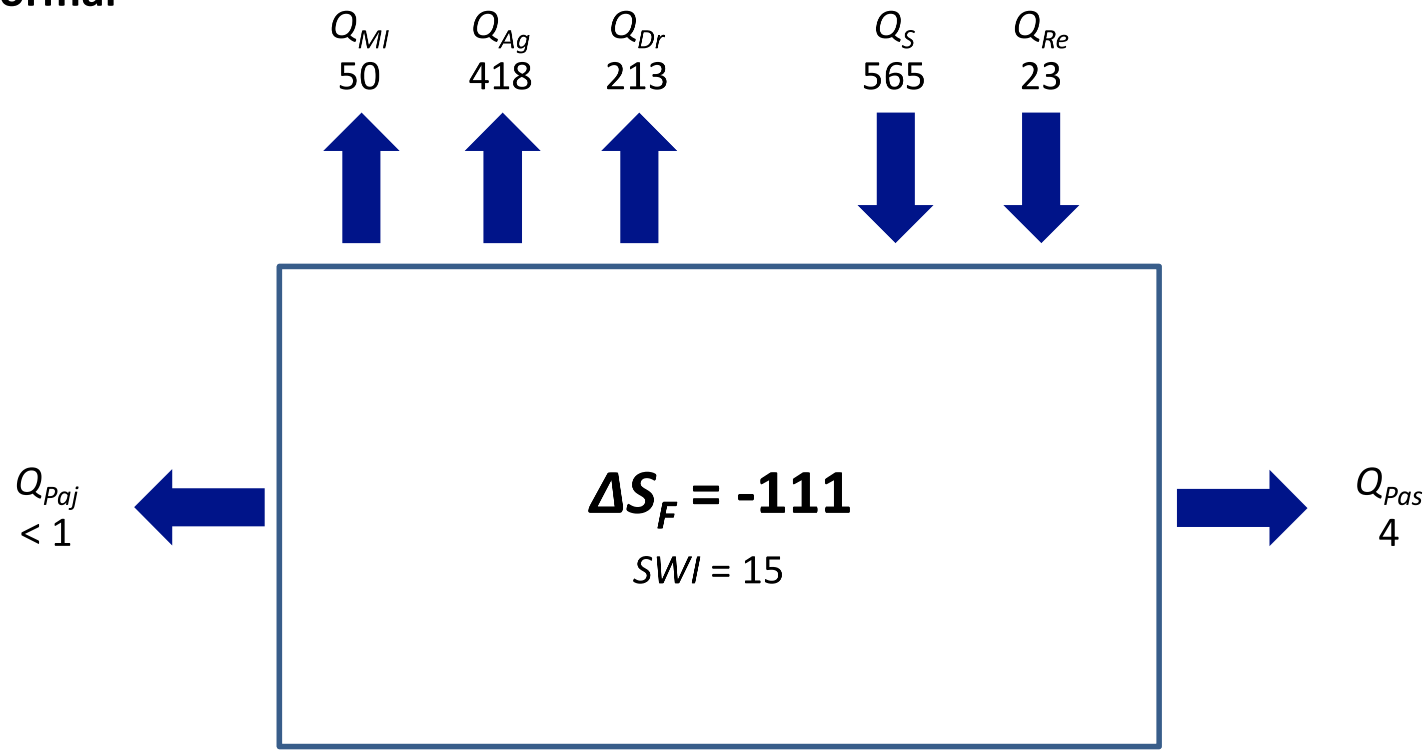
Historical Scenario

Area: **Entire Model Domain**

Year Type: **Normal**



MBD = -4

Abbreviations:

- Q_S = Groundwater-Surface Water Exchange
- Q_{MI} = Municipal & Industrial Pumping
- Q_{Ag} = Agricultural Pumping
- Q_{Dr} = Discharge to Drains
- Q_{Re} = Net Recharge
- Q_{Pas} = Groundwater Exchange with Paso Robles Basin
- Q_{Paj} = Groundwater Exchange with Pajaro Basin
- ΔS_F = Change in Fresh Groundwater Storage
- SWI = Seawater Intrusion
- MBD = Mass Balance Difference

Notes:

1. Water budget components are rounded to nearest 1,000 acre-feet per year and displayed in thousands of acre-feet per year; totals may not sum due to rounding and imperfect closure of the model mass balance (denoted by *MBD*).
2. Arrow orientation denotes direction of groundwater flow. Arrows pointing away from the box show groundwater leaving the aquifer volume under consideration. Arrows pointing toward the box show groundwater entering the aquifer volume.
3. See Section 3.3 of the text for the development of the SVIHM groundwater budget equation.

Figure 3-27

Average Annual Normal-Year Groundwater Budget, Historical Scenario

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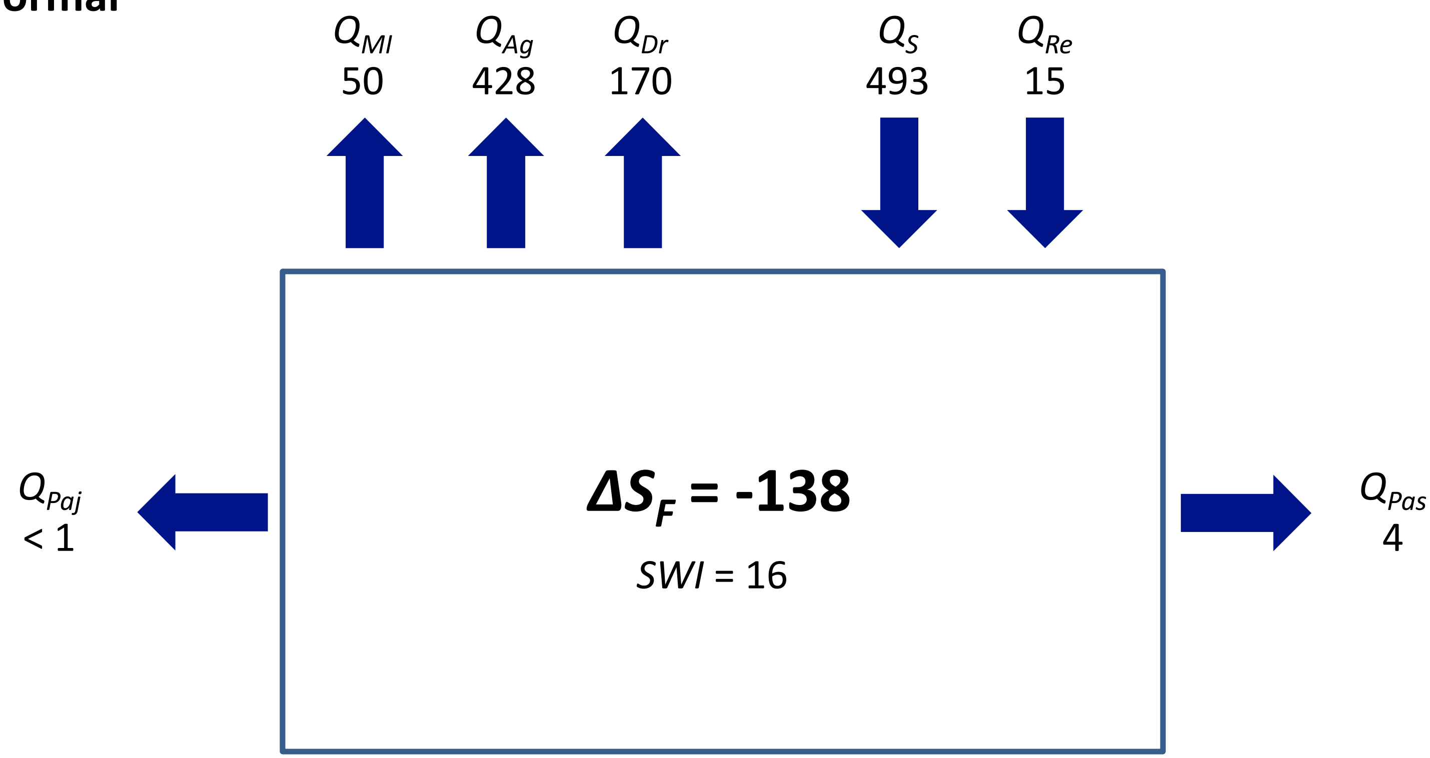
No Projects Scenario

Area: **Entire Model Domain**

Year Type: **Normal**



MBD < 1

Abbreviations:

- Q_S = Groundwater-Surface Water Exchange
- Q_{MI} = Municipal & Industrial Pumping
- Q_{Ag} = Agricultural Pumping
- Q_{Dr} = Discharge to Drains
- Q_{Re} = Net Recharge
- Q_{Pas} = Groundwater Exchange with Paso Robles Basin
- Q_{Paj} = Groundwater Exchange with Pajaro Basin
- ΔS_F = Change in Fresh Groundwater Storage
- *SWI* = Seawater Intrusion
- *MBD* = Mass Balance Difference

Notes:

1. Water budget components are rounded to nearest 1,000 acre-feet per year and displayed in thousands of acre-feet per year; totals may not sum due to rounding and imperfect closure of the model mass balance (denoted by *MBD*).
2. Arrow orientation denotes direction of groundwater flow. Arrows pointing away from the box show groundwater leaving the aquifer volume under consideration. Arrows pointing toward the box show groundwater entering the aquifer volume.
3. See Section 3.3 of the text for the development of the SVIHM groundwater budget equation.

Figure 3-28

Average Annual Normal-Year Groundwater Budget, No Projects Scenario

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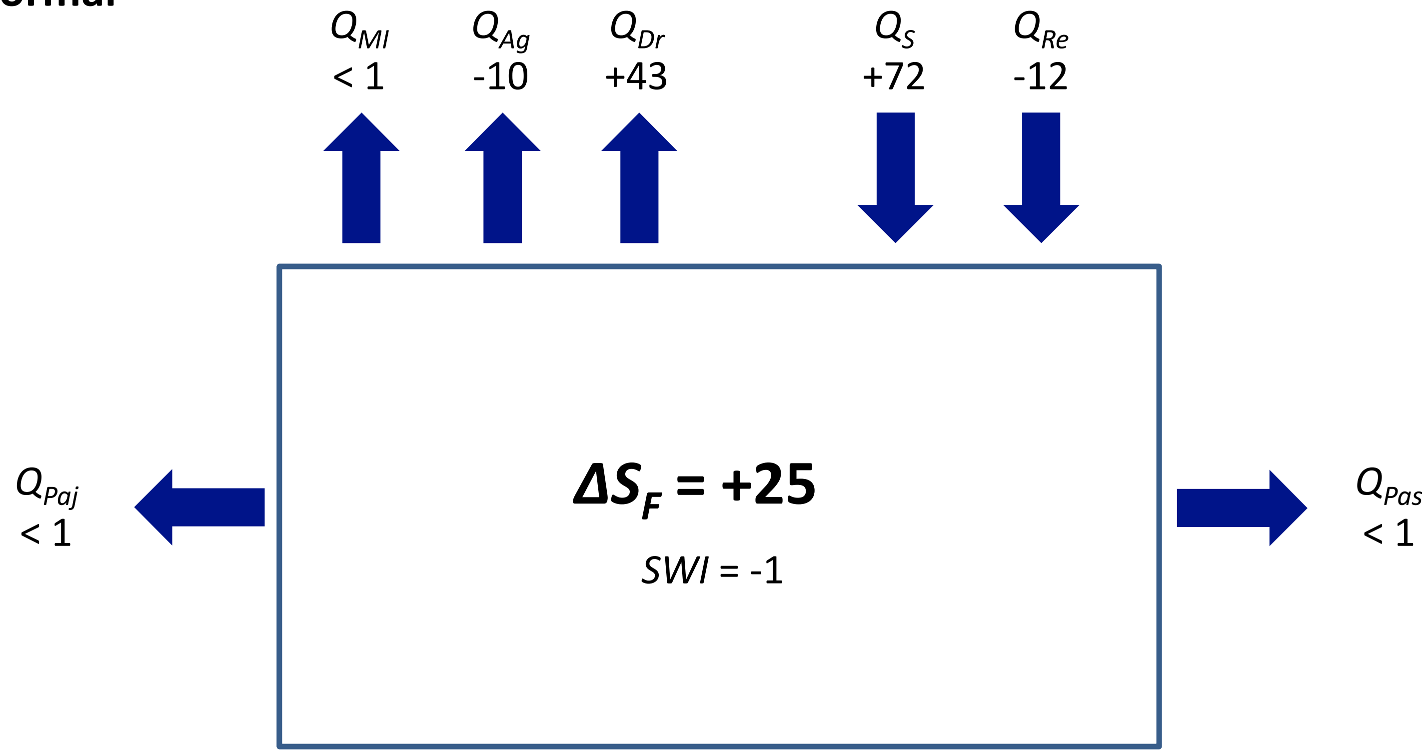
Difference Between Scenarios

Area: **Entire Model Domain**

Year Type: **Normal**



MBD = +1

Abbreviations:

- Q_S = Groundwater-Surface Water Exchange
- Q_{MI} = Municipal & Industrial Pumping
- Q_{Ag} = Agricultural Pumping
- Q_{Dr} = Discharge to Drains
- Q_{Re} = Net Recharge
- Q_{Pas} = Groundwater Exchange with Paso Robles Basin
- Q_{Paj} = Groundwater Exchange with Pajaro Basin
- ΔS_F = Change in Fresh Groundwater Storage
- *SWI* = Seawater Intrusion
- *MBD* = Mass Balance Difference

Notes:

1. Water budget components are rounded to nearest 1,000 acre-feet per year and displayed in thousands of acre-feet per year; totals may not sum due to rounding and imperfect closure of the model mass balance (denoted by *MBD*).
2. Arrow orientation denotes direction of groundwater flow. Arrows pointing away from the box show groundwater leaving the aquifer volume under consideration. Arrows pointing toward the box show groundwater entering the aquifer volume.
3. See Section 3.3 of the text for the development of the SVIHM groundwater budget equation.
4. Difference between scenarios is calculated as Historical Scenario minus No Projects Scenario

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Figure 3-29

Average Annual Normal-Year Groundwater Budget, Difference Between Scenarios

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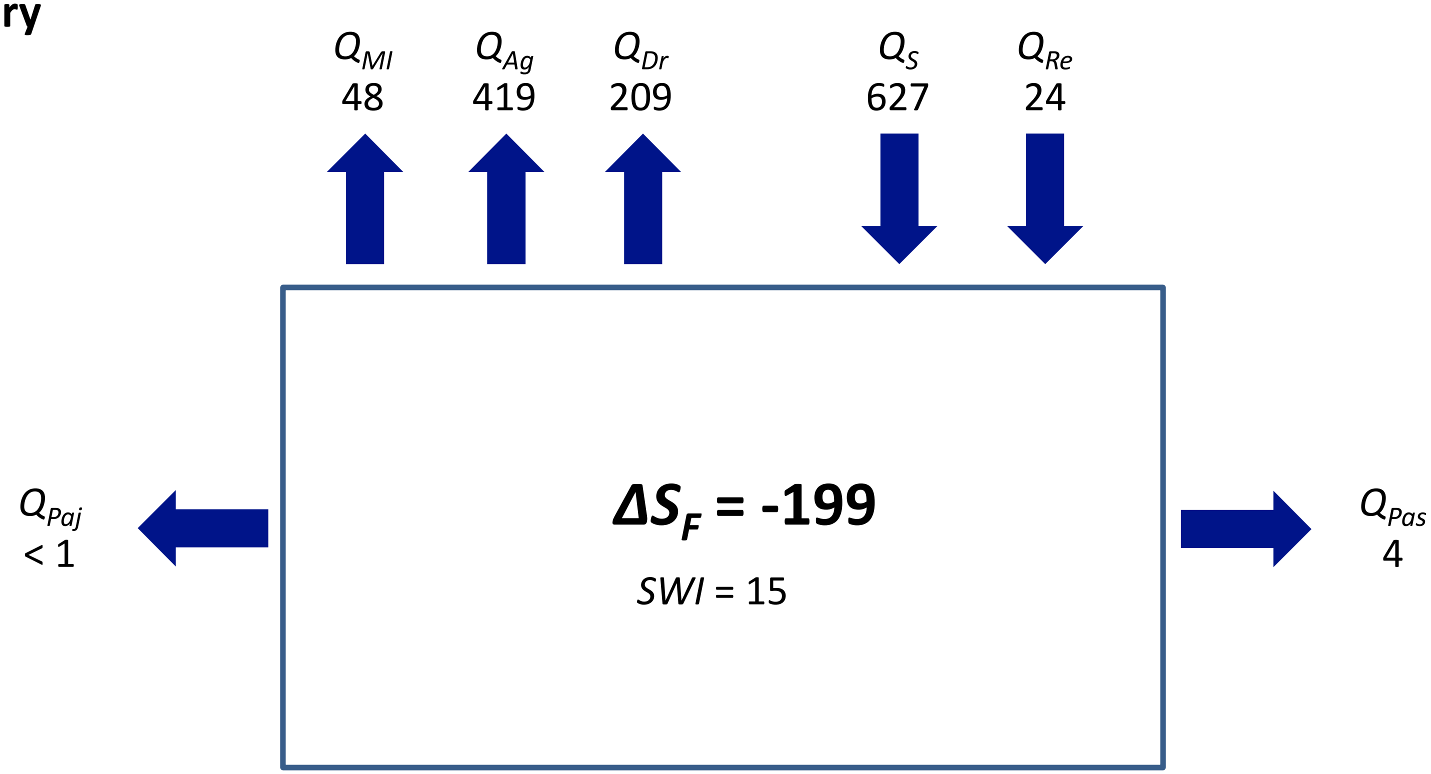
Historical Scenario

Area: **Entire Model Domain**

Year Type: **Dry**



MBD = -6

Abbreviations:

- Q_S = Groundwater-Surface Water Exchange
- Q_{MI} = Municipal & Industrial Pumping
- Q_{Ag} = Agricultural Pumping
- Q_{Dr} = Discharge to Drains
- Q_{Re} = Net Recharge
- Q_{Pas} = Groundwater Exchange with Paso Robles Basin
- Q_{Paj} = Groundwater Exchange with Pajaro Basin
- ΔS_F = Change in Fresh Groundwater Storage
- *SWI* = Seawater Intrusion
- *MBD* = Mass Balance Difference

Notes:

1. Water budget components are rounded to nearest 1,000 acre-feet per year and displayed in thousands of acre-feet per year; totals may not sum due to rounding and imperfect closure of the model mass balance (denoted by *MBD*).
2. Arrow orientation denotes direction of groundwater flow. Arrows pointing away from the box show groundwater leaving the aquifer volume under consideration. Arrows pointing toward the box show groundwater entering the aquifer volume.
3. See Section 3.3 of the text for the development of the SVIHM groundwater budget equation.

Figure 3-30

Average Annual Dry-Year Groundwater Budget, Historical Scenario

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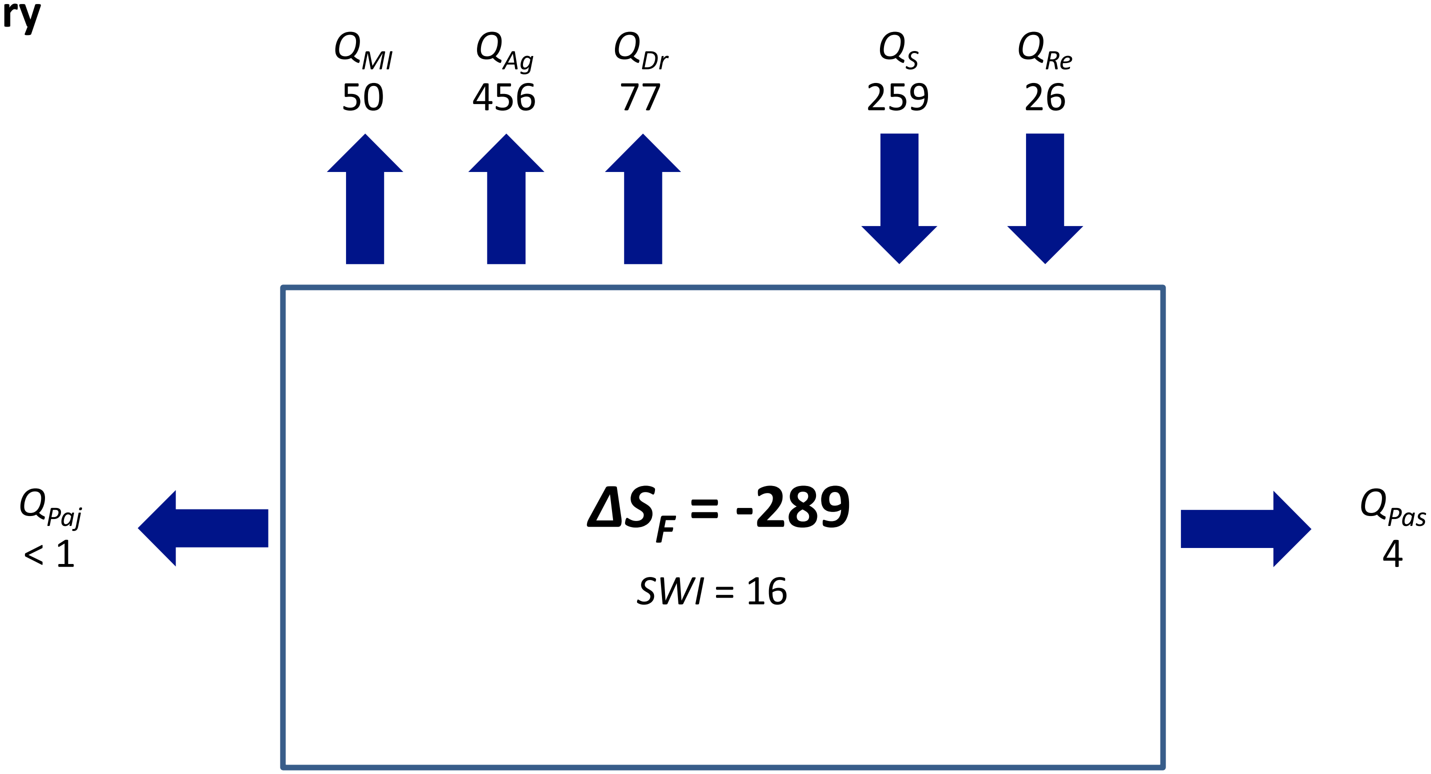
No Projects Scenario

Area: **Entire Model Domain**

Year Type: **Dry**



MBD = -7

Abbreviations:

- Q_S = Groundwater-Surface Water Exchange
- Q_{MI} = Municipal & Industrial Pumping
- Q_{Ag} = Agricultural Pumping
- Q_{Dr} = Discharge to Drains
- Q_{Re} = Net Recharge
- Q_{Pas} = Groundwater Exchange with Paso Robles Basin
- Q_{Paj} = Groundwater Exchange with Pajaro Basin
- ΔS_F = Change in Fresh Groundwater Storage
- *SWI* = Seawater Intrusion
- *MBD* = Mass Balance Difference

Notes:

1. Water budget components are rounded to nearest 1,000 acre-feet per year and displayed in thousands of acre-feet per year; totals may not sum due to rounding and imperfect closure of the model mass balance (denoted by *MBD*).
2. Arrow orientation denotes direction of groundwater flow. Arrows pointing away from the box show groundwater leaving the aquifer volume under consideration. Arrows pointing toward the box show groundwater entering the aquifer volume.
3. See Section 3.3 of the text for the development of the SVIHM groundwater budget equation.

Figure 3-31

Average Annual Dry-Year Groundwater Budget, No Projects Scenario

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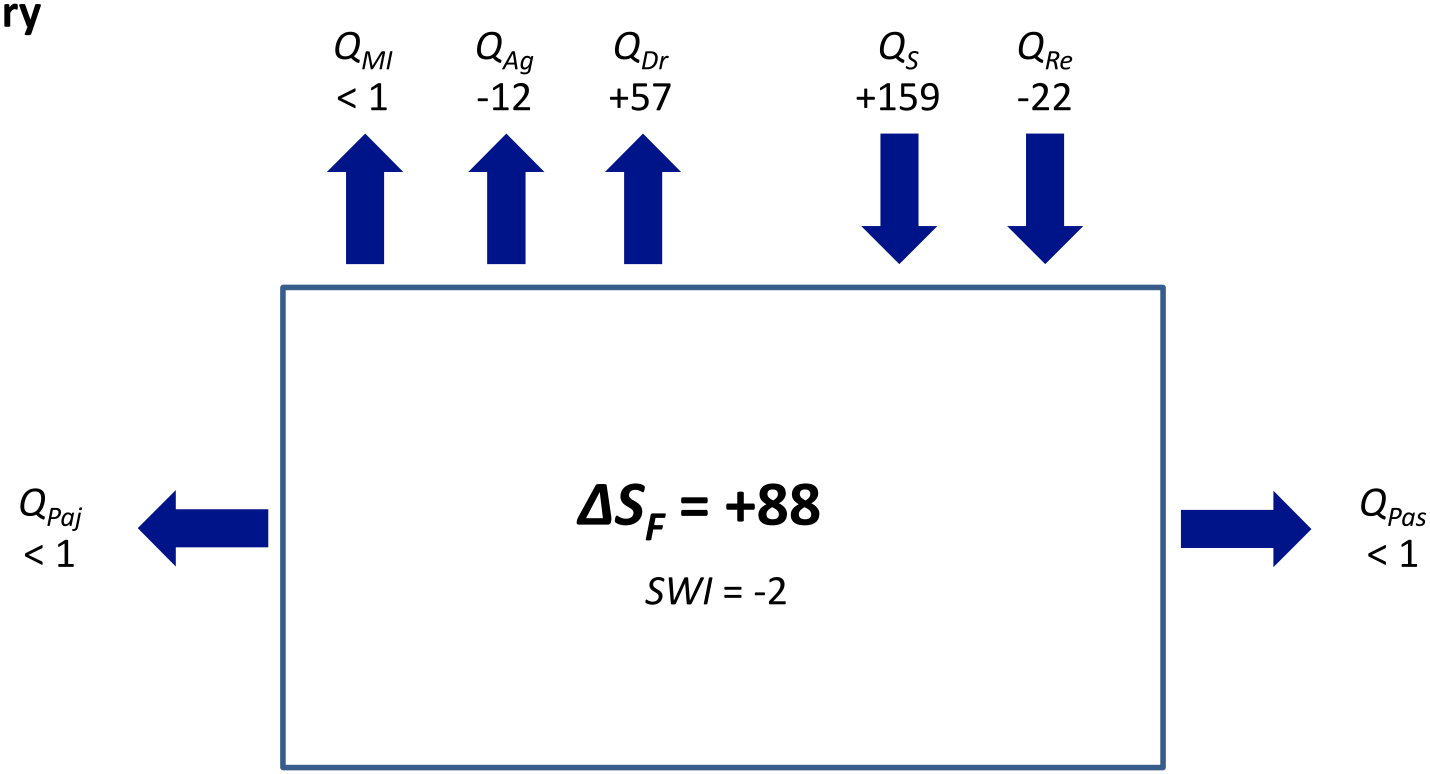
Difference Between Scenarios

Area: **Entire Model Domain**

Year Type: **Dry**



MBD = +2

Abbreviations:

- Q_S = Groundwater-Surface Water Exchange
- Q_{MI} = Municipal & Industrial Pumping
- Q_{Ag} = Agricultural Pumping
- Q_{Dr} = Discharge to Drains
- Q_{Re} = Net Recharge
- Q_{Pas} = Groundwater Exchange with Paso Robles Basin
- Q_{Paj} = Groundwater Exchange with Pajaro Basin
- ΔS_F = Change in Fresh Groundwater Storage
- *SWI* = Seawater Intrusion
- *MBD* = Mass Balance Difference

Notes:

1. Water budget components are rounded to nearest 1,000 acre-feet per year and displayed in thousands of acre-feet per year; totals may not sum due to rounding and imperfect closure of the model mass balance (denoted by *MBD*).
2. Arrow orientation denotes direction of groundwater flow. Arrows pointing away from the box show groundwater leaving the aquifer volume under consideration. Arrows pointing toward the box show groundwater entering the aquifer volume.
3. See Section 3.3 of the text for the development of the SVIHM groundwater budget equation.
4. Difference between scenarios is calculated as Historical Scenario minus No Projects Scenario

Figure 3-32

Average Annual Dry-Year Groundwater Budget, Difference Between Scenarios

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Table 3-3. Average Annual Wet-Year Groundwater Budget for Historical and No Projects Scenario, and Difference Between Scenarios (in afy)				
Groundwater Budget Component		Historical Scenario	No Projects Scenario	Difference
Inflows	Net Recharge	82,000	91,000	-9,000
	GW/SW Flux	989,000	1,026,000	-37,000
	GW Exchange with Ocean	15,000	16,000	-1,000
	Total In	**1,086,000**	**1,132,000**	**-46,000**
Outflows	M&I Pumping	48,000	48,000	< 1,000
	Ag Pumping	390,000	397,000	-7,000
	Drains	297,000	236,000	+34,000
	GW Exchange with Pajaro Basin	< 1,000	< 1,000	< 1,000
	GW Exchange with Paso Robles Basin	4,000	4,000	< 1,000
	Total Out	**739,000**	**712,000**	**+27,000**
Change in Storage		**348,000**	**423,000**	**-75,000**
Mass Balance Difference		**-1,000**	**-2,000**	**+1,000**

Notes:
- Groundwater budget components are rounded to the nearest 1,000 acre-feet per year; totals may not sum due to rounding
- Difference between scenarios is calculated as Historical Scenario minus No Projects Scenario

Table 3-4. Average Annual Normal-Year Groundwater Budget for Historical and No Projects Scenario, and Difference Between Scenarios (in afy)

Groundwater Budget Component		Historical Scenario	No Projects Scenario	Difference
Inflows	Net Recharge	3,000	15,000	-12,000
	GW/SW Flux	565,000	493,000	+72,000
	GW Exchange with Ocean	15,000	16,000	-1,000
	Total In	**538,000**	**524,000**	**+59,000**
Outflows	M&I Pumping	50,000	50,000	< 1,000
	Ag Pumping	418,000	428,000	-10,000
	Drains	213,000	170,000	+43,000
	GW Exchange with Pajaro Basin	< 1,000	< 1,000	< 1,000
	GW Exchange with Paso Robles Basin	4,000	4,000	< 1,000
	Total Out	**685,000**	**652,000**	**+33,000**
Change in Storage		**-97,000**	**-122,000**	**+25,000**
Mass Balance Difference		**-4,000**	**-5,000**	**+1,000**

Notes:
- Groundwater budget components are rounded to the nearest 1,000 acre-feet per year; totals may not sum due to rounding
- Difference between scenarios is calculated as Historical Scenario minus No Projects Scenario

Table 3-5. Average Annual Dry-Year Groundwater Budget for Historical and No Projects Scenario, and Difference Between Scenarios (in afy)

Groundwater Budget Component		Historical Scenario	No Projects Scenario	Difference
Inflows	Net Recharge	4,000	26,000	-22,000
	GW/SW Flux	418,000	259,000	+159,000
	GW Exchange with Ocean	15,000	16,000	-2,000
	Total In	**437,000**	**302,000**	**+135,000**
Outflows	M&I Pumping	45,000	45,000	< 1,000
	Ag Pumping	444,000	456,000	-12,000
	Drains	134,000	77,000	+57,000
	GW Exchange with Pajaro Basin	< 1,000	< 1,000	< 1,000
	GW Exchange with Paso Robles Basin	4,000	3,000	< 1,000
	Total Out	**627,000**	**582,000**	**+45,000**
Change in Storage		**-184,000**	**-272,000**	**+88,000**
Mass Balance Difference		**-6,000**	**-7,000**	**+2,000**

Notes:
- Groundwater budget components are rounded to the nearest 1,000 acre-feet per year; totals may not sum due to rounding
- Difference between scenarios is calculated as Historical Scenario minus No Projects Scenario

3.3.3 Subarea Groundwater Budgets

Groundwater budgets for individual Zone 2C Subareas (see Figure 1-6 for the Subarea locations) provide a more detailed understanding of the impact of the Projects on groundwater conditions in the Basin. Zone 2C includes the Pressure, East Side, Arroyo Seco, Forebay, Upper Valley, and Below Dam Subareas (the Above Dam Subarea is located outside of the active model domain and is therefore excluded from all groundwater budgets). The portion of the active model domain located south of the Monterey-San Luis Obispo County Line is considered the Paso Robles Basin for these groundwater budgets. The area of the active model domain off the coast is considered the Offshore Area. Areas of the active model domain that do not fall into any of the above categories are listed as Other Non-Zone 2C Areas.

Figure 3-33 and Table 3-6 present the average annual groundwater budget for the Historical Scenario, by Zone 2C Subarea. Figure 3-34 and Table 3-7 present the average annual groundwater budget for the No Projects Scenario, by Subarea. Figure 3-35 and Table 3-8 present the differences between the Subarea groundwater budget results for the two scenarios.

As described in Section 3.3.2, the most significant differences between the Historical and No Projects Scenarios are limited to the groundwater-surface water flux, discharge to drains, net recharge, agricultural pumping, and storage change. Differences in groundwater-surface water flux, amounting to 72,000 afy, are distributed to the Pressure Subarea (about 6,000 afy), Arroyo Seco Subarea (about 1,000 afy), Forebay Subarea (about 20,000 afy), Upper Valley Subarea (about 44,000 afy), and Below Dam Subarea (about 1,000 afy). The majority of the difference being limited to the Forebay and Upper Valley Subareas reflects the strong hydraulic connection between the Salinas River and the aquifers of these Subareas.

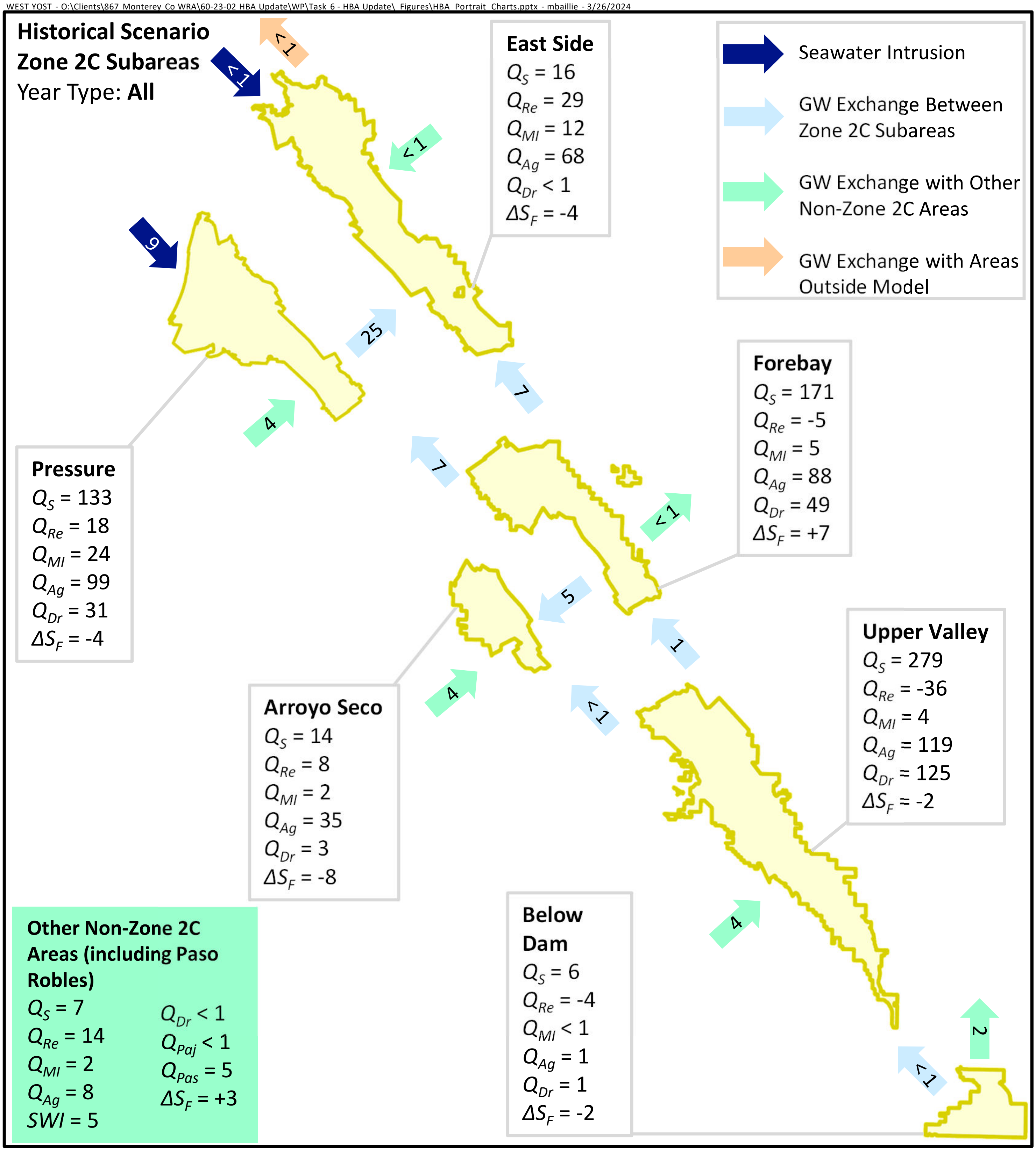
About 45,000 afy more discharge to drains was simulated under the Historical Scenario compared to the No Projects Scenario. The distribution of this difference between subareas strongly follows the difference in groundwater-surface water flux. About 3,000 afy more discharges to drains in the Pressure Subarea, about 1,000 afy more in the Arroyo Seco Subarea, about 11,000 afy more in the Forebay Subarea, and about 29,000 afy more in the Upper Valley Subarea. This indicates that the increase in drain discharge is likely to be driven by the increased groundwater-surface water flux maintaining groundwater heads closer to the elevations of the agricultural drains.

Similarly, the decrease in net recharge of about 14,000 afy under the Historical Scenario compared to the No Projects Scenario is limited to the Pressure Subarea (about 2,000 afy), Forebay Subarea (about 5,000 afy), and Upper Valley Subarea (about 7,000 afy). Average annual net recharge is negative in the Forebay, Upper Valley, and Below Dam Subareas under both scenarios, indicating that groundwater heads are close enough to the land surface in these areas to contribute significantly to the satisfaction of crop water demand.

The reduction in agricultural pumping under the Historical Scenario (about 10,000 afy) occurred in the Pressure Subarea (about 6,000 afy), Forebay Subarea (about 1,000 afy), and Upper Valley Subarea (about 2,000 afy). The SVIHM can simulate a reduction in agricultural pumping either because groundwater head in the pumping wells falls to a level where the well pump can no longer maintain the desired pumping rate, or because the irrigation demand of the crop is smaller (because, for example, the crops have increased access to groundwater within the root zone). In the Forebay and Upper Valley Subareas, the reduction in agricultural pumping is less than the decrease in net recharge (or increase in evapotranspiration of soil zone groundwater, as noted above), so increased head could explain the reduction in agricultural pumping due to reduced irrigation demand. The same is not true in the Pressure Subarea, where the reduction in agricultural pumping was larger than the decrease in net recharge. Figure 3-36 is a time series of cumulative Pressure Subarea agricultural groundwater pumping throughout the entire model duration for the Historical and No Projects Scenarios, as well as the difference between the scenarios. The difference in agricultural pumping in the Pressure Subarea is largely confined to the period from 1998 onward, indicating that the difference is likely due to the provision of recycled water and diverted surface water to the CSIP system reducing the demand for groundwater to be pumped by the agricultural wells.

Under the Historical Scenario, the model domain experiences an average annual reduction in total groundwater storage (ΔS) of about 11,000 afy, which represents the combined effect of about 15,000 afy of seawater intrusion (*SWI*) and a reduction in fresh groundwater storage (ΔS_F) of about 26,000 afy (see Equation 8; Figure 3-21). Under the No Projects Scenario, the average annual reduction in total groundwater storage (ΔS) is about 31,000 afy, which represents the combined effect of about 16,000 afy of seawater intrusion (*SWI*) and a reduction in fresh groundwater storage (ΔS_F) of about 47,000 afy (Figure 3-22); this means that the total groundwater storage loss under the Historical Scenario is about 20,000 afy less than under the No Projects Scenario (Figure 3-23). There is less storage loss (or more storage gain) simulated in every Subarea, as shown in Figure 3-35. The largest storage gain under the Historical Scenario occurs in the Upper Valley Subarea (about 8,000 afy), followed by the Pressure and Forebay Subareas (about 4,000 afy each), the East Side Subarea (about 2,000 afy), the Arroyo Seco Subarea (about 1,000 afy), other Non-Zone 2C Areas (about 1,000 afy), and the Below Dam Subarea, Paso Robles Basin, and offshore area (less than 1,000 afy each).

The reduction of about 1,000 afy of seawater intrusion simulated under the Historical Scenario compared to the No Projects Scenario is confined to the Pressure Subarea.



Abbreviations:
Q_S = Groundwater-Surface Water Exchange
Q_{MI} = Municipal & Industrial Pumping
Q_{Ag} = Agricultural Pumping
Q_{Dr} = Discharge to Drains
Q_{Re} = Net Recharge
Q_{Pas} = Groundwater Exchange with Paso Robles Basin
Q_{Paj} = Groundwater Exchange with Pajaro Basin
ΔS_F = Change in Fresh Groundwater Storage
SWI = Seawater Intrusion

Notes:
1. Water budget components are rounded to nearest 1,000 acre-feet per year and displayed in thousands of acre-feet per year; totals may not sum due to rounding and imperfect closure of the model mass balance.
2. Arrow orientation denotes direction of groundwater flow. Arrows pointing away from the box show groundwater leaving the aquifer volume under consideration. Arrows pointing toward the box show groundwater entering the aquifer volume.
3. See Section 3.3 of the text for the development of the SVIHM groundwater budget equation.
4. For this figure, the portion of the Paso Robles Basin within the model domain is included in the Other Non-Zone 2C Areas.
5. Net recharge can be negative if transpiration of groundwater exceeds deep percolation.
6. Difference between scenarios is calculated as Historical Scenario minus No Projects Scenario

Figure 3-33

Average Annual Groundwater Budget by Subarea, Historical Scenario

MONTEREY COUNTY WATER RESOURCES AGENCY 1947

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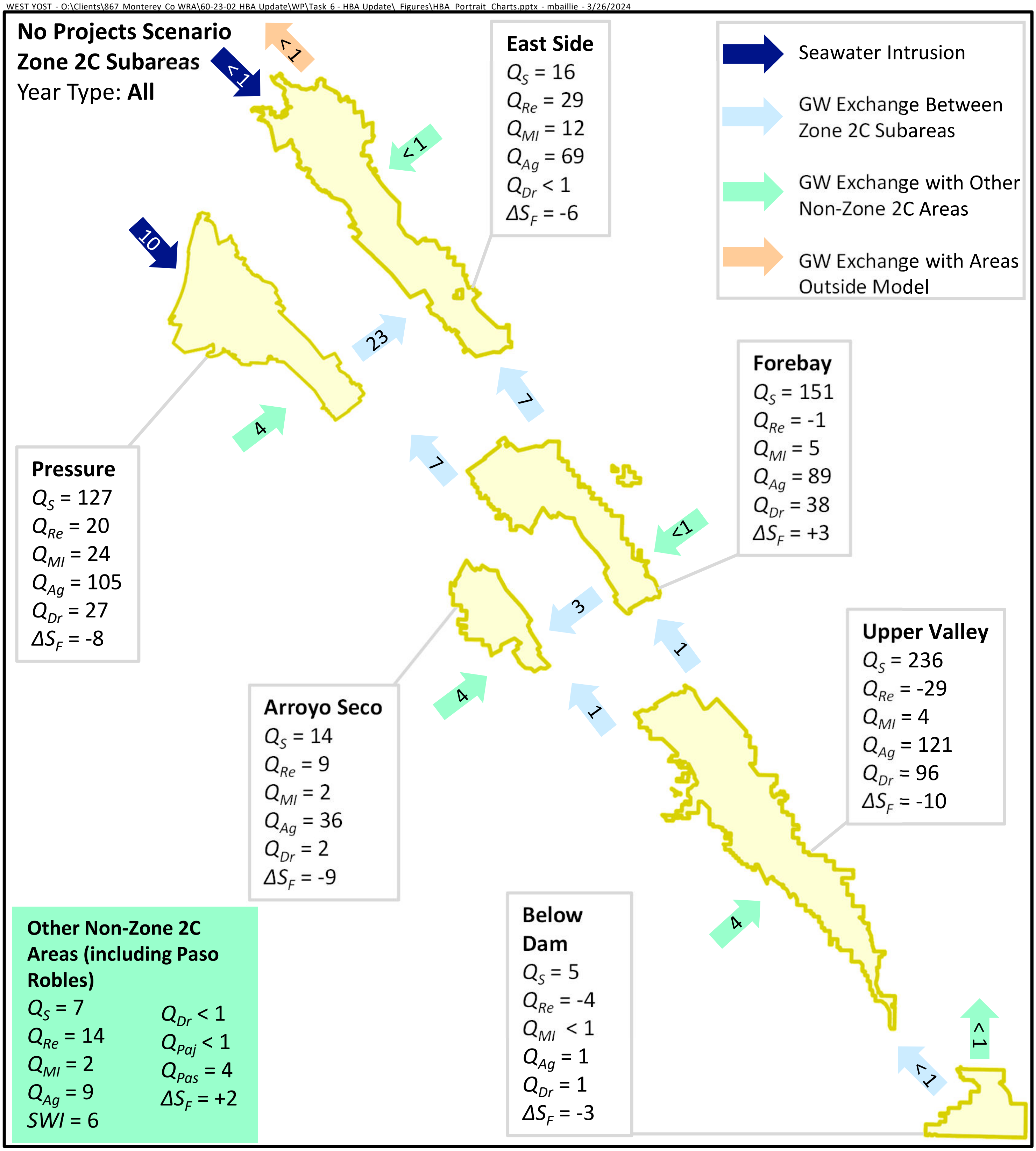

Abbreviations:

- Q_S = Groundwater-Surface Water Exchange
- Q_{MI} = Municipal & Industrial Pumping
- Q_{Ag} = Agricultural Pumping
- Q_{Dr} = Discharge to Drains
- Q_{Re} = Net Recharge
- Q_{Pas} = Groundwater Exchange with Paso Robles Basin
- Q_{Paj} = Groundwater Exchange with Pajaro Basin
- ΔS_F = Change in Fresh Groundwater Storage
- SWI = Seawater Intrusion

Notes:

1. Water budget components are rounded to nearest 1,000 acre-feet per year and displayed in thousands of acre-feet per year; totals may not sum due to rounding and imperfect closure of the model mass balance.
2. Arrow orientation denotes direction of groundwater flow. Arrows pointing away from the box show groundwater leaving the aquifer volume under consideration. Arrows pointing toward the box show groundwater entering the aquifer volume.
3. See Section 3.3 of the text for the development of the SVIHM groundwater budget equation.
4. For this figure, the portion of the Paso Robles Basin within the model domain is included in the Other Non-Zone 2C Areas.
5. Net recharge can be negative if transpiration of groundwater exceeds deep percolation.
6. Difference between scenarios is calculated as Historical Scenario minus No Projects Scenario

Figure 3-34

Average Annual Groundwater Budget by Subarea, No Projects Scenario

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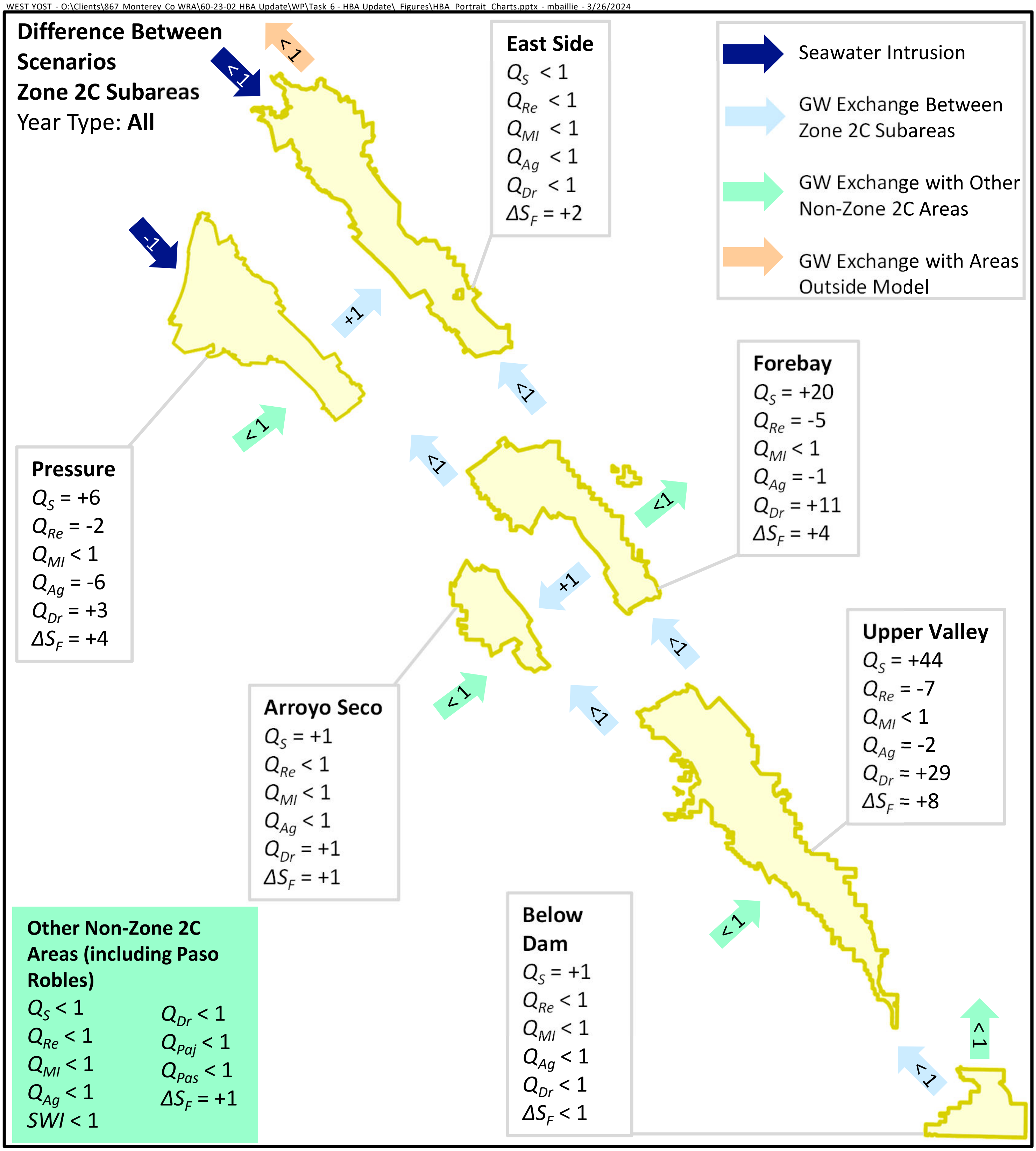

Abbreviations:

- Q_S = Groundwater-Surface Water Exchange
- Q_{MI} = Municipal & Industrial Pumping
- Q_{Ag} = Agricultural Pumping
- Q_{Dr} = Discharge to Drains
- Q_{Re} = Net Recharge
- Q_{Pas} = Groundwater Exchange with Paso Robles Basin
- Q_{Paj} = Groundwater Exchange with Pajaro Basin
- ΔS_F = Change in Fresh Groundwater Storage
- SWI = Seawater Intrusion

Notes:

1. Water budget components are rounded to nearest 1,000 acre-feet per year and displayed in thousands of acre-feet per year; totals may not sum due to rounding and imperfect closure of the model mass balance.
2. Arrow orientation denotes direction of groundwater flow. Arrows pointing away from the box show groundwater leaving the aquifer volume under consideration. Arrows pointing toward the box show groundwater entering the aquifer volume.
3. See Section 3.3 of the text for the development of the SVIHM groundwater budget equation.
4. For this figure, the portion of the Paso Robles Basin within the model domain is included in the Other Non-Zone 2C Areas.
5. Net recharge can be negative if transpiration of groundwater exceeds deep percolation.
6. Difference between scenarios is calculated as Historical Scenario minus No Projects Scenario

Figure 3-35

Average Annual Groundwater Budget by Subarea, Difference Between Scenarios

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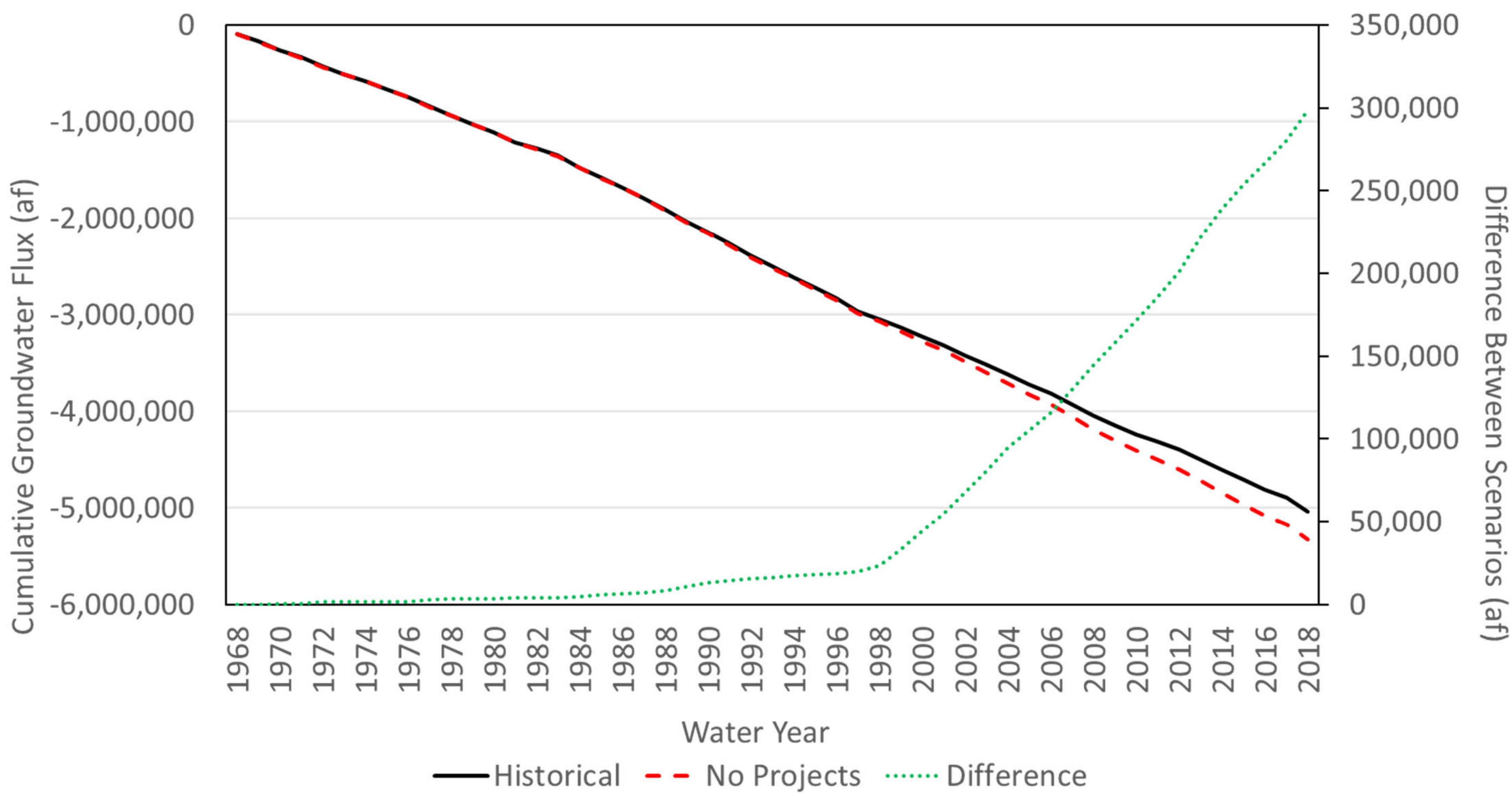

Figure 3-36

Cumulative Simulated Agricultural Pumping, Pressure Subarea

Monterey County Water Resources Agency
Historical Benefits Analysis Update
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Table 3-6. Average Annual Groundwater Budget by Subarea, Historical Scenario (in afy)										
	Groundwater Budget Component	Pressure	East Side	Arroyo Seco	Forebay	Upper Valley	Below Dam	Paso Robles Basin	Offshore	Other Non-Zone 2C Area
Inflows	Net Recharge	18,000	29,000	8,000	-5,000	-36,000	-4,000	1,000	0	13,000
	GW/SW Flux	133,000	16,000	14,000	171,000	279,000	6,000	1,000	0	7,000
	Seawater Intrusion	9,000	< 1,000	0	0	0	0	0	0	5,000
	GW Inflow from Other Subareas	11,000	32,000	9,000	1,000	4,000	< 1,000	1,000	0	2,000
	GW Inflow from Ocean	0	0	0	0	0	0	0	15,000	0
	Total In	**172,000**	**76,000**	**32,000**	**167,000**	**247,000**	**2,000**	**3,000**	**15,000**	**27,000**
Outflows	M&I Pumping	24,000	12,000	2,000	5,000	4,000	< 1,000	< 1,000	0	2,000
	Ag Pumping	99,000	68,000	35,000	88,000	119,000	1,000	< 1,000	0	8,000
	Drains	31,000	< 1,000	3,000	49,000	125,000	1,000	0	0	< 1,000
	GW Exchange with Pajaro Basin	0	< 1,000	0	0	0	0	0	0	< 1,000
	GW Exchange with Paso Robles Basin	0	0	0	0	0	0	4,000	0	1,000
	GW Outflow to Other Subareas	25,000	0	0	19,000	2,000	2,000	< 1,000	15,000	12,000
	Total Out	**178,000**	**81,000**	**40,000**	**161,000**	**250,000**	**4,000**	**4,000**	**15,000**	**23,000**
Change in Storage		**-4,000**	**-4,000**	**-8,000**	**+7,000**	**-2,000**	**-2,000**	**-1,000**	**< 1,000**	**+4,000**
Mass Balance Difference		**-1,000**	**< 1,000**	**< 1,000**	**-1,000**	**+1,000**	**< 1,000**	**< 1,000**	**< 1,000**	**< 1,000**

Notes:
- Groundwater budget components are rounded to the nearest 1,000 acre-feet per year; totals may not sum due to rounding

Table 3-7. Average Annual Groundwater Budget by Subarea, No Project Scenario (in afy)

	Groundwater Budget Component	Pressure	East Side	Arroyo Seco	Forebay	Upper Valley	Below Dam	Paso Robles Basin	Offshore	Other Non-Zone 2C Area
Inflows	Net Recharge	20,000	29,000	9,000	-1,000	-29,000	-4,000	1,000	0	13,000
	GW/SW Flux	127,000	16,000	14,000	151,000	236,000	5,000	1,000	0	7,000
	Seawater Intrusion	10,000	< 1,000	0	0	0	0	0	0	6,000
	GW Inflow from Other Subareas	12,000	30,000	8,000	1,000	4,000	< 1,000	1,000	0	2,000
	GW Inflow from Ocean	0	0	0	0	0	0	0	16,000	0
	Total In	**169,000**	**75,000**	**30,000**	**151,000**	**211,000**	**1,000**	**3,000**	**16,000**	**27,000**
Outflows	M&I Pumping	24,000	12,000	2,000	5,000	4,000	< 1,000	< 1,000	0	2,000
	Ag Pumping	105,000	69,000	36,000	89,000	121,000	1,000	< 1,000	0	8,000
	Drains	27,000	< 1,000	2,000	38,000	96,000	1,000	0	0	< 1,000
	GW Exchange with Pajaro Basin	0	< 1,000	0	0	0	0	0	0	< 1,000
	GW Exchange with Paso Robles Basin	0	0	0	0	0	0	4,000	0	1,000
	GW Outflow to Other Subareas	23,000	0	0	17,000	2,000	2,000	< 1,000	16,000	12,000
	Total Out	**179,000**	**81,000**	**40,000**	**149,000**	**223,000**	**4,000**	**4,000**	**16,000**	**24,000**
Change in Storage		**-8,000**	**-6,000**	**-9,000**	**+3,000**	**-10,000**	**+3,000**	**-1,000**	**< 1,000**	**3,000**
Mass Balance Difference		**-1,000**	**< 1,000**	**< 1,000**	**-1,000**	**+2,000**	**< 1,000**	**< 1,000**	**< 1,000**	**< 1,000**

Notes:

- Groundwater budget components are rounded to the nearest 1,000 acre-feet per year; totals may not sum due to rounding

Table 3-8. Average Annual Groundwater Budget by Subarea, Difference Between Scenarios (in afy)

	Groundwater Budget Component	Pressure	East Side	Arroyo Seco	Forebay	Upper Valley	Below Dam	Paso Robles Basin	Offshore	Other Non-Zone 2C Area
Inflows	Net Recharge	-2,000	< 1,000	< 1,000	-5,000	-7,000	< 1,000	0	0	< 1,000
	GW/SW Flux	+6,000	< 1,000	+1,000	+20,000	+44,000	+1,000	< 1,000	0	< 1,000
	Seawater Intrusion	-1,000	< 1,000	0	0	0	0	0	0	< 1,000
	GW Inflow from Other Subareas	< 1,000	+1,000	+1,000	< 1,000	< 1,000	< 1,000	< 1,000	0	< 1,000
	GW Inflow from Ocean	0	0	0	0	0	0	0	-1,000	0
	Total In	**+3,000**	**+2,000**	**+2,000**	**+15,000**	**+36,000**	**+1,000**	**< 1,000**	**-1,000**	**< 1,000**
Outflows	M&I Pumping	< 1,000	< 1,000	< 1,000	0	0	0	0	0	0
	Ag Pumping	-6,000	< 1,000	< 1,000	-1,000	-2,000	0	0	0	< 1,000
	Drains	+3,000	< 1,000	+1,000	+11,000	+29,000	< 1,000	0	0	< 1,000
	GW Exchange with Pajaro Basin	0	< 1,000	0	0	0	0	0	0	< 1,000
	GW Exchange with Paso Robles Basin	0	0	0	0	0	0	< 1,000	0	< 1,000
	GW Outflow to Other Subareas	+1,000	0	0	+2,000	< 1,000	< 1,000	< 1,000	-1,000	-1,000
	Total Out	**-1,000**	**< 1,000**	**+1,000**	**+11,000**	**+27,000**	**< 1,000**	**< 1,000**	**-1,000**	**-1,000**
Change in Storage		**+4,000**	**+2,000**	**+1,000**	**+4,000**	**+8,000**	**< 1,000**	**< 1,000**	**< 1,000**	**+1,000**
Mass Balance Difference		**< 1,000**	**< 1,000**	**< 1,000**	**< 1,000**	**+1,000**	**< 1,000**	**< 1,000**	**< 1,000**	**< 1,000**

Notes:
- Groundwater budget components are rounded to the nearest 1,000 acre-feet per year; totals may not sum due to rounding
- Difference between scenarios is calculated as Historical Scenario minus No Projects Scenario

3.3.4 Groundwater Budgets Summary

This section described the results of the effects of the Projects on the simulated fluxes of groundwater into and out of the aquifers of the Basin, as well as changes in the amount of groundwater stored within those aquifers. The groundwater budget analysis shows that the reservoirs (and related projects and programs) have resulted in substantially more groundwater held in storage (about 20,000 afy). Storage increases during wet years were greatly decreased (by about 75,000 afy) under the Historical Scenario compared to the No Projects Scenario but increased during normal (about 25,000 afy) and dry (about 88,000 afy) years. The increased groundwater storage provided by the operation of the Projects is distributed around Zone 2C, but the largest amount occurs in the Upper Valley Subarea (about 8,000 afy), followed by the Pressure and Forebay Subareas (each about 4,000 afy), the East Side Subarea (about 2,000 afy), and the Arroyo Seco Subarea (about 1,000 afy).

Changes to groundwater storage represent differences between the inflows and outflows to the groundwater system; when groundwater outflows are larger than inflows, groundwater storage declines. The groundwater budget component that exhibited the largest differences between scenarios was groundwater-surface water flux. The groundwater system receives streamflow losses throughout most of the study area. The model results indicate that the Projects have resulted in an average of about 72,000 afy more streamflow losses to the groundwater system. During wet years, this flux is smaller (by about 37,000 afy) because the reservoirs store high flows during wet years. Normal years see an increase in groundwater-surface water flux of about 72,000 afy and dry years see an increase of about 159,000 afy. These differences reflect the release of stored water from the reservoirs during drier years. Changes to the groundwater-surface water flux are highest in the Upper Valley Subarea (about 44,000 afy), followed by the Forebay Subarea (about 20,000 afy), the Pressure Subarea (about 6,000 afy), and the Arroyo Seco and Below Dam Subareas (about 1,000 afy each). Other areas experienced insignificant changes to groundwater-surface water flux.

Agricultural pumping was about 10,000 afy less with the Projects than without. This difference was less sensitive to water year type compared to the changes to groundwater storage and groundwater-surface water flux. During wet years, agricultural pumping was about 7,000 afy less, compared to about 10,000 afy for normal years and 12,000 afy for dry years. The reduction in agricultural pumping was largest in the Pressure Subarea (about 6,000 afy), followed by the Upper Valley Subarea (about 2,000 afy) and Forebay Subarea (about 1,000 afy). Differences were minimal in other parts of the study area. In the Pressure Subarea, the reduction in agricultural pumping seems to be due to the operation of the CSIP system, which delivers recycled and surface water to agricultural users and thereby offsets crop groundwater demand. In the Forebay and Upper Valley Subareas, the reduction in agricultural pumping seems to result from increased groundwater head values supplying more groundwater to crop root zones, reducing the need for supplemental groundwater to satisfy crop demands.

Other changes to the groundwater budget between the scenarios were minor, or resulted directly from the changes to groundwater-surface water flux and groundwater storage. For example, drain discharge was about 45,000 afy higher with the Projects than without, due to groundwater heads that were more consistently above the elevations of the drain bottoms. Similarly, net recharge was about 14,000 afy less with the Projects than without, because higher groundwater head resulted in more use of root zone groundwater by crops (reported as negative recharge), and in additional runoff of precipitation due to saturation of the ground.

3.4 SURFACE WATER BUDGETS

This section discusses surface water budgets for the study area, detailing various portions of it for the Historical and No Projects Scenarios, as well as the difference between the scenarios. This discussion focuses on changes in streamflow losses, tributary inflow, and outflow to the Pacific Ocean.

3.4.1 Development of Surface Water Budget Equation

A water budget can be constructed for a surface water body or network in much the same way as described in Section 3.3. for groundwater. A surface water budget equation is nearly identical to the basic groundwater budget equation (Equation 3). For typical stream networks, the water budget could include difference inflow and outflow components, for example:

$$\Delta S = Q_{in} + Q_{trib} + Q_P + Q_R - Q_E - Q_T - Q_{div} - Q_{out} \pm Q_S \quad (12)$$

where Q_{in} is inflow from upstream, Q_{trib} is inflow from tributaries, Q_P is direct precipitation into the stream network, Q_R is land surface runoff, Q_E is open water evaporation from the stream surface, Q_T is transpiration by plants tapping stream water, Q_{div} represents diversions from the stream network, and Q_{out} is outflow to downstream, and Q_S is groundwater-surface water interaction. Additional or fewer components in the surface water budget may be appropriate, depending on the setting.

Before presenting the surface water budget equation for the HBA Update, some relevant aspects of the approach to surface water routing in MODFLOW and in the SVIHM in particular are discussed. The SVIHM uses the MODFLOW Stream Flow Routing (SFR) Package (Prudic et al., 2004) to simulate streamflow routing within the model domain. The SFR Package does not simulate storage in the stream network; conditions within the stream network are not informed by streamflow conditions during the preceding timestep. This means that storage change is not simulated, and the sum of inflows is equal to the sum of outflows:

$$0 = Q_{in} - Q_{out} \quad (13)$$

$$Q_{in} = Q_{out} \quad (14)$$

Although MODFLOW can simulate direct precipitation into stream networks and evapotranspiration from them, the SVIHM does not include these components of the surface water budget. Q_P, Q_E, and Q_T in Equation 12 would all be zero in a surface water budget of the SVIHM stream network.

The SFR Package routes streamflow through a simulated stream network, according to a user-specified scheme. Each stream reach is connected to other stream reaches in the network; a given stream reach can receive water from one or more upstream reaches and can contribute water to a single downstream reach (or a downstream reach and a diversion, as appropriate). If the user does not specify a downstream reach as a destination for water in a stream reach, MODFLOW does not have any mechanism for routing it anywhere. As noted above, there is no simulation of storage in the stream network. This means that streamflow reaching the end of a stream reach with no defined destination effectively leaves the model domain without any further interactions with the groundwater or surface water systems. A water budget of the stream system must account for water lost in this manner to attain mass balance closure. The SVIHM includes a number of streams with no downstream destination defined, representing various ephemeral streams that flow down from the mountain front but disappear on the valley floor without reaching the Salinas River or one of its tributaries. For the purposes of these water budgets, these streams are referred to as "hanging streams."

Considering all of the above, a surface water budget equation for the SVIHM can be written as:

$$Q_{in} + Q_{trib} + Q_{head} + Q_R = Q_S + Q_{hang} + Q_{div} + Q_{out} \quad (15)$$

where Q_{head} is inflow at stream headwaters within the area of the surface water budget, and Q_{hang} is outflow from hanging streams that end within the area of the surface water budget; all other components are as defined in Equation 12 (as noted above, Q_P, Q_E, and Q_T are zero for the SVIHM and are excluded from Equation 15). Groundwater surface water interaction can result in an outflow from the stream network (i.e., stream loss) or inflow to the stream network (i.e., stream gain). In the Salinas Valley, streams generally lose water to the aquifers, so Equation 15 includes Q_S on the side of the equation with other outflows. This formulation of the surface water budget is used in this report. Generally, the Salinas River is the main surface water body of interest, and Q_{in} and Q_{out} represent the Salinas River inflows to and outflows from the area over which the surface water budget is computed; Q_{trib} represents other inflows generated from outside the surface water budget area that reach the Salinas River.

3.4.2 Model Domain Surface Water Budget

The average annual surface water budget for the entire model domain for the Historical Scenario is shown as Figure 3-37); that for the No Projects Scenario is shown as Figure 3-38. The difference in surface water budget components is shown as Figure 3-39. Tabular surface water budget information is presented in Table 3-9. Surface water budget components depicted in these and other figures are rounded to the nearest 1,000 afy; depicted averages may not sum exactly due to this rounding. As noted in Chapter 2, the difference shown is equal to the Historical Scenario surface water budget component minus the No Projects Scenario surface water budget component. A positive difference indicates that the magnitude of the surface water flux was greater under the Historical Scenario.

The surface water budget information indicates that, under the Historical Scenario, the Basin experienced about 72,000 afy more streamflow loss to groundwater, about 51,000 afy less outflow to Monterey Bay via the Salinas River, about 45,000 afy more land surface runoff, about 21,000 afy less inflow from the Nacimiento and San Antonio Rivers (the difference in headwater inflow on Figure 3-39 and Table 3-9), and about 2,000 afy more loss of streamflow at the ends of hanging streams compared to the No Projects Scenario. Changes to other surface water budget components are not significant in magnitude.

The increase of streamflow loss is discussed in Section 3.3.2, where it is depicted as a gain to groundwater; in general, it results from increased normal- and dry-year streamflow in the Salinas River leading to increased recharge of the aquifers, especially in the southern part of the Basin. The decrease in outflow to Monterey Bay via the Salinas River results from decreased flow during wet years due to storage of wet year flows in the reservoirs, as well as increased recharge to groundwater during normal and dry years capturing more Salinas River flow before it reaches the river mouth. Increased land surface runoff can occur because additional water is reaching the land surface (through increased precipitation or irrigation), or because higher groundwater heads in water table aquifers are resulting in the water table rising to the land surface or runoff of applied water that would otherwise have become recharge; both processes are likely resulting in the increased land surface runoff under the Historical Scenario. The reduction in "headwater" inflow represents a decrease of average annual inflow from the Nacimiento and San Antonio Rivers with the reservoirs. Finally, the Historical Scenario results in slightly more outflow from hanging streams, which may reflect increased groundwater head resulting in less recharge from hanging streams, or increased land surface runoff into them.

Figures 3-40, 3-41, and 3-42 provide the average annual wet-year surface water budgets for the Historical Scenario, No Projects Scenario, and difference between scenarios, respectively. Table 3-10 presents this surface water budget information in a tabular format. During wet years, there is a decrease of about 229,000 afy of inflow from the Nacimiento and San Antonio Rivers due to the presence of the reservoirs; this represents the ability of the reservoirs to store the high flows during wet years. This decrease in inflow results in a decrease (of about 37,000 afy) of streamflow loss to the aquifers and a further decrease of about 161,000 afy of outflow to Monterey Bay; this represents water that is kept within the system during wet years due to the Projects. The presence of the reservoirs results in an increase (of about 34,000 afy) of land surface runoff into the stream network, which, as noted above, likely represents the effect of higher groundwater head conditions reducing the ability for applied water to recharge to the aquifers, instead becoming runoff.

Figures 3-43, 3-44, and 3-45 provide the average annual normal-year surface water budgets for the Historical Scenario, No Projects Scenario, and difference between scenarios, respectively. Table 3-11 presents this surface water budget information in a tabular format. During normal years, there is a slight increase (of about 10,000 afy) of inflow from the Nacimiento and San Antonio Rivers, representing water that is held in the reservoirs and released during the dry summer season of normal years. Normal years also see an increase of about 43,000 afy of land surface runoff. The model simulates about 72,000 afy additional stream loss during normal years with the Projects; this likely results from a combination of factors, especially the modification of the timing of streamflows during normal years (shifting from the winter wet season to the summer dry season). About 22,000 afy less streamflow reaches Monterey Bay during normal years. Finally, the Projects result in an increase of about 2,000 afy lost from the ends of hanging streams, the same as in wet years.

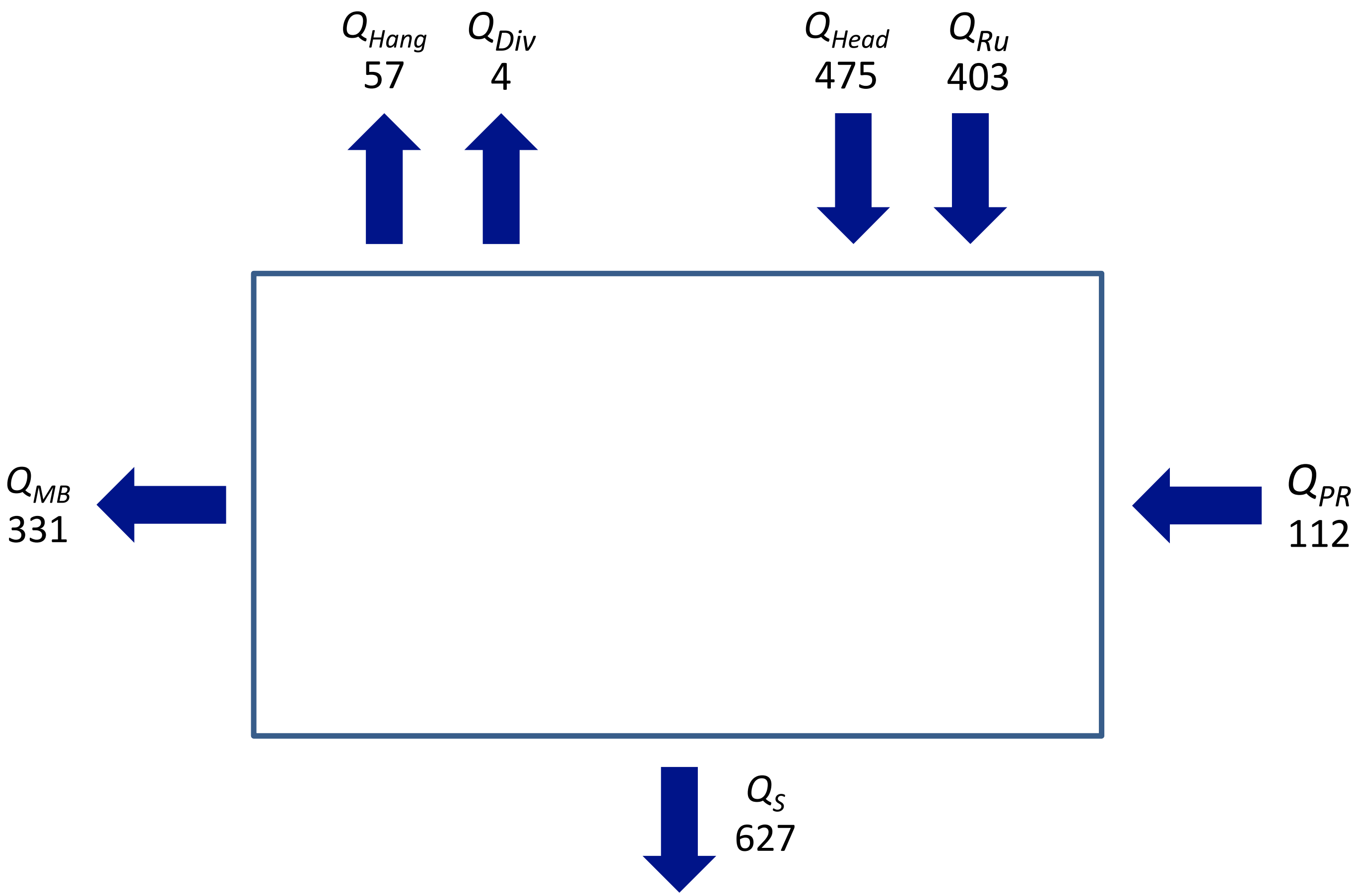
Figures 3-46, 3-47, and 3-48 provide the average annual dry-year surface water budgets for the Historical Scenario, No Projects Scenario, and difference between scenarios, respectively. Table 3-12 presents this surface water budget information in a tabular format. During dry years, both inflows and outflows are substantially larger in magnitude with the Projects than without. In particular, there is an increase of about 104,000 afy of inflow from the Nacimiento and San Antonio Reservoirs due to the storage and release of flows from wetter years. There is about 159,000 afy more streamflow loss to groundwater, representing a substantial increase in recharge to the groundwater system during dry years. Dry years also see an increase of about 57,000 afy of land surface runoff and about 2,000 afy of increased loss via hanging streams. The Historical Scenario simulates about 1,000 afy of SRDF diversion during dry years (averaged over the entire model duration), versus zero under the No Projects Scenario (by definition)[1]. Outflow to Monterey Bay is about 1,000 afy less with the Projects.

[1] On average, less than 1,000 afy of SRDF diversion was simulated under the Historical Scenario for wet and normal years. The SRDF did not start diverting water from the Salinas River until WY 2010, near the end of the model duration. For the 9 water years during the model after SRDF started operating, the average annual diversion was about 3,000 afy (about 4,000 afy during wet years, 6,000 afy during normal years, and 2,000 afy during dry years.

Historical Scenario

Area: **Entire Model Domain**

Year Type: **All**



Q_{Head} = Inflow at Stream Headwaters
Q_{Ru} = Land Surface Runoff
Q_S = Groundwater-Surface Water Exchange
Q_{Hang} = Outflow from Hanging Streams
Q_{Div} = Streamflow Diversion
Q_{PR} = Salinas River Inflow from Paso Robles Basin
Q_{MB} = Outflow to Monterey Bay

Notes:

1. Water budget components are rounded to nearest 1,000 acre-feet per year and displayed in thousands of acre-feet per year; totals may not sum due to rounding.
2. Arrow orientation denotes direction of surface water flow. Arrows pointing away from the box show surface water leaving the aquifer volume under consideration. Arrows pointing toward the box show surface water entering the aquifer volume.
3. See Section 3.4 of the text for the development of the SVIHM surface water budget equation.

Figure 3-37

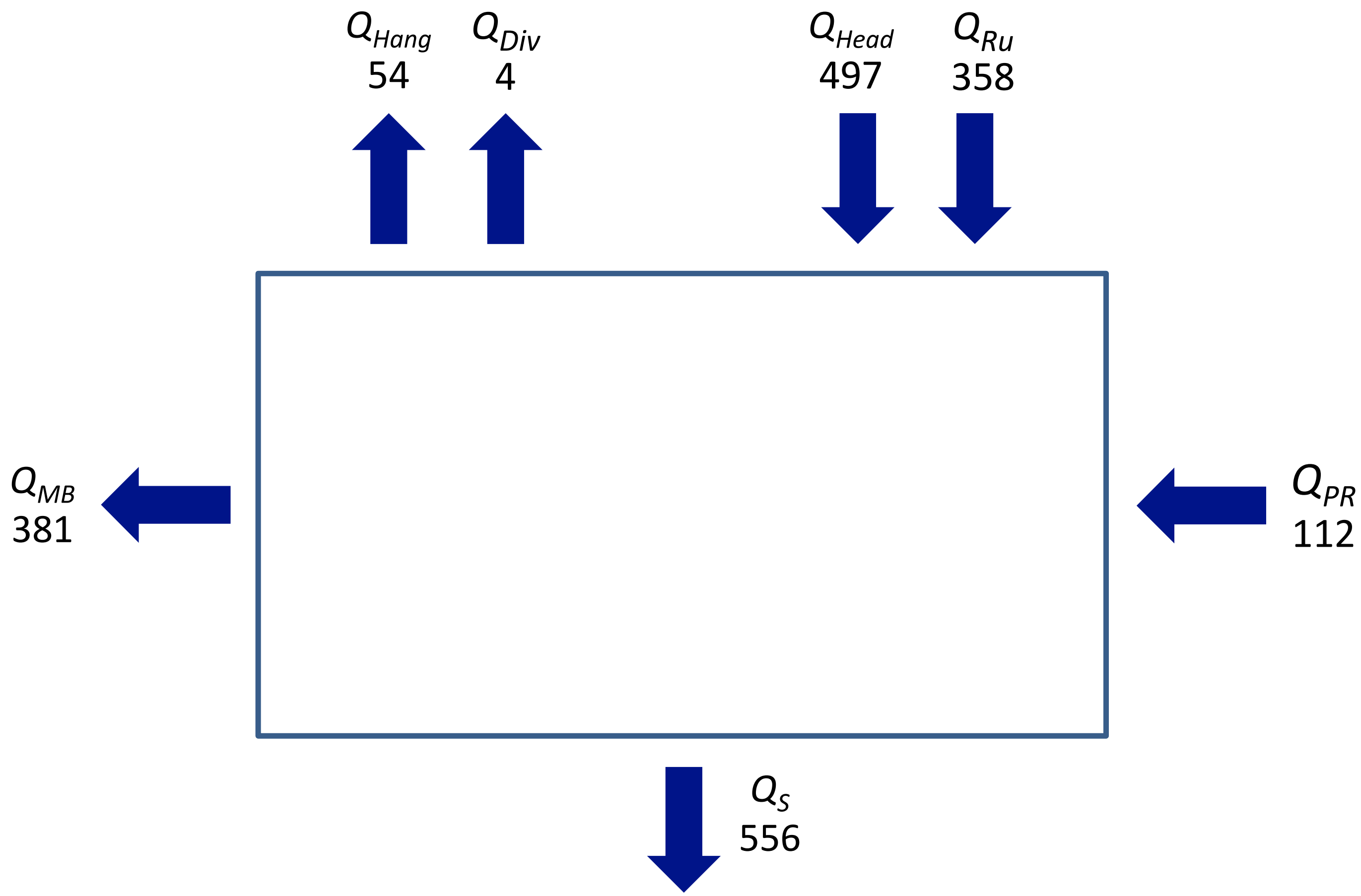
Average Annual Surface Water Budget, Historical Scenario

Monterey County Water Resources Agency
Historical Benefits Analysis Update
April 2025

No Projects Scenario

Area: **Entire Model Domain**

Year Type: **All**



Q_{Head} = Inflow at Stream Headwaters
Q_{Ru} = Land Surface Runoff
Q_S = Groundwater-Surface Water Exchange
Q_{Hang} = Outflow from Hanging Streams
Q_{Div} = Streamflow Diversion
Q_{PR} = Salinas River Inflow from Paso Robles Basin
Q_{MB} = Outflow to Monterey Bay

Notes:

1. Water budget components are rounded to nearest 1,000 acre-feet per year and displayed in thousands of acre-feet per year; totals may not sum due to rounding.
2. Arrow orientation denotes direction of surface water flow. Arrows pointing away from the box show surface water leaving the aquifer volume under consideration. Arrows pointing toward the box show surface water entering the aquifer volume.
3. See Section 3.4 of the text for the development of the SVIHM surface water budget equation.

Figure 3-38

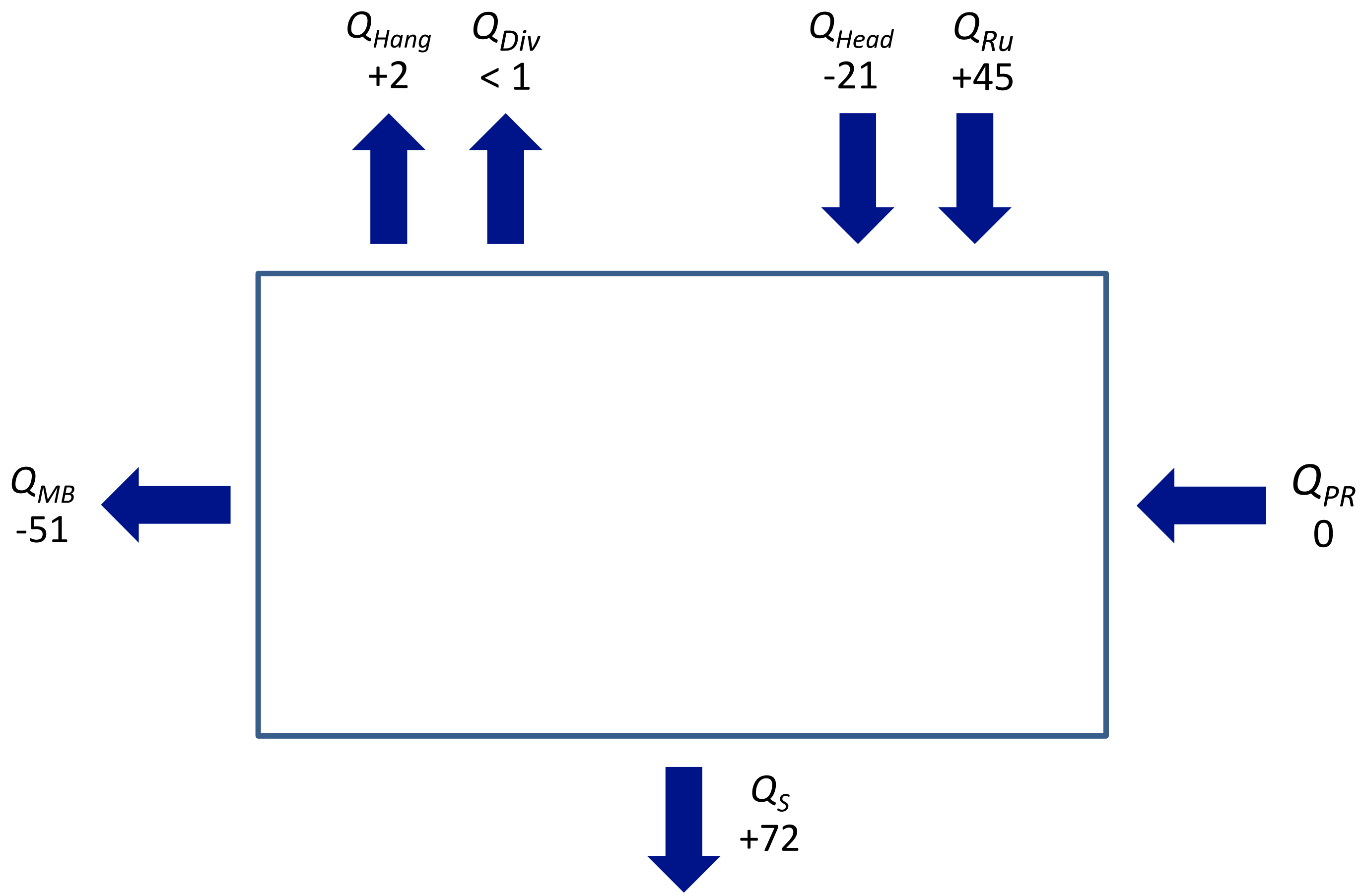
Average Annual Surface Water Budget, No Projects Scenario

Monterey County Water Resources Agency
Historical Benefits Analysis Update
April 20

Difference Between Scenarios

Area: **Entire Model Domain**

Year Type: **All**



Q_{Head} = Inflow at Stream Headwaters
Q_{Ru} = Land Surface Runoff
Q_S = Groundwater-Surface Water Exchange
Q_{Hang} = Outflow from Hanging Streams
Q_{Div} = Streamflow Diversion
Q_{PR} = Salinas River Inflow from Paso Robles Basin
Q_{MB} = Outflow to Monterey Bay

Notes:

1. Water budget components are rounded to nearest 1,000 acre-feet per year and displayed in thousands of acre-feet per year; totals may not sum due to rounding.
2. Arrow orientation denotes direction of surface water flow. Arrows pointing away from the box show surface water leaving the aquifer volume under consideration. Arrows pointing toward the box show surface water entering the aquifer volume.
3. See Section 3.4 of the text for the development of the SVIHM surface water budget equation.
4. Difference between scenarios is calculated as Historical Scenario minus No Projects Scenario

Figure 3-39

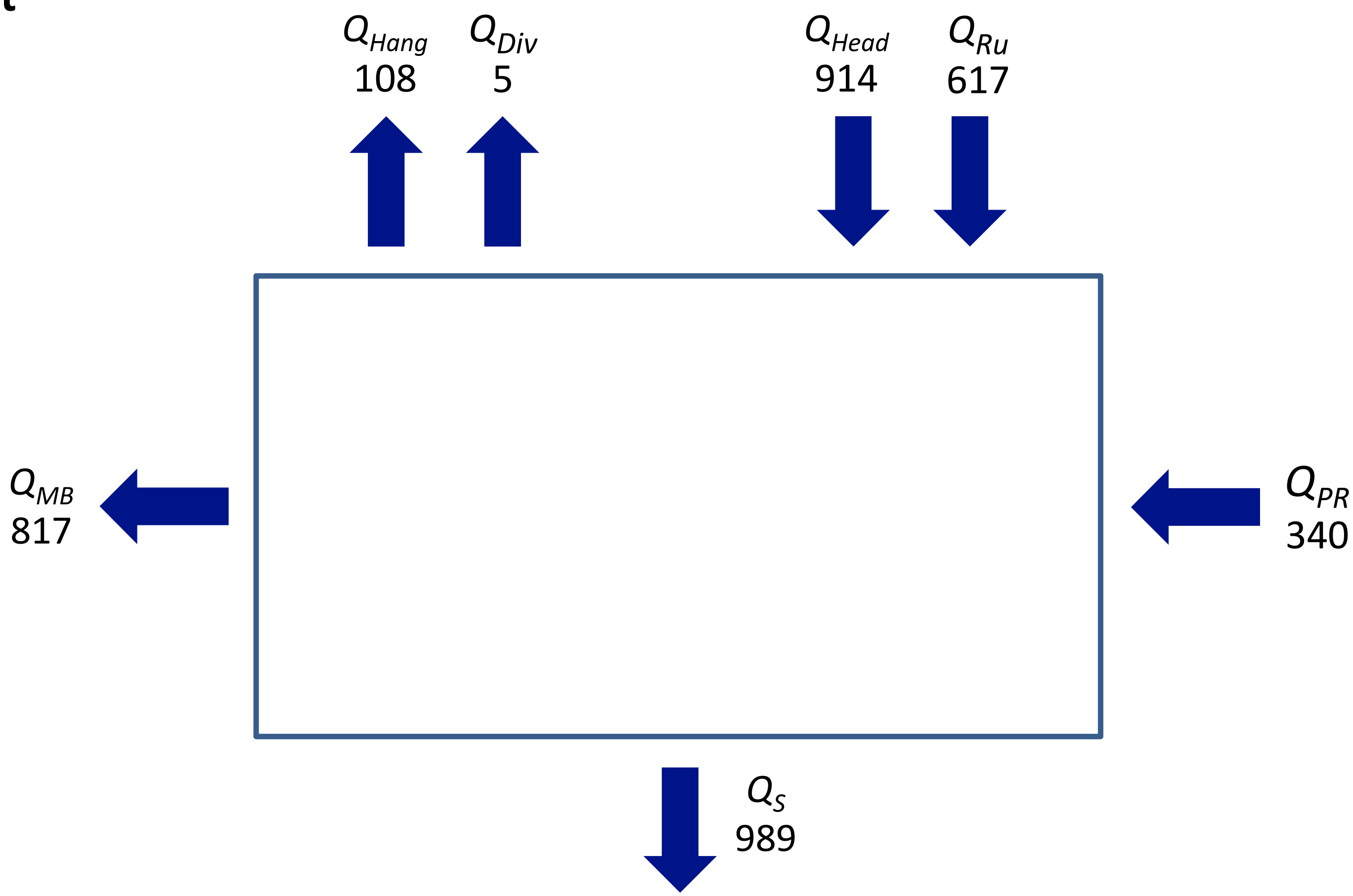
Average Annual Surface Water Budget, Difference Between Scenarios

Monterey County Water Resources Agency
Historical Benefits Analysis Update
April 2025

Historical Scenario

Area: **Entire Model Domain**

Year Type: **Wet**



Q_{Head} = Inflow at Stream Headwaters

Q_{Ru} = Land Surface Runoff

Q_S = Groundwater-Surface Water Exchange

Q_{Hang} = Outflow from Hanging Streams

Q_{Div} = Streamflow Diversion

Q_{PR} = Salinas River Inflow from Paso Robles Basin

Q_{MB} = Outflow to Monterey Bay

Notes:

1. Water budget components are rounded to nearest 1,000 acre-feet per year and displayed in thousands of acre-feet per year; totals may not sum due to rounding.
2. Arrow orientation denotes direction of surface water flow. Arrows pointing away from the box show surface water leaving the aquifer volume under consideration. Arrows pointing toward the box show surface water entering the aquifer volume.
3. See Section 3.4 of the text for the development of the SVIHM surface water budget equation.

Figure 3-40

Average Annual Wet-Year Surface Water Budget, Historical Scenario

Monterey County Water Resources Agency

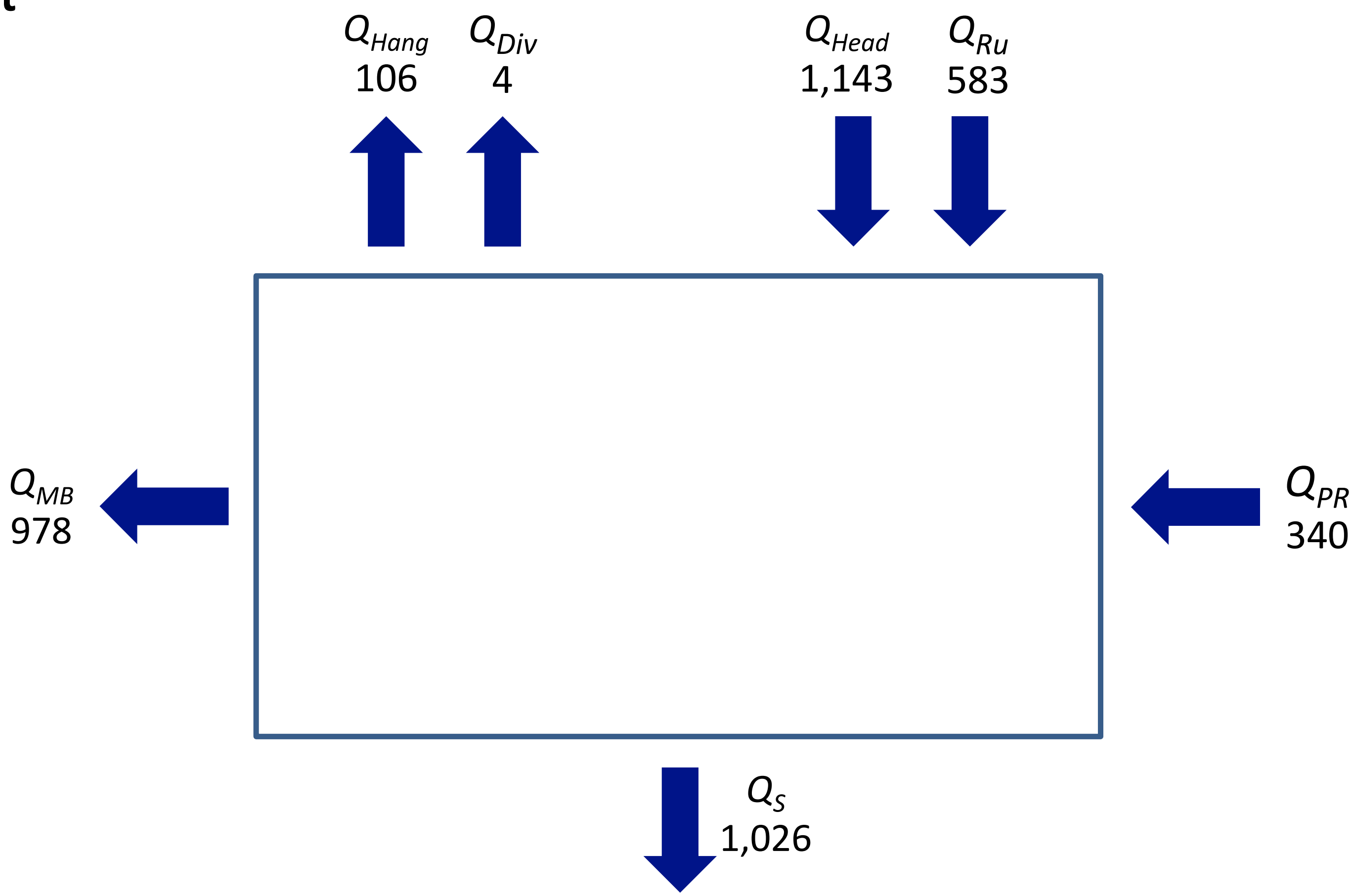
Historical Benefits Analysis Update

April 2025

No Projects Scenario

Area: **Entire Model Domain**

Year Type: **Wet**



Q_{Head} = Inflow at Stream Headwaters
Q_{Ru} = Land Surface Runoff
Q_{S} = Groundwater-Surface Water Exchange
Q_{Hang} = Outflow from Hanging Streams
Q_{Div} = Streamflow Diversion
Q_{PR} = Salinas River Inflow from Paso Robles Basin
Q_{MB} = Outflow to Monterey Bay

Notes:
1. Water budget components are rounded to nearest 1,000 acre-feet per year and displayed in thousands of acre-feet per year; totals may not sum due to rounding.
2. Arrow orientation denotes direction of surface water flow. Arrows pointing away from the box show surface water leaving the aquifer volume under consideration. Arrows pointing toward the box show surface water entering the aquifer volume.
3. See Section 3.4 of the text for the development of the SVIHM surface water budget equation.

Figure 3-41

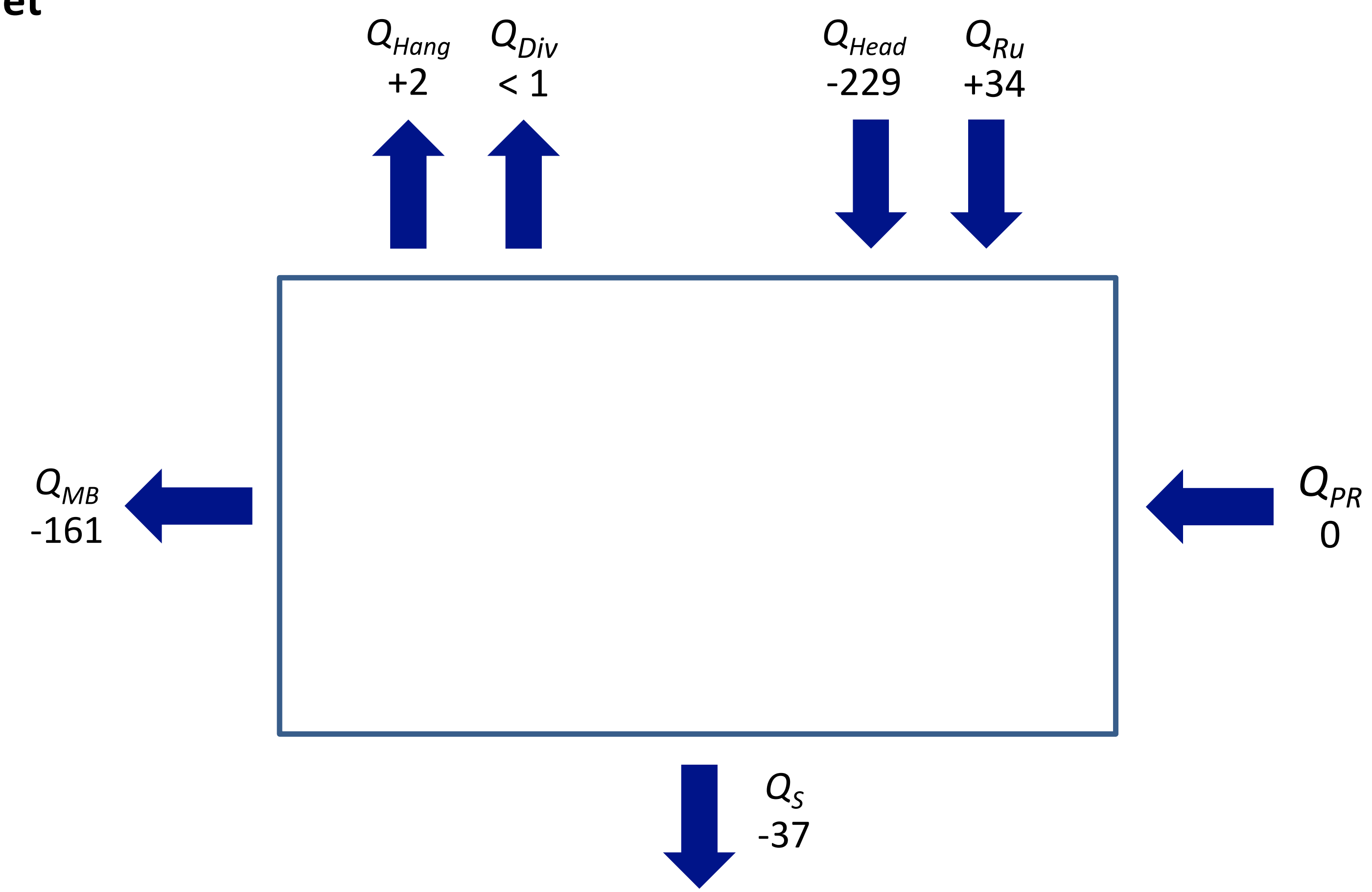
Average Annual Wet-Year Surface Water Budget, No Projects Scenario

Monterey County Water Resources Agency
Historical Benefits Analysis Update
April 2025

Difference Between Scenarios

Area: **Entire Model Domain**

Year Type: **Wet**



Q_{Head} = Inflow at Stream Headwaters
Q_{Ru} = Land Surface Runoff
Q_S = Groundwater-Surface Water Exchange
Q_{Hang} = Outflow from Hanging Streams
Q_{Div} = Streamflow Diversion
Q_{PR} = Salinas River Inflow from Paso Robles Basin
Q_{MB} = Outflow to Monterey Bay

Notes:

1. Water budget components are rounded to nearest 1,000 acre-feet per year and displayed in thousands of acre-feet per year; totals may not sum due to rounding.
2. Arrow orientation denotes direction of surface water flow. Arrows pointing away from the box show surface water leaving the aquifer volume under consideration. Arrows pointing toward the box show surface water entering the aquifer volume.
3. See Section 3.4 of the text for the development of the SVIHM surface water budget equation.
4. Difference between scenarios is calculated as Historical Scenario minus No Projects Scenario

Figure 3-42

Average Annual Wet-Year Surface Water Budget, Difference Between Scenarios

Monterey County Water Resources Agency

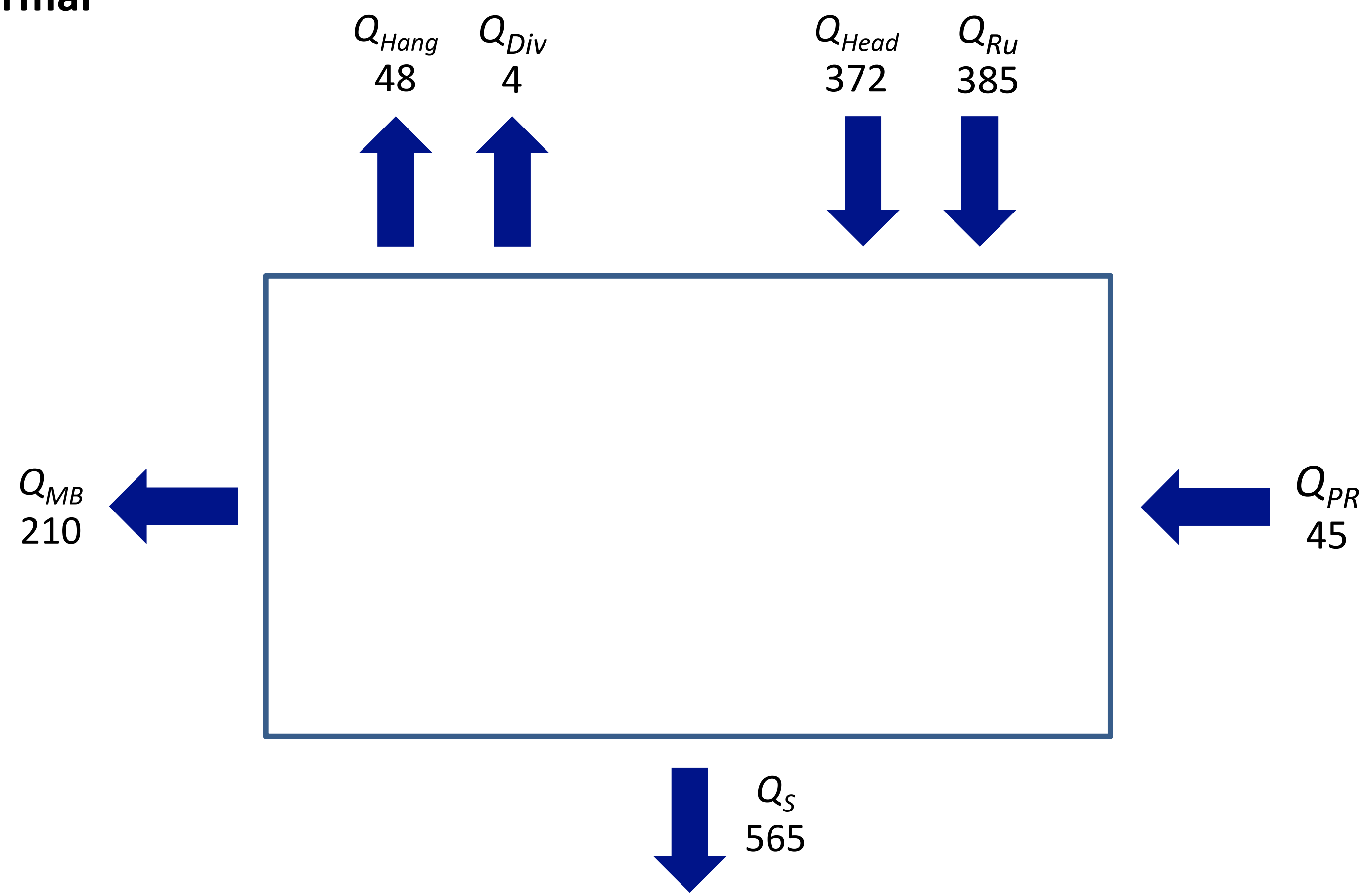
Historical Benefits Analysis Update

April 2025

Historical Scenario

Area: **Entire Model Domain**

Year Type: **Normal**



Q_{Head} = Inflow at Stream Headwaters
Q_{Ru} = Land Surface Runoff
Q_S = Groundwater-Surface Water Exchange
Q_{Hang} = Outflow from Hanging Streams
Q_{Div} = Streamflow Diversion
Q_{PR} = Salinas River Inflow from Paso Robles Basin
Q_{MB} = Outflow to Monterey Bay

Notes:
1. Water budget components are rounded to nearest 1,000 acre-feet per year and displayed in thousands of acre-feet per year; totals may not sum due to rounding.
2. Arrow orientation denotes direction of surface water flow. Arrows pointing away from the box show surface water leaving the aquifer volume under consideration. Arrows pointing toward the box show surface water entering the aquifer volume.
3. See Section 3.4 of the text for the development of the SVIHM surface water budget equation.

Figure 3-43

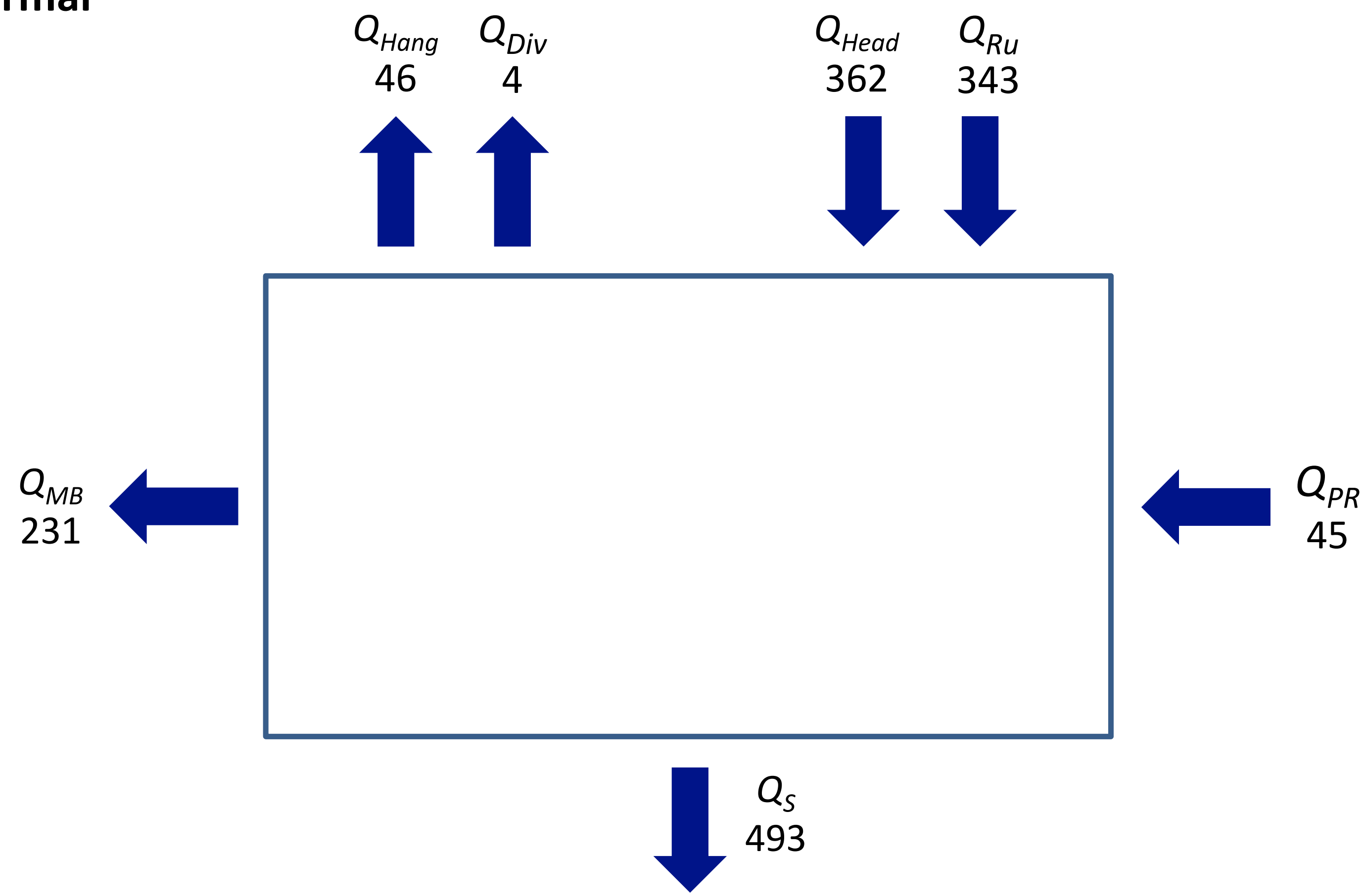
Average Annual Normal-Year Surface Water Budget, Historical Scenario

Monterey County Water Resources Agency
Historical Benefits Analysis Update
April 2025

No Projects Scenario

Area: **Entire Model Domain**

Year Type: **Normal**



Q_{Head} = Inflow at Stream Headwaters
Q_{Ru} = Land Surface Runoff
Q_S = Groundwater-Surface Water Exchange
Q_{Hang} = Outflow from Hanging Streams
Q_{Div} = Streamflow Diversion
Q_{PR} = Salinas River Inflow from Paso Robles Basin
Q_{MB} = Outflow to Monterey Bay

Notes:

1. Water budget components are rounded to nearest 1,000 acre-feet per year and displayed in thousands of acre-feet per year; totals may not sum due to rounding.
2. Arrow orientation denotes direction of surface water flow. Arrows pointing away from the box show surface water leaving the aquifer volume under consideration. Arrows pointing toward the box show surface water entering the aquifer volume.
3. See Section 3.4 of the text for the development of the SVIHM surface water budget equation.

Figure 3-44

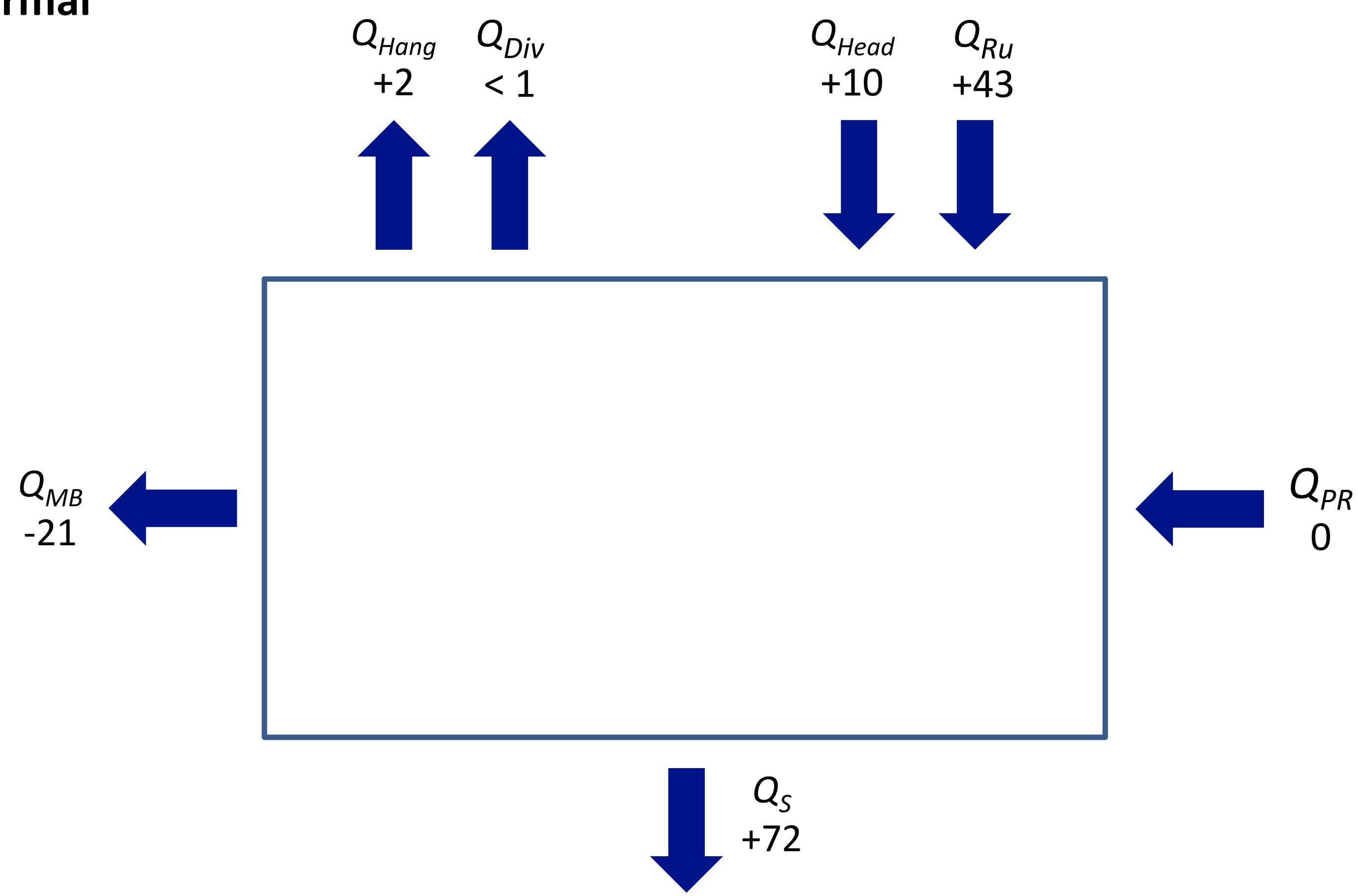
Average Annual Normal-Year Surface Water Budget, No Projects Scenario

Monterey County Water Resources Agency
Historical Benefits Analysis Update
April 2025

Difference Between Scenarios

Area: **Entire Model Domain**

Year Type: **Normal**



Q_{Head} = Inflow at Stream Headwaters
Q_{Ru} = Land Surface Runoff
Q_S = Groundwater-Surface Water Exchange
Q_{Hang} = Outflow from Hanging Streams
Q_{Div} = Streamflow Diversion
Q_{PR} = Salinas River Inflow from Paso Robles Basin
Q_{MB} = Outflow to Monterey Bay

Notes:

1. Water budget components are rounded to nearest 1,000 acre-feet per year and displayed in thousands of acre-feet per year; totals may not sum due to rounding.
2. Arrow orientation denotes direction of surface water flow. Arrows pointing away from the box show surface water leaving the aquifer volume under consideration. Arrows pointing toward the box show surface water entering the aquifer volume.
3. See Section 3.4 of the text for the development of the SVIHM surface water budget equation.
4. Difference between scenarios is calculated as Historical Scenario minus No Projects Scenario

Figure 3-45

Average Annual Normal-Year Surface Water Budget, Difference Between Scenarios

Monterey County Water Resources Agency

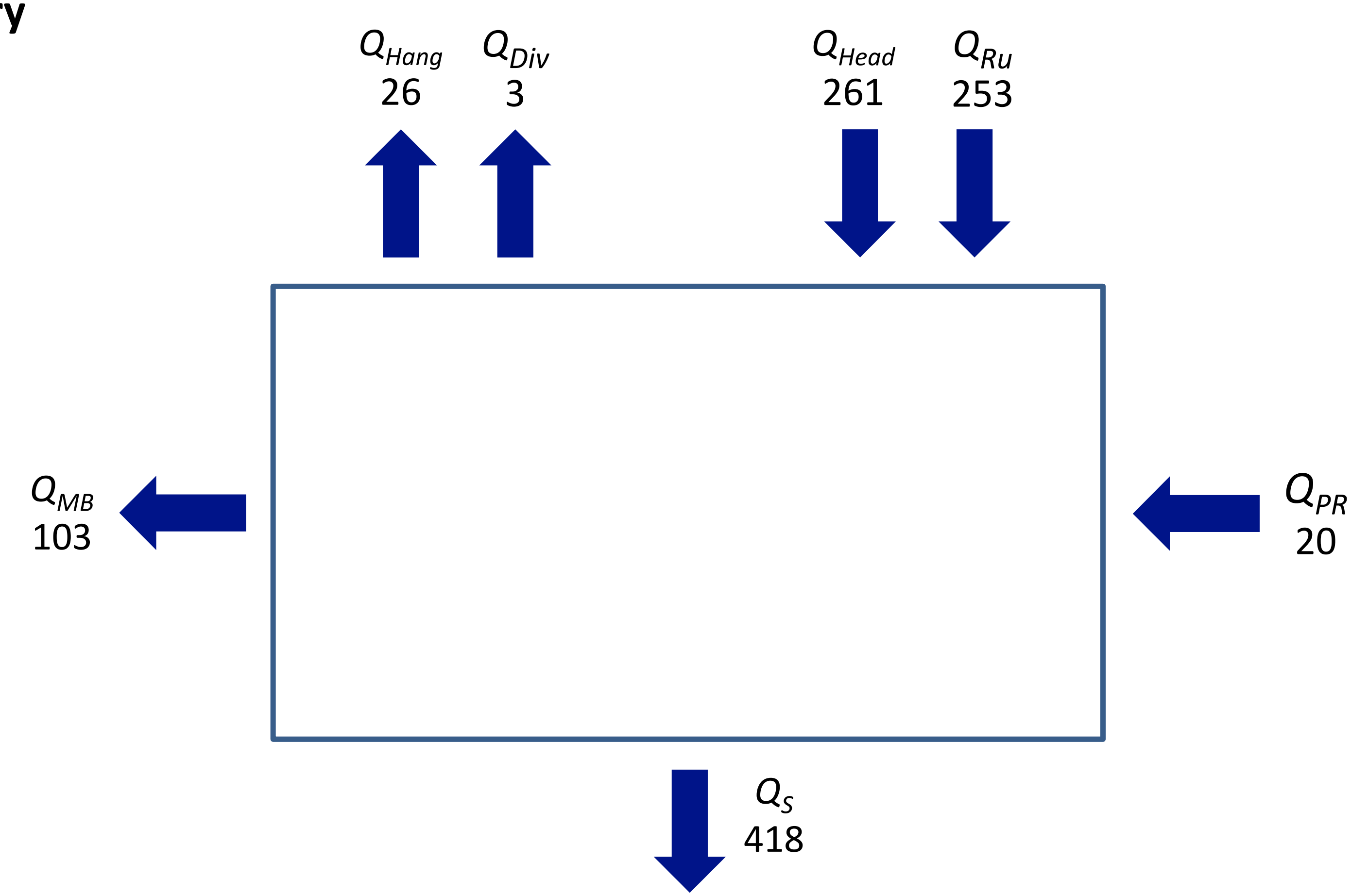
Historical Benefits Analysis Update

April 2025

Historical Scenario

Area: **Entire Model Domain**

Year Type: **Dry**



Q_{Head} = Inflow at Stream Headwaters
Q_{Ru} = Land Surface Runoff
Q_S = Groundwater-Surface Water Exchange
Q_{Hang} = Outflow from Hanging Streams
Q_{Div} = Streamflow Diversion
Q_{PR} = Salinas River Inflow from Paso Robles Basin
Q_{MB} = Outflow to Monterey Bay

Notes:
1. Water budget components are rounded to nearest 1,000 acre-feet per year and displayed in thousands of acre-feet per year; totals may not sum due to rounding.
2. Arrow orientation denotes direction of surface water flow. Arrows pointing away from the box show surface water leaving the aquifer volume under consideration. Arrows pointing toward the box show surface water entering the aquifer volume.
3. See Section 3.4 of the text for the development of the SVIHM surface water budget equation.

Figure 3-46

Average Annual Dry-Year Surface Water Budget, Historical Scenario

Monterey County Water Resources Agency
Historical Benefits Analysis Update
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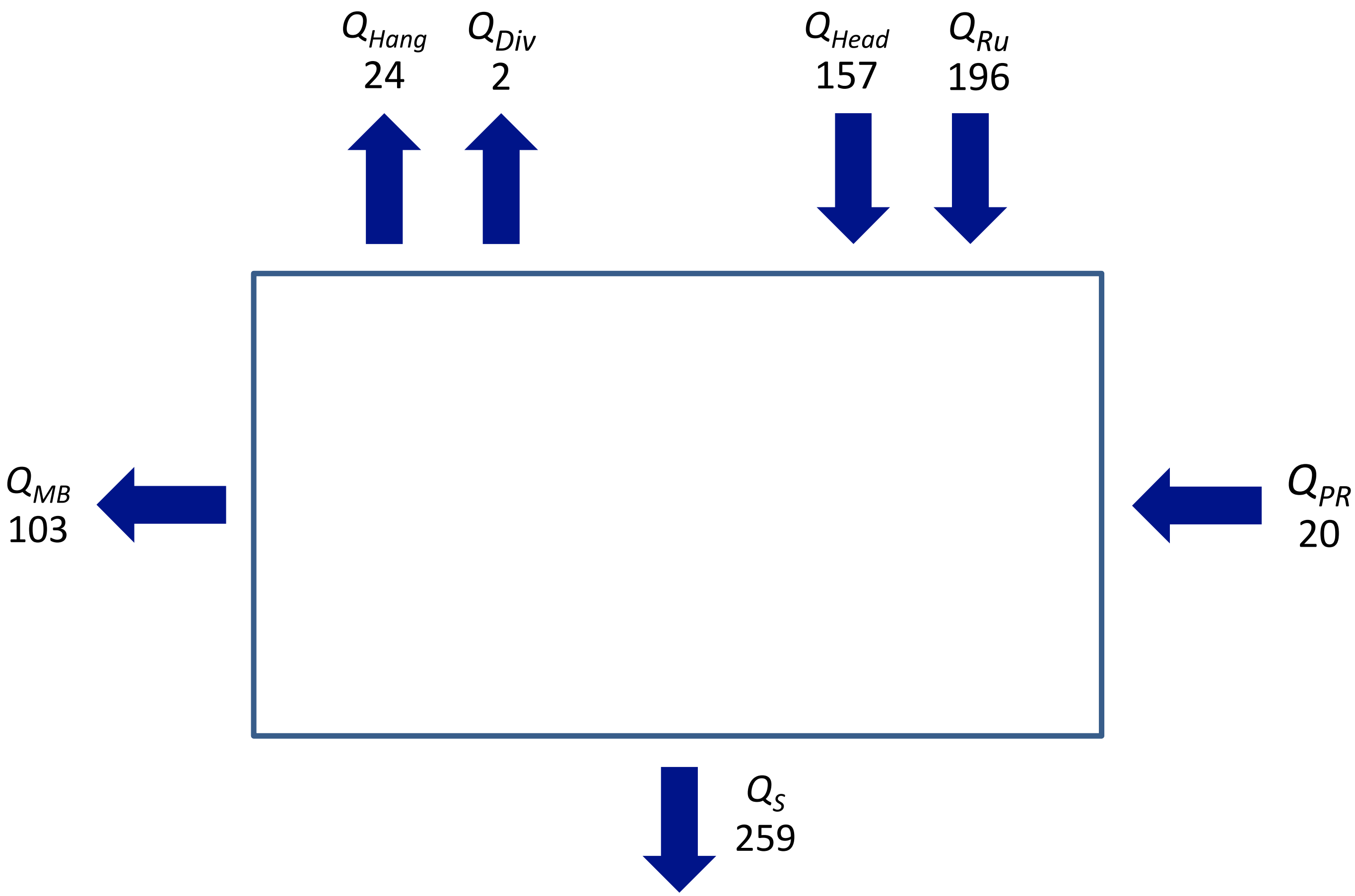
No Projects Scenario

Area: **Entire Model Domain**

Year Type: **Dry**



Q_{Head} = Inflow at Stream Headwaters
Q_{Ru} = Land Surface Runoff
Q_S = Groundwater-Surface Water Exchange
Q_{Hang} = Outflow from Hanging Streams
Q_{Div} = Streamflow Diversion
Q_{PR} = Salinas River Inflow from Paso Robles Basin
Q_{MB} = Outflow to Monterey Bay

Notes:

1. Water budget components are rounded to nearest 1,000 acre-feet per year and displayed in thousands of acre-feet per year; totals may not sum due to rounding.
2. Arrow orientation denotes direction of surface water flow. Arrows pointing away from the box show surface water leaving the aquifer volume under consideration. Arrows pointing toward the box show surface water entering the aquifer volume.
3. See Section 3.4 of the text for the development of the SVIHM surface water budget equation.

Figure 3-47

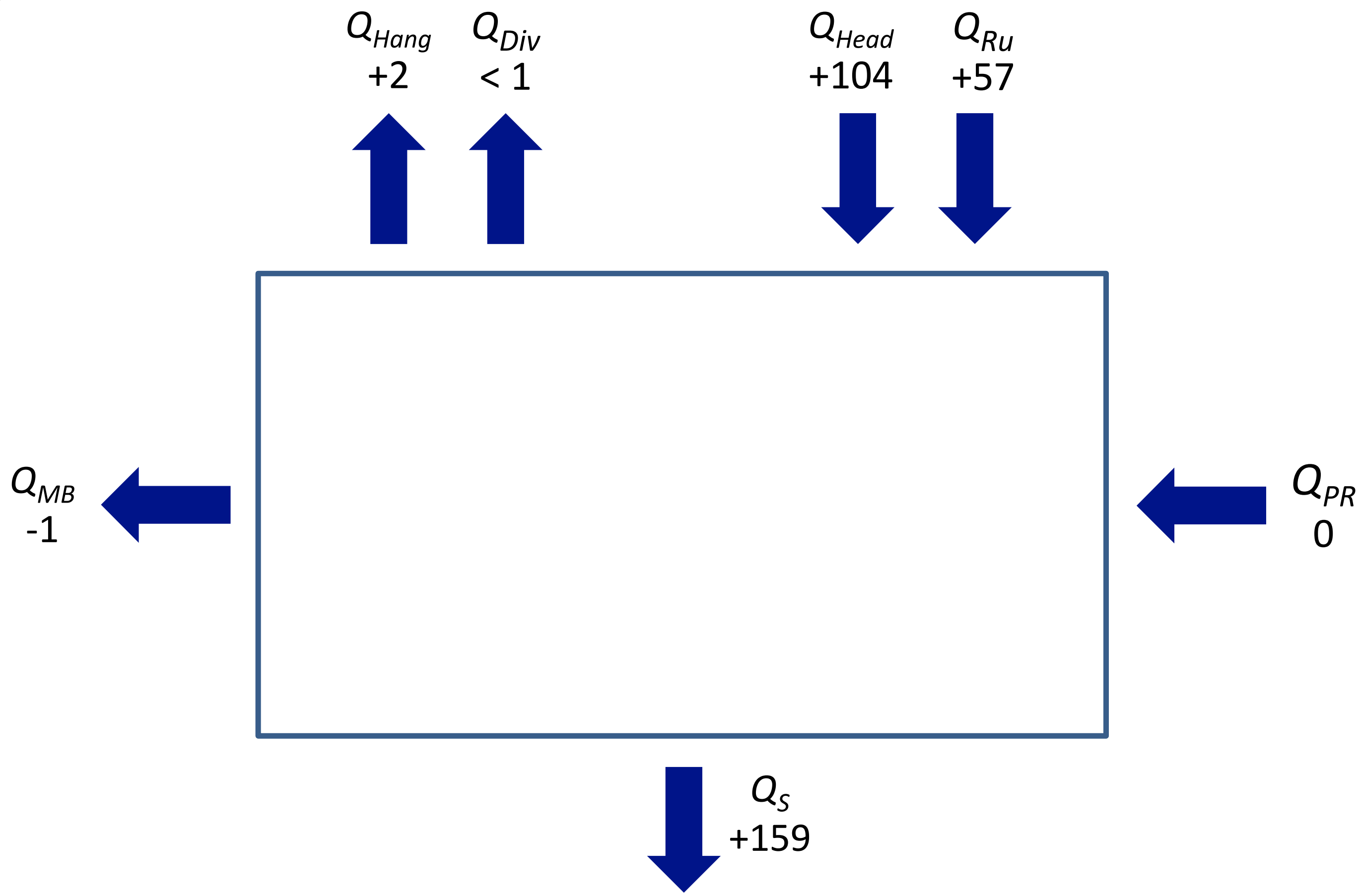
Average Annual Dry-Year Surface Water Budget, No Projects Scenario

Monterey County Water Resources Agency
Historical Benefits Analysis Update
April 2025

Difference Between Scenarios

Area: **Entire Model Domain**

Year Type: **Dry**



Q_{Head} = Inflow at Stream Headwaters
Q_{Ru} = Land Surface Runoff
Q_S = Groundwater-Surface Water Exchange
Q_{Hang} = Outflow from Hanging Streams
Q_{Div} = Streamflow Diversion
Q_{PR} = Salinas River Inflow from Paso Robles Basin
Q_{MB} = Outflow to Monterey Bay

Notes:

1. Water budget components are rounded to nearest 1,000 acre-feet per year and displayed in thousands of acre-feet per year; totals may not sum due to rounding.
2. Arrow orientation denotes direction of surface water flow. Arrows pointing away from the box show surface water leaving the aquifer volume under consideration. Arrows pointing toward the box show surface water entering the aquifer volume.
3. See Section 3.4 of the text for the development of the SVIHM surface water budget equation.
4. Difference between scenarios is calculated as Historical Scenario minus No Projects Scenario

Figure 3-48

Average Annual Dry-Year Surface Water Budget, Difference Between Scenarios

Monterey County Water Resources Agency
Historical Benefits Analysis Update
April 2025

Table 3-9. Average Surface Water Budget for Historical and No Projects Scenario, and Difference Between Scenarios (in afy)				
Surface Water Budget Component		Historical Scenario	No Projects Scenario	Difference
Inflows	Salinas River Inflow from Paso Robles Basin	112,000	112,000	0
	Inflow at Headwaters and from Tributaries	475,000	497,000	-21,000
	Land Surface Runoff	403,000	358,000	+45,000
	Total In	**990,000**	**967,000**	**+23,000**
Outflows	Groundwater-Surface Water Flux	627,000	556,000	+72,000
	Hanging Streams	57,000	54,000	+2,000
	Clark Colony Diversion	4,000	4,000	< 1,000
	SRDF Diversion	< 1,000	0	< 1,000
	Salinas River Outflow to Monterey Bay	273,000	324,000	-51,000
	Outflow from Other Monterey Bay Tributaries	58,000	58,000	< 1,000
	Total Out	**1,019,000**	**995,000**	**+24,000**
Mass Balance Difference		**-28,000**	**-28,000**	**-1,000**

Notes:
- Surface water budget components are rounded to the nearest 1,000 acre-feet per year; totals may not sum due to rounding
- Difference between scenarios is calculated as Historical Scenario minus No Projects Scenario

Table 3-10. Average Annual Wet-Year Surface Water Budget for Historical and No Project Scenario, and Difference Between Scenarios (in afy)

	Surface Water Budget Component	Historical Scenario	No Projects Scenario	Difference
Inflows	Salinas River Inflow from Paso Robles Basin	340,000	340,000	0
	Inflow at Headwaters and from Tributaries	914,000	1,143,000	-229,000
	Land Surface Runoff	617,000	583,000	+34,000
	Total In	**1,871,000**	**2,066,000**	**-195,000**
Outflows	Groundwater-Surface Water Flux	989,000	1,026,000	-37,000
	Hanging Streams	108,000	106,000	+2,000
	Clark Colony Diversion	4,000	4,000	< 1,000
	SRDF Diversion	< 1,000	0	< 1,000
	Salinas River Outflow to Monterey Bay	715,000	876,000	-161,000
	Outflow from Other Monterey Bay Tributaries	102,000	102,000	< 1,000
	Total Out	**1,918,000**	**2,113,000**	**-195,000**
Mass Balance Difference		**-48,000**	**-47,000**	**< 1,000**

Notes:
- Surface water budget components are rounded to the nearest 1,000 acre-feet per year; totals may not sum due to rounding
- Difference between scenarios is calculated as Historical Scenario minus No Projects Scenario

Table 3-11. Average Normal-Year Surface Water Budget for Historical and No Project Scenario, and Difference Between Scenarios (in afy)

Surface Water Budget Component		Historical Scenario	No Projects Scenario	Difference
Inflows	Salinas River Inflow from Paso Robles Basin	44,784	44,784	0
	Inflow at Headwaters and from Tributaries	372,066	362,021	+10,045
	Land Surface Runoff	385,385	342,750	+42,635
	Total In	**802,235**	**749,555**	**+52,680**
Outflows	Groundwater-Surface Water Flux	565,167	493,366	+71,802
	Hanging Streams	48,234	45,896	+2,338
	Clark Colony Diversion	4,190	4,215	-25
	SRDF Diversion	234	-36	+270
	Salinas River Outflow to Monterey Bay	158,499	180,185	-21,686
	Outflow from Other Monterey Bay Tributaries	51,291	50,952	+339
	Total Out	**827,614**	**774,577**	**+53,037**
Mass Balance Difference		**-25,379**	**-25,022**	**-357**

Notes:
- Surface water budget components are rounded to the nearest 1,000 acre-feet per year; totals may not sum due to rounding
- Difference between scenarios is calculated as Historical Scenario minus No Projects Scenario

Table 3-12. Average Annual Dry-Year Surface Water Budget for Historical and No Project Scenario, and Difference Between Scenarios (in afy)				
Surface Water Budget Component		Historical Scenario	No Projects Scenario	Difference
Inflows	Salinas River Inflow from Paso Robles Basin	20,000	20,000	0
	Inflow at Headwaters and from Tributaries	261,000	157,000	+104,000
	Land Surface Runoff	253,000	196,000	+57,000
	Total In	**534,000**	**373,000**	**+161,000**
Outflows	Groundwater-Surface Water Flux	418,000	259,000	+159,000
	Hanging Streams	26,000	24,000	+2,000
	Clark Colony Diversion	2,000	2,000	< 1,000
	SRDF Diversion	1,000	0	+1,000
	Salinas River Outflow to Monterey Bay	72,000	72,000	-1,000
	Outflow from Other Monterey Bay Tributaries	31,000	31,000	< 1,000
	Total Out	**550,000**	**388,000**	**+162,000**
Mass Balance Difference		**-16,000**	**-15,000**	**-1,000**

Notes:
- Surface water budget components are rounded to the nearest 1,000 acre-feet per year; totals may not sum due to rounding
- Difference between scenarios is calculated as Historical Scenario minus No Projects Scenario

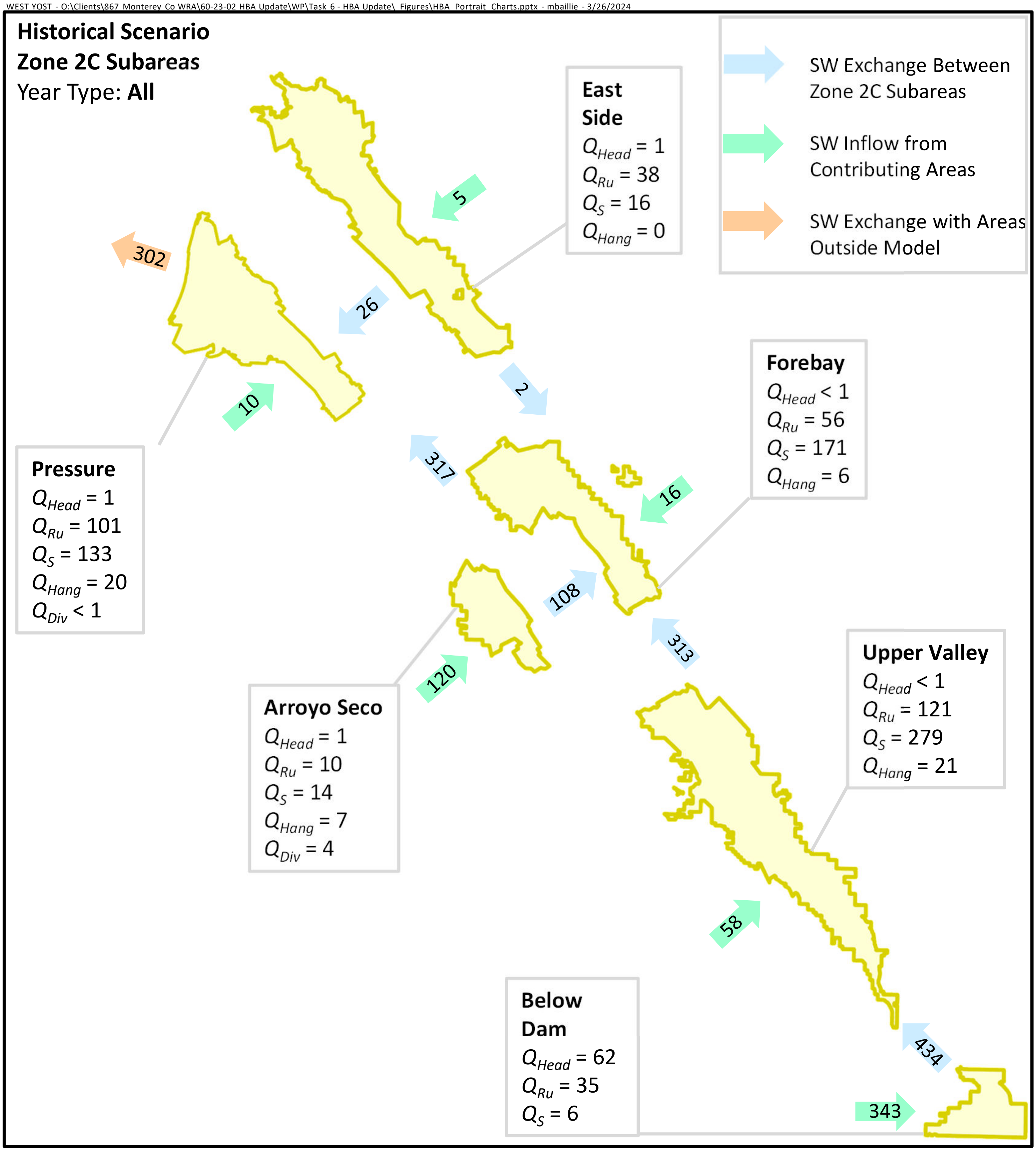
3.4.3 Subarea Surface Water Budgets

A more detailed understanding of the impact of the Projects on surface water conditions in the Basin can be achieved by looking at surface water budgets for individual Zone 2C Subareas (see Figure 1-6 for the Subarea locations). Zone 2C includes the Pressure, East Side, Arroyo Seco, Forebay, Upper Valley, and Below Dam Subareas (the Above Dam Subarea is located outside of the active model domain and is therefore excluded from all groundwater budgets). The portion of the active model domain located south of the Monterey-San Luis Obispo County Line is considered part of the contributing area to the Below Dam Subarea for the surface water budgets. Areas of the active model domain that do not fall into any of the above categories are assigned to the contributing areas for Zone 2C Subareas based on where individual streams flow (e.g., if a stream enters the Forebay Subarea from outside of Zone 2C, it is assigned to the Forebay Subarea contributing area). A few streams in the northern part of the study area are tributary to Monterey Bay rather than the Salinas River; outflow from these streams to Monterey Bay is accounted for separately from Salinas River outflow. The area of the active model domain off the coast is not included in the surface water budgets as no streams are present.

Figure 3-49 and Table 3-13 present the average annual groundwater budget for the Historical Scenario, by Zone 2C Subarea. Figure 3-50 and Table 3-14 present the average annual groundwater budget for the No Projects Scenario, by Subarea. Figure 3-51 and Table 3-15 present the differences between the Subarea groundwater budget results for the two scenarios.

As described in Section 3.4.2, the largest surface water budget differences between the Historical and No Projects Scenarios occur as increased streamflow loss to groundwater, land surface runoff, and loss of streamflow from hanging streams and decreased Salinas River outflow to Monterey Bay and inflow from the Nacimiento and San Antonio Rivers. The increase in streamflow loss under the Historical Scenario is greatest in the Upper Valley Subarea (about 44,000 afy), followed by the Forebay Subarea (about 20,000 afy), the Pressure Subarea (about 6,000 afy), and the Below Dam and Arroyo Seco Subareas (each about 1,000 afy). Changes to streamflow losses in the East Side Subarea, contributing areas to the various subareas, and areas outside Zone 2C tributary to Monterey Bay are all less than 1,000 afy (these differences are identical to the differences in groundwater-surface water flux given in Section 3.3.3 because it is the same flux, just from the perspective of the surface water system rather than the groundwater system).

The increase in land surface runoff is spatially distributed in much the same way as the increase in streamflow loss. The greatest difference occurs in the Upper Valley Subarea (about 19,000 afy), followed by the Pressure Subarea (about 10,000 afy), the Forebay Subarea (about 8,000 afy), the Below Dam Subarea (about 5,000 afy), and the Arroyo Seco Subarea, Upper Valley Subarea contributing area, and Below Dam Subarea contributing area (each about 1,000 afy). Increased land surface runoff in the southern part of the study area (the Arroyo Seco, Forebay, Upper Valley, and Below Dam Subareas and their contributing areas) is likely related to the increased streamflow losses in this area, which results in higher groundwater head and less opportunity for water present at the land surface to become recharge. In the northern part of the study area (the Pressure Subarea), the increased land surface runoff likely reflects increased crop irrigation due to the provision of recycled water and surface water supplies to the CSIP area, some of which ends up running off into the stream system.



Q_{Head} = Inflow at Stream Headwaters
Q_{Ru} = Land Surface Runoff
Q_S = Groundwater-Surface Water Exchange
Q_{Hang} = Outflow from Hanging Streams
Q_{Div} = Streamflow Diversion

Notes:
1. Water budget components are rounded to nearest 1,000 acre-feet per y and displayed in thousands of acre-feet per year; totals may not sum du to rounding and imperfect closure of the model mass balance.
2. Arrow orientation denotes direction of surface water flow. Arrows point away from the box show surface water leaving the aquifer volume unde consideration. Arrows pointing toward the box show surface water entering the aquifer volume.
3. See Section 3.4 of the text for the development of the SVIHM surface water budget equation.

Figure 3-49

Average Annual Surface Water Budget by Subarea, Historical Scenario

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Monterey County Water Resources Agency

Historical Benefits Analysis Upda

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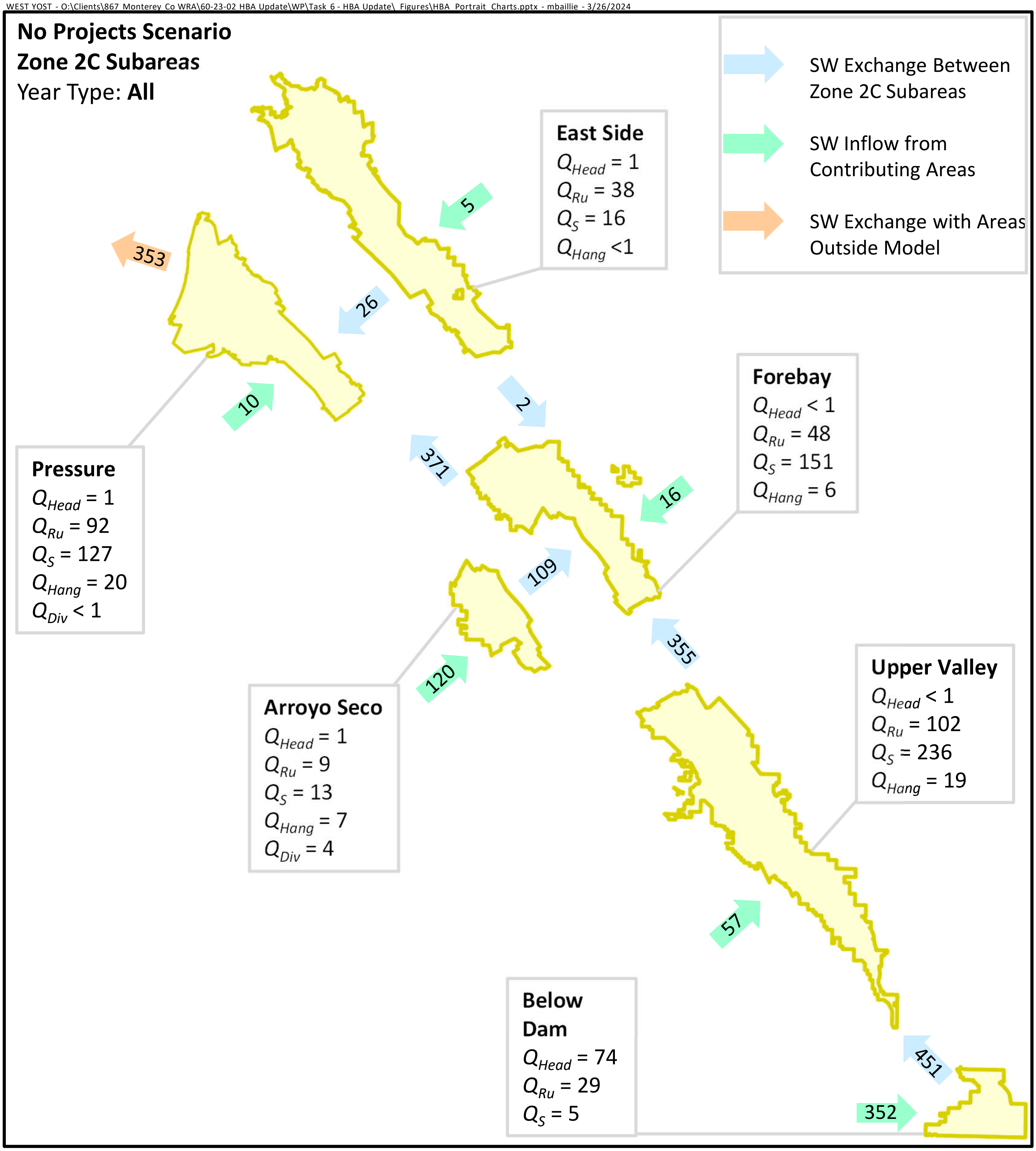


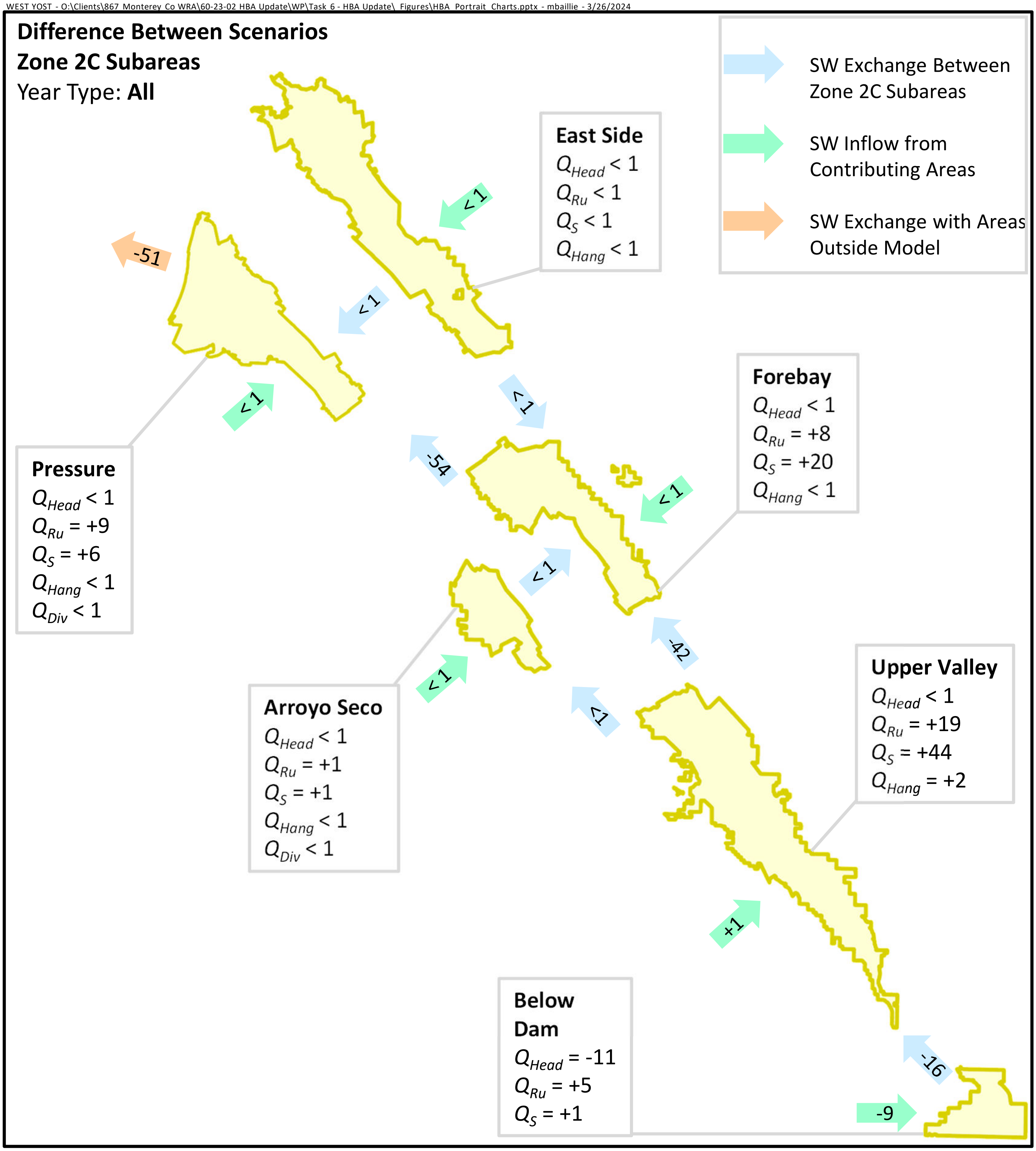
Q_{Head} = Inflow at Stream Headwaters
Q_{Ru} = Land Surface Runoff
Q_S = Groundwater-Surface Water Exchange
Q_{Hang} = Outflow from Hanging Streams
Q_{Div} = Streamflow Diversion

Notes:

1. Water budget components are rounded to nearest 1,000 acre-feet per y and displayed in thousands of acre-feet per year; totals may not sum du to rounding and imperfect closure of the model mass balance.
2. Arrow orientation denotes direction of surface water flow. Arrows point away from the box show surface water leaving the aquifer volume unde consideration. Arrows pointing toward the box show surface water entering the aquifer volume.
3. See Section 3.4 of the text for the development of the SVIHM surface water budget equation.

Figure 3-50

Average Annual Surface Water Budget by Subarea, No Projects Scenario



Q_{Head} = Inflow at Stream Headwaters
Q_{Ru} = Land Surface Runoff
Q_S = Groundwater-Surface Water Exchange
Q_{Hang} = Outflow from Hanging Streams
Q_{Div} = Streamflow Diversion

Notes:
1. Water budget components are rounded to nearest 1,000 acre-feet per y and displayed in thousands of acre-feet per year; totals may not sum du to rounding and imperfect closure of the model mass balance.
2. Arrow orientation denotes direction of surface water flow. Arrows point away from the box show surface water leaving the aquifer volume unde consideration. Arrows pointing toward the box show surface water entering the aquifer volume.
3. See Section 3.4 of the text for the development of the SVIHM surface water budget equation.
4. Difference between scenarios is calculated as Historical Scenario minus Projects Scenario

Figure 3-51

Average Annual Surface Water Budget by Subarea, Difference Between Scenarios

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Table 3-13. Average Annual Surface Water Budget by Subarea, Historical Scenario (in afy)

	Surface Water Budget Component	Zone 2C Subareas (Including Contributing Areas)						Area Draining to Monterey Bay
		Pressure	East Side	Arroyo Seco	Forebay	Upper Valley	Below Dam	
Inflows	Salinas River Inflow from Paso Robles Basin	0	0	0	0	0	112,000	0
	Inflow at Headwaters and from Tributaries	7,000	6,00	124,000	12,000	49,000	277,000	0
	Land Surface Runoff	105,000	40,000	13,000	60,000	132,000	53,000	0
	Inflow from Other Subareas	343,000	0	5,000	428,000	434,000	0	29,000
	Total In	**456,000**	**46,000**	**142,000**	**500,000**	**615,000**	**442,000**	**29,000**
Outflows	Groundwater-Surface Water Flux	134,000	17,000	16,000	171,000	280,000	8,000	< 1,000
	Hanging Streams	20,000	1,000	9,000	6,000	21,000	0	0
	Clark Colony Diversion	0	0	4,000	0	0	0	0
	SRDF Diversion	< 1,000	0	0	0	0	0	0
	Salinas River Outflow to Monterey Bay	273,000	0	0	0	0	0	0
	Outflow from Other Monterey Bay Tributaries	29,000	0	0	0	0	0	29,000
	Outflow to Other Subareas	0	28,000	113,000	323,000	313,000	434,000	0
	Total Out	**457,000**	**46,000**	**142,000**	**500,000**	**614,000**	**442,000**	**29,000**
Mass Balance Difference		**-1,000**	**< 1,000**	**< 1,000**	**< 1,000**	**1,000**	**< 1,000**	**< 1,000**

Notes:
- Surface water budget components are rounded to the nearest 1,000 acre-feet per year; totals may not sum due to rounding

Table 3-14. Average Annual Surface Water Budget by Subarea, No Project Scenario (in afy)								
Surface Water Budget Component		Zone 2C Subareas (Including Contributing Areas)						Area Draining to Monterey Bay
		Pressure	East Side	Arroyo Seco	Forebay	Upper Valley	Below Dam	
Inflows	Salinas River Inflow from Paso Robles Basin	0	0	0	0	0	112,000	0
	Inflow at Headwaters and from Tributaries	7,000	6,000	124,000	12,000	49,000	298,000	0
	Land Surface Runoff	96,000	40,000	12,000	52,000	112,000	47,000	0
	Inflow from Other Subareas	397,000	0	5,000	470,000	451,000	0	29,000
	Total In	**500,000**	**46,000**	**141,000**	**533,000**	**612,000**	**457,000**	**29,000**
Outflows	Groundwater-Surface Water Flux	128,000	17,000	16,000	151,000	237,000	7,000	< 1,000
	Hanging Streams	20,000	1,000	8,000	6,000	19,000	0	0
	Clark Colony Diversion	0	0	4,000	0	0	0	0
	SRDF Diversion	0	0	0	0	0	0	0
	Salinas River Outflow to Monterey Bay	324,000	0	0	0	0	0	0
	Outflow from Other Monterey Bay Tributaries	29,000	0	0	0	0	0	29,000
	Outflow to Other Subareas	0	28,000	113,000	376,000	355,000	451,000	0
	Total Out	**501,000**	**46,000**	**141,000**	**533,000**	**611,000**	**457,000**	**29,000**
Mass Balance Difference		**< 1,000**	**< 1,000**	**< 1,000**	**< 1,000**	**1,000**	**< 1,000**	**< 1,000**

Notes:
- Surface water budget components are rounded to the nearest 1,000 acre-feet per year; totals may not sum due to rounding

Table 3-15. Average Annual Surface Water Budget by Subarea, Difference Between Scenarios (in afy)

	Surface Water Budget Component	Zone 2C Subareas (Including Contributing Areas)						Area Draining to Monterey Bay
		Pressure	East Side	Arroyo Seco	Forebay	Upper Valley	Below Dam	
Inflows	Salinas River Inflow from Paso Robles Basin	0	0	0	0	0	0	0
	Inflow at Headwaters and from Tributaries	0	< 1,000	0	0	0	-21,000	0
	Land Surface Runoff	+10,000	< 1,000	+1,000	+8,000	+20,000	+6,000	0
	Inflow from Other Subareas	-54,000	0	+1,000	-41,000	-16,000	0	< 1,000
	Total In	**-44,000**	**< 1,000**	**+1,000**	**-33,000**	**+4,000**	**-15,000**	**< 1,000**
Outflows	Groundwater-Surface Water Flux	+6,000	< 1,000	+1,000	+20,000	+44,000	+1,000	< 1,000
	Hanging Streams	< 1,000	0	< 1,000	< 1,000	+2,000	0	0
	Clark Colony Diversion	0	0	< 1,000	0	0	0	0
	SRDF Diversion	< 1,000	0	0	0	0	0	0
	Salinas River Outflow to Monterey Bay	-51,000	0	0	0	0	0	0
	Outflow from Other Monterey Bay Tributaries	< 1,000	0	0	0	0	0	< 1,000
	Outflow to Other Subareas	0	< 1,000	< 1,000	-53,000	-42,000	-16,000	0
	Total Out	**-44,000**	**< 1,000**	**+1,000**	**-33,000**	**+4,000**	**-15,000**	**< 1,000**
Mass Balance Difference		**< 1,000**	**< 1,000**	**< 1,000**	**< 1,000**	**< 1,000**	**< 1,000**	**< 1,000**

Notes:
- Surface water budget components are rounded to the nearest 1,000 acre-feet per year; totals may not sum due to rounding
- Difference between scenarios is calculated as Historical Scenario minus No Projects Scenario

The increase in loss from the ends of hanging streams occurs in the Upper Valley Subarea (about 2,000 afy), with this increase being less than 1,000 afy in all other areas.

The reduction in inflow from the Nacimiento and San Antonio Rivers occurs in the Below Dam Subarea (about 11,000 afy), where the San Antonio River enters the active model domain, and in the Below Dam Subarea contributing area (about 10,000 afy), where the Nacimiento River enters the active model domain. The reduction in Salinas River outflow to Monterey Bay (about 51,000 afy) occurs in the Pressure Subarea, where the river mouth is located.

3.4.4 Surface Water Budgets Summary

This section described the results of the effects of the Projects on the streamflows in the Basin. The largest change to the surface water budget was an increase in groundwater-surface water flux (i.e., streamflow loss), which is discussed from the perspective of the groundwater system in Section 3.3.4. The stream network lost less water to the aquifers during wet years, but substantially more during normal and dry years. The change in streamflow loss was greatest in the Upper Valley and Forebay Subareas, with less difference occurring in the Pressure Subarea and very little difference elsewhere.

The change in streamflow loss between the scenarios results from reduced flow in the Salinas River during wet years and increased flow during normal and dry years because of the storage and subsequent release of wet year flows along the Nacimiento and San Antonio Rivers. In wet years, the Basin received about 229,000 afy less inflow from these rivers with the reservoirs in place. During normal years, this changed to an increase of about 10,000 afy; during dry years, the increase was about 104,000 afy. The overall average change across all model years was a decrease of about 21,000 afy.

The presence of the Projects results in the retention of more water within the Basin than would otherwise occur. One manifestation of this in the model was a reduction in the amount of water flowing out to Monterey Bay from the Salinas River. The overall average change in this outflow was a reduction of about 51,000 afy for all year types. The reduction was largest in wet years (about 161,000 afy), with less during normal years (about 22,000 afy) and very little during dry years (about 1,000 afy).

The increased recharge that occurred with the Projects in certain places led to higher groundwater head values and a greater propensity for groundwater head to be close to the land surface, which would result in more precipitation (and applied water) running off into the stream system because there is less available storage space in the unsaturated zone.

3.5 WELL IMPACTS ANALYSIS

The 1998 HBA included an analysis of the effect of the Projects on the ability of extraction wells to operate. This analysis focused on groundwater head at the pumping wells for which detailed construction information (well location, well depth, and well perforation interval) were available from MCWRA. A pumping well was considered “impacted” if the pumping groundwater head was simulated to drop a threshold of at least 10 feet below the top of the perforated interval. This threshold value was chosen to account for the fact that the SVIGSM was, like the SVIHM, a regional model, and was designed to re-create overall regional conditions rather than conditions at any single model location (e.g., a well).

Chapter 2 describes some key differences between the SVIGSM and the SVIHM that have bearing on this HBA Update. One important difference is how each model simulates pumping. The SVIGSM simulated the same amount of pumping under the historical and "without reservoirs" cases, indicating that SVIGSM had no mechanism for modifying pumping based on changes to crop demand, or that crop demand was identical between cases. FMP, which calculates crop water demand and satisfies it using available sources, can increase or decrease the amount of agricultural well pumping due to differences in the availability of other water sources.

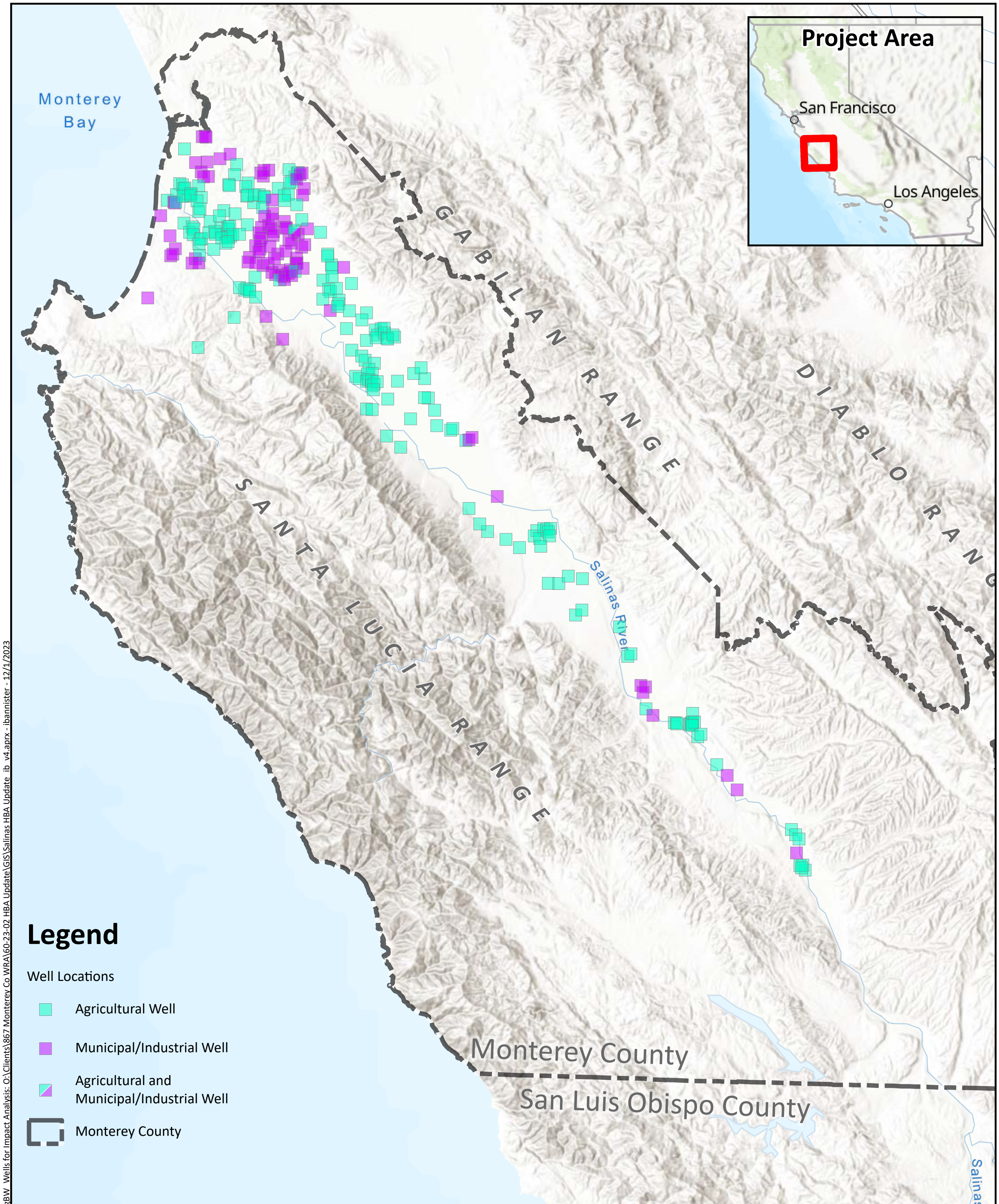
Because of the above, impact to wells can be considered in two ways. First, the approach of the 1998 HBA can be maintained (i.e., a well is impacted if pumping head drops at least 10 feet below the top of the screened interval). A second indication of impact to wells is changes to well pumping due to increased reliance on groundwater pumping to satisfy crop demands. Both approaches are investigated in this section. Results of this well impact analysis are presented in tabular form only; this follows the approach of the 1998 HBA.

3.5.1 Well Head Impact Analysis

The 1998 HBA only considered impacts on pumping heads when assessing well impacts, determining that about 5 percent of wells included in the analysis experienced some amount of impact. For wells in the northern part of the study area, the 1998 HBA determined that impacted wells could largely be modified (e.g., have their pump bowls lowered), whereas a portion of the impacted wells in the southern part of the study area would have to be replaced due to the magnitude of the impact.

Following the approach of the 1998 HBA, the well head impact analysis is limited to those wells for which detailed construction information was available from MCWRA; this represents a subset of 292 wells (out of 2,356 wells included in the model, not all of which actively pump during the model duration). Of the analyzed wells, 131 are in the Pressure Subarea, 100 in the East Side Subarea, 6 in the Arroyo Seco Subarea, 22 in the Forebay Subarea, 32 in the Upper Valley Subarea, none in the Below Dam Subarea, and 1 outside of the defined subareas. Municipal or industrial wells make up 96 of the 292 analyzed, and the remaining 196 are agricultural. Table 3-16 provides a tabulation of the number of wells included in the SVIHM in each subarea, plus how many of them were included in the well impact analysis. Figure 3-52 shows the locations of these wells; note that the locations are approximate, with the center of the well symbol representing the center of the model grid cell containing the well, rather than the coordinates of the well location itself.

Of the 292 wells included in the well head impact analysis, only two (one in the Pressure Subarea and one in the Upper Valley Subarea) experienced pumping head below the impact threshold (10 feet below the top of the screened interval) under the No Projects Scenario but not the Historical Scenario. In other words, due to the presence of the Projects, there are only two wells where head stays above the impact threshold. Both of these wells are agricultural. Table 3-17 presents the number of impacted wells in each subarea under the Historical and No Projects Scenarios and indicates the number of wells that are impacted without the Projects; Table 3-18 presents the same information by ESU. The two wells impacted under the No Projects Scenario but not under the Historical Scenario are located in ESUs 3 and 11.



FigBW_Wells for Impact Analysis: O:\Clients\867 Monterey Co WRA\60-23-02 HBA Update\GIS\Salinas HBA Update_ib_v4.aprx - ibannister - 12/1/2023

Note: Symbols represent model cells containing at least one well included in the well impact analysis. Symbol locations do not correspond to exact well locations. Model cells containing both a municipal/industrial well and an agricultural well are shown as bi-colored.

Prepared by:

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0 5 10 Miles

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Prepared for:
Monterey County
Water Resources Agency
Salinas Valley HBA
April 2025

Wells Included in Well Impact Analysis

Figure 3-52

Table 3-16. Wells in Each Subarea, with Proportion Included in Well Impact Analysis

Area		Wells in SVIHM				Wells in Well Head Impact Analysis			
		Municipal/Industrial	Agricultural	Other	Total	Municipal/Industrial	Agricultural	Other	Total
Zone 2 C Subareas	**Pressure**	146	648	8	**802**	47	84	0	**131**
	East Side	85	446	0	**531**	39	61	0	**100**
	Arroyo Seco	12	166	0	**178**	0	6	0	**6**
	Forebay	42	306	0	**348**	3	19	0	**22**
	Upper Valley	54	373	0	**427**	7	25	0	**32**
	Below Dam	2	18	0	**20**	0	0	0	**0**
Paso Robles Basin		0	0	0	**0**	0	0	0	**0**
Offshore		0	0	0	**0**	0	0	0	**0**
Other Non-Zone 2C Areas		5	45	0	**50**	0	1	0	**1**

Table 3-17. Well Impact Analysis Results by Subarea									
Area		Wells Impacted Under Historical Scenario				Wells Impacted Under No Projects Scenario			
		Municipal/Industrial	Agricultural	Other	Total	Municipal/ Industrial	Agricultural	Other	Total
Zone 2 C Subareas	**Pressure**	9	14	0	**23**	9	15	0	**24**
	East Side	29	21	0	**50**	29	21	0	**50**
	Arroyo Seco	0	1	0	**1**	0	1	0	**1**
	Forebay	1	3	0	**4**	1	3	0	**4**
	Upper Valley	3	13	0	**16**	3	14	0	**17**
	Below Dam	0	0	0	**0**	0	0	0	**0**
Paso Robles Basin		0	0	0	**0**	0	0	0	**0**
Offshore		0	0	0	**0**	0	0	0	**0**
Other Non-Zone 2C Areas		0	1	0	**1**	0	1	0	**1**

Table 3-18. Wells Head Impact Analysis Results by ESU

ESU	Wells Impacted Under Historical Scenario				Wells Impacted Under No Projects Scenario			
	Municipal/Industrial	Agricultural	Other	Total	Municipal/ Industrial	Agricultural	Other	Total
1	0	0	0	0	0	0	0	0
2	28	10	0	38	28	10	0	38
3	8	6	0	14	8	7	0	15
4	1	1	0	2	1	1	0	2
5	1	11	0	12	1	11	0	12
6	0	0	0	0	0	0	0	0
7	0	7	0	7	0	7	0	7
8	0	0	0	0	0	0	0	0
9	1	3	0	4	1	3	0	4
10	0	1	0	1	0	1	0	1
11	1	12	0	13	1	13	0	14
12	2	1	0	3	2	1	0	3
13	0	0	0	0	0	0	0	0
14	0	1	0	1	0	1	0	1

3.5.2 Well Pumping Impact Analysis

As discussed above, the SVIGSM simulated the same amount of well pumping under the historical and "without reservoirs" cases. Because of this, the 1998 HBA did not include an analysis on the effects of the reservoirs on well pumping. Because the SVIHM uses FMP to simulate agricultural supply and demand, effects on well pumping could be analyzed for this HBA Update. This could include increased well pumping because of increased agricultural demand or reduced well pumping because of decreased agricultural demand or head in pumping wells being reduced beyond the well's capability to continue pumping.

As noted in Section 3.3.2, there is about 10,000 afy less agricultural pumping simulated under the Historical Scenario than the No Projects Scenario. Over the entire model duration, this difference amounts to about 500,000 af. The largest proportion of this difference (about 299,000 af) occurs in the Pressure Subarea, followed by the Upper Valley Subarea (about 104,000 af), Forebay Subarea (about 76,000 af), Arroyo Seco Subarea (about 12,000 af), East Side Subarea (about 7,000 af), and other areas outside of Zone 2C (about 2,000 af). There is approximately no difference in agricultural pumping in the Below Dam Subarea or Paso Robles Basin.

Figure 3-53 shows a time series of the cumulative difference in agricultural pumping between the Historical and No Projects Scenario by subarea. The difference in agricultural pumping in the Pressure and East Side Subareas increases substantially once CSIP starts operating in 1998; up to that point (covering the first 31 years of the model duration), the cumulative difference (i.e., decreased pumping) in agricultural pumping was about 24,000 af in the Pressure Subarea and less than 1,000 af in the East Side Subarea. Over the remaining 20 years of the model duration, the cumulative difference in agricultural pumping increases by about 275,000 af in the Pressure Subarea and 7,000 af in the East Side Subarea. The bulk of this difference is likely due to the operation of CSIP, which receives recycled water from Monterey One Water and Salinas River water from the SRDF. The application of these water sources to agricultural fields within the CSIP area results in reduced demand from wells supplying those fields. Impacts extend into the East Side Subarea likely due to increased water present within the root zone of crops, reducing the need for groundwater pumping to supply crops.

In contrast, the cumulative difference in agricultural pumping increases more uniformly in the other parts of the study area (Figure 3-53). In the Arroyo Seco, Forebay, and Upper Valley Subareas, the cumulative difference over the entire model duration is about 193,000 af. Through 1998 (61 percent of the model duration), the cumulative difference is about 104,000 af, about 54 percent of the total. The difference in agricultural pumping in these subareas is likely due to operation of the reservoirs raising groundwater head levels, increasing the ability for agricultural crops to rely on water present in the soil zone and reducing the need for groundwater pumping for irrigation.

There is effectively no difference (less than 1,000 af total over entire domain and duration of the model) in municipal and industrial pumping, indicating that operation of municipal and industrial wells is not affected by the presence of the Projects.

Table 3-19 presents the average annual pumping by well type for each ESU for the Historical and No Projects Scenarios, as well as the difference between the two scenarios. Average annual pumping is largest in ESUs 11 and 3, which are within the Upper Valley and Pressure Subareas, respectively. These ESUs also see the largest difference in pumping between the scenarios; pumping is about 5,400 afy lower in ESU 3 under the Historical Scenario than under the No Projects Scenario, and about 1,100 afy smaller in ESU 11. ESUs 9 and 12 each had about 900 afy less pumping under the Historical Scenario than under the No Projects Scenario, and ESU 8 had about 600 afy less. All other ESUs had 300 afy or less difference between the scenarios.

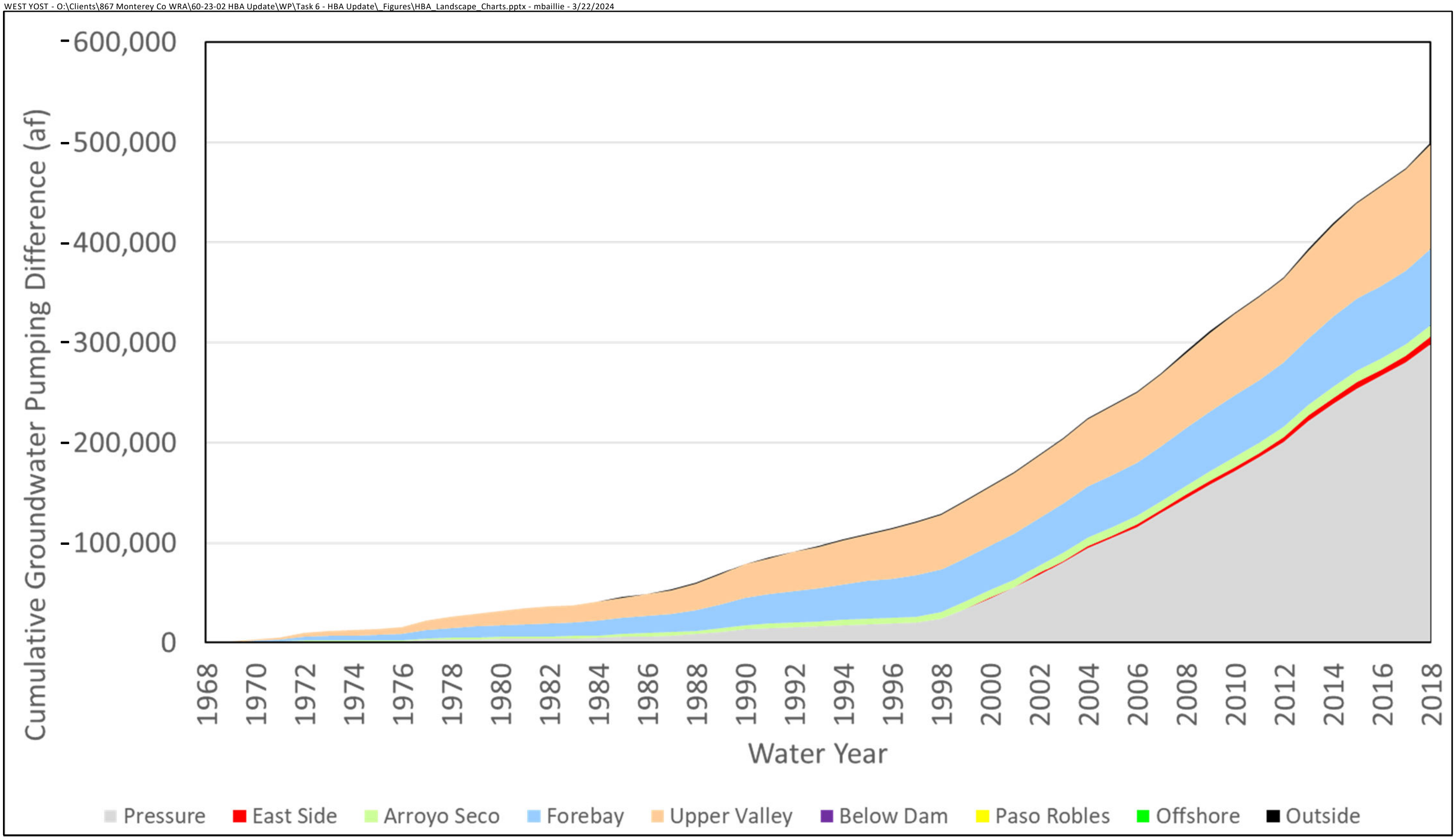

Figure 3-53

Cumulative Difference in Agricultural Pumping by Subarea

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Table 3-19. Average Annual Pumping (in afy) by ESU, Historical and No Projects Scenarios

ESU	Historical Scenario				No Projects Scenario				Difference Between Scenarios			
	Municipal/ Industrial	Agricultural	Other	Total	Municipal/ Industrial	Agricultural	Other	Total	Municipal/ Industrial	Agricultural	Other	Total
1	100	100	0	100	100	100	0	100	0	0	0	0
2	9,700	17,800	0	27,500	9,700	18,000	0	27,700	< 100	-100	0	-100
3	17,000	44,200	0	61,200	17,000	49,500	0	66,600	0	-5,400	0	-5,400
4	4,600	300	0	5,000	4,600	300	0	5,000	< 100	< 100	0	< 100
5	2,100	50,500	0	52,600	2,100	50,500	0	52,600	0	< 100	0	< 100
6	700	25,100	0	25,800	700	25,400	0	26,100	0	-300	0	-300
7	1,200	29,100	0	30,300	1,200	29,300	0	30,500	0	-200	0	-200
8	2,600	40,000	0	42,600	2,600	40,600	0	43,200	0	-600	0	-600
9	2,400	47,800	0	50,200	2,400	48,700	0	51,200	0	-900	0	-900
10	1,700	35,500	0	37,200	1,700	35,700	0	37,400	< 100	-200	0	-200
11	2,800	86,300	0	89,100	2,800	87,400	0	90,200	0	-1,100	0	-1,100
12	1,100	32,600	0	33,700	1,100	33,600	0	34,700	0	-900	0	-900
13	100	1,100	0	1,200	100	1,100	0	1,200	0	0	0	0
14	1,700	8,500	0	10,200	1,700	8,500	0	10,300	0	< 100	0	< 100

Notes:
- Pumping totals are rounded to the nearest 100 acre-feet per year; totals may not sum due to rounding

3.6 SEAWATER INTRUSION

As discussed in Chapter 2, the SVIHM does not have the capability to directly simulate the intrusion of seawater into freshwater aquifers, which is driven in part by the density difference between seawater and freshwater. The interfaces between the freshwater aquifers simulated by the SVIHM and the Pacific Ocean at Monterey Bay are characterized as general head boundaries (i.e., head-dependent flux boundaries), which allows the model to calculate flux across the boundary based on the user-specified head at the boundary, user-specified conductance of the boundary, and simulated head within the model. Head at these interfaces is set based on the fluctuation of sea level over the historical period, scaled by a factor to account for the difference between seawater and freshwater density (i.e., turning the sea level data into "equivalent freshwater head" values). The SVIHM includes undersea general head boundaries on Model Layers 1, 3, 5, 8, and 9. Within the Pressure Subarea, these model layers generally represent the Shallow Aquifer (Model Layer 1), 180-Foot Aquifer (Model Layer 3), 400-Foot Aquifer (Model Layer 5), and Deep Aquifers (Model Layers 8 and 9). It is important to note that the connection between the Deep Aquifers and the Pacific Ocean is currently not well-understood, and that the presence of a boundary condition allowing communication between the Deep Aquifers and the Pacific Ocean represents an assumption about the system that cannot be confirmed or disproven without further studies.

The SVIHM-simulated flux of groundwater across the coast can be taken as a reasonable estimate of the rate of seawater intrusion into the freshwater aquifers of the study area, keeping in mind the limitations noted above. The difference in this coastal flux represents the effect of the Projects on the amount of seawater intrusion.

The cumulative simulated seawater intrusion flux across the coast was about 763,000 af under the Historical Scenario and about 831,000 af under the No Projects Scenario, indicating that the Projects have resulted in a total decrease in seawater intrusion of about 68,000 af over the 51-year period of this analysis. Table 3-20 provides the cumulative total and average annual simulated seawater intrusion for the entire model duration for each of the important freshwater aquifers identified in the Pressure Subarea (the Shallow, 180-Foot, 400-Foot, and Deep Aquifers). The largest difference between the scenarios (about 38,000 af) occurred in the 400-Foot Aquifer (Model Layer 5). An additional difference of about 24,000 af occurred in the 180-Foot Aquifer (Model Layer 3). The Shallow (Model Layer 1) and Deep (Model Layers 7 through 9) Aquifers each had about 3,000 af less seawater intrusion under the Historical Scenario.

Figures 3-54 and 3-55 show the simulated seawater intrusion flux into the 180-Foot and 400-Foot Aquifers, respectively, under both scenarios, as well as the difference between the scenarios. These time series charts show that there is a major inflection in the difference between scenarios after 1998, with the bulk of the difference between scenarios in both aquifers occurring mainly after this point. The cumulative difference between the scenarios was only about 1,000 af up to this point in both aquifers, meaning that there was a reduction in seawater intrusion of about 23,000 af in the 180-Foot Aquifer and about 37,000 af in the 400-Foot Aquifer. This indicates that the difference between the scenarios in terms of seawater intrusion was likely the result of operation of the CSIP system, which deceased agricultural pumping demand in the coastal area, leading to higher groundwater heads in this area and a smaller landward head gradient.

The active model domain at the coast falls into two Zone 2C Subareas (the Pressure and East Side Subareas), plus areas outside of Zone 2C (e.g., parts of the Seaside Basin). The coastal part of the East Side Subarea is extremely small, limited to 2 model cells (i.e., about 1,000 feet). The total cumulative simulated seawater intrusion into the East Side Subarea was about 1,000 af for both scenarios, and is not considered further in this discussion. Under the Historical Scenario, about 63 percent of the simulated seawater intrusion (about 483,000 af) occurred into the Pressure Subarea, with the remaining 37percent (about 280,000 af) occurring outside of Zone 2C. Under the No Projects Scenario, about 64 percent (about 533,000 af) occurred into the Pressure Subarea, with the remaining 36 percent (about 297,000 af) occurring outside of Zone 2C. The difference between scenarios was about 50,000 af into the Pressure Subarea, and about 17,000 af outside of Zone 2C.

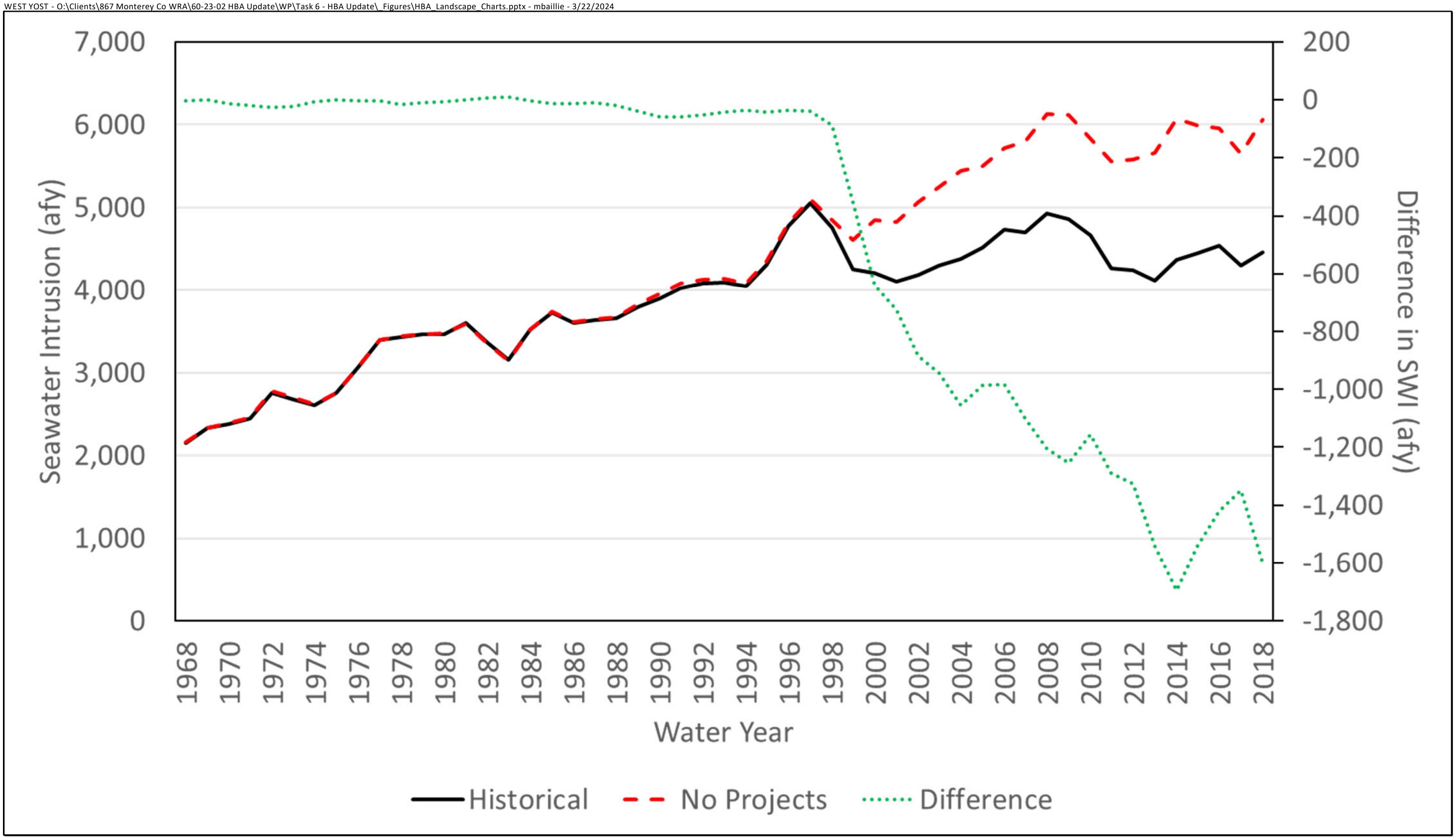


Figure 3-54

Annual Seawater Intrusion into 180-Foot Aquifer and Equivalent, Historical and No Projects Scenarios

Monterey County Water Resources Agency
Historical Benefits Analysis Update
April 2025

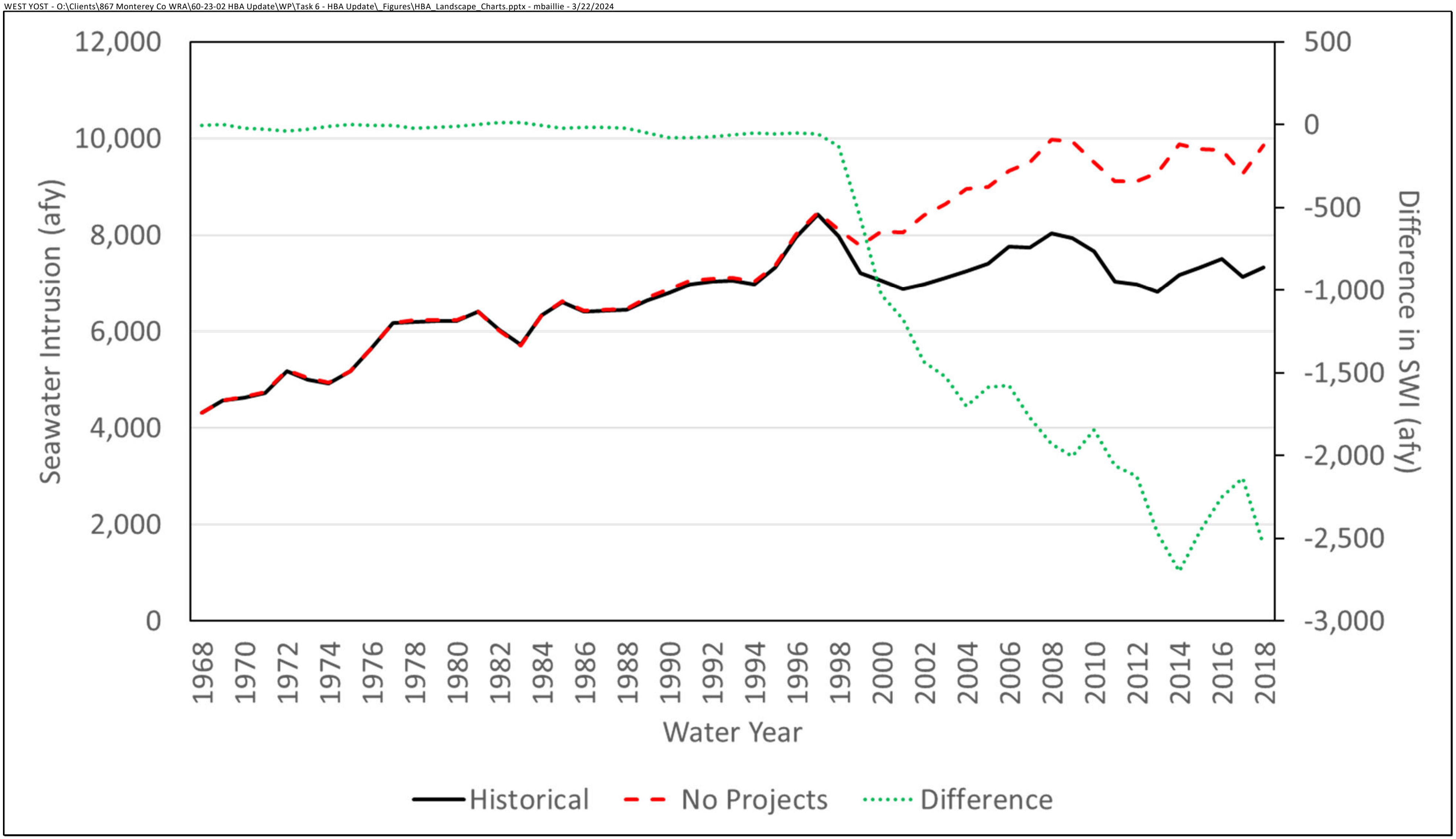


Figure 3-55

Annual Seawater Intrusion into 400-Foot Aquifer and Equivalent, Historical and No Projects Scenarios

Table 3-20. Cumulative and Average Annual Simulated Seawater Intrusion Flux by Aquifer							
Aquifer	Model Layer(s)	Historical		No Projects		Difference	
		Cumulative, af	Average, afy	Cumulative, af	Average, afy	Cumulative, af	Average, afy
Shallow	1	136,000	2,680	139,000	2,740	-3,000	-60
180-Foot	3	197,000	3,860	220,000	4,320	-24,000	-470
400-Foot	5	339,000	6,650	377,000	7,390	-38,000	-740
Deep	7-9	91,000	1,780	94,000	1,840	-3,000	-60

Notes:
- Cumulative seawater intrusion volumes are rounded to the nearest 1,000 acre-feet and average annual seawater intrusion fluxes are rounded to the nearest 10 acre-feet per year; totals may not sum due to rounding
- Difference between scenarios is calculated as Historical Scenario minus No Projects Scenario

CHAPTER 4
Flood Control Benefits Analysis

This chapter of the HBA Update describes the effects that the Projects have had on the frequency and severity of inundation under peak flows in the Salinas River within the study area. This analysis quantifies how the statistical distribution of peak flows has changed due to the presence and operation of the Nacimiento and San Antonio Reservoirs and related projects and programs since San Antonio Reservoir began operating (WY 1968). This analysis of the Flood Control Benefit relies on a combination of historical streamflow measurements, streamflow simulation, and groundwater-surface water modeling.

4.1 DATA SOURCES

The Flood Control Benefits Analysis relies on several different sources of data. At its core, this analysis is built from streamflow observations collected by the USGS. These are supplemented by various modeling results to produce estimates of streamflow with and without the Projects.

Figure 1-7 shows the locations of USGS streamflow gauges (active and inactive) in and surrounding the study area. This Flood Control Benefits Analysis utilized data from the stream gauges listed in Table 4-1, especially the gauge in the Salinas River at Bradley.

In addition to streamflow observations from the USGS gauges, this Flood Control Benefits Analysis utilizes simulated streamflow data to develop flood frequency curves and to simulate the effects of peak flows on the Salinas River floodplain. These include simulated streamflow from the USGS SVWM and simulated groundwater-surface water interaction from the SVIHM. The SVWM provides simulated mean daily streamflow for the historical period in the Salinas River at a point just downstream of San Miguel (i.e., the location where the Salinas River enters the SVIHM domain). The SVIHM provides simulated groundwater-surface water flux along the Salinas River from where it enters the SVIHM domain to the location of the Salinas River at Bradley stream gauge and along the Nacimiento and San Antonio Rivers from their respective dams to their confluences with the Salinas River.

The SVIHM results represent simulated groundwater-surface water flux representative of conditions during each model timestep, which is from five to six days depending on the length of each month. The simulated streamflow values used to calculate the groundwater-surface water flux are highly dependent on the monthly streamflow inputs that occur along the edges of the model (e.g., the San Antonio River at San Antonio Dam, the Nacimiento River about five miles downstream of the Nacimiento Dam, and the Salinas River just downstream of San Miguel). The time discretization of the SVIHM (5- to 6-day timesteps within monthly stress periods) has a major impact on the time series of simulated streamflow within that model, making SVIHM-simulated streamflow poorly suited to direct use for understanding the statistical distribution of peak flows.

Section 4.2 below summarizes the SVIHM-simulated effects on total streamflow at selected locations in the surface water network. Section 4.3 describes how the available data were used to determine the statistical distribution of peak flows in the Salinas River at Bradley.

Table 4-1. Stream Gauges Used in Flood Control Benefit Analysis										
Gauge Name	Gauge Number	Latitude	Longitude	Datum	Mean Daily Observations		15-Minute Observations		Status	Type
					Start Date	End Date	Start Date	End Date		
NACIMIENTO R BL SAPAQUE C NR BRYSON CA	11148900	35.78861111	121.0927778	NAD27	9/16/1971	Present	10/1/1988	Present	Active	Stream
NACIMIENTO RES NR BRADLEY CA	11149300	35.75782222	120.8845417	NAD83	None	None	11/19/2020	Present	Active	Lake
NACIMIENTO R BL NACIMIENTO DAM NR BRADLEY CA	11149400	35.76138889	120.8544444	NAD27	10/1/1957	Present	10/1/1988	Present	Active	Stream
SAN ANTONIO R NR LOCKWOOD CA	11149900	35.89666667	121.0872222	NAD27	10/1/1965	Present	12/14/1986	Present	Active	Stream
SAN ANTONIO RES NR BRADLEY CA	11150100	35.79681667	120.8857806	NAD83	None	None	12/9/2020	Present	Active	Lake
SALINAS R NR BRADLEY CA	11150500	35.93027778	120.8677778	NAD27	10/1/1948	Present	10/1/1988	Present	Active	Stream
SAN LORENZO C BL BITTERWATER C NR KING CITY CA	11151300	36.26805556	121.0652778	NAD27	10/1/1958	Present	10/1/1988	Present	Active	Stream
SALINAS R A SOLEDAD CA	11151700	36.41111111	121.3183333	NAD27	10/1/1968	Present	10/1/1988	Present	Active	Stream
ARROYO SECO BL RELIZ C NR SOLEDAD CA	11152050	36.39972222	121.3230556	NAD27	10/1/1944	Present	11/1/1994	Present	Active	Stream
SALINAS R NR CHUALAR CA	11152300	36.55361111	121.5483333	NAD27	10/1/1976	Present	10/1/1988	Present	Active	Stream
SALINAS R NR SPRECKELS CA	11152500	36.63111111	121.6713889	NAD27	10/1/1929	Present	1/25/1989	Present	Active	Stream

4.2 MEAN ANNUAL SIMULATED STREAMFLOW

Changes to the average annual streamflow at various locations in the stream network indicate how the Projects have affected the Salinas River and its tributaries. This section describes the simulated changes to streamflow at selected locations in the stream network based on simulated streamflows from the SVIHM. As noted above, the SVIHM is not well-suited to the estimation of peak streamflows due to the temporal discretization of the model, but it is useful for understanding overall streamflow changes under averaged conditions.

Table 4-2 provides the average annual streamflow at various points in the Salinas River and its tributaries for the Historical and No Projects Scenarios, as well as the difference between the scenarios. Annual averages are provided in both afy and cfs for all years as well as wet, normal, and dry years.

On average, there was about 445,000 afy of flow in the Salinas River at Bradley under the Historical Scenario, which combines inflows from the Paso Robles Basin to the south, the Nacimiento River (about 194,000 afy), and the San Antonio River (about 62,000 afy). This flow decreased to about 270,000 afy in the Salinas River at Soledad. With inflow of about 117,000 afy from Arroyo Seco, streamflow in the Salinas River increased to about 295,000 afy at Chualar. Flow in the Salinas River decreased to about 264,000 afy at Spreckels. The average annual streamflow varies little below Spreckels, increasing very slightly to about 272,000 afy at the head of the Salinas River Lagoon and about 273,000 afy at the mouth of the Salinas River, representing outflow to Monterey Bay. Changes to streamflow below Spreckels result from simulated land surface runoff and agricultural return flow entering the Salinas River.

Under the No Projects Scenario, there was slightly more flow entering the Salinas River from the Nacimiento River (about 204,000 afy, about 10,000 afy more than the Historical Scenario) and San Antonio River (about 73,000 afy, about 11,000 afy more compared to the Historical Scenario). At Bradley, the No Projects Scenario simulated about 460,000 afy of streamflow, about 15,000 afy more than under the Historical Scenario.

The differences of flows between the two scenarios increased below Bradley. Under the No Projects Scenario, average annual simulated streamflow was about 319,000 afy in the Salinas River at Soledad (about 49,000 afy more than under the Historical Scenario), about 350,000 afy at Chualar (about 55,000 afy more than under the Historical Scenario), about 317,000 afy at Spreckels (about 53,000 afy more than under the Historical Scenario), about 323,000 afy at the head of the Salinas River Lagoon, and about 324,000 afy at the mouth of the Salinas River (both about 51,000 afy more than under the Historical Scenario).

Simulated average annual flow during wet years was substantially higher compared to normal and dry years. The differences between the scenarios was also largest during wet years throughout the system, with about 161,000 afy less flow out to Monterey Bay under the Historical Scenario compared to the No Projects Scenario (there was also less outflow to the ocean during average normal and dry years as a result of the Projects). This demonstrates the ability of the Projects to keep additional water within the Basin, resulting from the storage of high flows during wet periods in the Nacimiento and San Antonio Reservoirs and subsequent release during drier periods. Much of this difference in streamflow represents additional recharge to the groundwater system through increased streamflow losses with the Projects in place. This is demonstrated by the differences in streamflow simulated during dry years; the Projects resulted in about 112,000 afy of additional flow in the Salinas River at Bradley during dry years, but this difference disappeared by about Chualar.

Table 4-2. Average Annual Simulated Streamflow (in acre-feet per year and cubic feet per second) at Selected Locations in Stream Network

Average Annual Streamflow, acre-feet per year	Historical Scenario				No Projects Scenario				Difference			
	All Years	Wet Years	Normal Years	Dry Years	All Years	Wet Years	Normal Years	Dry Years	All Years	Wet Years	Normal Years	Dry Years
Nacimiento River below Nacimiento Dam	194,000	324,000	164,000	131,000	204,000	451,000	155,000	72,000	-10,000	-127,000	+9,000	+59,000
San Antonio River below San Antonio Dam	62,000	72,000	52,000	68,000	73,000	175,000	51,000	22,000	-11,000	-102,000	+1,000	+46,000
Salinas River below San Antonio River Confluence	422,000	846,000	302,000	242,000	439,000	1,072,000	288,000	132,000	-17,000	-225,000	+14,000	+110,000
Salinas River at Bradley	445,000	889,000	321,000	254,000	460,000	1,112,000	305,000	142,000	-15,000	-223,000	+16,000	+112,000
Salinas River at Soledad	270,000	681,000	158,000	90,000	319,000	867,000	176,000	70,000	-49,000	-186,000	-18,000	+20,000
Arroyo Seco below Reliz Creek	117,000	242,000	98,000	43,000	117,000	242,000	97,000	43,000	< 1,000	< 1,000	< 1,000	< 1,000
Salinas River at Chualar	295,000	767,000	175,000	76,000	350,000	939,000	201,000	76,000	-55,000	-173,000	-26,000	< 1,000
Salinas River at Spreckels	264,000	706,000	148,000	64,000	317,000	872,000	172,000	67,000	-53,000	-166,000	-24,000	-3,000
Salinas River Lagoon	272,000	713,000	157,000	71,000	323,000	875,000	179,000	72,000	-51,000	-161,000	-22,000	-1,000
Salinas River Outflow to Monterey Bay	273,000	715,000	158,000	72,000	324,000	876,000	180,000	72,000	-51,000	-161,000	-22,000	-1,000

Notes:
- Streamflow totals are rounded to the nearest 1,000 acre-feet per year and displayed in thousands of acre-feet per year; totals may not sum due to rounding
- Difference between scenarios is calculated as Historical Scenario minus No Projects Scenario

Table 4-2. Average Annual Simulated Streamflow (in acre-feet per year and cubic feet per second) at Selected Locations in Stream Network												
Average Annual Streamflow, cubic feet per second	Historical Scenario				No Projects Scenario				Difference			
	All Years	Wet Years	Normal Years	Dry Years	All Years	Wet Years	Normal Years	Dry Years	All Years	Wet Years	Normal Years	Dry Years
Nacimiento River below Nacimiento Dam	268	447	226	180	282	622	213	99	-14	-175	+13	+81
San Antonio River below San Antonio Dam	85	100	71	93	101	241	70	30	-16	-141	+1	+63
Salinas River below San Antonio River Confluence	582	1,169	417	334	606	1,480	397	183	-23	-311	+19	+151
Salinas River at Bradley	614	1,227	443	350	635	1,535	421	196	-21	-308	+22	+154
Salinas River at Soledad	373	941	218	124	440	1,197	243	96	-67	-256	-25	+28
Arroyo Seco below Reliz Creek	162	334	135	60	162	334	135	59	0	0	0	0
Salinas River at Chualar	407	1,059	242	105	483	1,297	278	105	-76	-239	-36	0
Salinas River at Spreckels	364	975	204	88	438	1,204	237	92	-74	-229	-33	-4
Salinas River Lagoon	375	985	217	98	446	1,208	247	99	-70	-223	-30	-2
Salinas River Outflow to Monterey Bay	377	987	219	99	447	1,210	249	100	-70	-223	-30	-1

Notes:
- Streamflow totals are rounded to the nearest cfs; totals may not sum due to rounding
- Difference between scenarios is calculated as Historical Scenario minus No Projects Scenario

Figure 4-1 shows the mean monthly streamflow in the Salinas River at Bradley for the Historical and No Projects Scenarios. The No Projects Scenario simulated much higher mean monthly streamflow in the winter, and very little flow from May to November. Figure 4-2 provides time series of observed and simulated total annual streamflow in the Salinas River at Bradley. Again, the Historical Scenario largely matched the pattern of historical streamflow, although it over-predicted streamflow for certain high-flow years (e.g., WY 1998). The No Projects Scenario simulated much higher total streamflow during many of the wet years (e.g., WY 1995 and 1998), and lower total streamflow during the driest years (e.g., WY 1976 and 1977). These figures provide another demonstration of how the Projects have affected the distribution of streamflow in the Salinas River. The Projects effectively redistribute streamflow from wet years and wet months of the year to drier periods, moderating the natural pattern of streamflow variability in the system.

4.3 FLOOD FLOW FREQUENCY ANALYSIS

The estimation of the magnitude of peak flows with and without the reservoirs relies on a statistical analysis of annual peak flows. As with the 1998 HBA, this HBA Update estimates the peak instantaneous, 1-day, 3-day, and 5-day flows corresponding to various return periods for the system. These peak flows represent the highest flow observed each water year (instantaneous), as well as the highest mean daily flow (1-day), 3-day average flow (3-day), and 5-day average flow (5-day). The peak instantaneous flow is equal to or higher than the peak 1-day flow, which is equal to or higher than the peak 3-day flow, which is equal to or higher than the peak 5-day flow. Peak instantaneous flows are determined from the data, and so may be affected by the data resolution. The USGS' automated stream gauges measure streamflow every 15 minutes, which is a fine enough temporal resolution to capture the approximate peak flow.

This section summarizes the approach that was used to estimate the parameters of the peak flow statistical distribution for the Salinas River at Bradley, which informed the shape of the Flood Frequency Curves. Because the analysis required the development of Flood Frequency Curves for the No Projects Scenario, an approach that could estimate peak flows from the available modeling tools head to be developed. The approach is described in more detail in Appendix B, including comparisons between the statistical peak flow distributions for the streamflow measurements taken during the historical period and those estimated based on the available modeling results.

The streamflow estimation process performs a simple mass balance of mean daily streamflow in the system above the location of the Salinas River at Bradley gauge (see Figure 4-3 for the area of the streamflow estimation). The data sources used for this analysis are described in Section 4.1; the exact data sources used depended on the scenario being analyzed. Both scenarios utilized the daily inflow into the Salinas River near San Miguel as the inflow along the Salinas River. The Historical Scenario used the mean daily reservoir release from Nacimiento and San Antonio Reservoirs, provided by MCWRA, as the inflows into the Nacimiento and San Antonio Rivers. The No Projects Scenario used the estimated mean daily reservoir inflow to the Nacimiento and San Antonio Reservoirs, provided by MCWRA, as inflows at the same locations. For each scenario, the groundwater-surface water flux was derived from the results of the respective SVIHM scenario; as noted above, the model timestep for the SVIHM lasts from 5 to 6 days, and the mean daily streamflow estimation used the simulated groundwater-surface water flux corresponding to each day of the analytical period. For example, the mean daily streamflow estimation for the period from September 1, 1967 to September 5, 1967 (the period of the first model timestep) used a single value of simulated groundwater-surface water flux while the various inflow components changed each day. Because the timescale of groundwater flow is substantially longer than surface water flow, and because the magnitude of the groundwater-surface water flux is very small compared to the streamflow (especially during the peak flows used for this analysis), this was considered an acceptable approximation.

As noted, Appendix B provides a comprehensive discussion of the streamflow estimation process, along with a comparison between its results and the historical streamflow measurements, including how the estimation process matches the statistical distribution of annual peak flows in the historical measurement time series.

Figure 4-4 provides a time series of annual (water year) peak instantaneous streamflow in the Salinas River at Bradley for the historical record, Historical Scenario, and No Projects Scenario, covering the period from WY 1968 to 2018. Differences in total and mean monthly streamflow between the Historical Scenario and the observed record (Figures 4-1 and 4-2) do not affect the ability of the estimation method to match the observed annual peak instantaneous flows. Figure 4-5 provides a cumulative distribution function (CDF) of the annual peak instantaneous streamflows in the observed record (WY 1968 to 2018) and estimated for the Historical and No Projects Scenario. Together, Figures 4-4 and 4-5 show that the streamflow estimation approach does an excellent job of re-creating the distribution of annual peak flows in the Salinas River at Bradley. The figures also demonstrate the effect that the Projects have on the peak flow distribution, substantially decreasing the magnitude of peak flows, particularly for the highest peak flows.

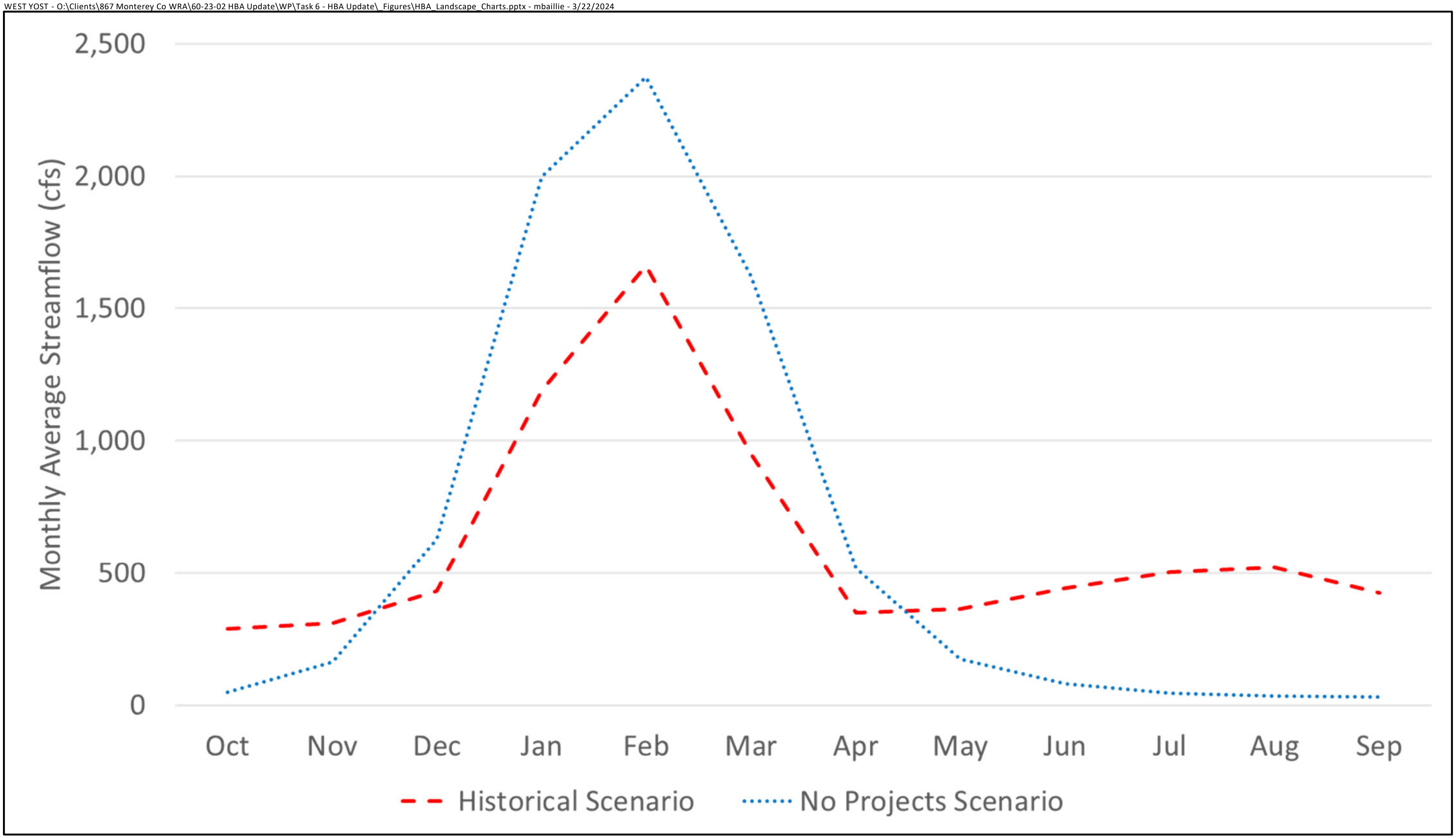


Figure 4-1

Monthly Average Simulated Streamflow in the Salinas River at Bradley

Monterey County Water Resources Agency

Historical Benefits Analysis Update

April 2025

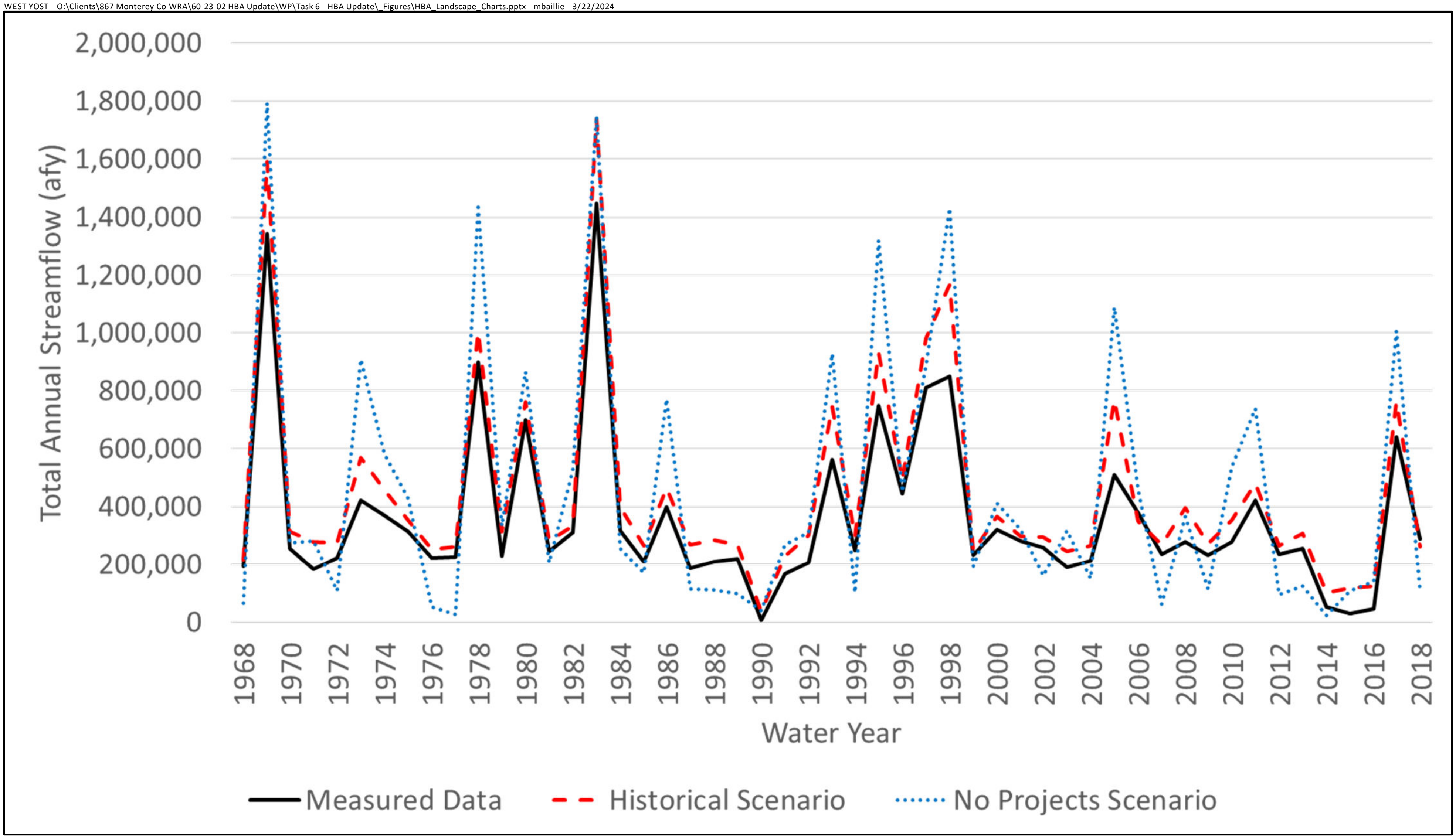


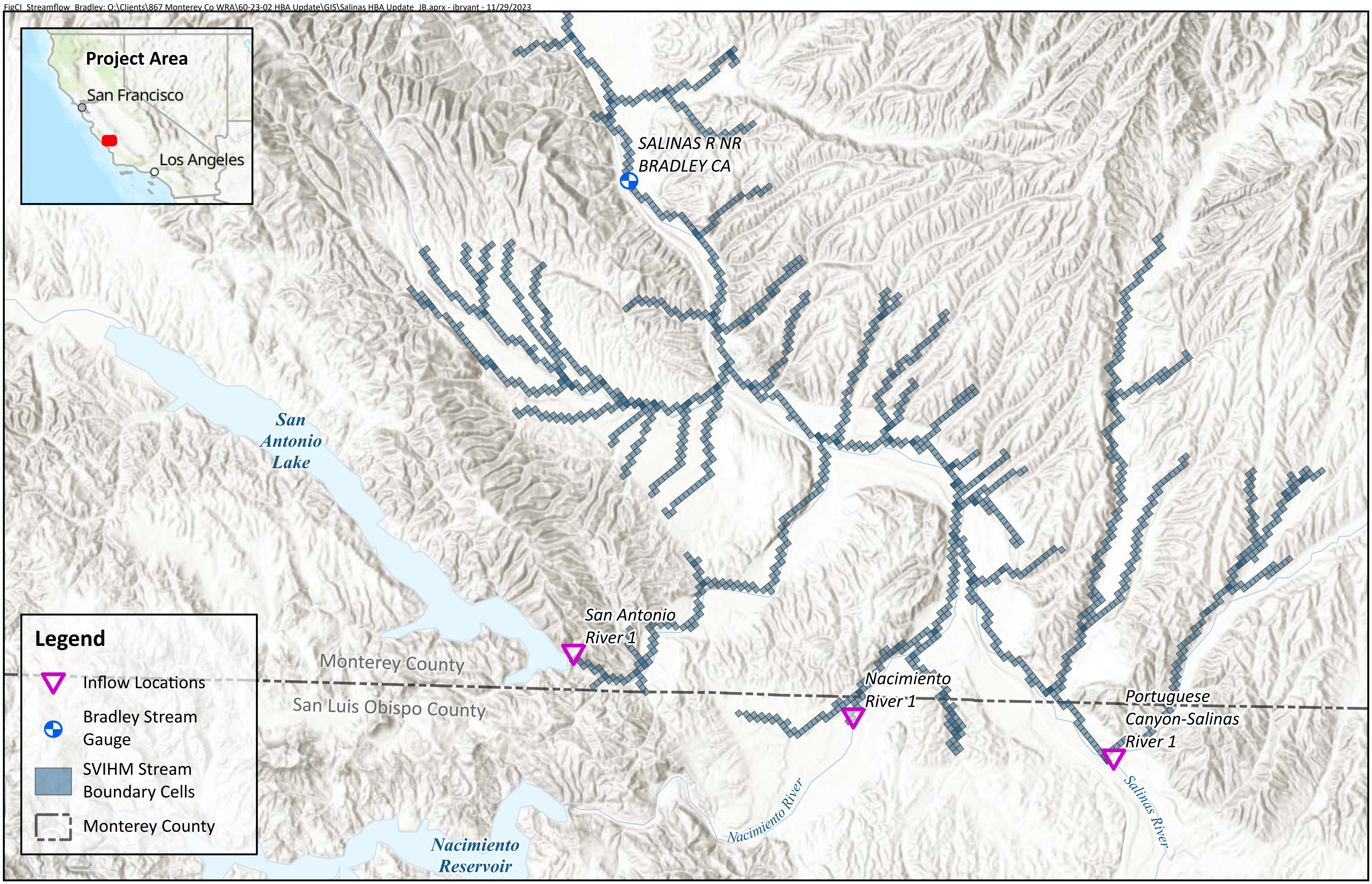
Figure 4-2

Annual Total Streamflow in the Salinas River at Bradley, Observed and Simulated

Monterey County Water Resources Agency

Historical Benefits Analysis Update

April 2025



Prepared by:

WEST YOST

Prepared for:
Monterey County Water Resources Agency
Salinas Valley HBA
April 2025

Area of Streamflow Estimation for the Salinas River at Bradley
Figure 4-3

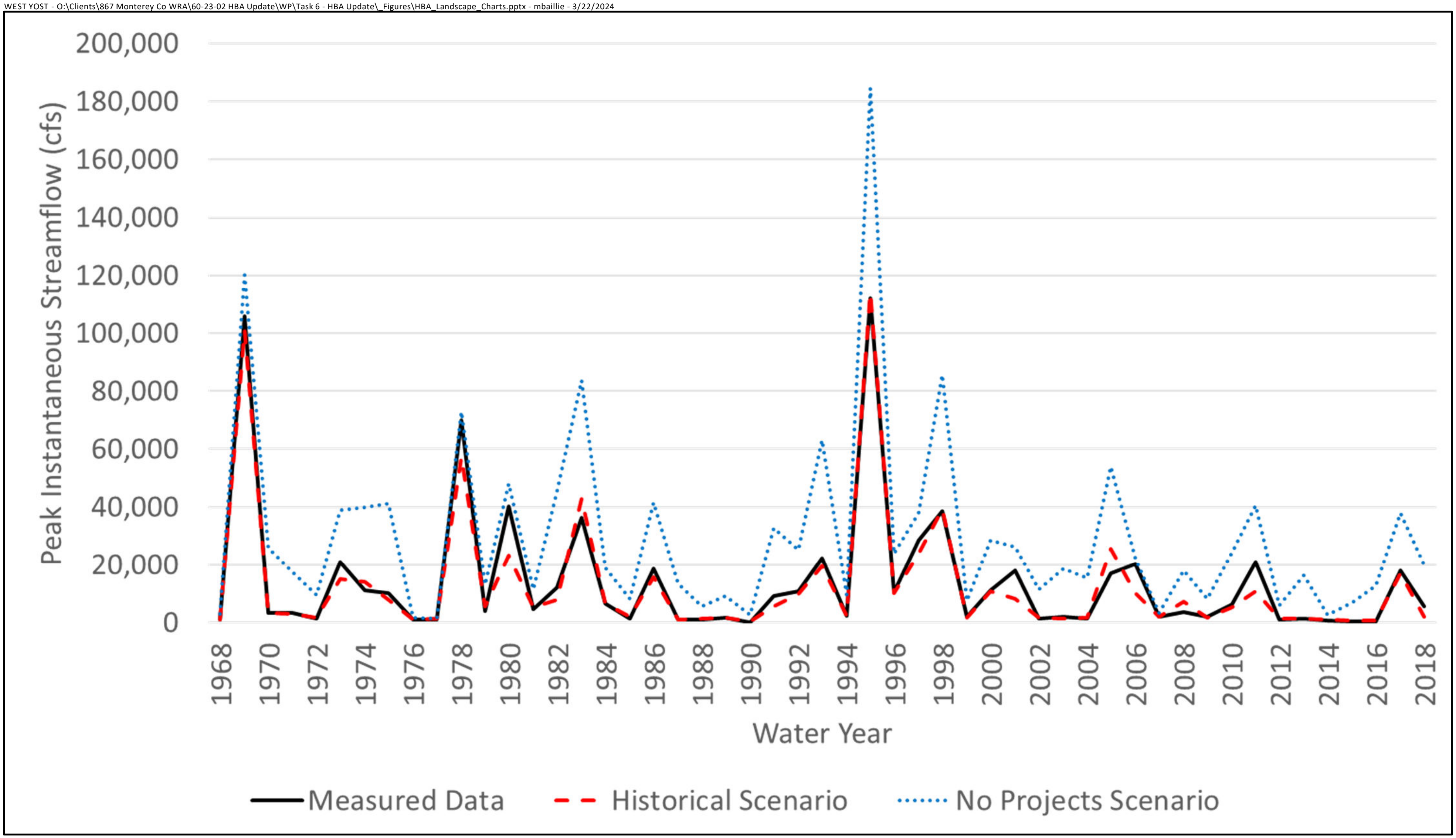


Figure 4-4

Annual Peak Streamflow in the Salinas River at Bradley, Observed and Estimated

Monterey County Water Resources Agency

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April 2025

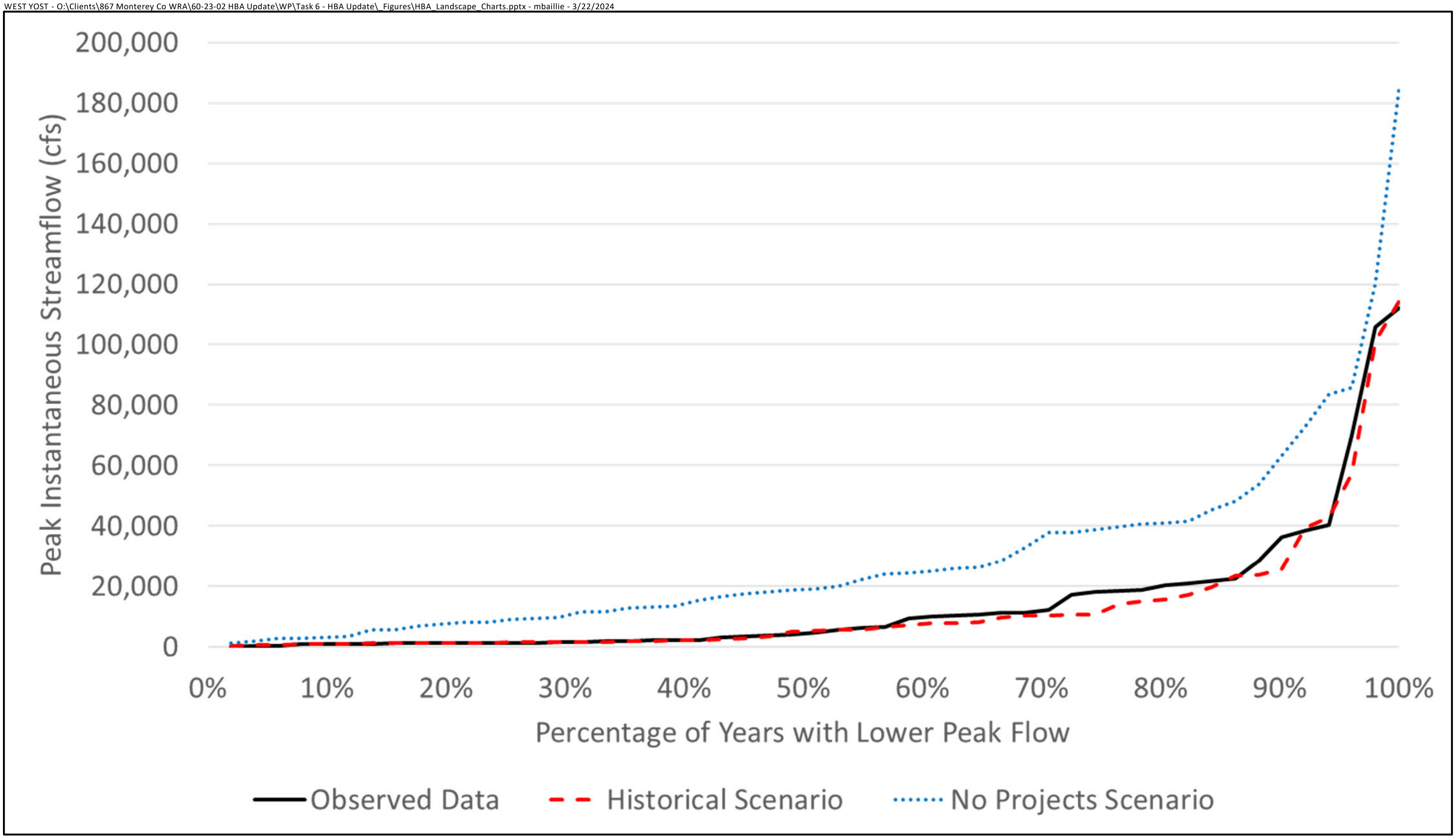

Figure 4-5

Cumulative Distribution Function of Annual Peak Streamflow in the Salinas River at Bradley, Observed and Estimated

Monterey County Water Resources Agency

Historical Benefits Analysis Update

April 2025

4.3.1 Flood Flow Frequency Approach

The 1998 HBA provided the magnitude of peak flow for selected flood events (25-year and 100-year floods), as well as the extent of inundation experienced under these events. The determination of the magnitude of these flood events relied on an analysis that matched a statistical distribution to the observed and simulated peak flow datasets. The parameters of this statistical distribution were used to estimate the magnitude of the peak flows. The statistical distribution determines the peak flow magnitude that corresponds to a given Annual Exceedance Probability (AEP). The peak flow with an AEP of 0.1 has a 10 percent probability during any given year of being met or exceeded; the peak flow with an AEP of 0.01 has a 1 percent probability of being met or exceeded each year. Typically, the AEP = 0.01 event is referred to as the 100-year flood (or to have a 100-year Return Period). In reality, the 100-year flood can occur several times during a given 100-year period, or not at all. The AEP is a more precise framework for describing peak flows compared to the Return Period, but this HBA Update preserves the use of the terminology of the Return Period to follow the approach of the 1998 HBA.

The Flood Flow Frequency Analysis for this HBA Update relied on updated guidelines for the determination of the peak flow statistical distribution (England et al., 2019). The USGS software package PeakFQ (Flynn et al., 2006) was used to automatically fit Flood Flow Frequency Curves to the annual peak flow values for the observed streamflow record (WY 1968 to 2018) and the estimated streamflow under the Historical and No Projects Scenarios for the Salinas River at Bradley. Limitations to the approach for determining the Flood Flow Frequency Curves are included in Appendix B. It is important to note that the shape of a Flood Flow Frequency Curve can change over time as additional years of data are added to the period of record, expanding the sample size and theoretically improving the ability to characterize the “real” state of the system. The curves can also change due to changes to the physical system, including natural channel modification processes and the construction and operation of surface water control features such as reservoirs. The presence of flow structures is a critical consideration for this HBA Update, which is concerned with the effect that the Nacimiento and San Antonio Reservoirs (and related projects and programs) have had on the system, including on the frequency and severity of flood flows. The application of this Flood Flow Frequency Analysis to this system must be made with these limitations in mind. It is noted that the analysis performed for the 1998 HBA included a period (WY 1958 to 1967) when only Nacimiento Reservoir was operating; for this HBA Update, the analysis covers the period from WY 1968 to 2018, when both reservoirs had already been constructed and were operating. This means that this HBA Update uses an analytical period during which the system was closer to “stationary” because there were no major changes to the infrastructure above Bradley (although it is important to note that the operational approach for the reservoirs has changed during the analytical period).

4.3.2 Flood Flow Frequency Curves

Figure 4-6 presents the peak instantaneous, 1-day, 3-day, and 5-day flood flow frequency curves for the observed streamflow data in the Salinas River at Bradley for the period from WY 1968 to 2018. Figure 4-7 provides the Flood Flow Frequency Curves for the Historical Scenario, and Figure 4-8 for the No Projects Scenario. Figure 4-9 shows curves that represent the difference between the Historical Scenario and No Projects Scenario Flood Flow Frequency Curves (note that this figure uses a difference calculated as the No Projects Scenario minus the Historical Scenario to keep the differences positive). Table 4-3 lists the magnitude of peak flows for selected AEPs for each dataset presented in these figures.

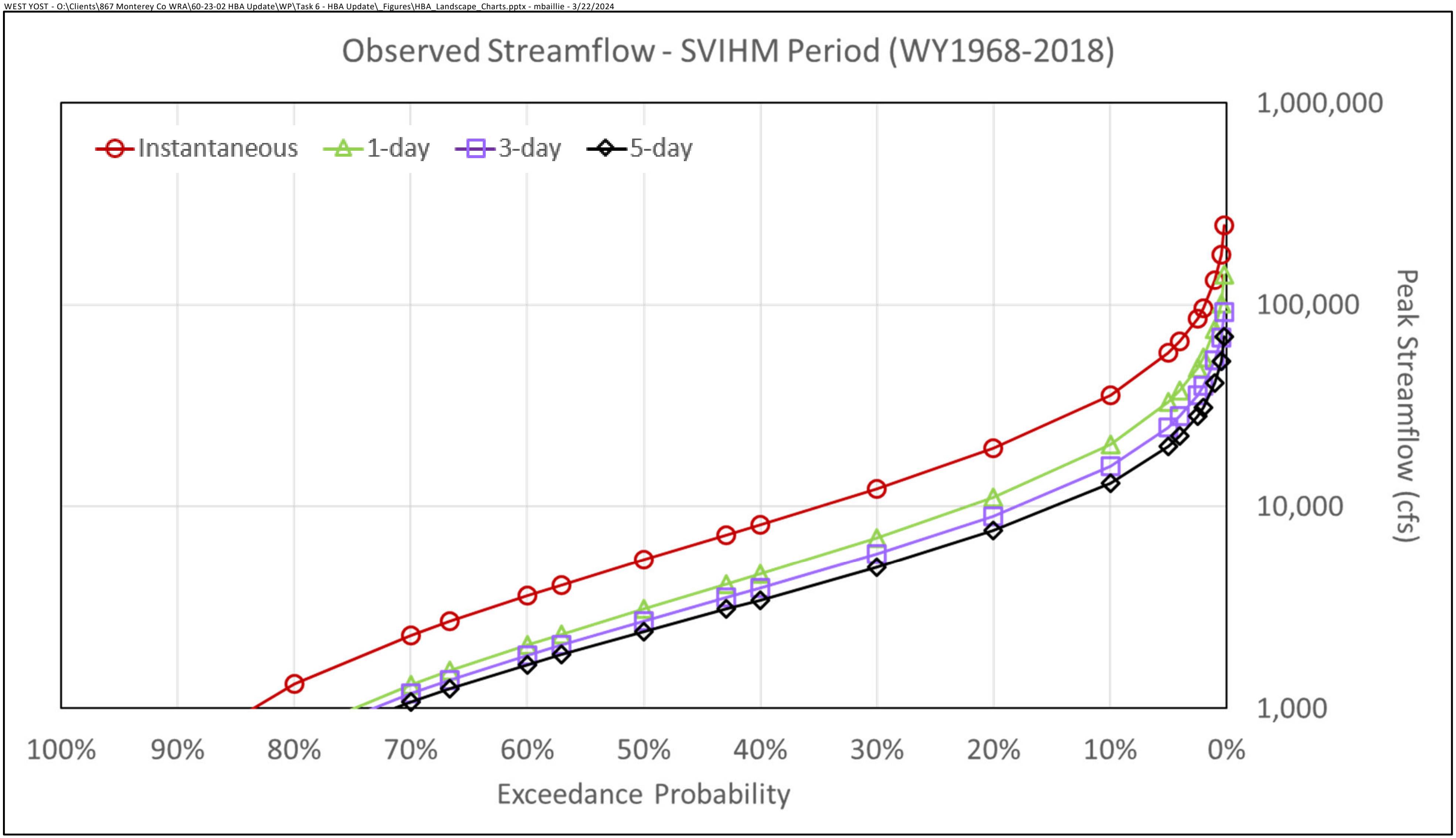

Figure 4-6

Flood Flow Frequency Curves for the Salinas River at Bradley, Observed Data

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April 2025

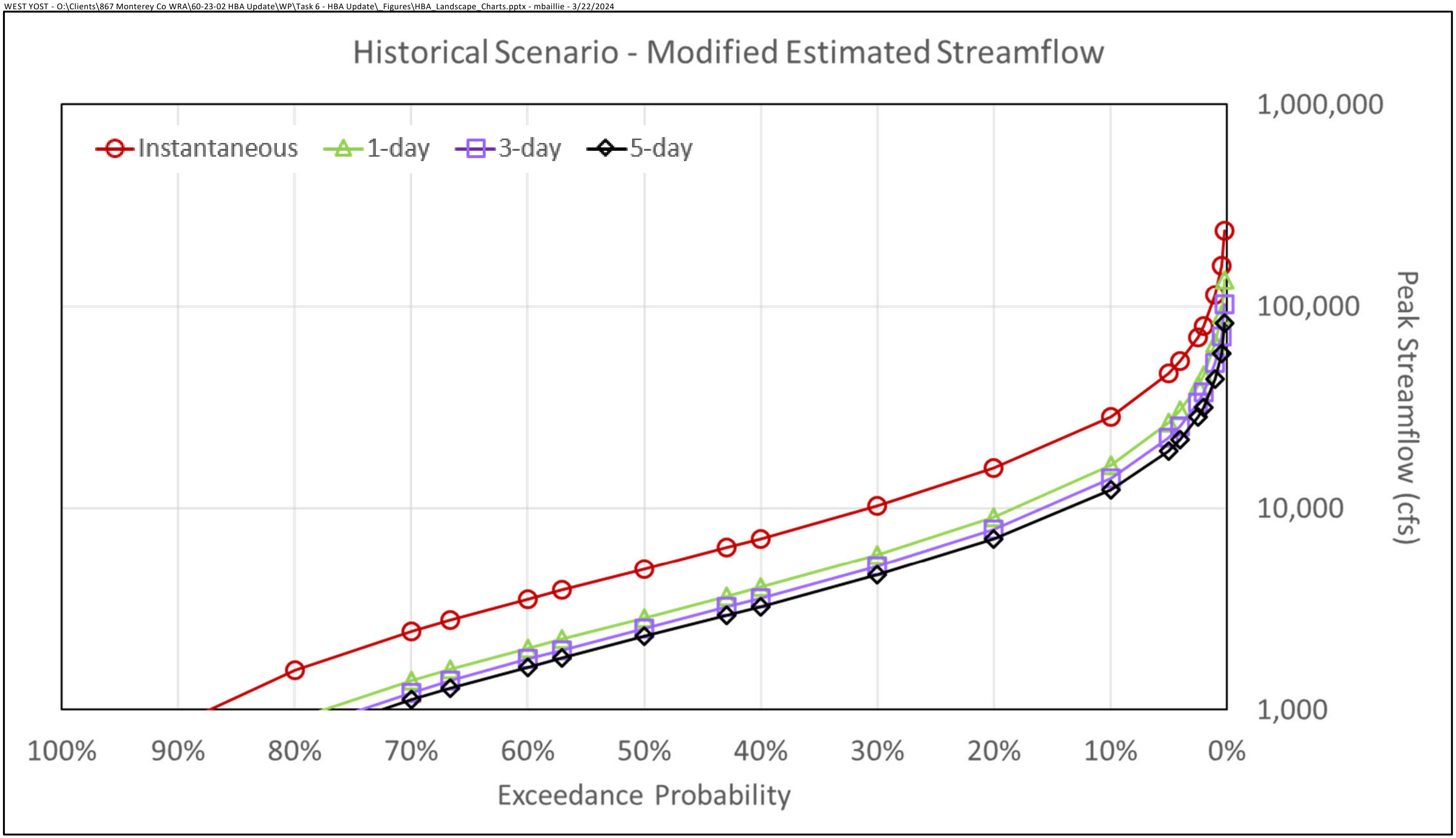

Figure 4-7

Flood Flow Frequency Curves for the Salinas River at Bradley, Historical Scenario

Monterey County Water Resources Agency
Historical Benefits Analysis Update
April 2025

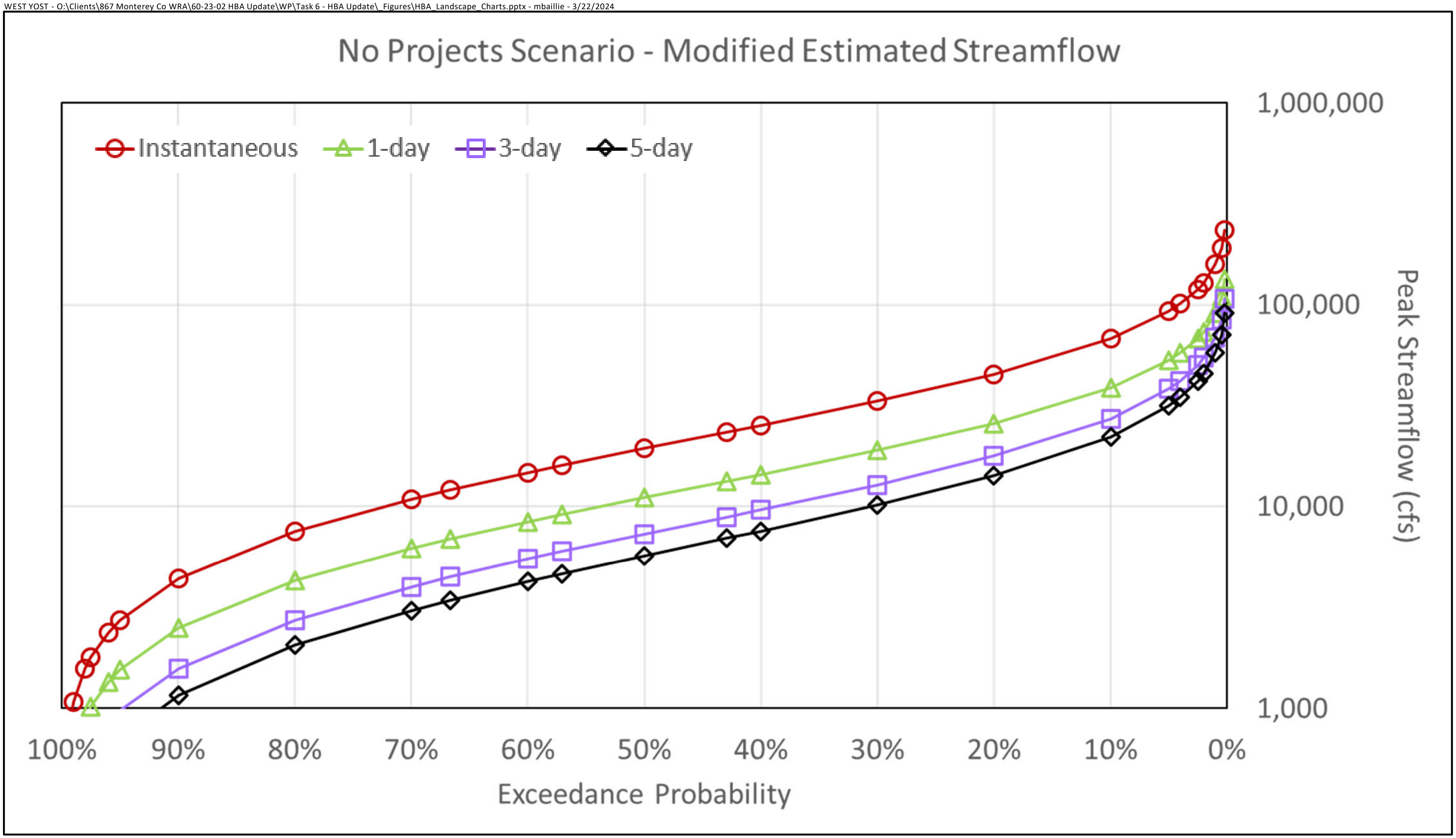

Figure 4-8

Flood Flow Frequency Curves for the Salinas River at Bradley, No Projects Scenario

Monterey County Water Resources Agency
Historical Benefits Analysis Update
April 2025

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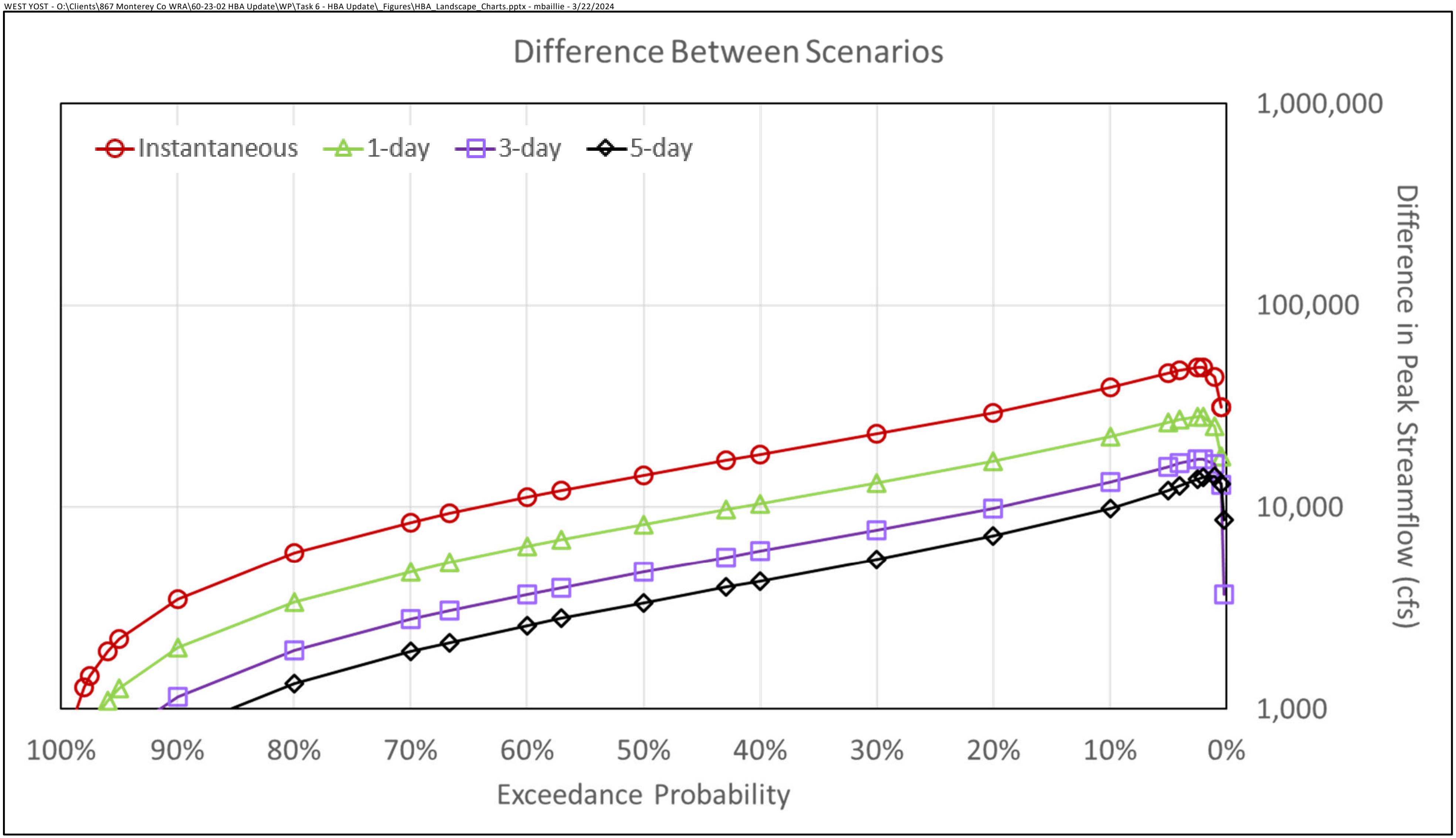


Figure 4-9

Flood Flow Frequency Curves for the Salinas River at Bradley, Difference Between Scenarios

Monterey County Water Resources Agency

Historical Benefits Analysis Update

April 2025

Table 4-3. Peak Flow Magnitudes for Selected Annual Exceedance Probabilities, Observed and Estimated Streamflow Datasets

	Instantaneous Peak Flow					1-Day Mean Streamflow					3-Day Mean Streamflow					5-Day Mean Streamflow				
Return Period (Years)	5	10	25	50	100	5	10	25	50	100	5	10	25	50	100	5	10	25	50	100
AEP	0.2	0.1	0.04	0.02	0.01	0.2	0.1	0.04	0.02	0.1	0.2	0.01	0.04	0.02	0.01	0.2	0.1	0.04	0.02	0.01
Observed Streamflow (WY 1968-2018)	19,300	35,700	65,900	96,000	132,900	11,000	20,400	37,600	54,800	75,900	9,000	15,800	27,900	39,400	52,900	7,600	13,100	22,400	31,100	41,100
Historical Scenario	15,700	28,500	53,400	79,900	114,600	9,000	16,300	30,500	45,600	65,500	7,900	14,000	25,500	37,400	52,400	7,000	12,300	21,900	31,600	43,600
No Projects Scenario	45,200	67,600	100,900	128,800	158,700	27,800	28,600	57,600	73,500	90,600	17,700	27,300	42,000	54,700	68,700	14,200	22,200	34,700	45,600	57,800
Difference Between Scenarios	+29,400	+39,100	+47,500	+48,900	+44,100	+16,800	+22,300	+27,200	+27,900	+25,200	+9,900	+13,300	+16,500	+17,300	+16,300	+7,200	+9,900	+12,700	+14,000	+14,200
Percent Decrease Due to Projects	65%	58%	47%	38%	28%	65%	58%	47%	38%	28%	56%	49%	39%	32%	24%	51%	45%	37%	31%	25%

Notes:
- All peak flows are in cubic feet per second (cfs); flows are rounded to the nearest 100 cfs and totals may not sum due to rounding
- Difference between scenarios is calculated as No Projects Scenario peak flow minus Historical Scenario peak flow; this is the opposite of the calculation used in the Hydrologic Benefits Analysis, and is used here to avoid plotting negative differences on logarithmic charts
- AEP = Annual Exceedance Probability
- WY = Water Year

This analysis indicates that the magnitude of the 100-year flood in the Salinas River at Bradley under the Historical Scenario was about 115,000 cfs, versus about 159,000 cfs under the No Projects Scenario, meaning that the Projects have reduced the magnitude of the 100-year flood by about 44,000 cfs (a decrease of about 28 percent). Flood flows with a higher AEP (i.e., lower return period) experienced larger percentage decreases, ranging from about 65 percent for the 5-year event to about 38 percent for the 50-year event (Table 4-3).

The 100-year flood event under the Historical Scenario, with a magnitude of about 115,000 cfs, corresponds to an AEP under the No Projects Scenario of about 2.9 percent, equating to a return period of about 34 years. This means that the magnitude of the flood event that might only occur once every 100 years on average under the current configuration of the system (i.e., the Historical Scenario) may have happened about three times as frequently without the Projects. Indeed, the Historical Scenario 100-year flood flow was exceeded twice during the 51-year analytical period under the No Projects Scenario (in WY 1969 and 1995), compared to the Historical Scenario that had no exceedances of this flow.

4.4 PEAK FLOW INUNDATION SIMULATION

To understand the effects on the study area, the peak flows estimated with the Flood Flow Frequency Analysis (see Section 4.3) were used as inflow conditions for an existing hydraulic model of the Salinas River and its floodplain (FlowWest, 2015). This model was developed using HEC-RAS 2D to investigate the management of flood risk along the Salinas River from San Ardo to Highway 1. It is being used for this HBA Update without modification, aside from the magnitude of the inflows. FlowWest (2015) noted one limitation of the HEC-RAS software is its inability to simulate groundwater-surface water interactions. However, at the peak flow magnitudes being simulated for this study, losses to the groundwater system are assumed to be relatively small.

The Salinas River HEC-RAS Model takes as input streamflow in the Salinas River at Bradley (Figure 1-7) as well as tributary flows from Arroyo Seco and San Lorenzo Creek (the major gauged tributaries to the Salinas River below Bradley). Appendix B details the approach for estimating tributary inflows at these two locations for the Salinas River at Bradley peak flows. The 100-year, 50-year, 25-year, and 10-year flood event for both the Historical and No Projects Scenarios were used as inputs to the HEC-RAS model (see Section 4.3.2 for the development of these event flows, and Table 4-3 for the flow magnitudes). This section presents the results of the HEC-RAS modeling of these peak flows, analyzing how they affect the study area in terms of the extent and depth of inundation, as well as flood flow velocities within the inundated area.

The Salinas River HEC-RAS Model does not simulate the passage of a realistic hydrograph, with rising and falling limbs, through the system. Instead, the model simulates the quasi-steady state effects of the peak flow on the system. The input hydrograph for the HEC-RAS model starts at a relatively low flow, then ramps up to the peak flow. The peak flow in effect acts as the model inflow for an extended period. This approach results in simulated inundation that is representative of the effects of the peak flow magnitude, but not the realistic movement of an event hydrograph through the system. This analysis is useful for understanding the maximum extent of inundation under each peak flow value, but not temporal aspects of the event, such as duration of inundation.

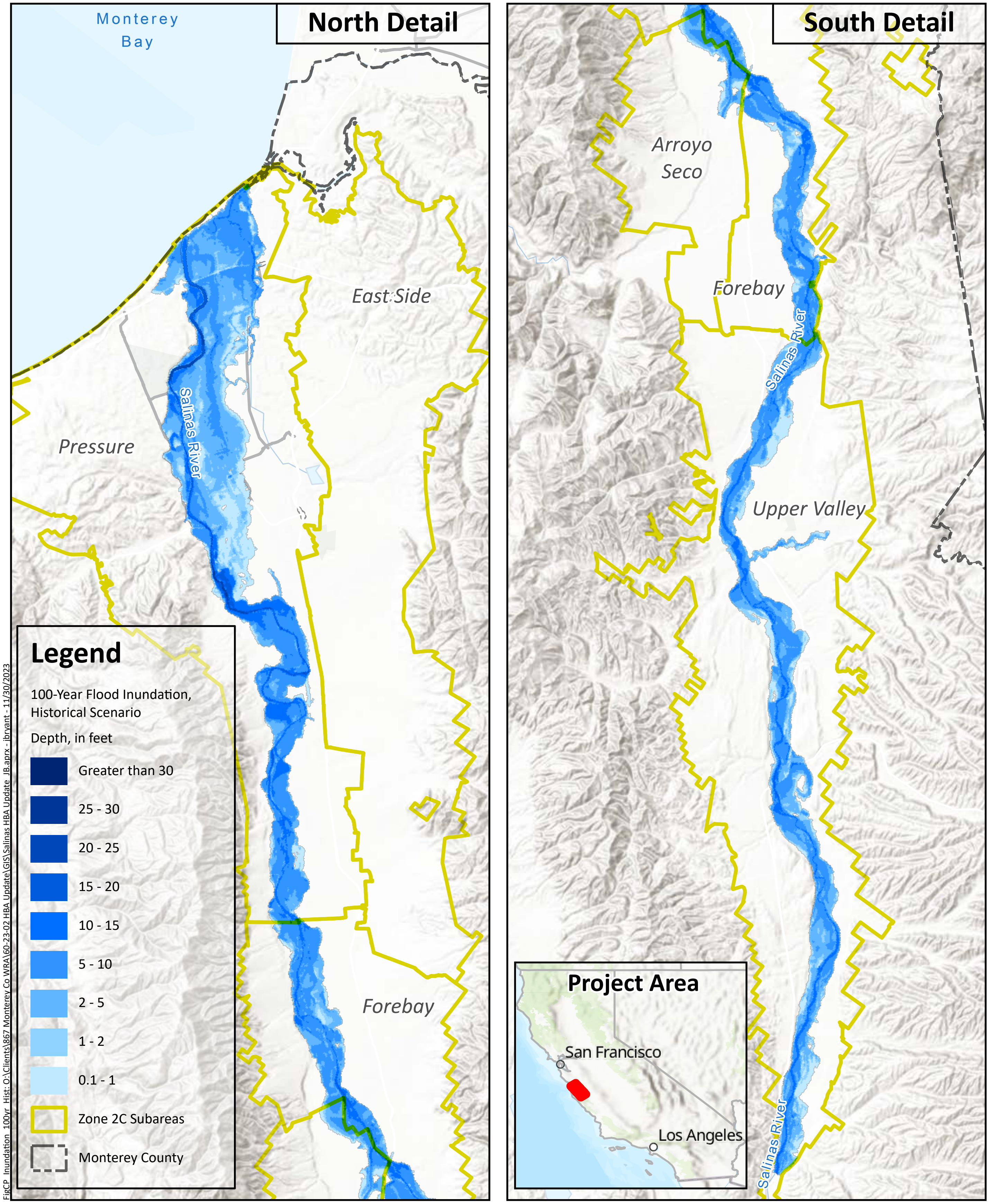
4.4.1 Extent and Depth of Inundation

The extent of inundation represents the area of the floodplain that is covered by floodwater under each peak flow value. To avoid inclusion of areas experiencing minimal inundation depth, a minimum inundation threshold of 0.1 feet was used in determining the extent of inundation. This section presents the extent of inundation for the 100-year, 50-year, 25-year, and 10-year flood events under the Historical and No Projects Scenarios simulated using the Salinas River HEC-RAS model. The peak flowrates for each of these events are provided in Table 4-3.

Figure 4-10 shows the inundated area and inundation depth under the 100-year flood event for the Historical Scenario, with a peak flow of about 115,000 cfs. For this event, the simulated extent of inundation was about 60,000 acres and the maximum depth of inundation was about 31 feet within the Salinas River channel around Spreckels. Table 4-4 provides the simulated inundation area above selected depth thresholds for this and the other model scenarios, as well as the maximum simulated inundation depth for each. The 100-year flood for the Historical Scenario simulated an area of about 34,000 acres under at least 5 feet of inundation, and about 56,000 acres under at least 1 foot of inundation.

Figure 4-11 shows the inundated area and inundation depth under the 50-year flood event for the Historical Scenario, with a peak flow of about 80,000 cfs. For this event, the simulated extent of inundation was about 54,000 acres and the maximum depth of inundation was about 30 feet. Figure 4-12 shows the inundated area and inundation depth under the 25-year flood event for the Historical Scenario, with a peak flow of about 53,000 cfs. For this event, the simulated extent of inundation was about 45,000 acres and the maximum depth of inundation was about 29 feet. Figure 4-13 shows the inundated area and inundation depth under the 10-year flood event for the Historical Scenario, with a peak flow of about 28,000 cfs. For this event, the simulated extent of inundation was about 32,000 acres and the maximum depth of inundation was about 28 feet.

Figure 4-14 shows the inundated area and inundation depth under the 100-year flood event for the No Projects Scenario, with a peak flow of about 159,000 cfs. For this event, the simulated extent of inundation was about 65,000 acres and the maximum depth of inundation was about 33 feet within the Salinas River channel near Spreckels. This event simulated an area of about 42,000 acres under at least 5 feet of inundation and about 62,000 acres under at least 1 foot of inundation. The total area of inundation was about 5,000 acres larger than the inundated area for the Historical Scenario 100-year event; the area of at least 5 feet of inundation was about 8,000 acres larger and the area of at least 1 foot of inundation was about 5,000 acres larger compared to the Historical Scenario 100-year event.



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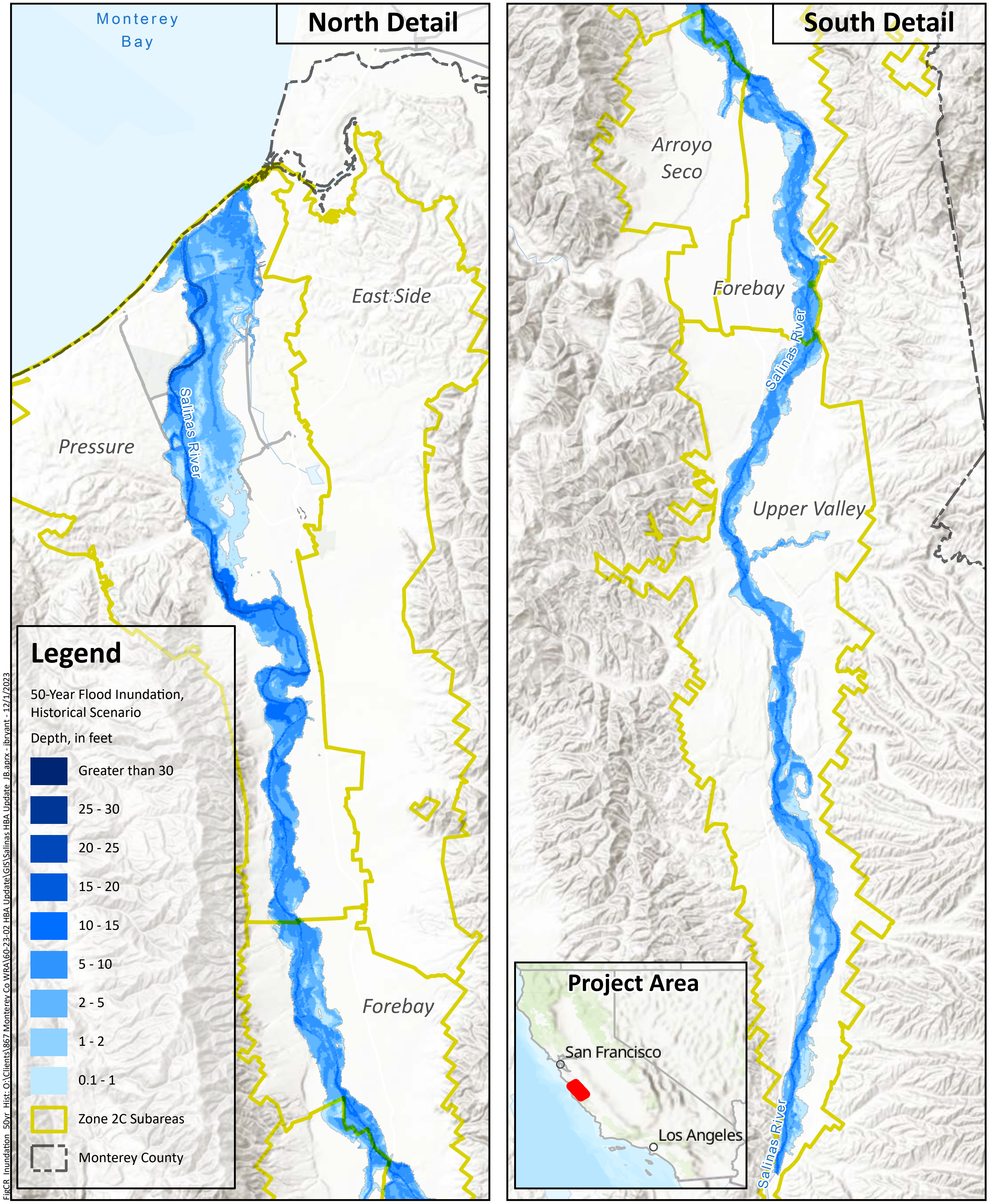
Inundation Area and Depth for 100-Year Flood

Historical Scenario

Figure 4-10



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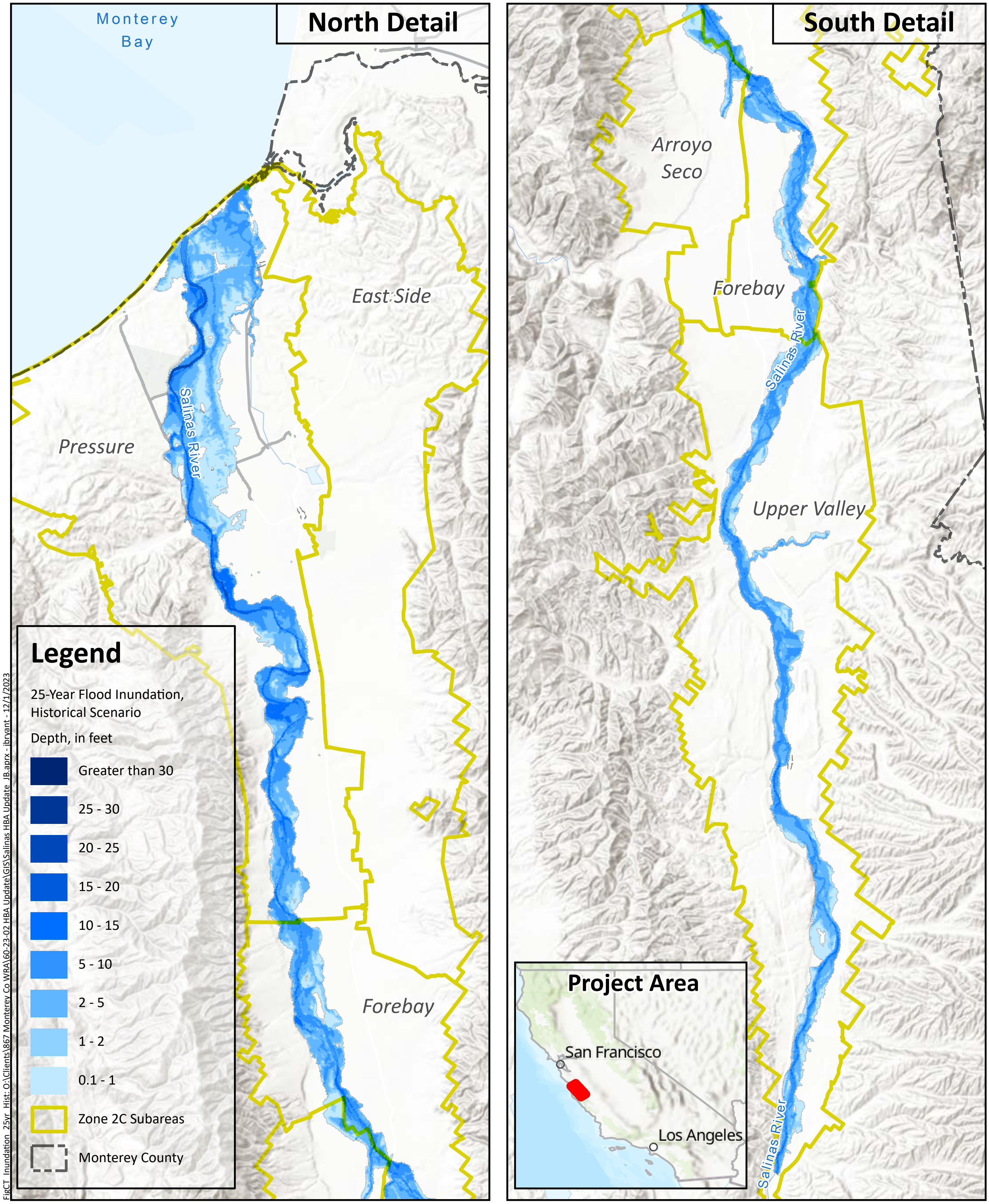
Inundation Area and Depth for 50-Year Flood

Historical Scenario

Figure 4-11



FigCT_Inundation_25yr_Hist: O:\Clients\867 Monterey Co WRA\60-23-02 HBA Update\GIS\Salinas HBA Update_JB.aprx - ibryant - 12/1/2023

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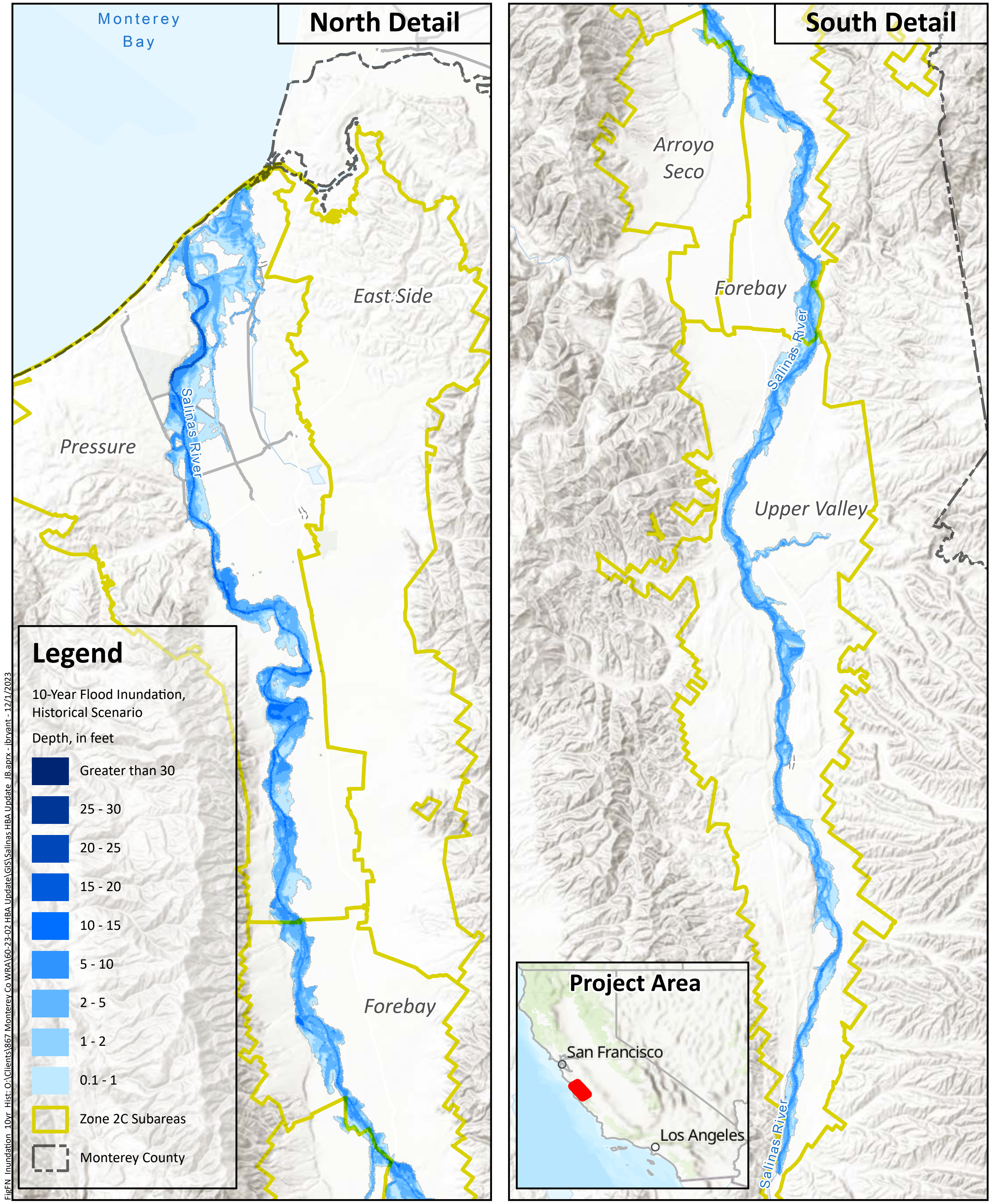
Inundation Area and Depth for 25-Year Flood
Historical Scenario

Figure 4-12



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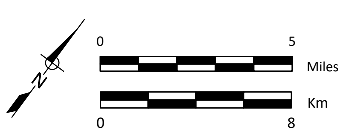
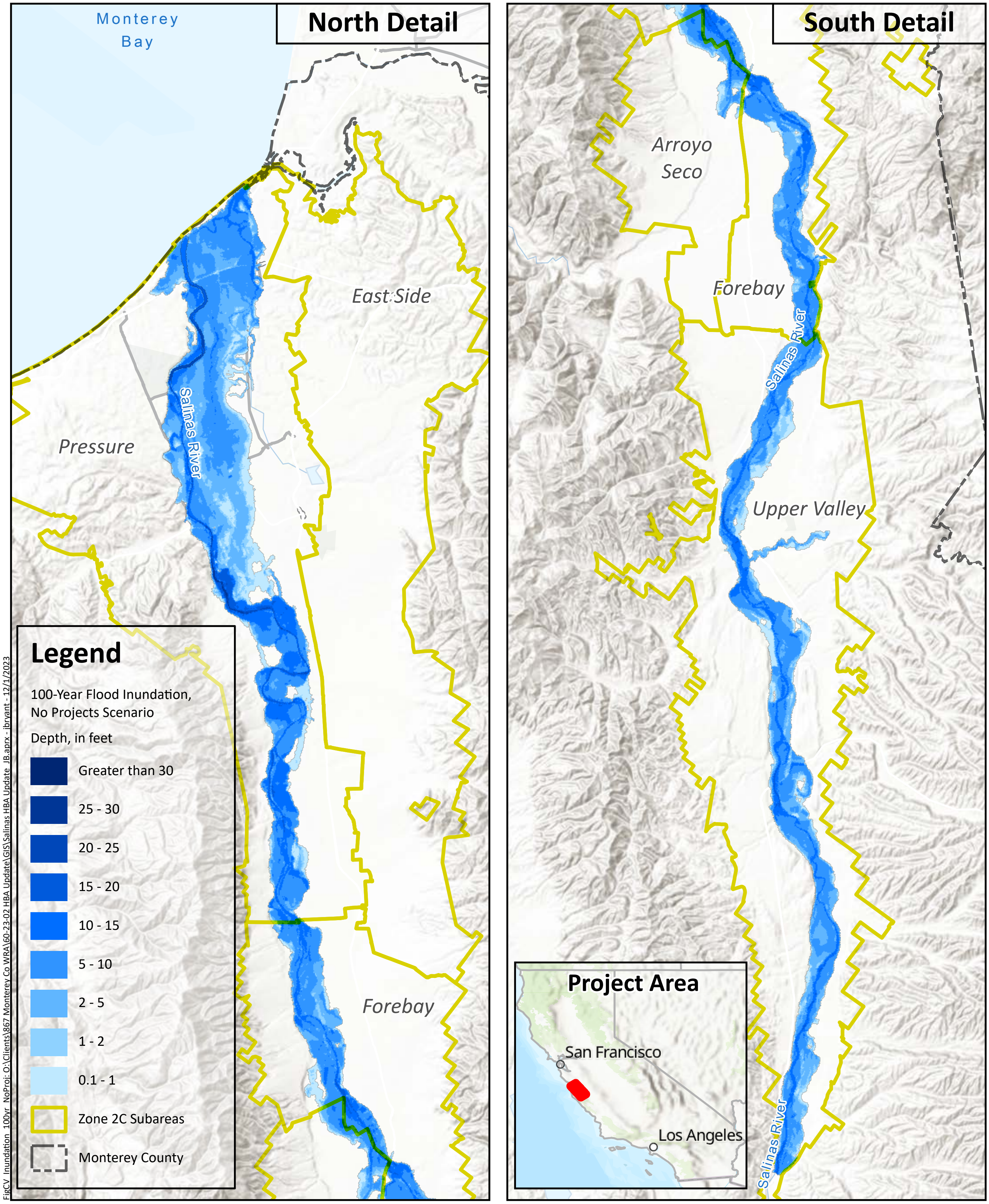


Inundation Area and Depth for 10-Year Flood
Historical Scenario

Figure 4-13



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Inundation Area and Depth for 100-Year Flood
No Projects Scenario

Figure 4-14

Table 4-4. Maximum Inundation Depth and Area Inundated Under Selected Depths, Historical and No Projects Scenario						
	Maximum Depth, ft		100-year Event	50-year Event	25-year Event	10-year Event
Historical Scenario			31	30	29	28
	Area Above Inundation Depth (acres)	30’	6	0	0	0
		25’	100	50	20	0
		20’	320	260	200	80
		15’	1,440	880	560	320
		10’	8,130	5,510	3,710	1,740
		5’	34,000	24,600	16,700	9,100
		2’	51,200	43,200	33,700	21,100
		1’	56,100	48,900	39,700	26,600
		0.1’	60,000	53,500	45,400	31,700
No Projects Scenario	**Maximum Depth, ft**		33	31	30	29
	Area Above Inundation Depth (acres)	30'	17	6	0	0
		25'	150	100	70	30
		20'	410	320	280	220
		15'	2,400	1,550	1,070	620
		10'	13,020	8,800	6,460	4,200
		5'	42,200	35,400	28,700	18,900
		2'	57,400	52,200	47,100	36,500
		1'	61,500	56,900	52,200	42,600
		0.1'	65,000	60,700	56,500	48,100
Difference Between Scenarios	**Maximum Depth, ft**		-1	-1	-1	-1
	Area Above Inundation Depth (acres)	30'	-11	-6	0	0
		25'	-50	-50	-40	-30
		20'	-90	-60	-80	-130
		15'	-960	-670	-510	-300
		10'	-4,890	-3,290	-2,750	-2,450
		5'	-8,200	-10,800	-12,000	-9,900
		2'	-6,300	-9,000	-13,400	-15,400
		1'	-5,400	-8,000	-12,500	-15,900
		0.1’	-4,900	-7,200	-11,100	-16,500

Notes:

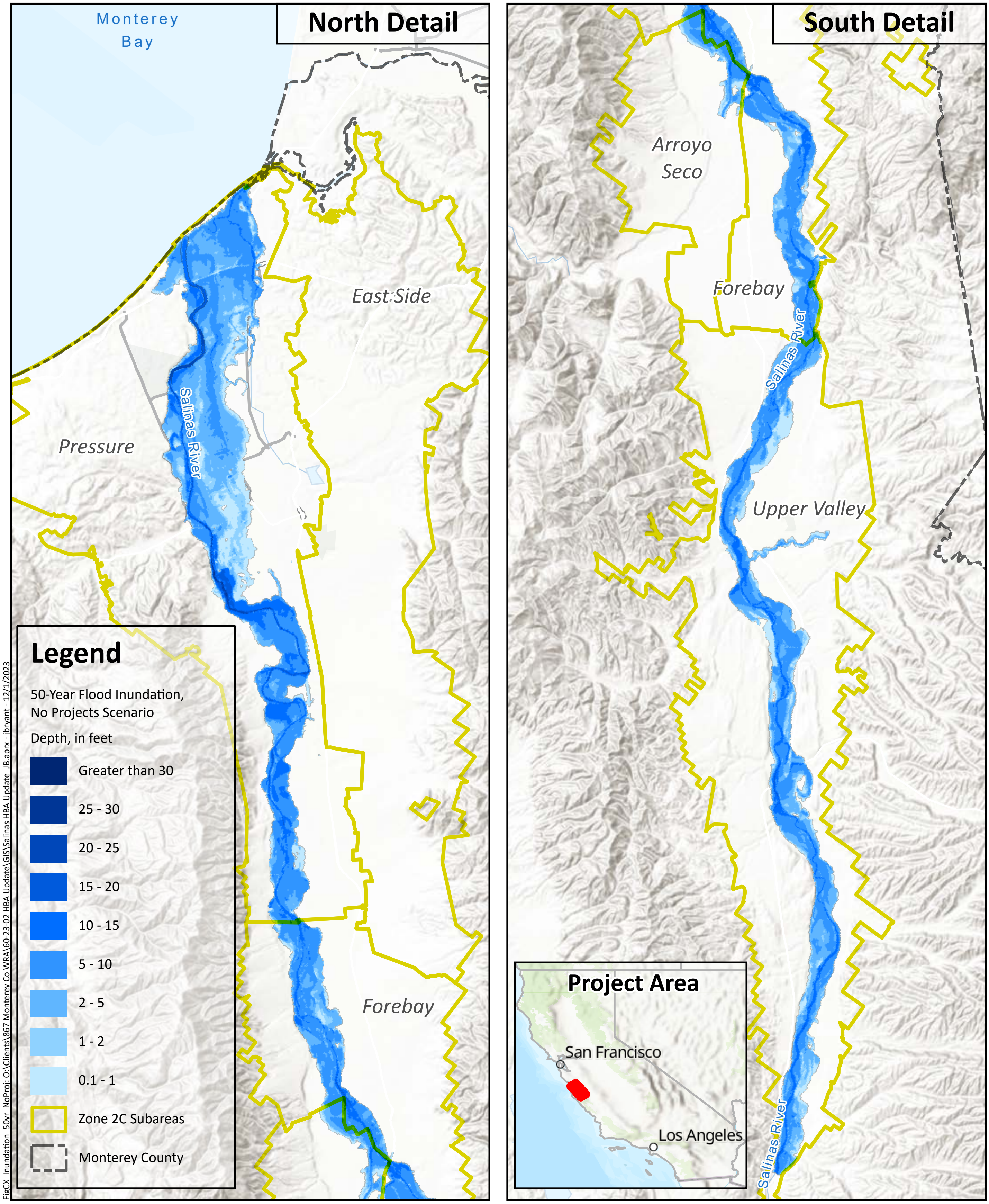
- Areas are rounded to the nearest acre (30’ inundation depth), 10 acres (10’ to 25’ inundation depth), or 100 acres (0.1’ to 5’ inundation depth) depending on the magnitude of the values; totals may not sum due to rounding
- Maximum inundation depth is rounded to the nearest foot; totals may not sum due to rounding
- Difference between scenarios is calculated as Historical Scenario minus No Projects Scenario

Figure 4-15 shows the inundated area and inundation depth under the 50-year flood event for the No Projects Scenario, with a peak flow of about 129,000 cfs. For this event, the simulated extent of inundation was about 61,000 acres and the maximum depth of inundation was about 31 feet. Figure 4-16 shows the inundated area and inundation depth under the 25-year flood event for the No Projects Scenario, with a peak flow of about 101,000 cfs. For this event, the simulated extent of inundation was about 56,000 acres and the maximum depth of inundation was about 30 feet. Figure 4-17 shows the inundated area and inundation depth under the 10-year flood event for the No Projects Scenario, with a peak flow of about 68,000 cfs. For this event, the simulated extent of inundation was about 48,000 acres and the maximum depth of inundation was about 29 feet.

Table 4-4 includes the difference in the inundated areas between scenarios. These results indicate that the Projects result in about 16,000 fewer acres (about 34 percent fewer) inundated during a 10-year event, 11,000 fewer acres (about 20 percent) inundated during a 25-year event, 7,000 fewer acres (about 12 percent) inundated during a 50-year event, and 5,000 fewer acres (about 8 percent) inundated during a 100-year event. These differences indicate areas that are protected from inundation by the presence and operation of the Projects.

In addition to the area protected from inundation, the results indicate that the depth of inundation is lower in those areas that are still flooded with the Projects in place. Figure 4-18 shows the difference in inundation depth for the 100-year floods under the Historical and No Projects Scenarios (for this and other inundation depth figures, the difference is calculated as the No Projects Scenario depth minus the Historical Scenario depth). Figure 4-19 shows the difference in inundation depth for the 50-year floods under the Historical and No Projects Scenarios. Figure 4-20 shows the difference in inundation depth for the 25-year floods under the Historical and No Projects Scenarios. Figure 4-21 shows the difference in inundation depth for the 10-year floods under the Historical and No Projects Scenarios. Table 4-4 also includes the difference between scenarios in the area inundated by each depth threshold.

These results indicate that the Projects have greatly decreased the extent and severity of flood-driven inundation of the Salinas River floodplain. The effect of the Projects is relatively modest for the largest events (e.g., an 8 percent reduction for the 100-year flood), because the reservoirs can only store part of the inflow for the biggest events generated in the watersheds feeding the Nacimiento and San Antonio Reservoirs. Events with a shorter recurrence interval experience a larger decrease in the inundated area, up to a 34 percent reduction for the 10-year event. This demonstrates the ability of the Projects to protect stakeholders in the Basin from repeated inundation from floods that occur more frequently. As shown in Table 4-4, the inundation for the 100-year event under the Historical Scenario is smaller than the inundation for the 50-year event under the No Projects Scenario, the inundation for the 50-year event under the Historical Scenario is smaller than the inundation for the 25-year event under the No Projects Scenario, and the inundation for the 25-year event under the Historical Scenario is smaller than the inundation for the 10-year event under the No Projects Scenario.



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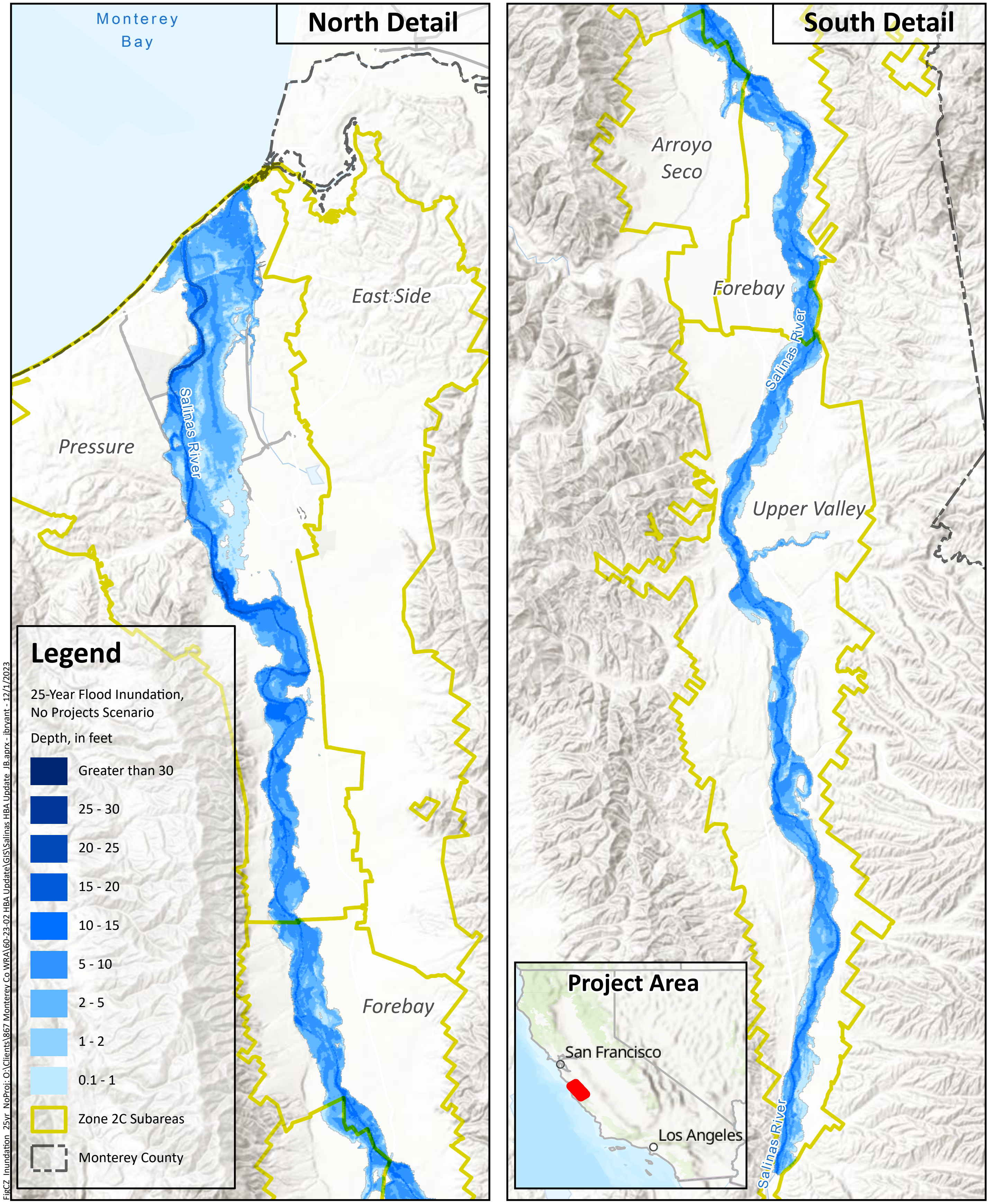
Inundation Area and Depth for 50-Year Flood

No Projects Scenario

Figure 4-15



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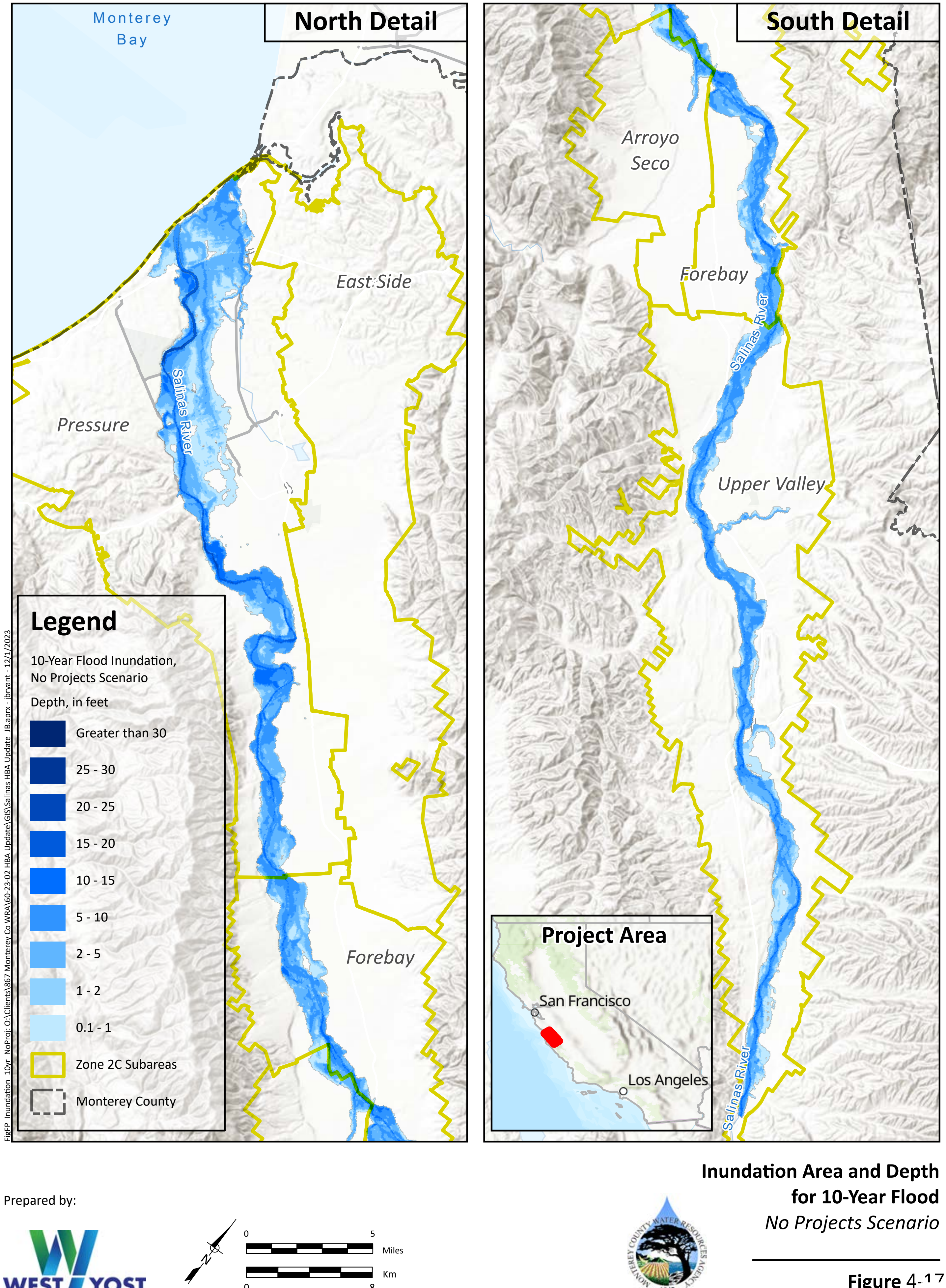
Inundation Area and Depth for 25-Year Flood

No Projects Scenario

Figure 4-16



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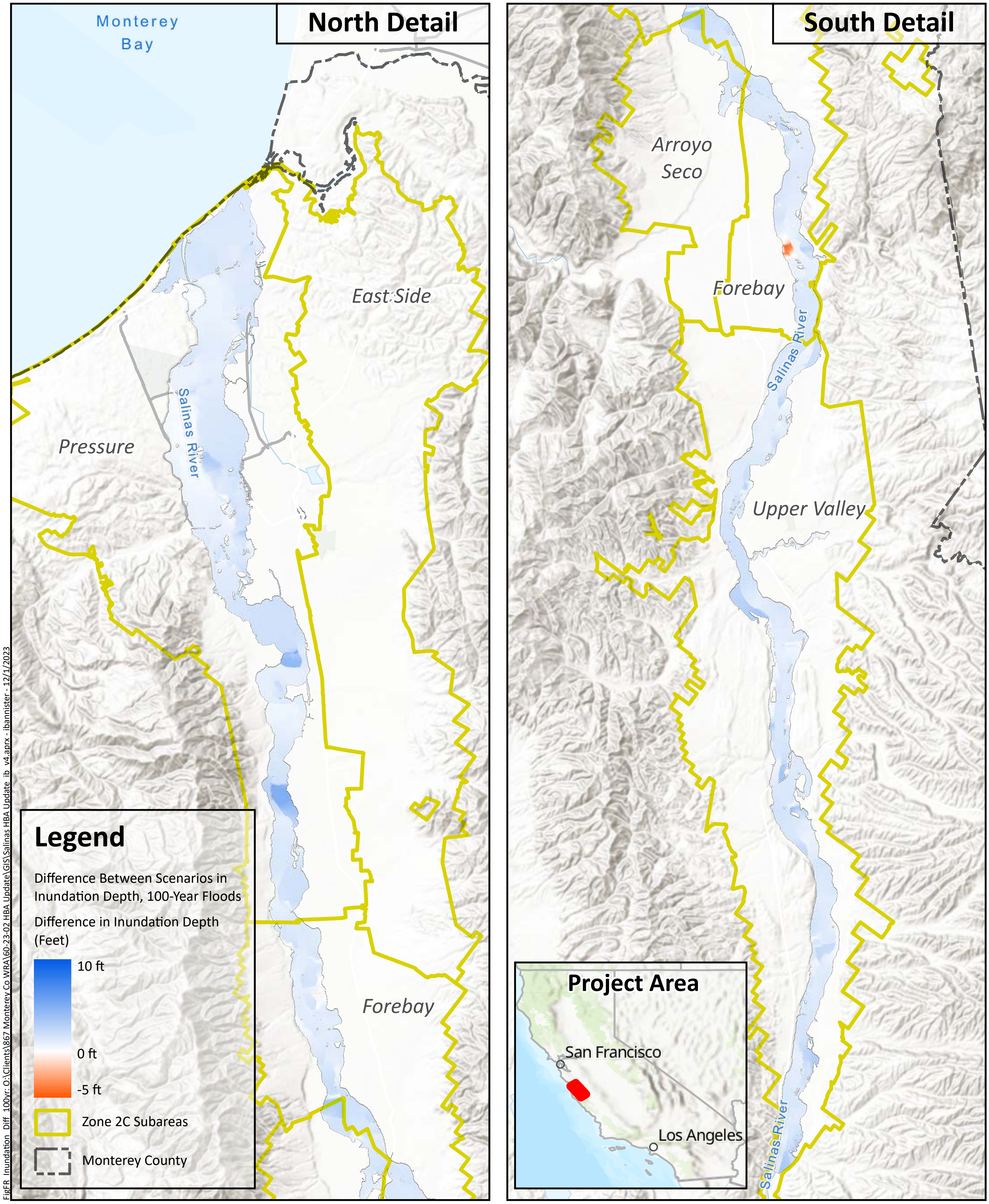
Inundation Area and Depth for 10-Year Flood
No Projects Scenario

Figure 4-17



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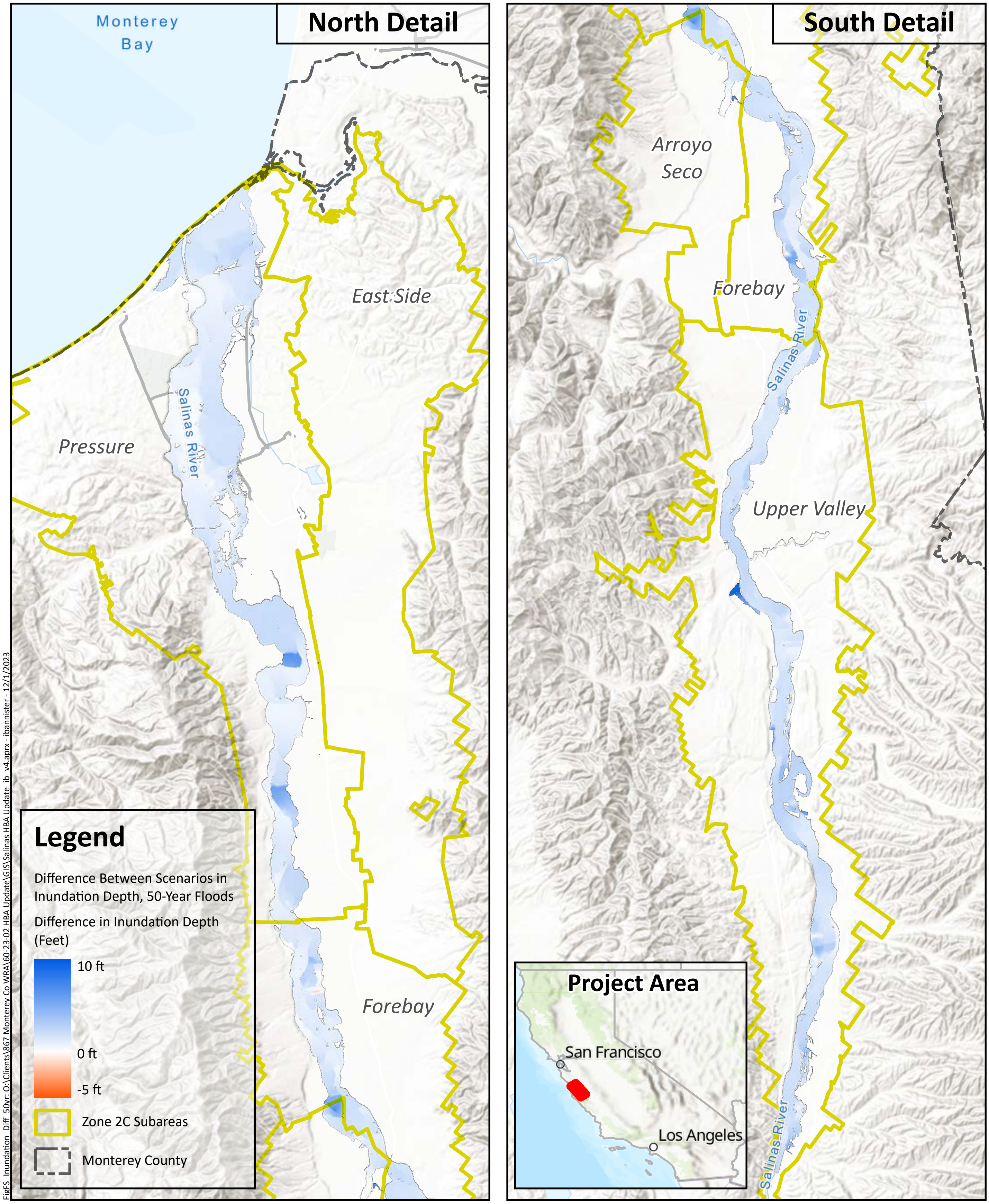
Difference Between Scenarios in Inundation Depth for 100-Year Flood

Figure 4-18



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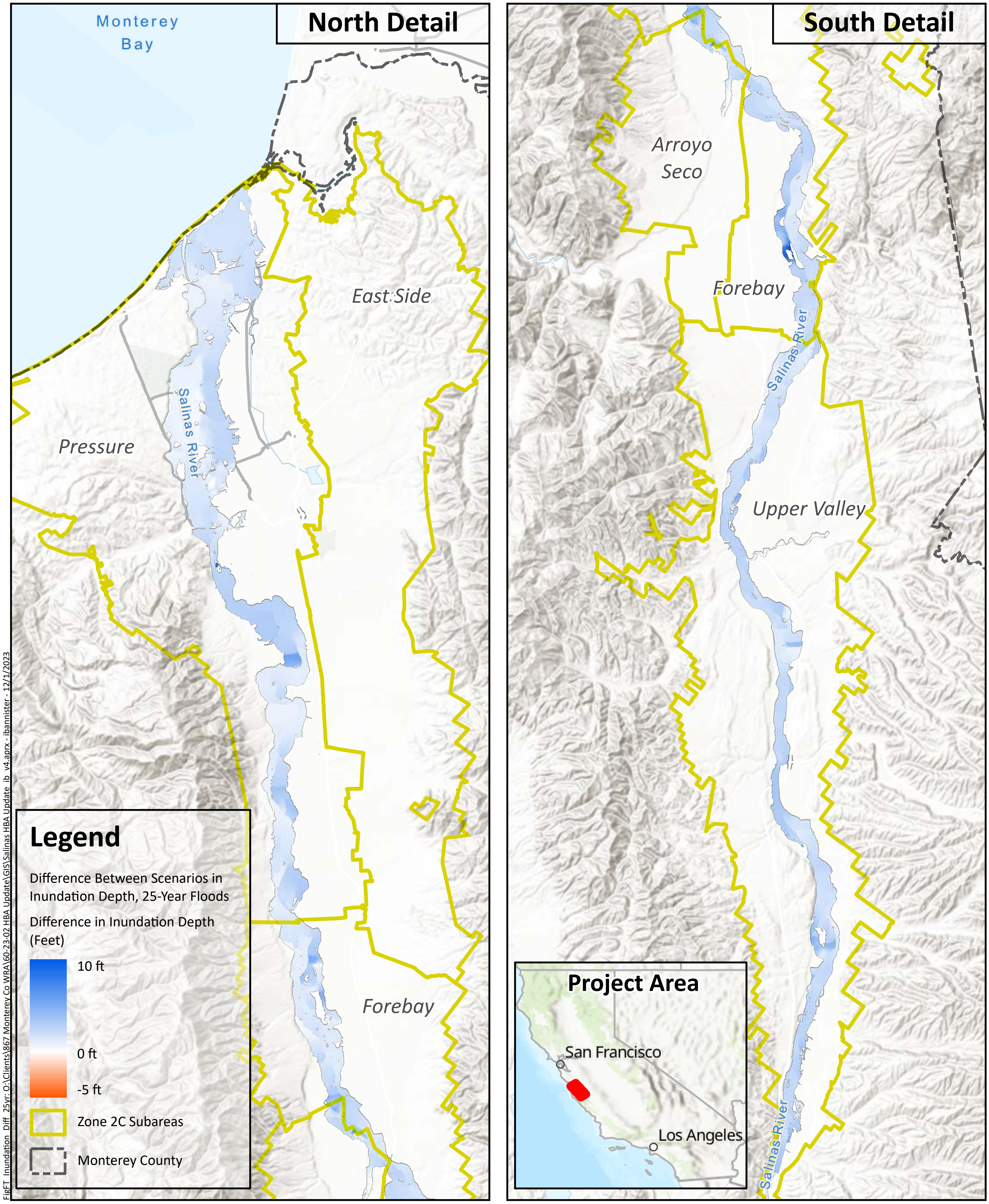
Difference Between Scenarios in Inundation Depth for 50-Year Flood

Figure 4-19



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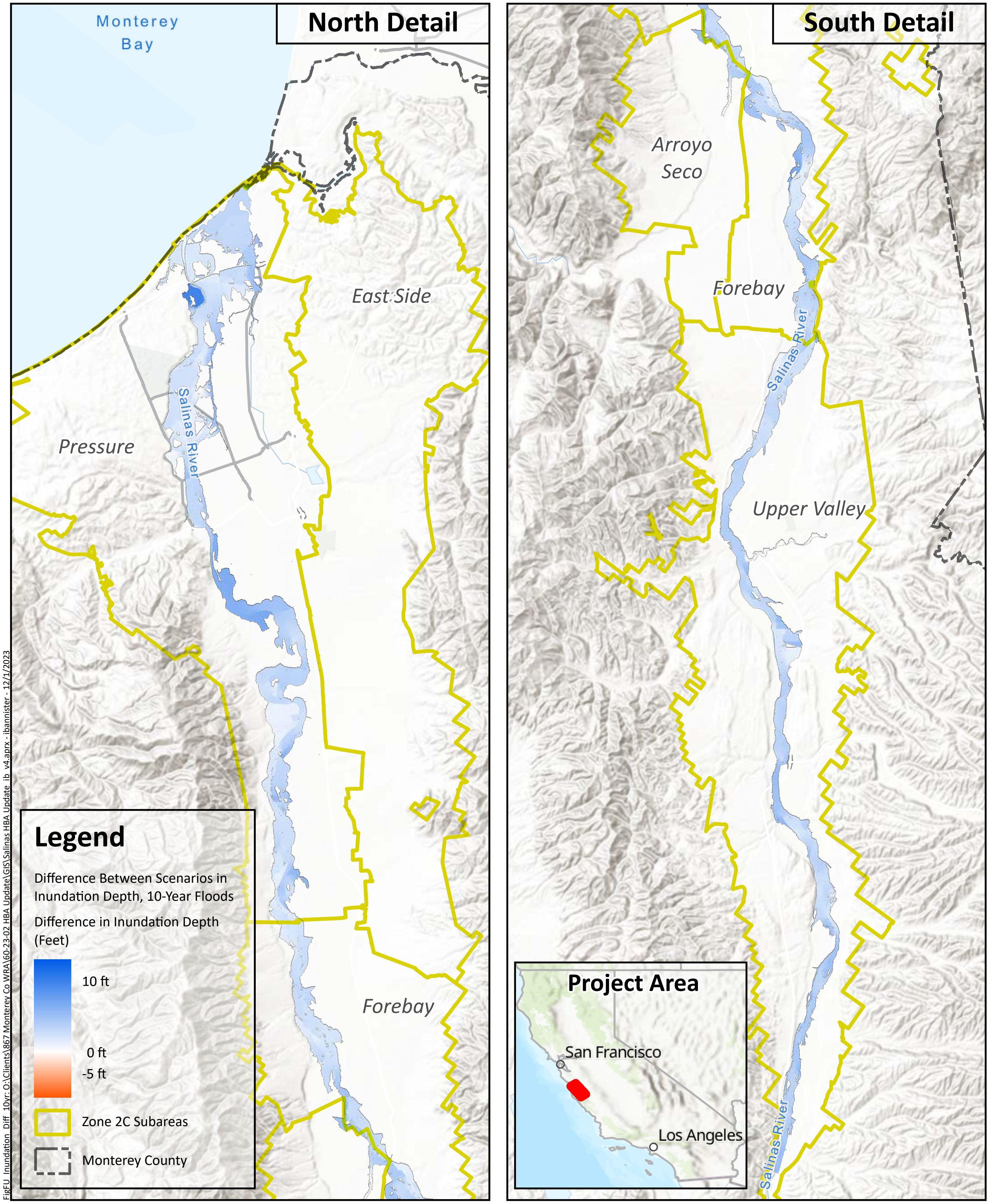
Difference Between Scenarios in Inundation Depth for 25-Year Flood

Figure 4-20



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Difference Between Scenarios in Inundation Depth for 10-Year Flood

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0 8 Km

Figure 4-21

Figure 4-22 shows a map of Flood Study Units (FSUs), which (as in the 1998 HBA) are derived directly from the extent of the ESUs (see Section 3.2.3). The extent of each FSU is equivalent to the extent of the corresponding ESU, clipped to the extent of the Salinas River HEC-RAS Model domain. Because the HEC-RAS model does not cover the entire area of Zone 2C, some ESUs (i.e., 1 and 13) do not have corresponding FSUs. Table 4-5 provides the inundated acreage for the 100-year, 50-year, 25-year, and 10-year events under the Historical and No Projects Scenarios by FSU; as above, an area is considered inundated if the HEC-RAS model simulates at least 0.1 foot depth of water there. Reductions in inundated area are spread across the FSUs, with the largest reductions occurring in FSU 3. The reductions in inundated acreage are largest for the 10-year event, both in magnitude and percentage, reflecting the fact that the Projects have the greatest effect on these more frequent events, as noted above.

4.4.2 Flow Velocity

The velocity of water flowing in inundated areas has important ramifications for the degree of impact that flood events will have on agricultural resources (e.g., crops and soil) and the built environment (e.g., buildings) within the inundated area. This section presents the distribution of flow velocity within the inundated area under each of the events included in this Flood Benefits Analysis.

Figure 4-23 shows the simulated flow velocity for the 100-year flood event under the Historical Scenario. The flow velocity of water in the inundated area is mostly about 5 feet per second (fps) or less. Flow velocities tend to be lower in the northern part of the study area compared to the southern area, where the floodplain is more constrained laterally. Flow velocities within the Salinas River channel are generally below 20 fps.

Figures 4-24, 4-25, and 4-26 show the simulated flow velocities for the 50-year, 25-year, and 10-year flood events, respectively, under the Historical Scenario. As the recurrence period shortens, the simulated flow velocities decline, with the lowest simulated flow velocities occurring under the 10-year event. For each, flow velocities are highest in the southern part of the study area, where the floodplain is narrower.

Figure 4-27 shows the simulated flow velocity for the 100-year flood event under the No Projects Scenario. The overall pattern of flow velocities is similar to the Historical Scenario 100-year event (Figure 4-23), but flow velocities are generally higher under the No Projects Scenario. In the southern part of the study area, flow velocities are generally between 5 and 10 fps across the majority of the floodplain, compared to between 2 and 10 fps under the Historical Scenario. In the northern part of the study area, north of about Chualar, flow velocities are generally about 2 to 10 fps, compared to mostly about 1 to 5 fps under the Historical Scenario.

Figures 4-28, 4-29, and 4-30 show the simulated flow velocities for the 50-year, 25-year, and 10-year flood events, respectively, under the No Projects Scenario. As under the Historical Scenario, simulated flow velocities decrease as the recurrence period shortens. Simulated flow velocities are higher for each event under the No Projects Scenario than under the Historical Scenario.

These results show that, by reducing the magnitude of peak flow events, the Projects reduce the velocity of flow within the inundated area of the Salinas River floodplain during floods. Because the floodplain is fairly narrow south of about King City, this area still experiences higher flow velocities compared to the northern part of the study area, but the Projects reduce flow velocities throughout. These reduced flow velocities reduce the chances of flood-induced damage to crops, agricultural soils, buildings, and other structures.

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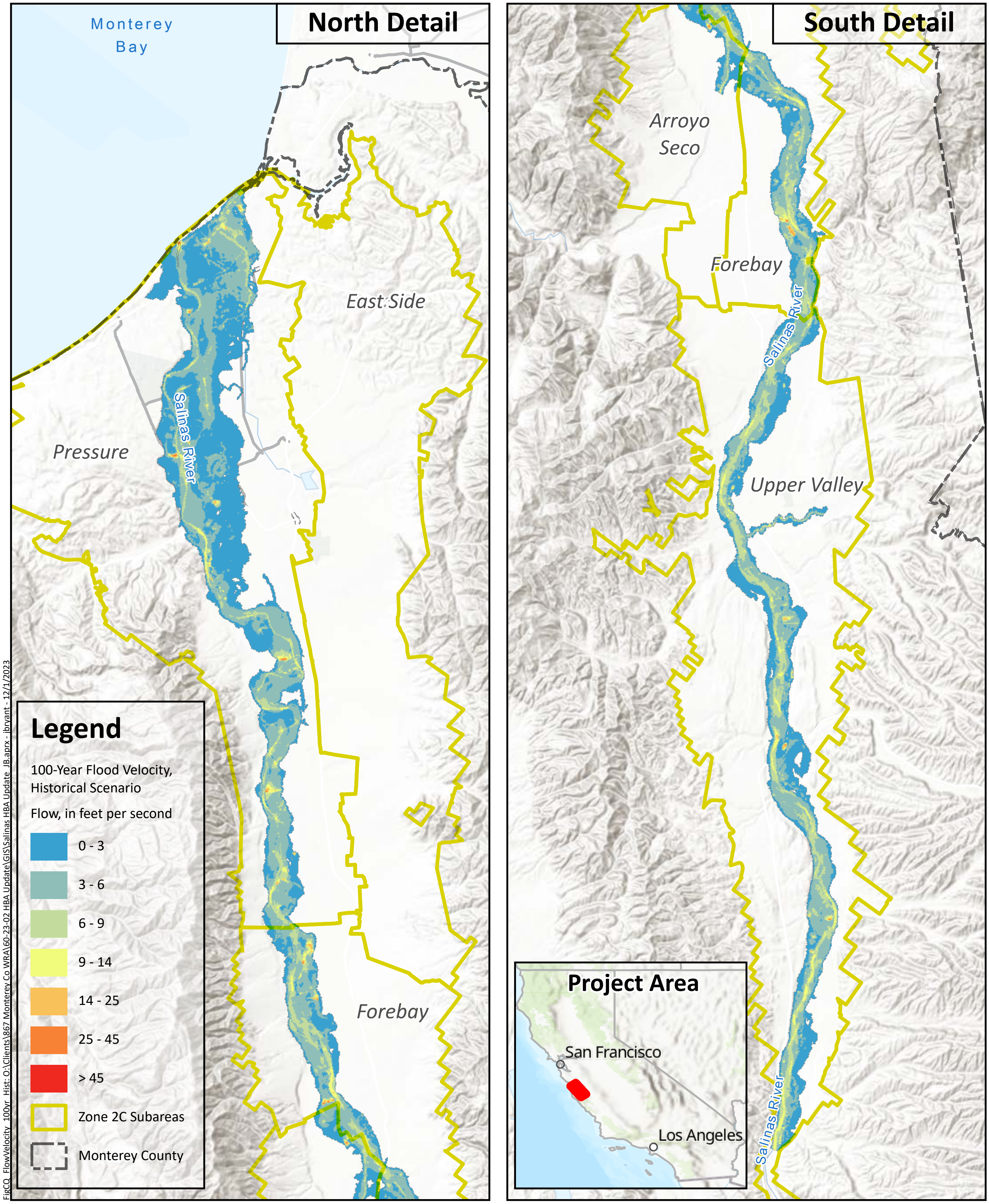
MONTEREY COUNTY WATER RESOURCES AGENCY 1947

Flood Study Units

Figure 4-22



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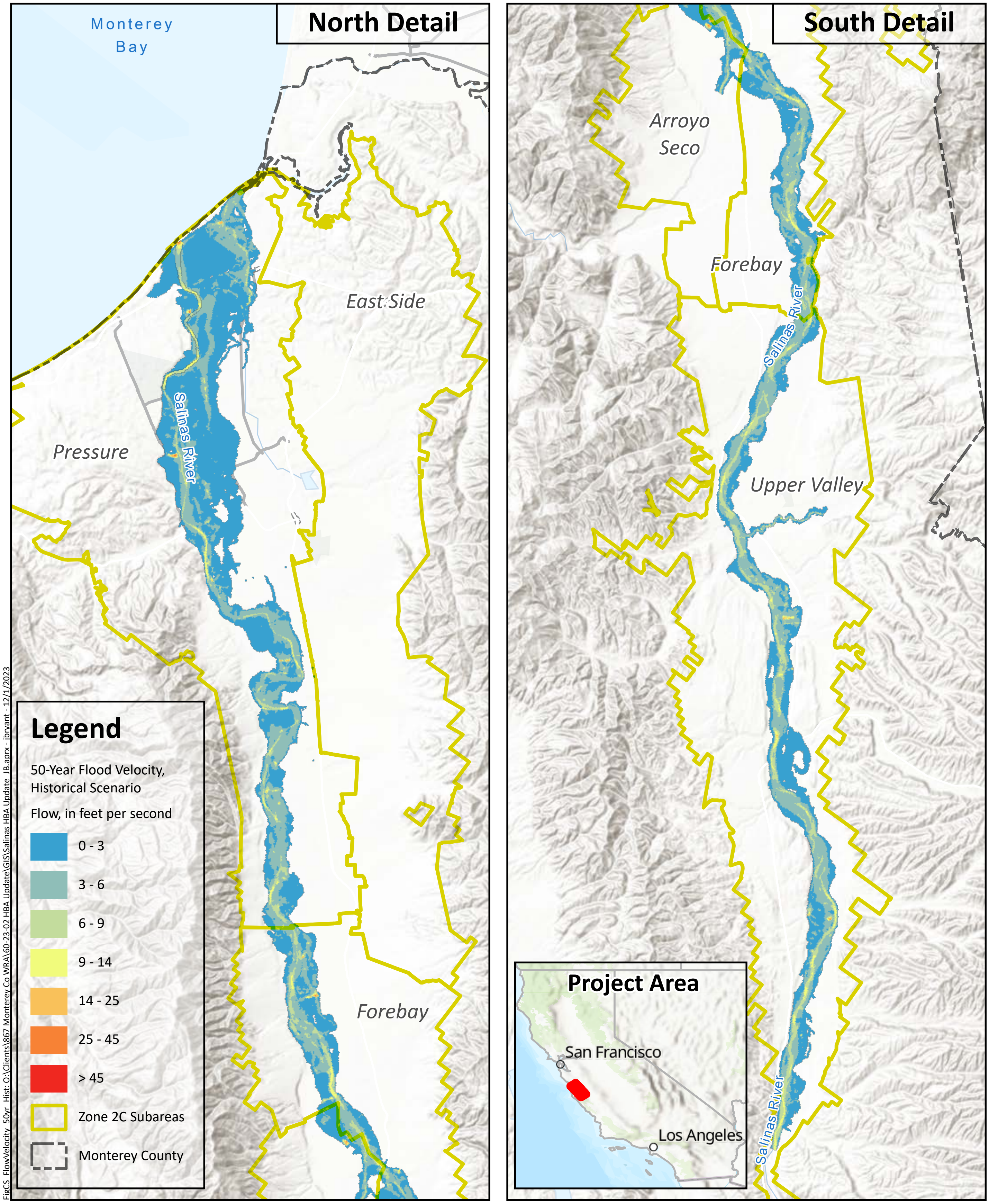
Flow Velocity for 100-Year Flood

Historical Scenario

Figure 4-23



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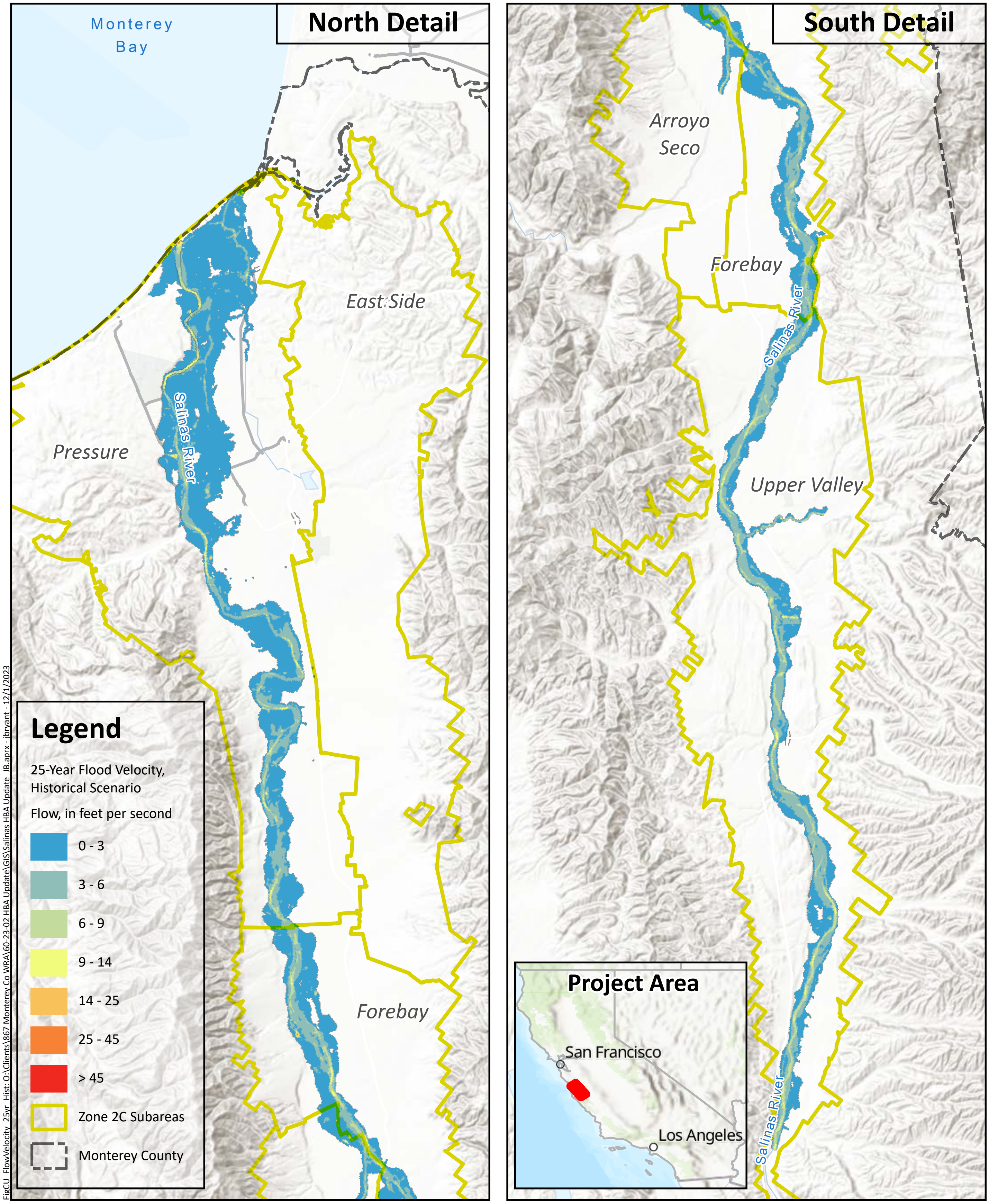
Flow Velocity for 50-Year Flood
Historical Scenario

Figure 4-24



FigCU_FlowVelocity_25yr_Hist: O:\Clients\867 Monterey Co WRA\60-23-02 HBA Update\GIS\Salinas HBA Update_JB.aprx - lbryant - 12/1/2023

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WEST YOST

N

0 5 Miles

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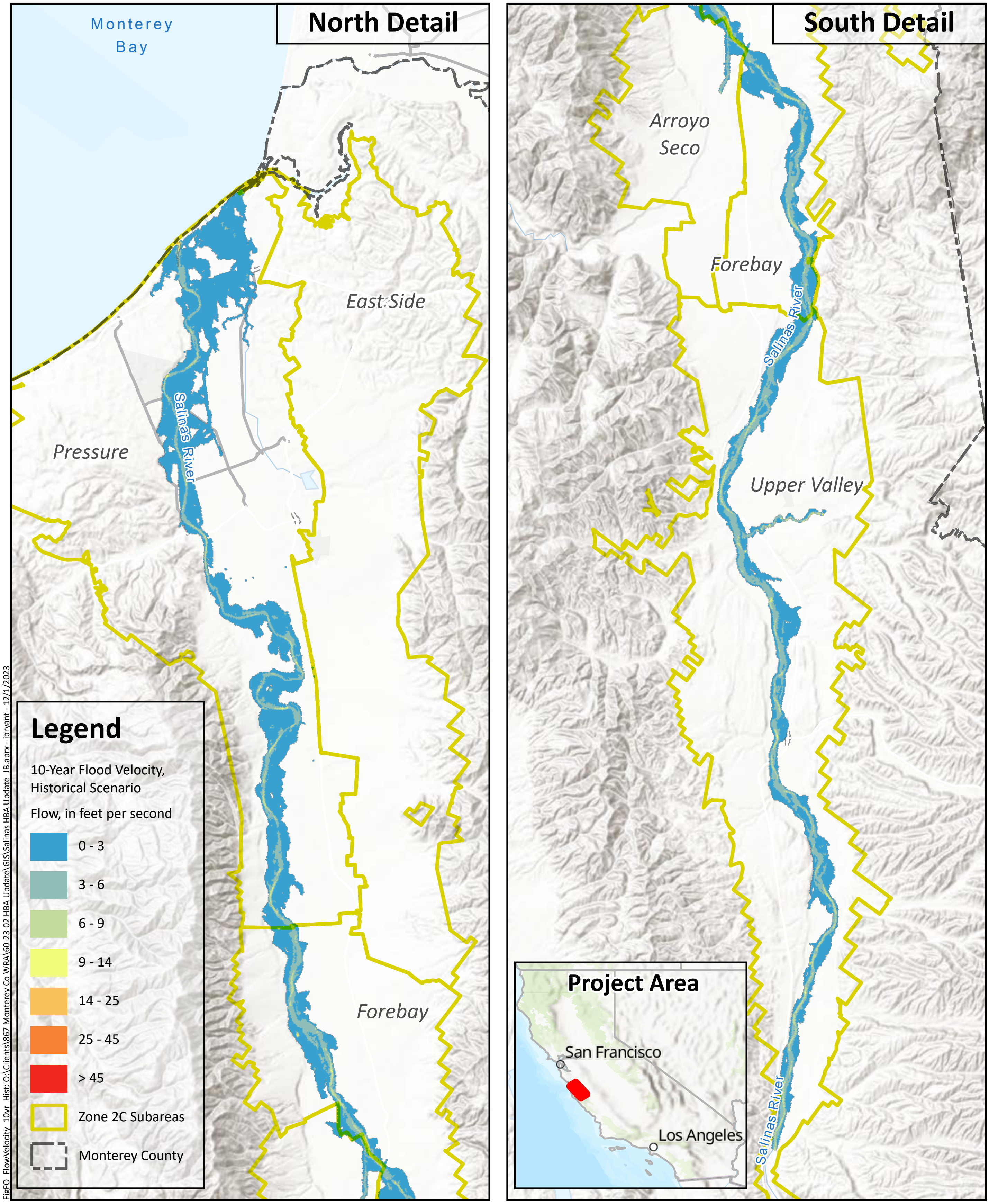
Flow Velocity for 25-Year Flood

Historical Scenario

Figure 4-25

FigFO_FlowVelocity_10yr_Hist: O:\Clients\867 Monterey Co WRA\60-23-02 HBA Update\GIS\Salinas HBA Update_JB.aprx - lbryant - 12/1/2023



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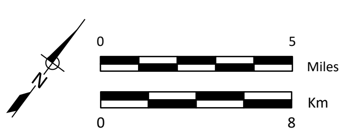
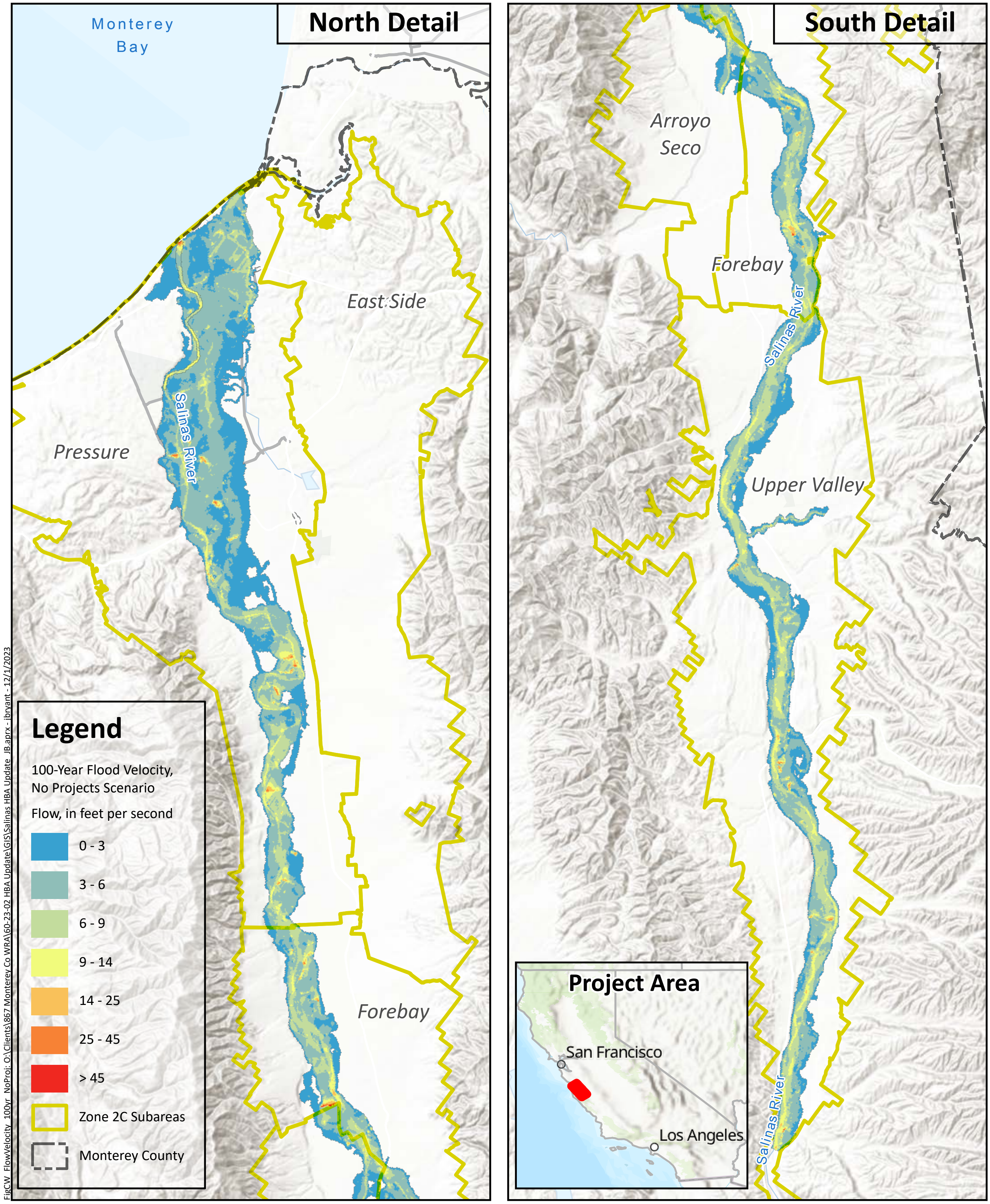


MONTEREY COUNTY WATER RESOURCES AGENCY 1947

Flow Velocity for
10-Year Flood
Historical Scenario

Figure 4-26



Prepared by:

WEST YOST

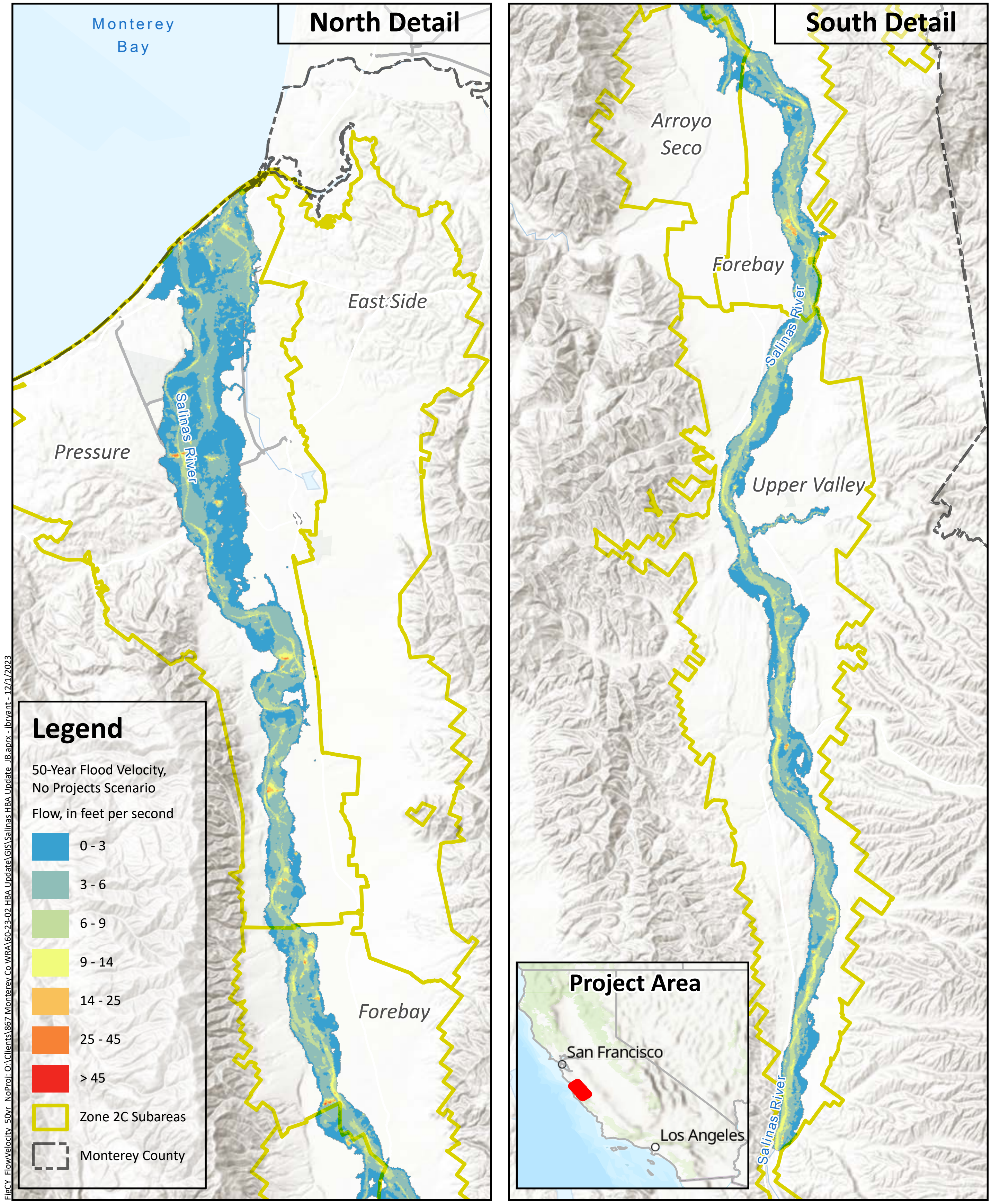
0 5 Miles

0 8 Km

Flow Velocity for 100-Year Flood

No Projects Scenario

Figure 4-27



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0 5 Miles

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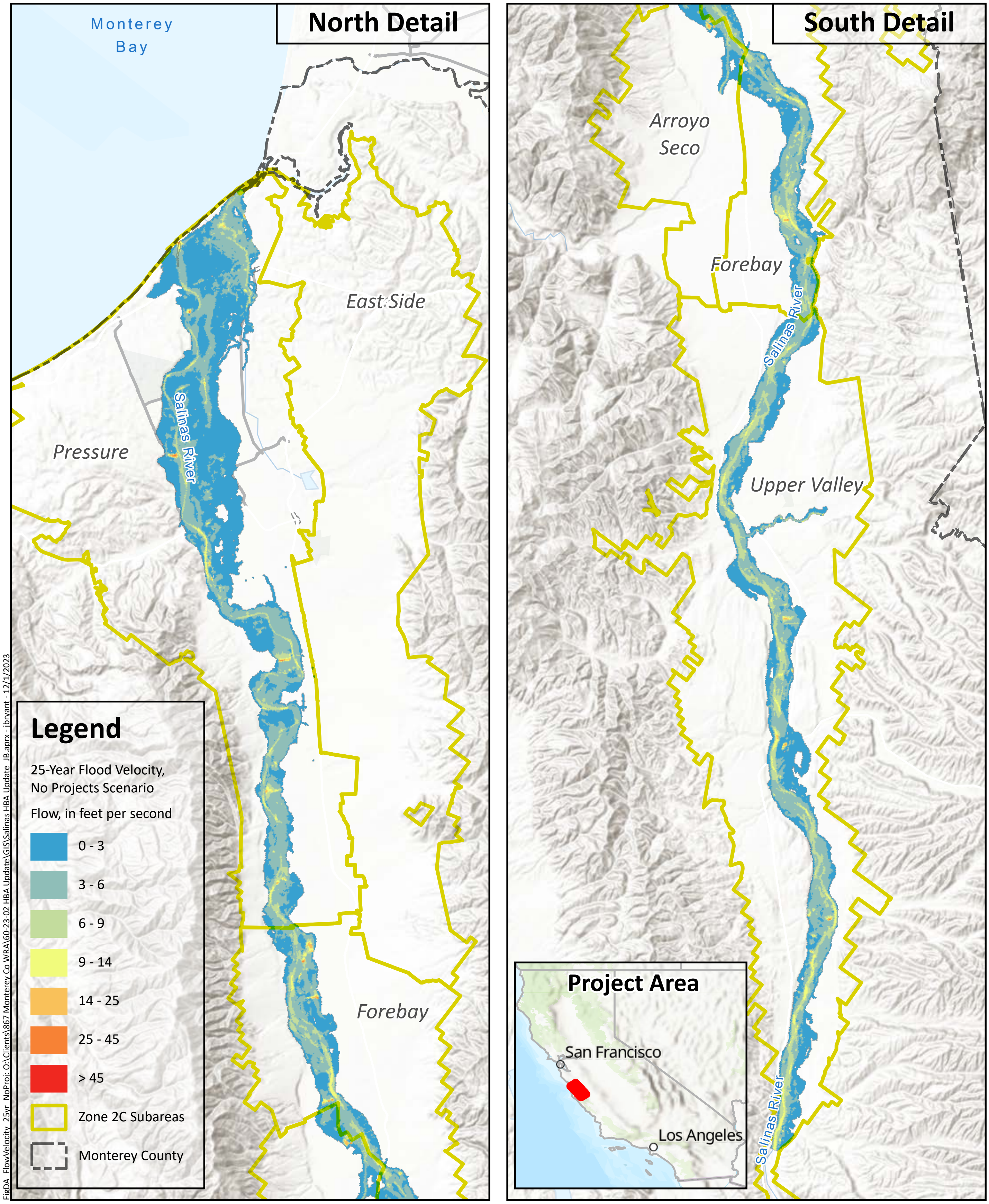
Flow Velocity for 50-Year Flood

No Projects Scenario

Figure 4-28



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Prepared by:

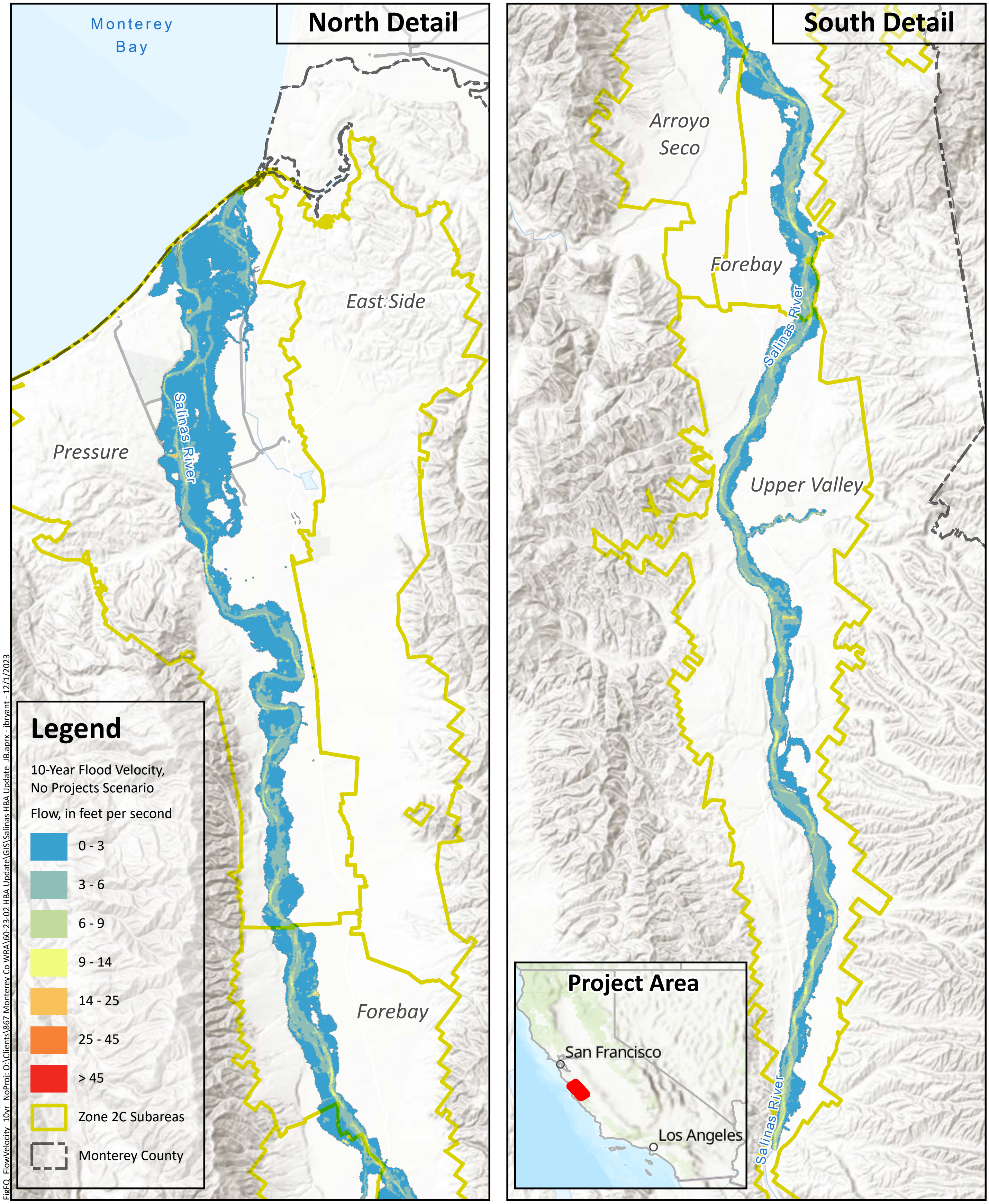
WEST YOST

0 5 Miles

0 8 Km

Flow Velocity for
25-Year Flood
No Projects Scenario

Figure 4-29



FigFQ_FlowVelocity_10yr_NoProj: O:\Clients\867 Monterey Co WRA\60-23-02 HBA Update\GIS\Salinas HBA Update_JB.aprx - jbryant - 12/1/2023

Prepared by:

WEST YOST

0 5 Miles

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Flow Velocity for
10-Year Flood
No Projects Scenario

Figure 4-30

Table 4-5. Inundated Area (in acres) by FSU, Historical and No Projects Scenarios

	Historical Scenario				No Projects Scenario				Difference Between Scenarios			
Return Period	100	50	25	10	100	50	25	10	100	50	25	10
Annual Exceedance Probability	0.01	0.02	0.04	0.1	0.01	0.02	0.04	0.1	0.01	0.02	0.04	0.1
FSU 2	0	0	0	0	0	0	0	0	0	0	0	0
FSU 3	18,900	16,700	13,800	8,100	20,300	18,900	17,300	14,400	-1,500	-2,300	-3,500	-6,300
FSU 4	310	290	260	150	370	300	290	260	-60	-20	-40	-120
FSU 5	0	0	0	0	0	0	0	0	0	0	0	0
FSU 6	6,500	6,000	5,500	4,600	7,400	6,600	6,100	5,600	-800	-600	-600	-1,000
FSU 7	3,800	3,700	3,500	2,700	4,200	3,800	3,700	3,500	-300	-200	-200	-800
FSU 8	4,900	4,600	4,300	2,800	5,200	4,900	4,700	4,400	-300	-200	-500	-1,600
FSU 9	7,000	6,600	5,700	4,300	7,300	7,100	6,900	6,100	-200	-500	-1,200	-1,800
FSU 10	1,500	1,200	1,000	400	1,700	1,500	1,300	1,000	-200	-300	-300	-500
FSU 11	7,500	6,400	5,700	4,400	8,500	7,800	7,100	6,000	-900	-1,400	-1,400	-1,600
FSU 12	9,500	8,200	5,800	4,200	10,100	9,800	9,200	6,900	-600	-1,600	-3,400	-2,700

Notes:
- Areas are rounded to the nearest hundred acres, except for FSU 4, which is rounded to the nearest ten acres because of the smaller areas; totals may not sum due to rounding.
- Difference between scenarios is calculated as Historical Scenario minus No Projects Scenario

4.4.3 Soil Erosion Susceptibility

The 1998 HBA presented an estimation of the extent to which soil present within the Salinas River floodplain might be susceptible to erosion due to inundation during flood events. Soils were categorized into low, medium, or high erosion potential index categories based on published soil information and simulated flow velocities from inundation modeling under peak flow events. A similar approach was utilized here to estimate the potential for soil erosion with and without the Projects.

The estimation of soil erosion susceptibility for this HBA Update utilized a similar approach to that of the 1998 HBA. Two data sources contributed to this analysis: published soil data from the U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) Soil Series Geographic (SSURGO) Database (Soil Survey Staff, 2023) and streamflow velocities output by the Salinas River HEC-RAS Model (see Section 4.4).

The SSURGO database contains data related to mapped soil types throughout the study area. Spatial data consist of soil map units, each of which may contain several different soil types. Each soil type is assigned a soil erodibility factor (K_w) that denotes the susceptibility of that soil type to erosion by runoff; soils with multiple horizons (i.e., vertical variability) may have different K_w values for different soil horizons. For simplicity, the K_w value for the shallowest soil horizon was used, since the shallowest soil layer would be most exposed to erosion by runoff. For map units with multiple different soil types present, the K_w value for the soil making up the largest percentage of the map unit was used. Within the study area, K_w values vary from 0.02 to 0.49. This analysis used the same soil erodibility factor categories as the 1998 HBA, except that the lower end of the range was lowered to the minimum value of 0.02: low from 0.02 to 0.28; medium from 0.29 to 0.47; and high from 0.48 to 0.64.

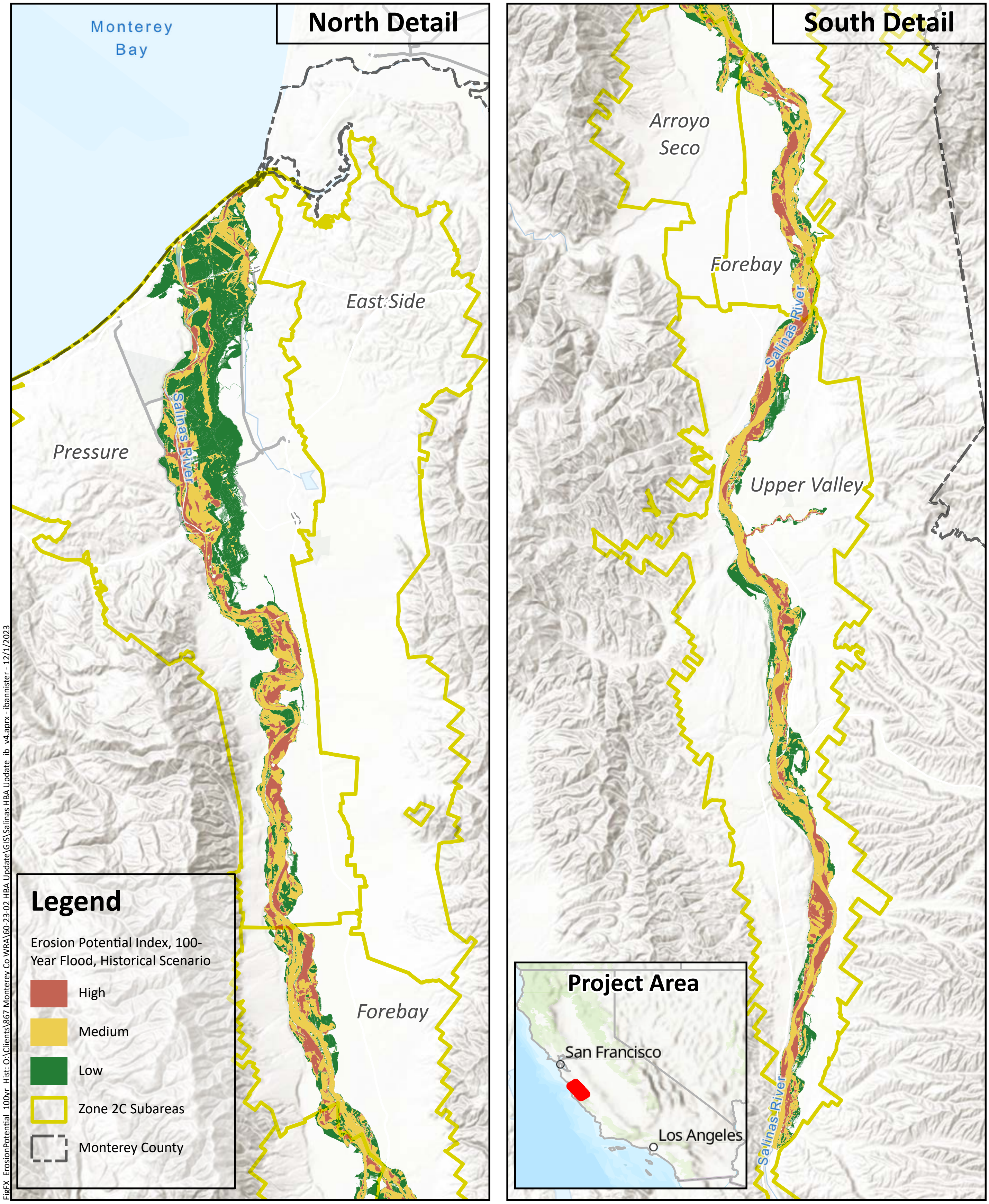
Following the approach of the 1998 HBA, inundation flow velocities were categorized into low (0 to 2 feet per second), medium (2 to 4 feet per second) and fast (at least 4 feet per second). See Figures 4-23 and 4-27 for the simulated flow velocities for the 100-year floods under the Historical and No Projects scenarios, respectively.

The categorization based on K_w and the categorization based on flow velocity were combined to create a categorization of soil erosion susceptibility, termed the Erosion Potential Index (EPI) to follow the 1998 HBA. The three categorizations relate to each other as follows:

- low EPI groups areas with low K_w and low velocity, low K_w and medium velocity, and medium K_w and low velocity;
- medium EPI groups areas with low K_w and high velocity, medium K_w and medium velocity, and high K_w and low velocity; and
- high EPI groups areas with medium K_w and high velocity, high K_w and medium velocity, and high K_w and high velocity.

Figure 4-31 shows the EPI categories for the Historical Scenario 100-year flood. Figure 4-32 shows the EPI categories for the No Projects 100-year flood. Table 4-6 provides a tabulation of the acreage within each FSU of low, medium, and high EPI for the 100-year flood for both scenarios. Because the 100-year flood under the No Projects Scenario inundates a larger area than the same event under the Historical Scenario, the total area is larger for the No Projects Scenario than the Historical Scenario. The No Projects Scenario 100-year flood results in larger acreages of medium and high EPI and fewer acres of low EPI compared to the Historical Scenario. The differences between the 100-year flood events for the two scenarios represents the benefit provided by the Projects in terms of the prevention of soil erosion. The largest reductions in the area of high EPI occurred in FSUs 12 (about 1,300 acres), 6 (about 1,000 acres), and 3 (about 900 acres). No FSU experienced an increase in the area of high EPI.

This analysis does not take into account the duration of flooding, since the Salinas River HEC-RAS Model was run in a quasi-steady state to only represent the conditions under the peak flow magnitude.



FigFX_ErosionPotential_100yr_Hist: O:\Clients\867 Monterey Co WRA\60-23-02 HBA Update\GIS\Salinas HBA Update_ib_v4.aprx - ibannister - 12/1/2023

Prepared by:

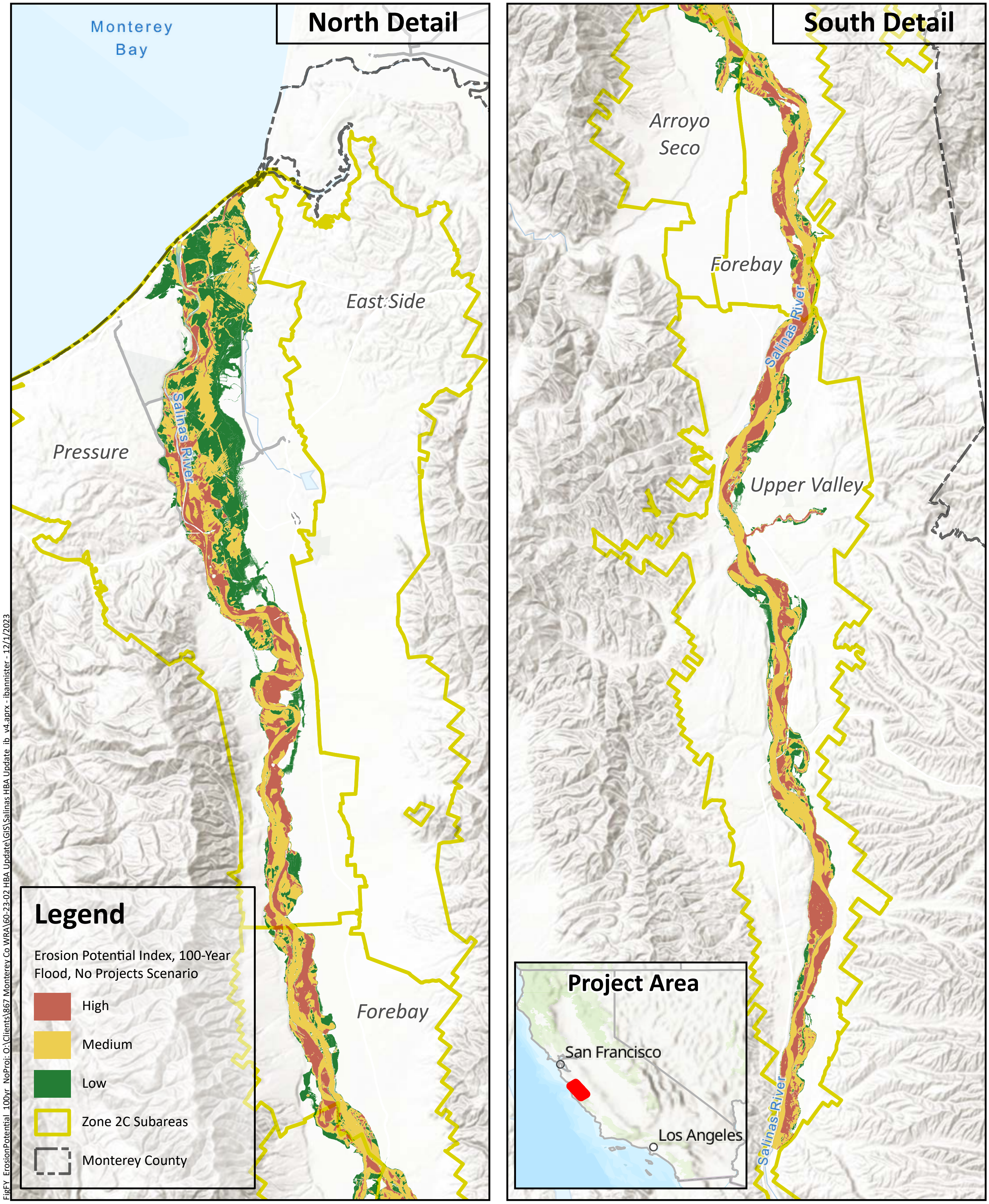
WEST YOST

0 5 Miles

0 8 Km

Erosion Potential Index
100-Year Flood
Historical Scenario

Figure 4-31



FigFY_ErosionPotential_100yr_NoProj: O:\Clients\867 Monterey Co WRA\60-23-02 HBA Update\GIS\Salinas HBA Update_ib_v4.aprx - ibannister - 12/1/2023

Prepared by:

0 5 Miles
0 8 Km

Erosion Potential Index
100-Year Flood
No Projects Scenario

Figure 4-32

Table 4-6. Area (in acres) in Each Erosion Potential Index Category by FSU for 100-Year Event, Historical and No Projects Scenarios									
	Historical Scenario			No Projects Scenario			Difference Between Scenarios		
Erosion Potential Index Category	Low	Medium	High	Low	Medium	High	Low	Medium	High
FSU 2	0	0	0	0	0	0	0	0	0
FSU 3	12,080	5,040	1,480	9,900	7,710	2,380	+2,180	-2,670	-900
FSU 4	100	120	70	130	110	110	-30	+10	-40
FSU 5	0	0	0	0	0	0	0	0	0
FSU 6	2,050	2,950	1,580	2,020	2,840	2,600	+30	+110	-1,020
FSU 7	890	2,030	920	730	2,140	1,290	+160	-120	-370
FSU 8	1,100	2,630	1,150	970	2,560	1,710	+130	+60	-550
FSU 9	1,380	790	1,430	820	4,220	2,130	+550	-3,430	-700
FSU 10	530	790	190	460	850	370	+60	-50	-180
FSU 11	1,990	3,730	1,870	1,610	4,210	2,670	+380	-480	-800
FSU 12	2,170	5,130	2,280	1,150	5,410	3,600	+1,030	-280	-1,320

Notes:
- Areas are rounded to the nearest 10 acres; totals may not sum due to rounding
- Difference between scenarios is calculated as Historical Scenario minus No Projects Scenario

CHAPTER 5
Economic Benefits Analysis

The goal of the 1998 HBA was to develop an estimate for the benefit that stakeholders in the Salinas Valley have received due to the construction and operation of the Nacimiento and San Antonio Reservoirs. This Economic Benefit Analysis was accomplished by translating the Hydrologic and Flood Control Benefits into monetary benefits.

This HBA Update does not include an Economic Benefits Analysis; it is being prepared by One Water Econ under separate cover based on the results of this report.

CHAPTER 6
Other Benefits

The 1998 HBA included a qualitative discussion of other benefits that the Nacimiento and San Antonio Reservoirs have provided to stakeholders in the Basin. None of these additional benefits were included in the Hydrologic, Flood Control, or Economic Benefits in the 1998 HBA. This HBA Update similarly discusses, in general terms, additional benefits that the Projects provide to stakeholders in the Basin, guided by the equivalent discussion in the 1998 HBA.

6.1 RECREATION AND TOURISM

The Nacimiento and San Antonio Reservoirs provide recreational benefits to the study area. Since they were constructed, they have enabled stakeholders and visitors to the Basin to experience various outdoor activities, including camping, hiking, and fishing. Communities like Heritage Ranch have developed around the reservoirs. Recreation and tourism do not provide stakeholders in the Basin with additional water or flood protection, but they do embody economic benefits. Recreational benefits are evaluated and quantified in further detail in the Economic Benefits Analysis prepared by One Water Econ.

6.2 ENVIRONMENTAL BENEFITS

In addition to the benefits that have accrued to the groundwater system and to lands in the floodplain, the Projects have, through their operation, maintained streamflow in the Salinas, Nacimiento, and San Antonio Rivers that has supported fish and wildlife habitat in the stream network. A major focus of this activity is the migration of endangered Steelhead trout through the Salinas River and its tributaries. The Flow Prescription (MCWRA, 2005) has been used since its publication as a guidance document for MCWRA's operation of the Nacimiento and San Antonio Reservoirs. This document provides information on the life cycle of Steelhead trout in the system and recommendations for streamflow targets whose timing, location, and magnitude are designed to best support migration to and from spawning grounds.

These environmental benefits are not quantified for this HBA Update. Studies are ongoing on how to operate the reservoirs to minimize negative effects on endangered Steelhead trout and other fish and wildlife in the Salinas River and its tributaries.

6.3 SYSTEM RELIABILITY

The model results presented in this HBA Update indicate that the Salinas River and its tributaries are critical to maintaining groundwater head levels in the study area as the stream network loses water to the study area aquifers. While streamflow losses are generally higher with higher streamflow, the proportion of streamflow lost to groundwater is higher during dry and normal years than during wet years (see data in Tables 3-10, 3-11, and 3-12). This indicates that the benefit of water stored during wet years is increased flow in the Salinas River during drier years. The Projects' effect on groundwater head and storage are quantified in Chapter 3. However, there is an unquantifiable benefit to providing peace of mind to stakeholders in the Basin in terms of the reliability of streamflow in the Salinas River and recharge to the groundwater system. Figure 4-2 shows the annual total simulated streamflow in the Salinas River at Bradley. These model results suggest that there might have been many more years with little flow (i.e., below 200,000 af) in the Salinas River without the Projects (dotted line) – as compared to the observed Historical data (solid line).

6.4 INSURANCE AGAINST UNCERTAIN FUTURE CONDITIONS

There is no clear consensus in the available climate projections to indicate that precipitation in the Salinas Valley should be expected to either increase or decrease in the future, although each is possible. However, the year-to-year precipitation is expected to become more variable in the future as a result of climate change (Bedsworth et al., 2018). The Projects may become more and more important in the future as rainfall conditions become even more unpredictable than they already are. This represents a reduction in future risk and a benefit to stakeholders in the future, rather than a historical benefit.

CHAPTER 7
Discussion of Uncertainty

This HBA Update relies on the support of complex numerical models built from conceptual models and historical datasets that have been developed over decades; these tools are considered to be the best available for characterizing the benefits of the Projects. Uncertainties and limitations inherent to the tools and analyses on which this HBA Update are built are acknowledged and discussed in this section. This discussion is not a rigorous quantitative uncertainty analysis, which would involve a systematic modification of model parameters and investigation of the effect of those changes. Instead, presented herein is a listing of the sources of uncertainty and limitations inherent to the analyses.

This chapter categorizes uncertainties and limitations into those related to the understanding of the Basin (based on observed data), the models used, and the interpretation of the model results. This discussion is not exhaustive.

7.1 UNCERTAINTIES RELATED TO THE BASIN CONCEPTUAL MODEL

Natural hydrogeologic systems host a level of complexity that cannot be fully represented with empirical data and models. Hydrogeologic complexity (i.e., heterogeneity) exists on different scales and can impact the system's behavior in many ways. Typically, a calibrated model in its best practice sense seeks to define parameters (such as aquifer hydraulic conductivity) that best represent the overall behavior but may not capture the full range of variability in a hydrogeologic system.

Although a defined hydrostratigraphy (i.e., aquifers and aquitards) helps with conceptualizing a system, it is a simplification of the actual distribution of the materials making up the porous medium in which groundwater exists. Various studies of the Salinas Valley (e.g., Kennedy/Jenks, 2004, Brown and Caldwell, 2015a) focused on the hydrostratigraphy of the Basin aquifers and shown that the recognized aquitards and aquifers in the Basin conceptual model (e.g., the 180-Foot, 400-Foot, and Deep Aquifers in the Pressure Subarea) are highly variable in terms of their thickness and interconnection. Gaps exist in the aquitards separating aquifers from each other, including between the Shallow Aquifer and the 180-Foot Aquifer in the Pressure Subarea. The kind of large-scale hydrostratigraphic heterogeneity discussed here can be captured in a modeling tool like the SVIHM through changes to model layer thickness and parameters. Smaller-scale variability may be difficult to reflect in a modeling tool like the SVIHM that is intended to investigate an entire system.

Of particular importance to future of water resources development in the Salinas Valley is the characteristic of the connection between the Deep Aquifers and the Pacific Ocean. The other major production aquifers, the 180-Foot and 400-Foot Aquifers, have been shown to be directly connected to the Ocean beneath Monterey Bay. Seawater intrusion into the 180-Foot and 400-Foot Aquifers has led to an increase in the number of production wells being drilled in the Deep Aquifers. Increased use of groundwater in the Deep Aquifers has increased the urgency for a resolution of the state of connection with the Pacific Ocean. MCWRA has convened a Deep Aquifer Roundtable of hydrogeologic experts familiar with the study area to address gaps in the understanding of the Deep Aquifers and their connection to the Ocean, and to help guide data collection efforts in the future to address these uncertainties. In January 2022, the Salinas Valley Basin Groundwater Sustainability Agency initiated a study of the Deep Aquifers, the results of which are anticipated in 2024.

7.2 UNCERTAINTIES RELATED TO THE MODELING TOOLS

The models used in this study, the SVIHM and the Salinas River HEC-RAS model, represent the natural environment. They are effective tools for understand the system and are built from conceptual models that best represent the inherent heterogeneity in the study area's surface water and groundwater systems. Although the integrated use of models (SVIHM/HEC-RAS) is very informative, the models are not expected to fully capture the full complexity of the groundwater and surface water systems.

The SVIHM simulates conditions in both the groundwater and surface water systems across a very large geographical area (the model domain is almost 100 miles long from its southern to northern ends) and includes a number of processes that are extremely complex on their own (especially groundwater-surface water interaction and agricultural supply and demand estimation). Developing a complex tool like the SVIHM requires that decisions be made early on to identify the focus of the calibration. For a tool that is designed to simulate conditions throughout a large basin, calibration cannot focus on local conditions everywhere in the model domain. Usually, calibration will concentrate on the overall ability of the model to reproduce observed historical conditions, as quantified using calibration statistics. This report cannot comment on the calibration focus or quality for the SVIHM as its documentation has not yet been published by the USGS. No model produces a perfect match to observed conditions, and the quality of the match varies from place to place. A basin-wide model like the SVIHM should not be expected to reproduce conditions equally well at all locations in the model and should not be considered indicative of small-scale conditions (e.g., at an individual well).

An important assumption made for the SVIHM is that the Nacimiento River is not part of the active model domain until a location about 5 miles downstream of the location of Nacimiento Dam. Figure 4-3 shows where the SVIHM stream boundary condition cells are present along the Nacimiento River. This approach assumes that no interaction occurs between the Nacimiento River and underlying sediments within this 5-mile stretch just downstream of Nacimiento Dam.

The software packages used to build the modeling tools used in this analysis (MODFLOW-OWHM for the SVIHM and HEC-RAS 2D for the Salinas River HEC-RAS Model) rely on their own sets of assumptions to simulated natural groundwater and surface water flow processes. The documentation for these software packages (Boyce et al., 2020; USACE, 2016) discuss these assumptions, and it is beyond the scope of this report to discuss these assumptions here.

7.3 UNCERTAINTIES RELATED TO THE ANALYSIS

The last source of uncertainty affecting the results of the benefit estimation discussed herein stems from the analyses used to prepare the HBA Update. These analyses translate the SVIHM and Salinas River HEC-RAS Model results into indicators of the effects of the Projects on the system. The results of these analyses are presented throughout this HBA Update. Limitations and uncertainties related to the analyses that are specific to the Flood Control Benefits Analysis are presented in their own section in Appendix B.

The benefits quantified in this HBA Update are based on differences between the Historical and No Projects Scenarios results. The Historical Scenario was simulated using the SVIHM as delivered by the USGS with very little modification. Simulation of the No Projects Scenario required certain modifications to the SVIHM to approximate the system without the Projects. This followed the approach used for the 1998 HBA to simulate the Basin in a "without reservoirs" condition. Estimated daily reservoir inflow time series were provided by MCWRA for each reservoir over their periods of operation, and these inflow time series were used as the inputs to the SVIHM where the Nacimiento and San Antonio Rivers enter the active model domain (locations shown on Figure 4-3). The application of the reservoir inflow time series as inputs to the SVIHM assumes that there is no lag between where the inflow is determined and where that water enters the SVIHM domain. It also assumes no interaction between that inflow and the surrounding environment (e.g., no groundwater-surface water interaction). The temporal discretization of the SVIHM (monthly stress periods) means that any lag would be insignificant compared to the stress period length. The Nacimiento and San Antonio Lakes are located in valleys largely floored with bedrock, minimizing the extent to which the rivers would interact with their surroundings.

Other than the changes described in Chapter 2, the SVIHM was not modified from the configuration used for the Historical Scenario to produce the No Projects Scenario. It is reasonable to assume that if the Projects had not been present in the system, groundwater users would have been forced to compensate in certain ways for the impacts they would have experienced; for example, additional wells might have been installed in the Deep Aquifers due to decreased heads in the 180-foot and 400-foot Aquifers in the Pressure Area. This HBA Update does not make changes (for example, to the construction or locations of pumping wells in the study area) to anticipate or respond to conditions without the reservoirs.

As described in Appendix B, the estimation of peak flow magnitudes on which the Flood Control Benefits Analysis is based depends on a number of assumptions and correlative relationships between datasets. Each linear regressions that went into determining the peak flow magnitudes - that fed into the Salinas River HEC-RAS Model - introduces some amount of uncertainty to the results. It is beyond the scope of this study to quantify these uncertainties. A modeling tool that could realistically simulate short-term streamflow conditions (i.e., sub-daily) and longer-term groundwater flow conditions together at the same time might obviate some of these limitations, but no such tool exists for this system. The modeling tools utilized for this HBA Update (the SVIHM and the Salinas River HEC-RAS Model are the best available tools for understanding the dynamic groundwater-surface water system of the Salinas Valley.

CHAPTER 8
Summary and Conclusions

This HBA Update represents an update to the 1998 Salinas Valley Historical Benefits Analysis (MW, 1998), an important document in the hydrology of the study area. The 1998 HBA quantified the benefits that the stakeholders of the Basin have received from the operation of the Nacimiento and San Antonio Reservoirs from when each came online to the end of WY 1994. These benefits were quantified in terms of monetary benefits received due to the avoidance of costs related to modification of wells, reduction of energy required for groundwater pumping, and decreased frequency and magnitude of damaging inundation of the Salinas River floodplain. The 1998 HBA found that the reservoirs had provided, up to the end of the period of analysis, about $11.8 million per year of benefit to stakeholders in the Basin.

In the 25 years since the 1998 HBA was published, there have been numerous changes to the Basin conceptual model, additional data collected, new projects (including the SVWP), and new and better tools for analyzing conditions in the Basin. These changes have resulted in a need for an updated HBA. This study was accomplished by simulating conditions within the Salinas Valley with and without the Projects (including the reservoirs) in place over the historical period from WY 1968 (when San Antonio Reservoir began operating) and WY 2018 (the end of the SVIHM period as of the publication of this document). The difference between the with-Projects (Historical Scenario) and without-Projects (No Projects Scenario) is taken to be the effect of the Projects. An analysis that separately quantifies the benefits of individual Projects (e.g., only Nacimiento Reservoir or just the SVWP) would be impractical because the various Projects are deeply interrelated, and their effects cannot be fully separated from each other. Therefore, this study presents the benefits provided by all the Projects together. This report includes some qualitative discussion of the Project or Projects that are likely to have contributed most substantially to particular differences between the scenarios.

This study utilizes the USGS' SVIHM, which is a preliminary MODFLOW-OWHM model of the groundwater-surface water system of the Salinas Valley, including the dynamic estimation of agricultural supply and demand. As described in Chapter 2, the SVIHM has not yet been published by the USGS and remains a preliminary product without available documentation as of the publication of this HBA Update.

8.1 HYDROLOGIC BENEFITS

The Salinas Valley has experienced an overall increase in the amount of fresh groundwater in storage in the Basin aquifers due to the presence of the Projects. This has manifested as increased groundwater head and decreased seawater intrusion from Monterey Bay. Higher head values have resulted in reduced pumping lift in wells and reduced energy use. Groundwater pumping has also been reduced in the CSIP area due to the provision of recycled water and diverted Salinas River flow to this area. The hydrologic benefits of the Projects are discussed in Chapter 3.

The Projects result in higher head values in the study area aquifers. Higher heads were concentrated in two portions of the study area: the area between Castroville and Salinas and along the Salinas River from about Bradley to Gonzales. By the end of the model period (September 2018), head was as much as about 67 feet higher in the 400-Foot Aquifer of the Pressure Subarea in the area between Castroville and Salinas. Head along the Salinas River was up to about 15 feet higher by September 2018. Although head in much of the study area was lower at the end of the model period compared to the start even with the Projects, this decline was substantially smaller than it would have been without the Projects. Head declined by up to about 3.0 feet per year in the area between Castroville and Salinas with the Projects; the average annual head decline was about 3.3 feet per year in the same area without the Projects.

The increased groundwater heads reflect an increase in groundwater storage resulting from additional water entering the groundwater system. Groundwater budgets indicate that the Projects have resulted in about 72,000 afy more streamflow losses from the Salinas River and its tributaries to the study area aquifers; most of the increase has occurred in the Upper Valley Subarea (about 44,000 afy) and the Forebay Subarea (about 20,000 afy). The resulting higher head values have resulted in about 45,000 afy more discharge to agricultural drains and about 14,000 afy less net recharge, also mostly focused in the Upper Valley and Forebay Subareas. The Projects have also resulted in about 10,000 afy less agricultural pumping, with most of the reduction taking place in the Pressure Subarea. Although storage declined (by an average of about 11,000 afy) with the Projects, this storage loss would have been substantially greater (about 31,000 afy) without the Projects.

Although the SVIHM cannot be used in its current state to directly simulate the intrusion of seawater into the freshwater aquifers of the study area, model results indicate that seawater intrusion has been about 1,000 afy lower with the Projects than it would have been without the Projects.

Surface water budget information indicates that the increase in streamflow losses (about 72,000 afy) caused by the Projects has resulted in a decrease in Salinas River outflow to Monterey Bay of about 51,000 afy. The Projects have also resulted in about 21,000 afy less inflow along the Nacimiento and San Antonio Reservoirs, likely reflecting evaporation from the reservoir surfaces and the provision of water to San Luis Obispo County and lakeside users from Nacimiento Reservoir. Increased head values due to the Projects have resulted in about 45,000 afy more land surface runoff in the study area.

The Projects have resulted in little difference in the ability of groundwater wells to operate (for example, due to lowered groundwater head values). However, the Projects have led to substantially less agricultural pumping, especially in the Pressure Subarea, where there has been about 299,000 af less pumping than would have occurred without the Projects. Smaller reductions in agricultural pumping have taken place in the Upper Valley (about 104,000 af) and Forebay (about 76,000 af) Subareas.

The above changes to the groundwater and surface water systems demonstrate how the Projects have benefited the Salinas Valley over the past 50 years. The Nacimiento and San Antonio Reservoirs have held back high winter flows for release during the summer period and during dry years to recharge the aquifers of the Basin. Less water has flowed out to Monterey Bay, and therefore been kept within the Basin. Streamflow losses have been substantially larger during dry and normal years. The implementation of the CSIP west of Salinas has maintained substantially higher heads in the area between Castroville and Salinas and reduced agricultural pumping in this area, as well as decreased the rate of seawater intrusion into the Basin; these changes can be attributed to the operation of CSIP because their onset coincides with the beginning of CSIP operation in 1998.

8.2 FLOOD CONTROL BENEFITS

The Projects have resulted in a decrease in the frequency and magnitude of major inundation events in the floodplain of the Salinas River. The Nacimiento and San Antonio Reservoirs have provided this benefit by storing high flows during wet winter periods and releasing flows during drier parts of the year. The reservoirs act to attenuate flood peaks generated in the Nacimiento and San Antonio River watersheds rather than passing them directly to the Salinas River. The flood control benefits of the Projects are discussed in Chapter 4.

The operation of the reservoirs has resulted in smaller floods in the system. This is shown in the Flood Frequency Curves for the Salinas River at Bradley with and without the Projects, which quantify the magnitude of events of various return periods. These curves indicate that the 100-year flood event is about 115,000 cfs with the Projects in place, versus about 159,000 cfs without the Projects (a reduction of about 44,000 cfs, 28 percent of the No Projects 100-year flood). For more frequent events, the Projects have resulted in larger proportional reductions in the magnitude of the peak flows; for example, the 10-year event (about 28,000 cfs with the Projects and about 68,000 cfs without) has a 58 percent decrease in magnitude. The larger proportional decreases in peak flow magnitudes for smaller events reflects the fact that the reservoirs cannot necessarily capture the entirety of the highest flow events because reservoir capacity may not be sufficient to fully store the event inflow.

The reduced magnitude of peak flow events has resulted in less inundation of the Salinas River floodplain than would have occurred had the Projects not been in place. The 100-year flood without the Projects would result in about 65,000 acres inundated, versus about 60,000 acres for the 100-year flood with the Projects. Larger decreases in inundated area are estimated for more frequent events; for example, the 10-year event would result in about 48,000 acres inundated without the Projects and about 32,000 acres inundated with the Projects.

In addition to decreasing the extent of inundation, the Projects, by reducing the magnitude of peak flows, result in lower streamflow velocities in the Salinas River floodplain. This results in decreased potential for erosion in the floodplain; for the 100-year flood, the area of high potential for erosion was about 11,000 acres with the Projects and about 17,000 without.

These results indicate that the Projects have led to less flooding in the Salinas River floodplain, protecting both agricultural resources (crops and soils) and structural resources (buildings).

8.3 ECONOMIC BENEFITS

The economic benefit provided by the Projects can be estimated from the other types of benefits described in this HBA Update, but this report does not provide a quantification of the monetary benefits; instead, these are being prepared separately for MCWRA based on the results of this study. The economic benefits analysis will be published under separate cover.

8.4 OTHER BENEFITS

The Projects provide additional benefits other than the hydrologic and flood control benefits that are difficult or impossible to quantify. These include recreational and tourism benefits, environmental benefits, improved system reliability, and insurance against uncertain future conditions. Other benefits are described briefly in Chapter 6.

CHAPTER 9
References

9.1 REFERENCES

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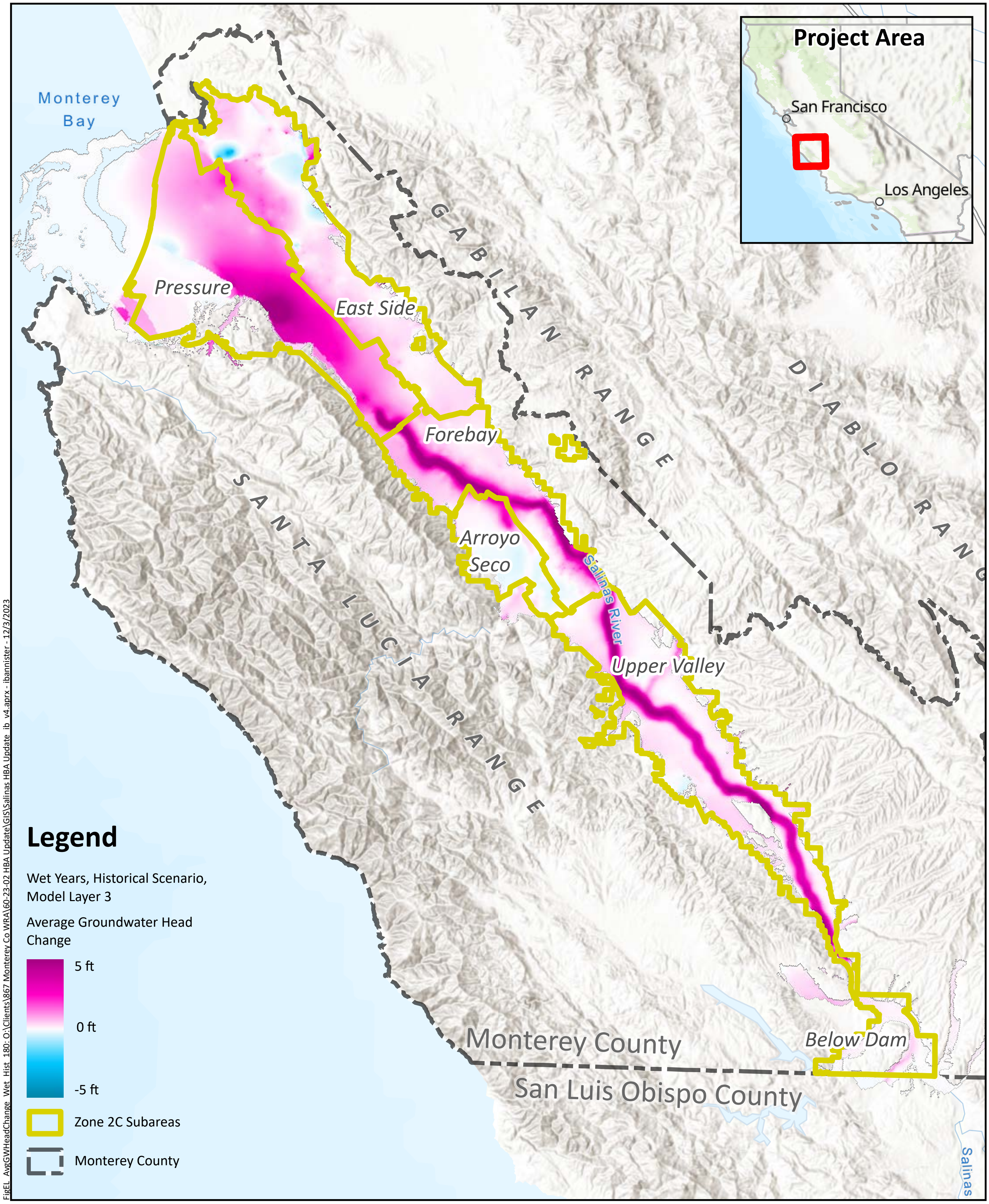
Appendix A

Additional Simulated Groundwater Head Maps

LIST OF FIGURES



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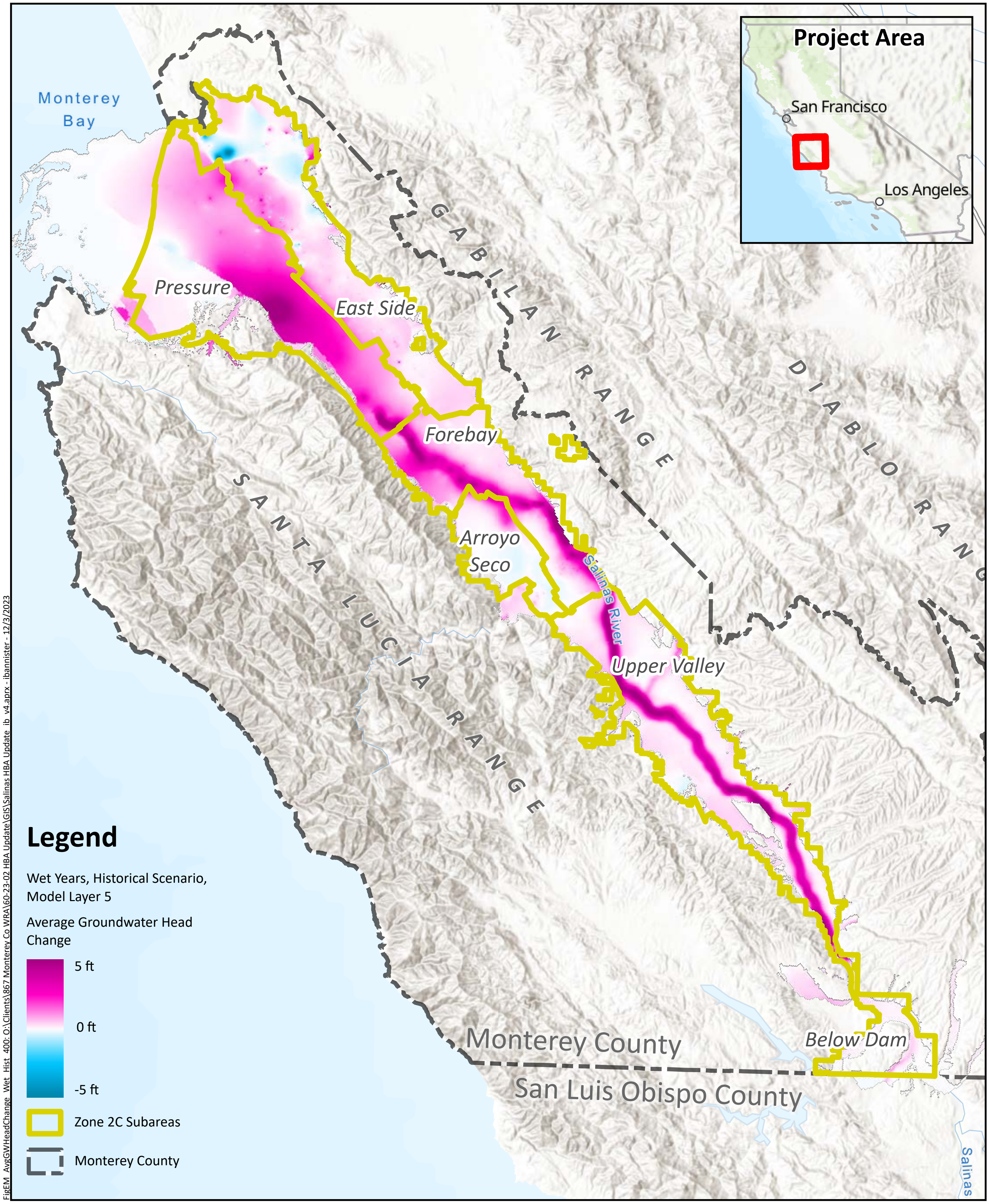
Average Annual Groundwater Head Change Historical Scenario, Wet Years
180-Foot Aquifer & Equivalent

Figure A1



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Average Annual
Groundwater Head Change
Historical Scenario, Wet Years
400-Foot Aquifer & Equivalent

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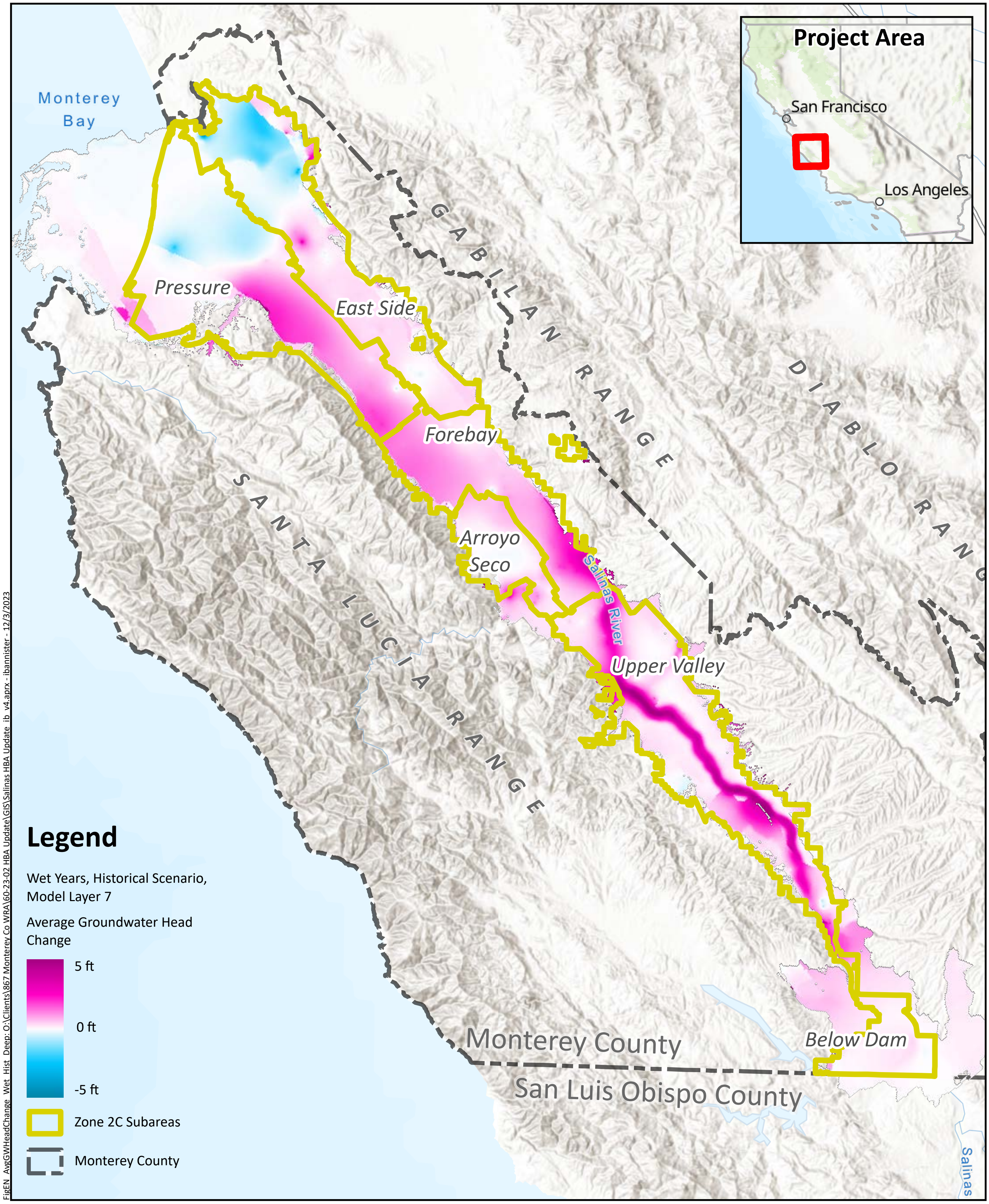

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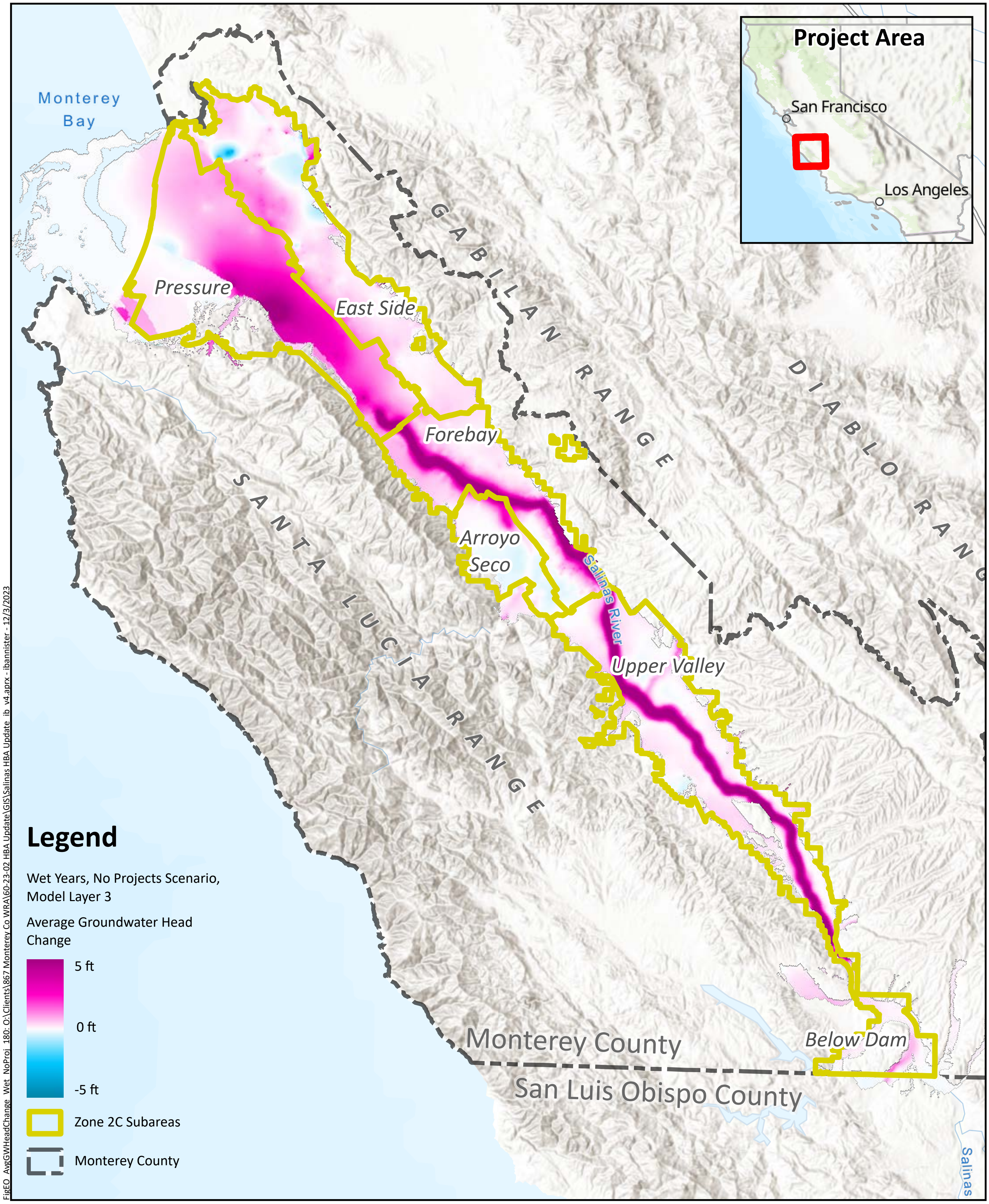
Average Annual Groundwater Head Change Historical Scenario, Wet Years
Deep Aquifer

Figure A?



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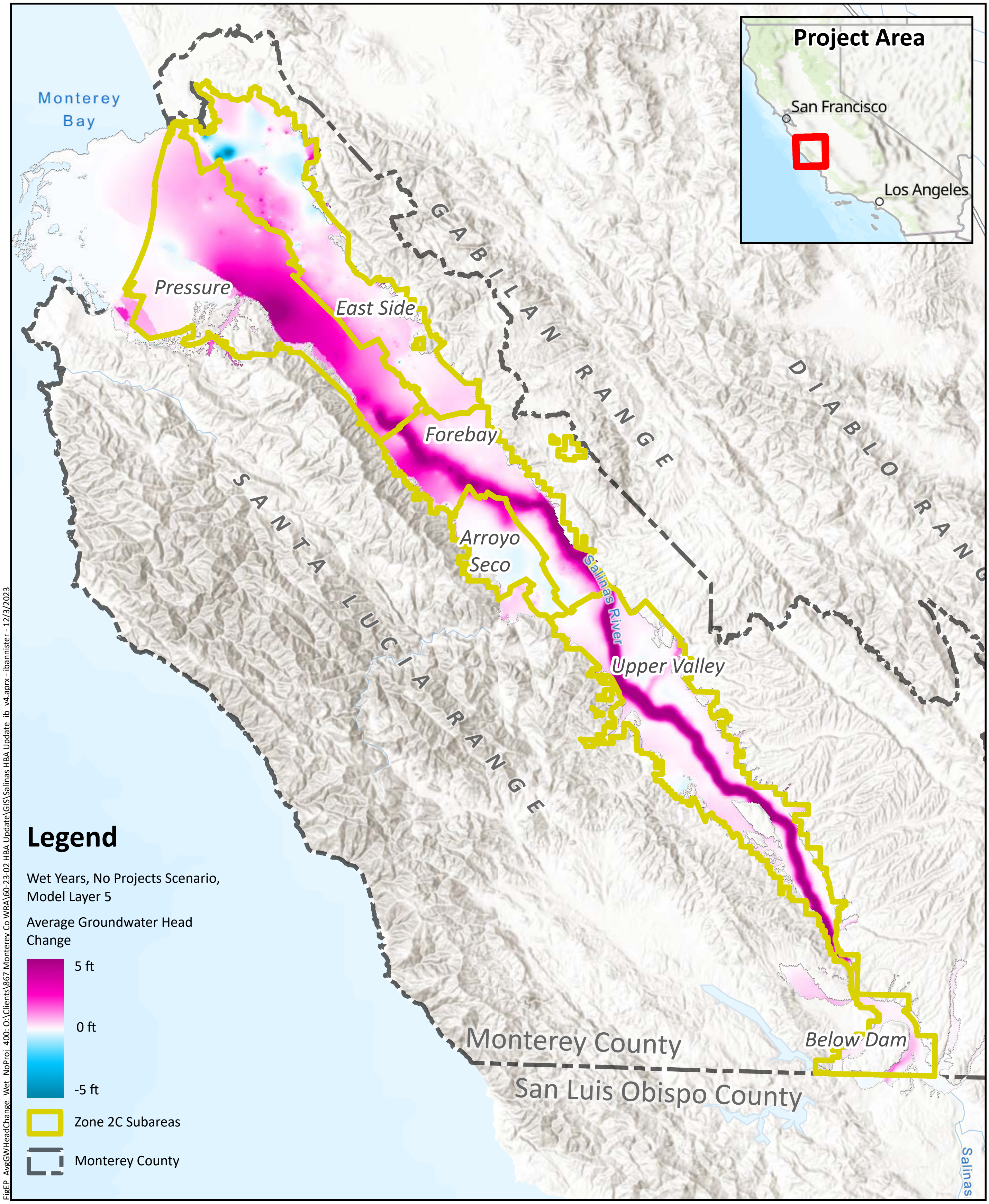
Average Annual Groundwater Head Change No Projects Scenario, Wet Years

180-Foot Aquifer & Equivalent

Figure A4



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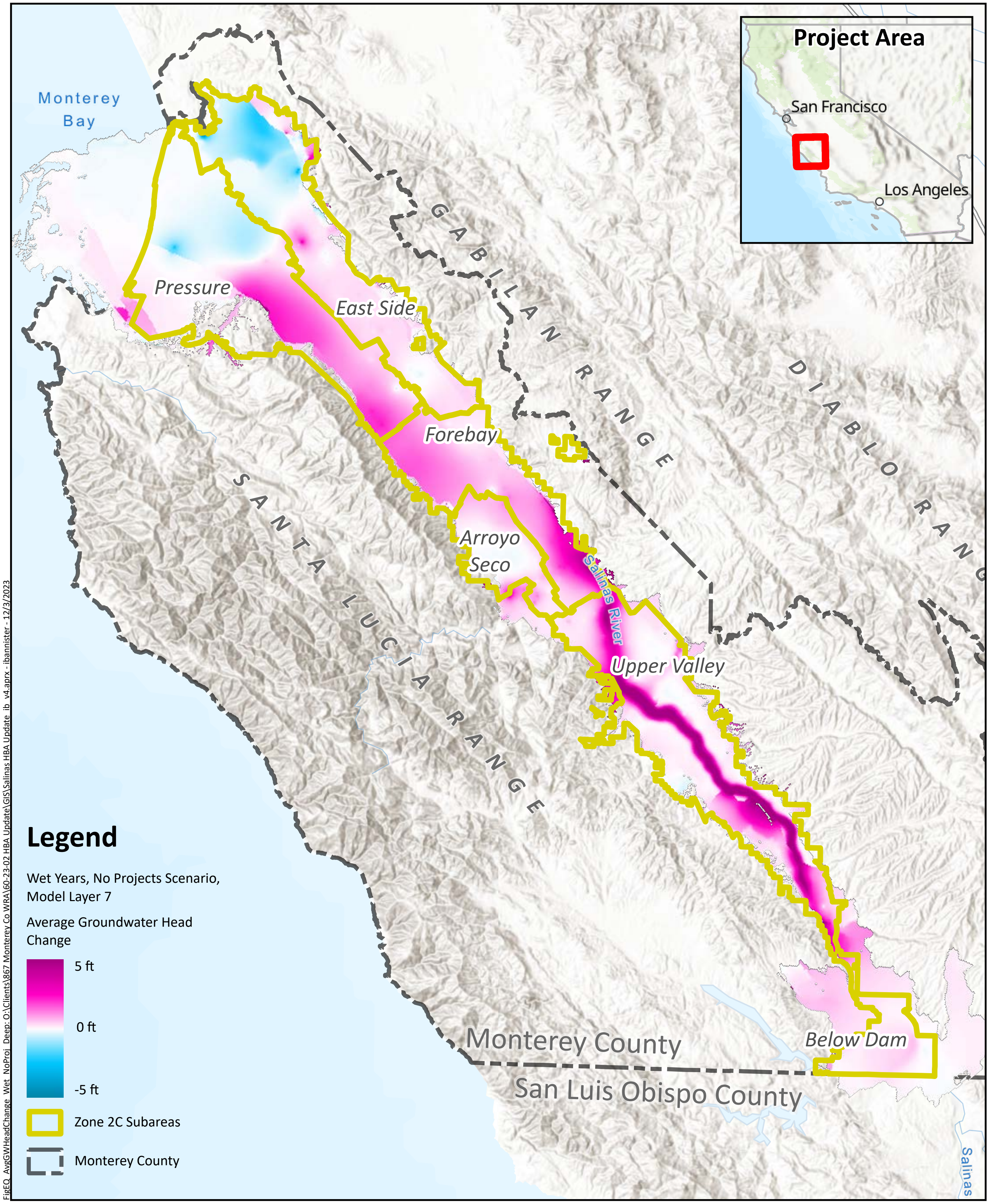
April 2025

Average Annual Groundwater Head Change No Projects Scenario, Wet Years

400-Foot Aquifer & Equivalent

Figure A5



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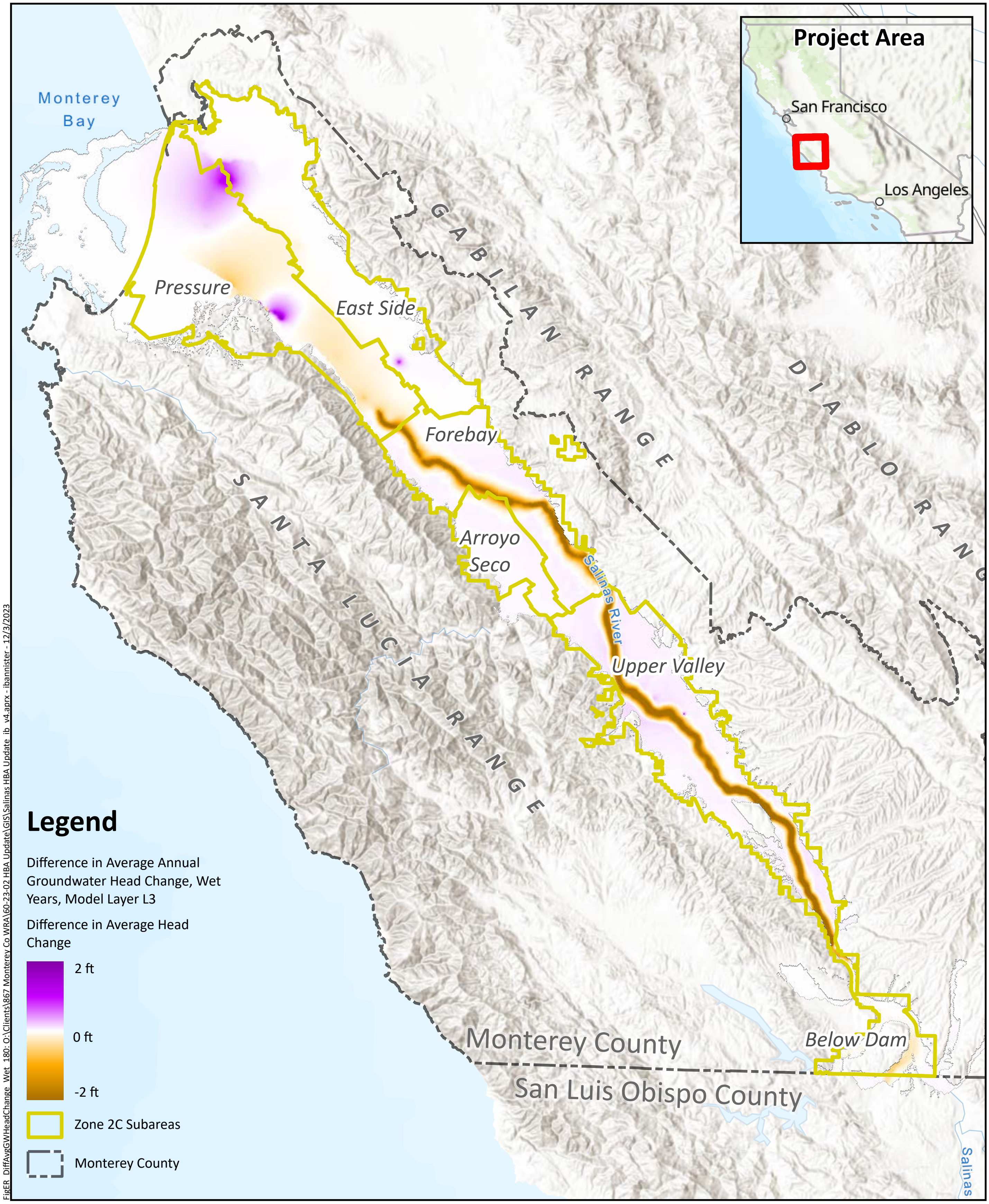
Average Annual Groundwater Head Change No Projects Scenario, Wet Years

Deep Aquifer

Figure A6



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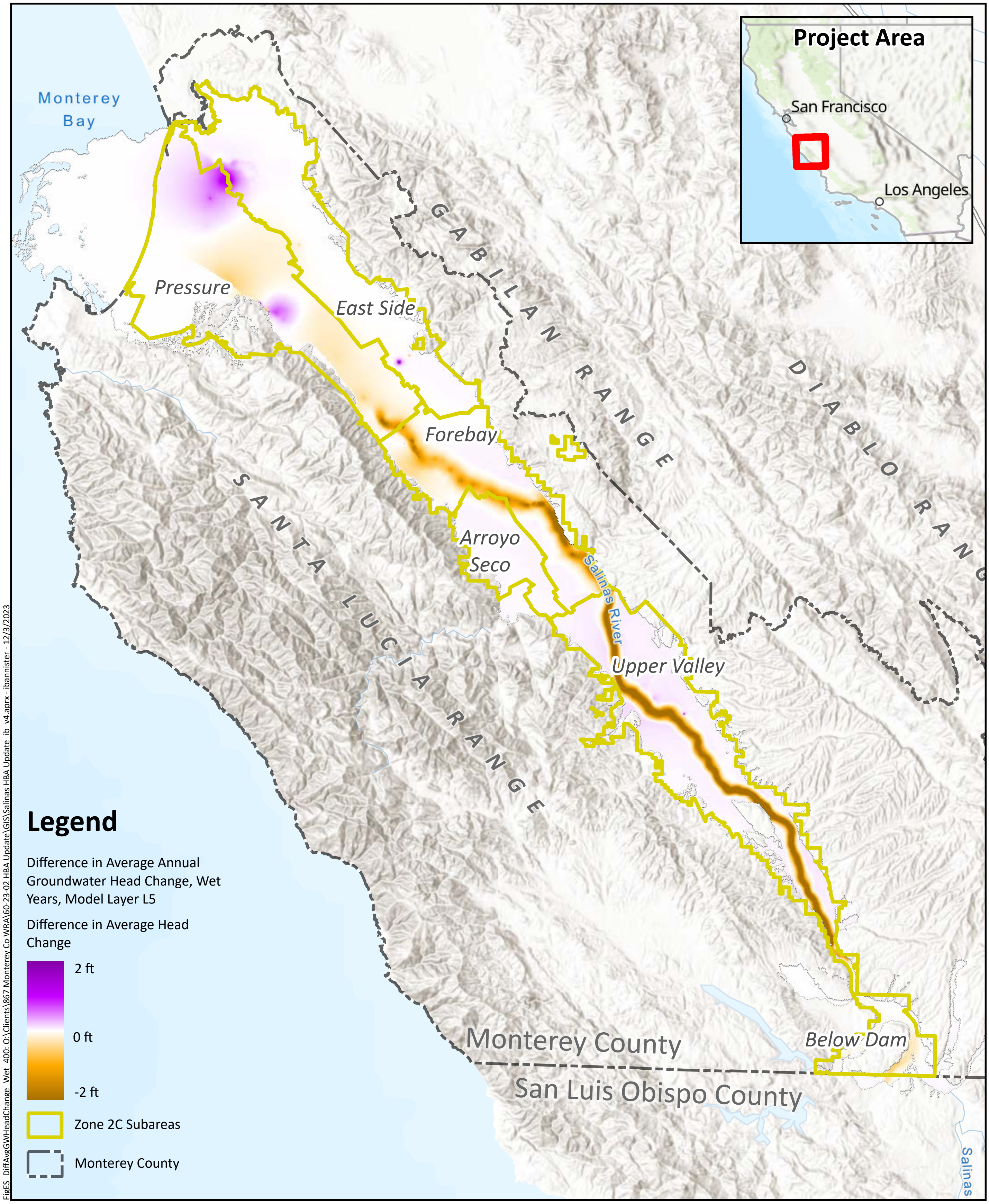
Difference in Average Annual Groundwater Head Change Wet Years
180-Foot Aquifer & Equivalent

Figure A7



Difference in Average Annual Groundwater Head Change Wet Years

400-Foot Aquifer & Equivalent

Figure A8

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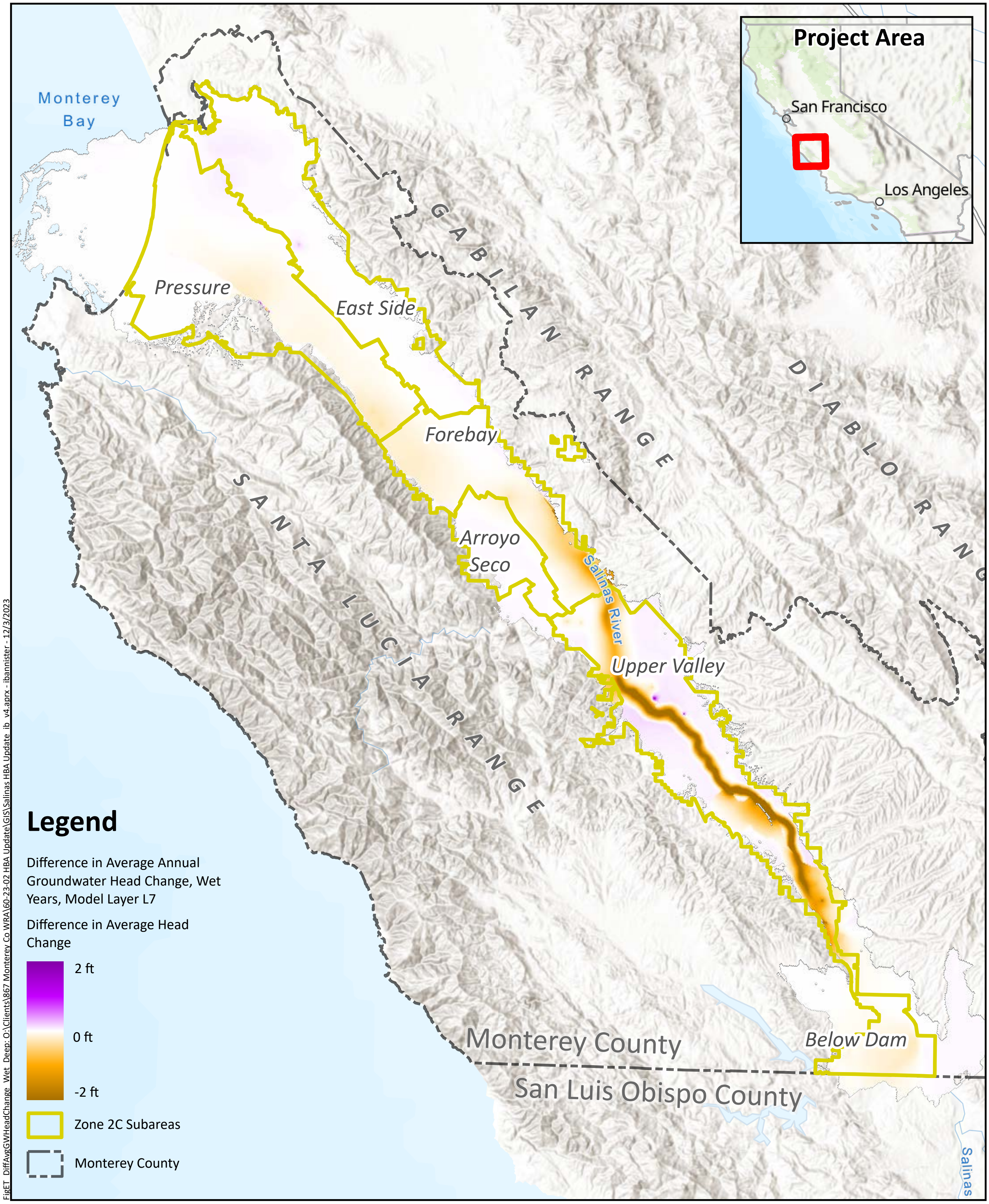

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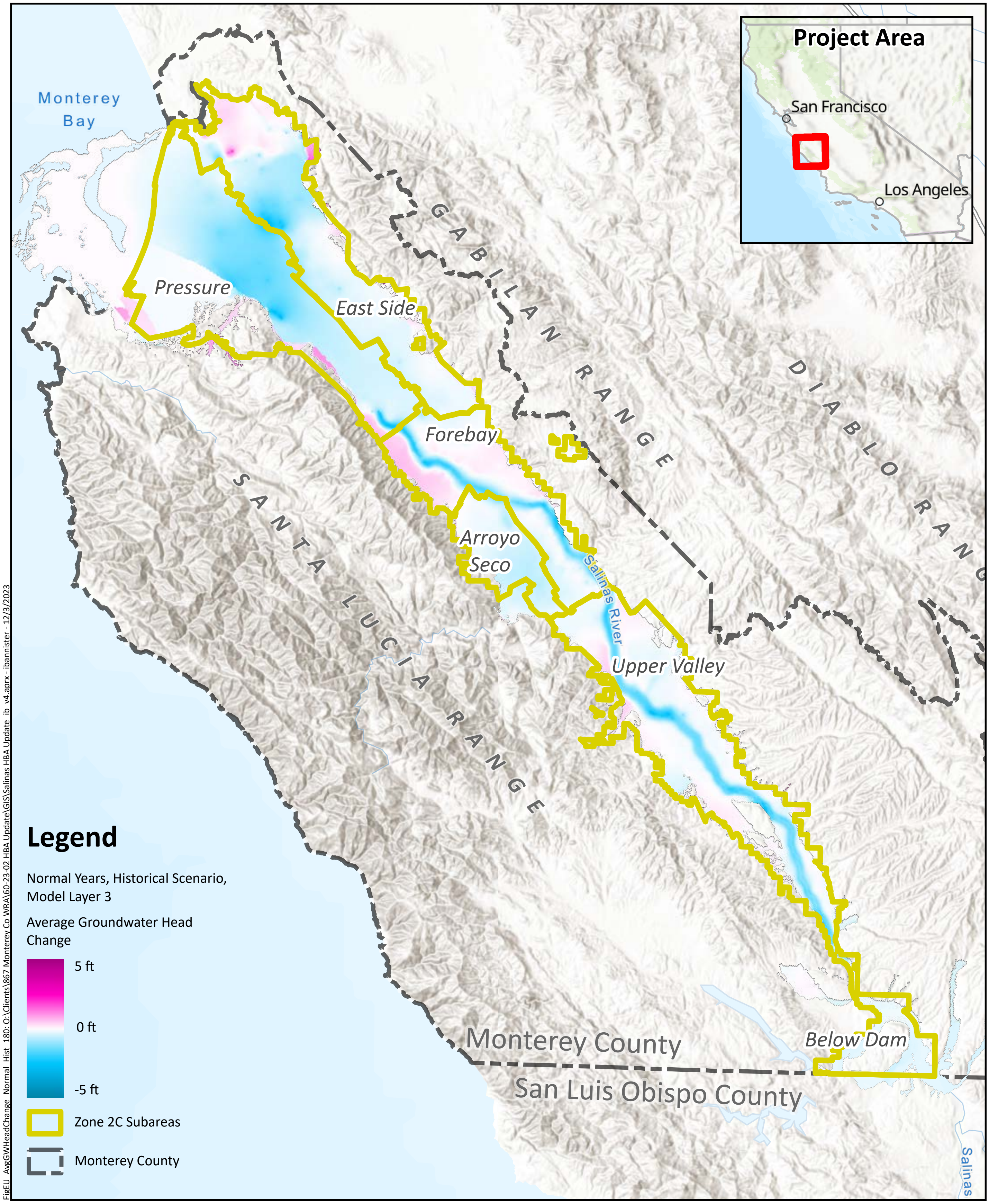
Difference in Average Annual Groundwater Head Change Wet Years
Deep Aquifer

Figure A



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Average Annual Groundwater Head Change Historical Scenario, Normal Years

180-Foot Aquifer & Equivalent

Figure A10

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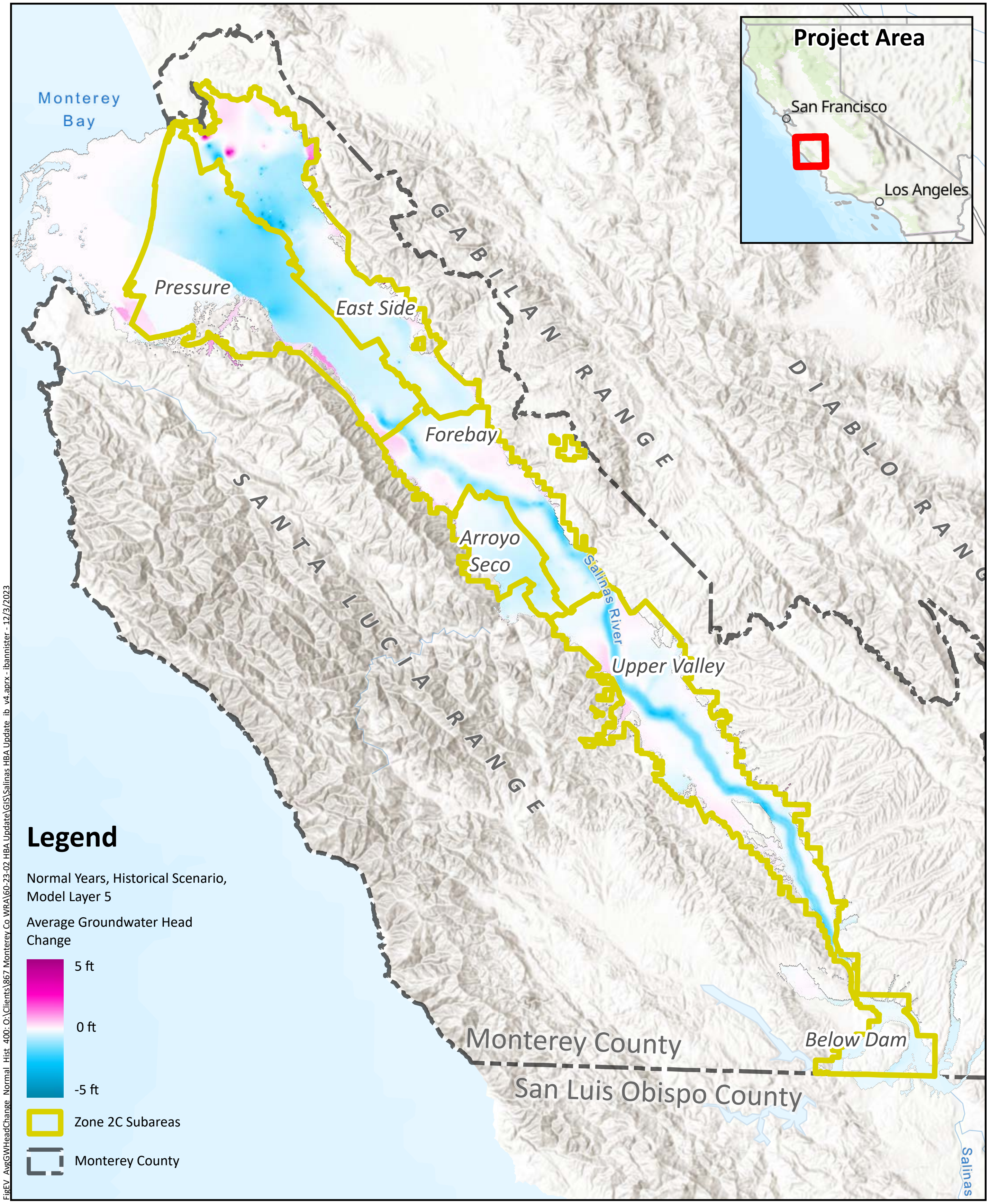

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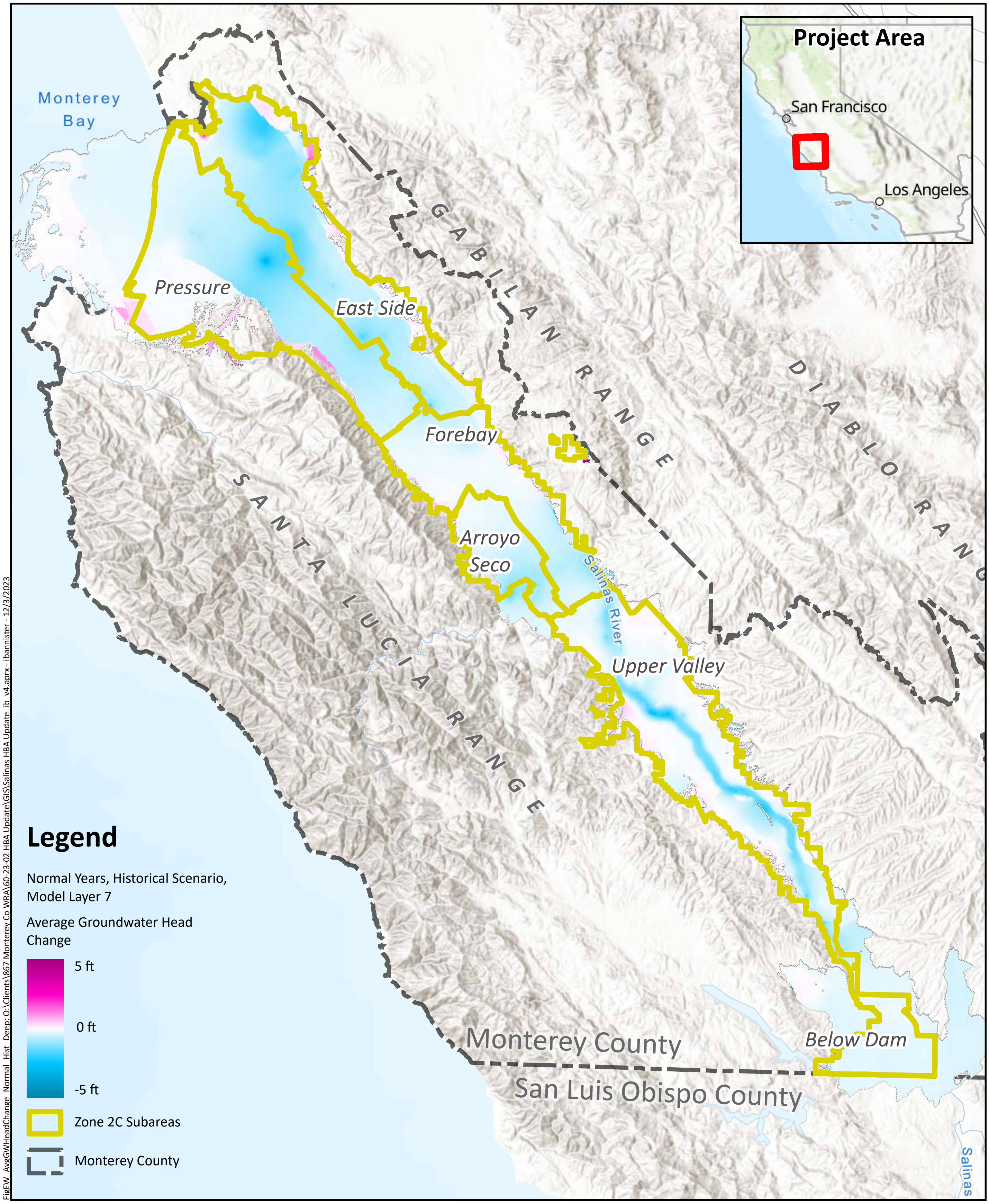
April 2025

Average Annual Groundwater Head Change Historical Scenario, Normal Years
400-Foot Aquifer & Equivalent

Figure A11



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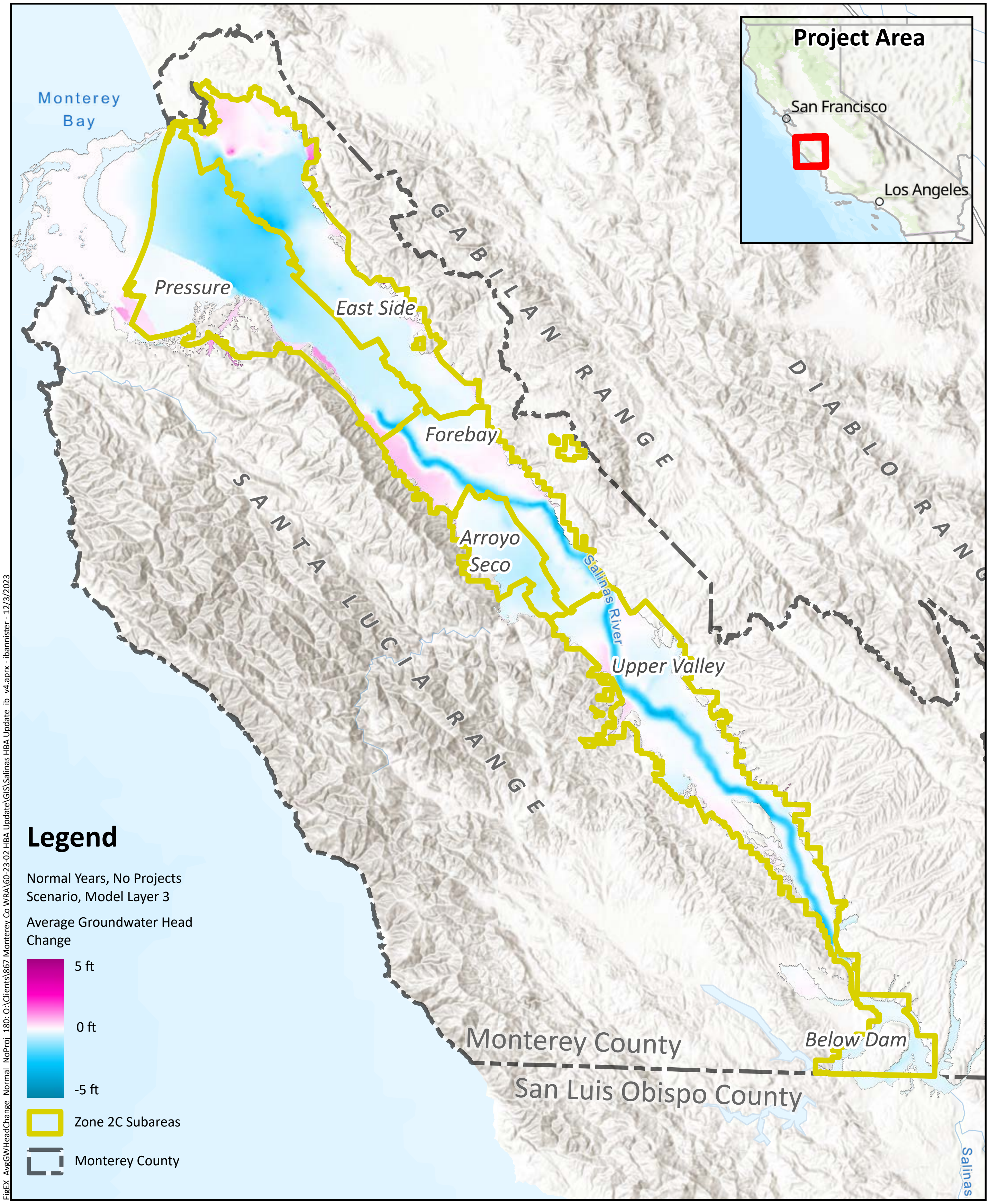
April 2025

Average Annual Groundwater Head Change Historical Scenario, Normal Years

Deep Aquifer

Figure A.12



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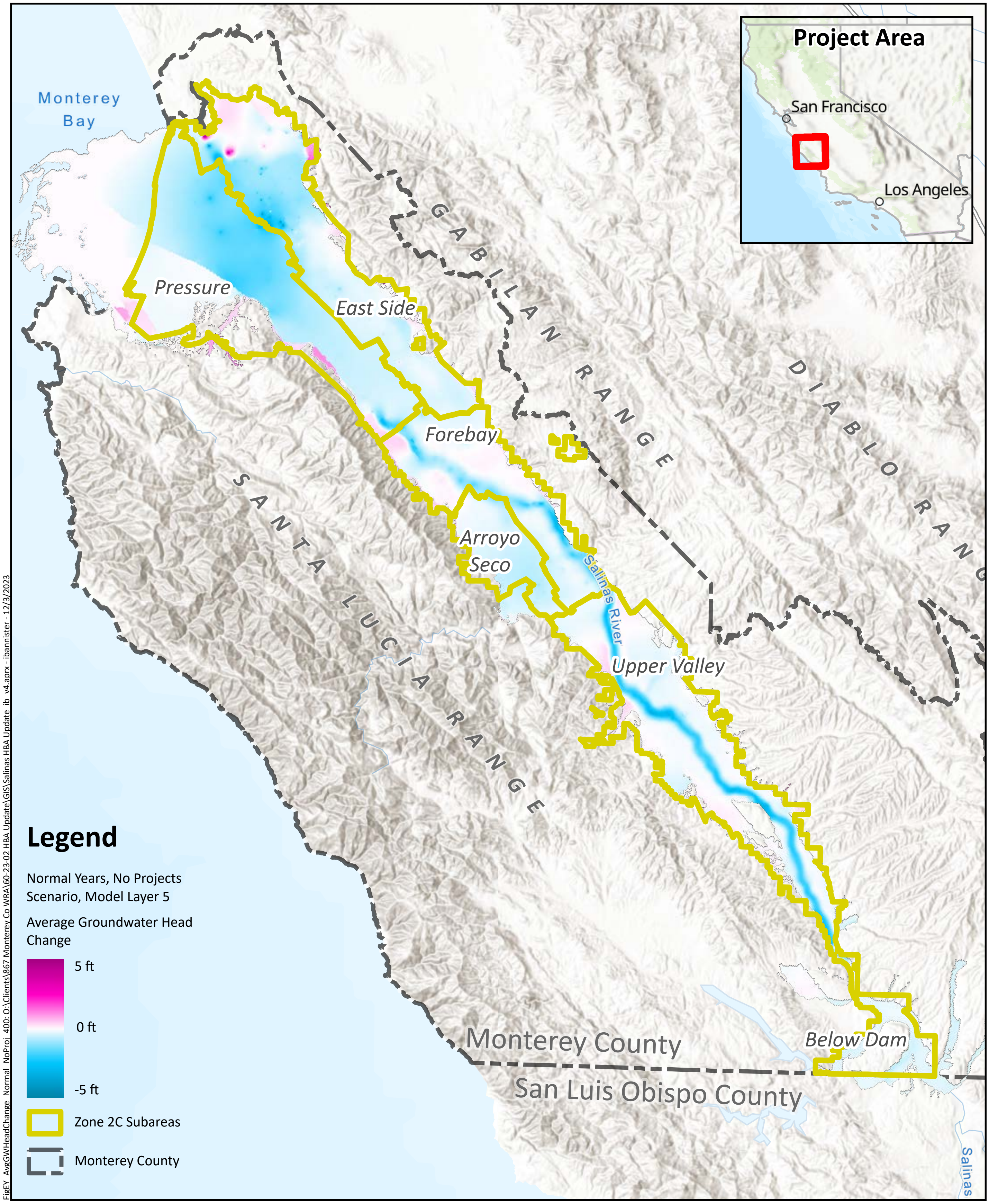
Average Annual Groundwater Head Change, No Projects Scenario, Normal Years
180-Foot Aquifer & Equivalent

Figure A1



Average Annual Groundwater Head Change, No Projects Scenario, Normal Years

400-Foot Aquifer & Equivalent

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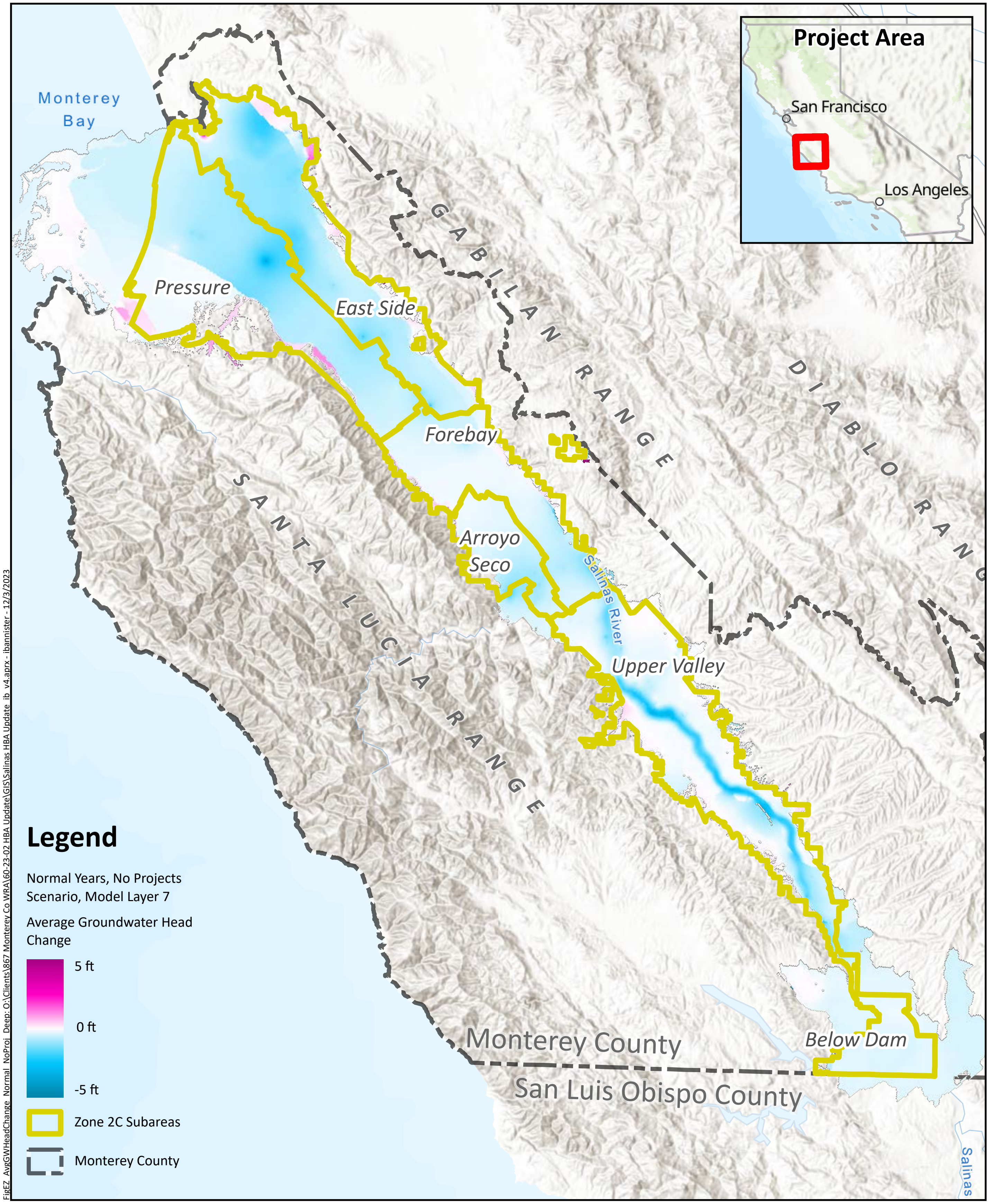
Figure A14



Average Annual Groundwater Head Change, No Projects Scenario, Normal Years

Deep Aquifer

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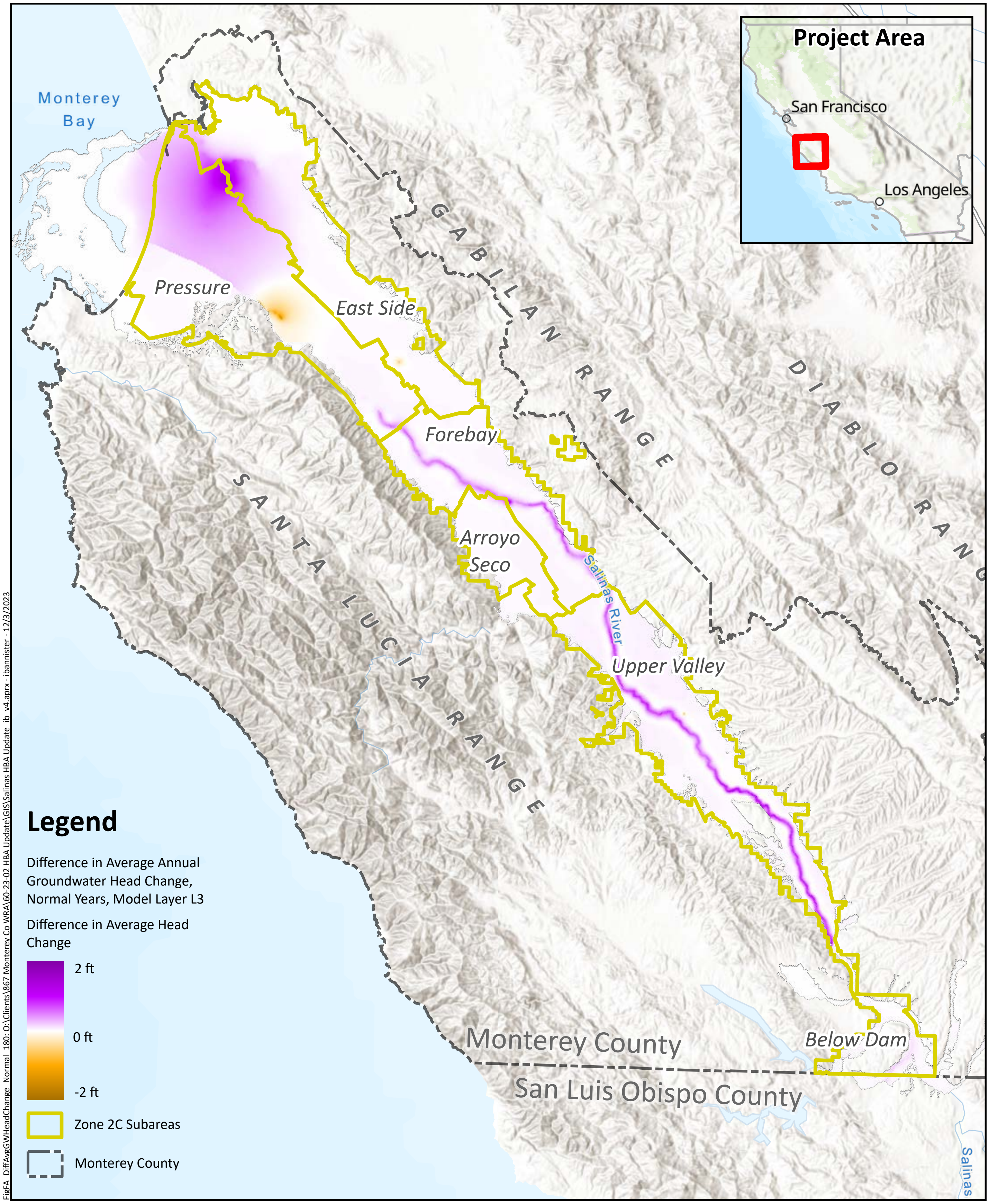
April 2025

Figure A15



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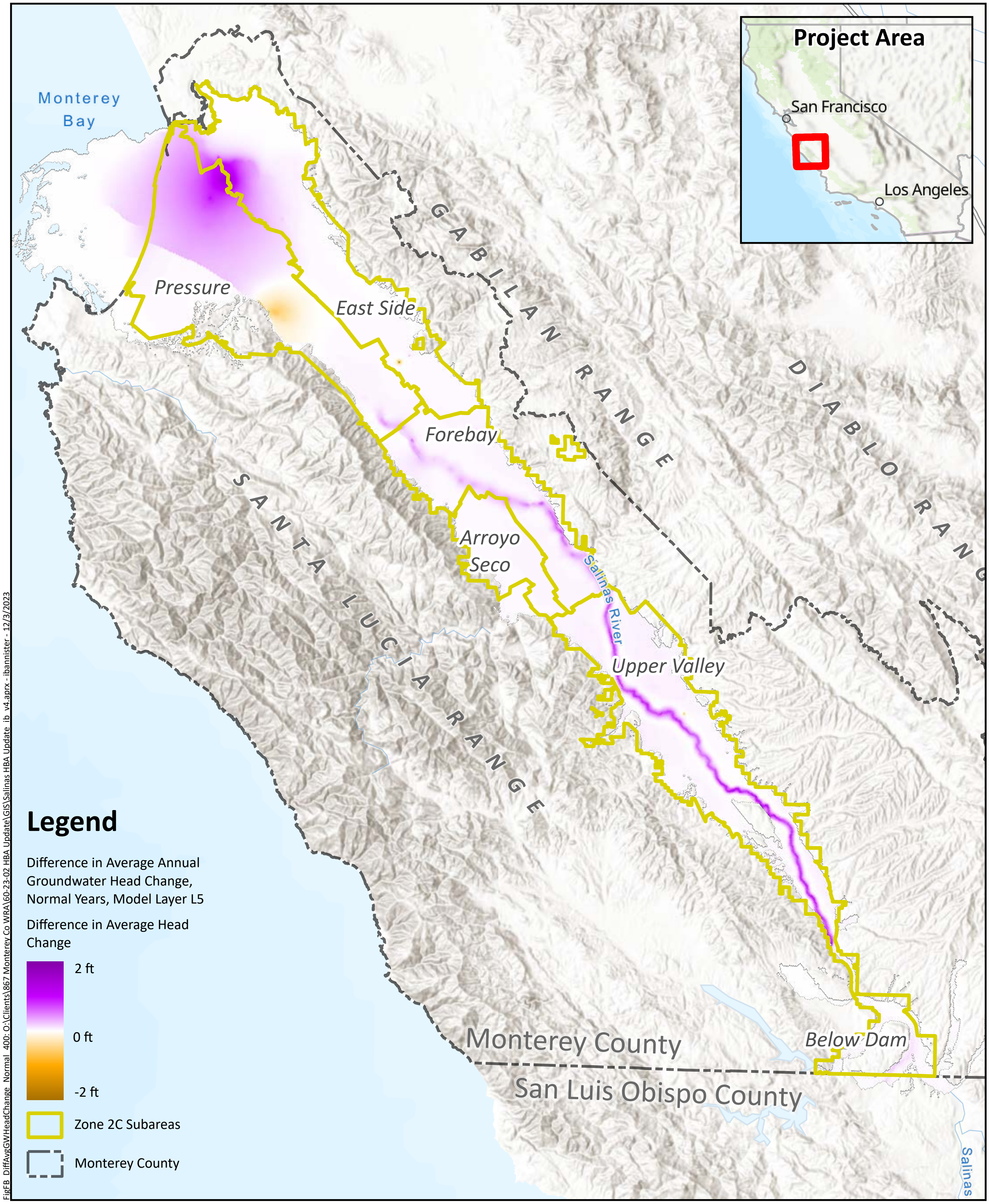
Difference in Average Annual Groundwater Head Change Normal Years

180-Foot Aquifer & Equivalent

Figure A.16



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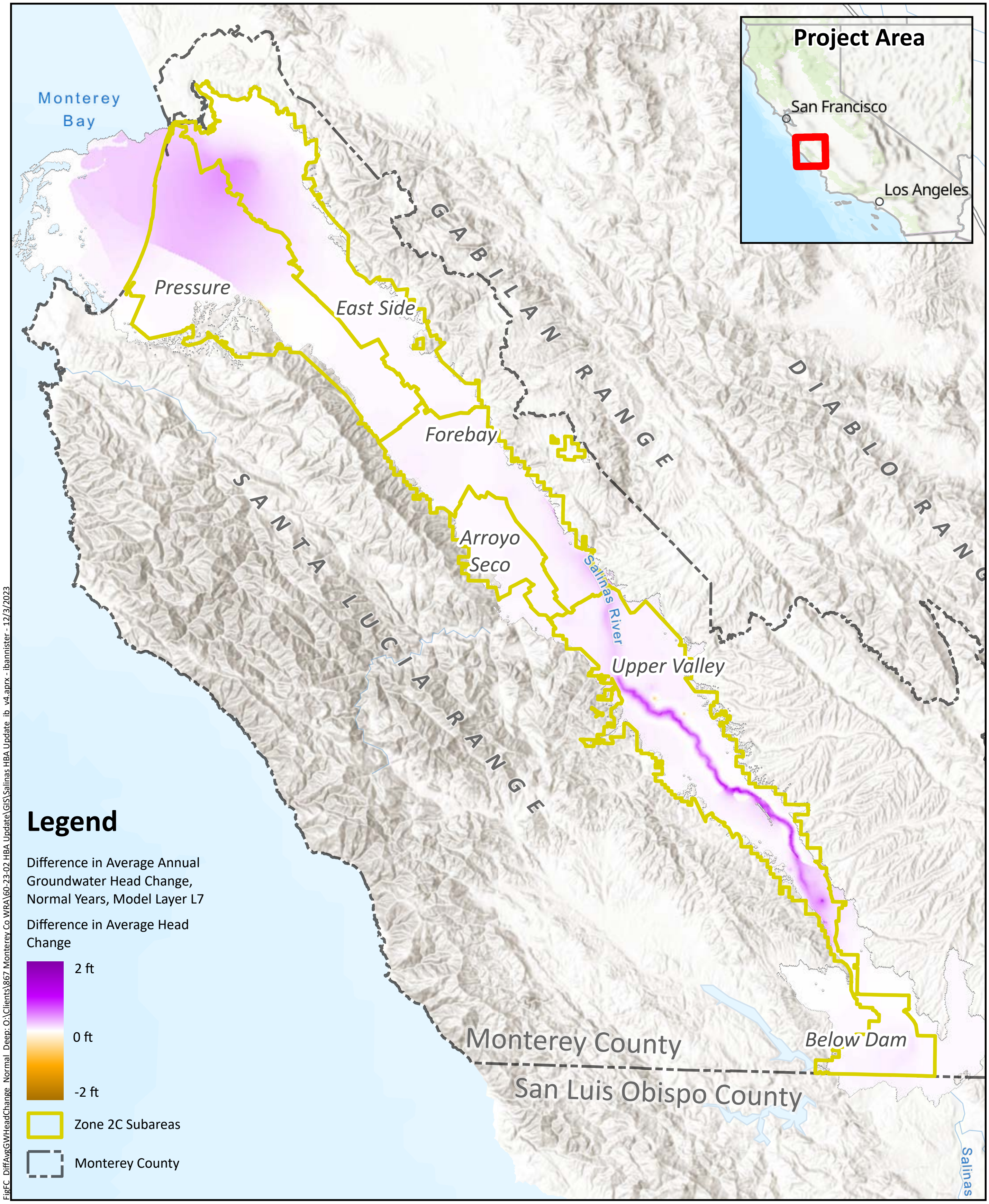
April 2025

Difference in Average Annual Groundwater Head Change Normal Years
400-Foot Aquifer & Equivalent

Figure A.17



Difference in Average Annual Groundwater Head Change
Normal Years
Deep Aquifer

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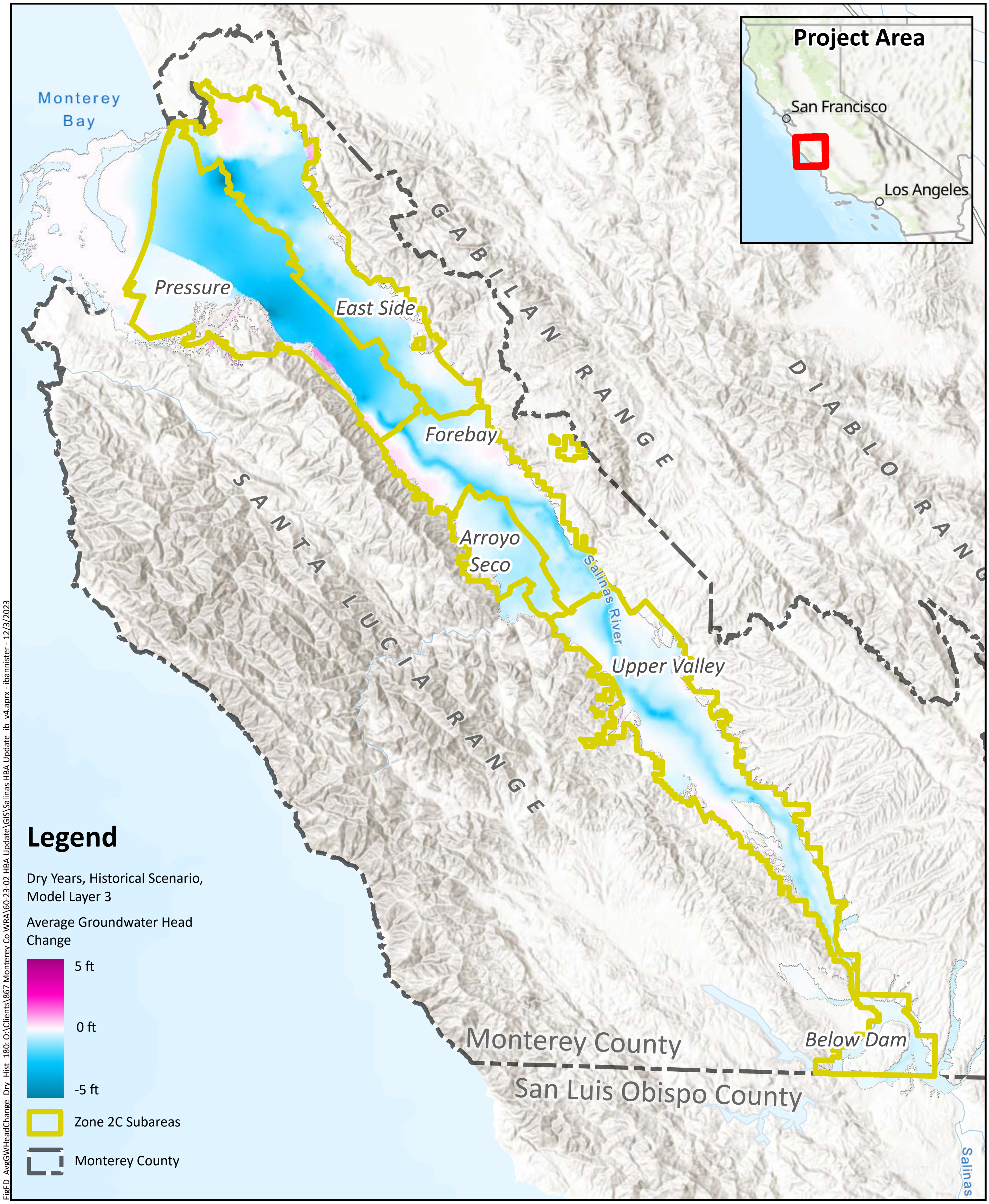
Figure A1



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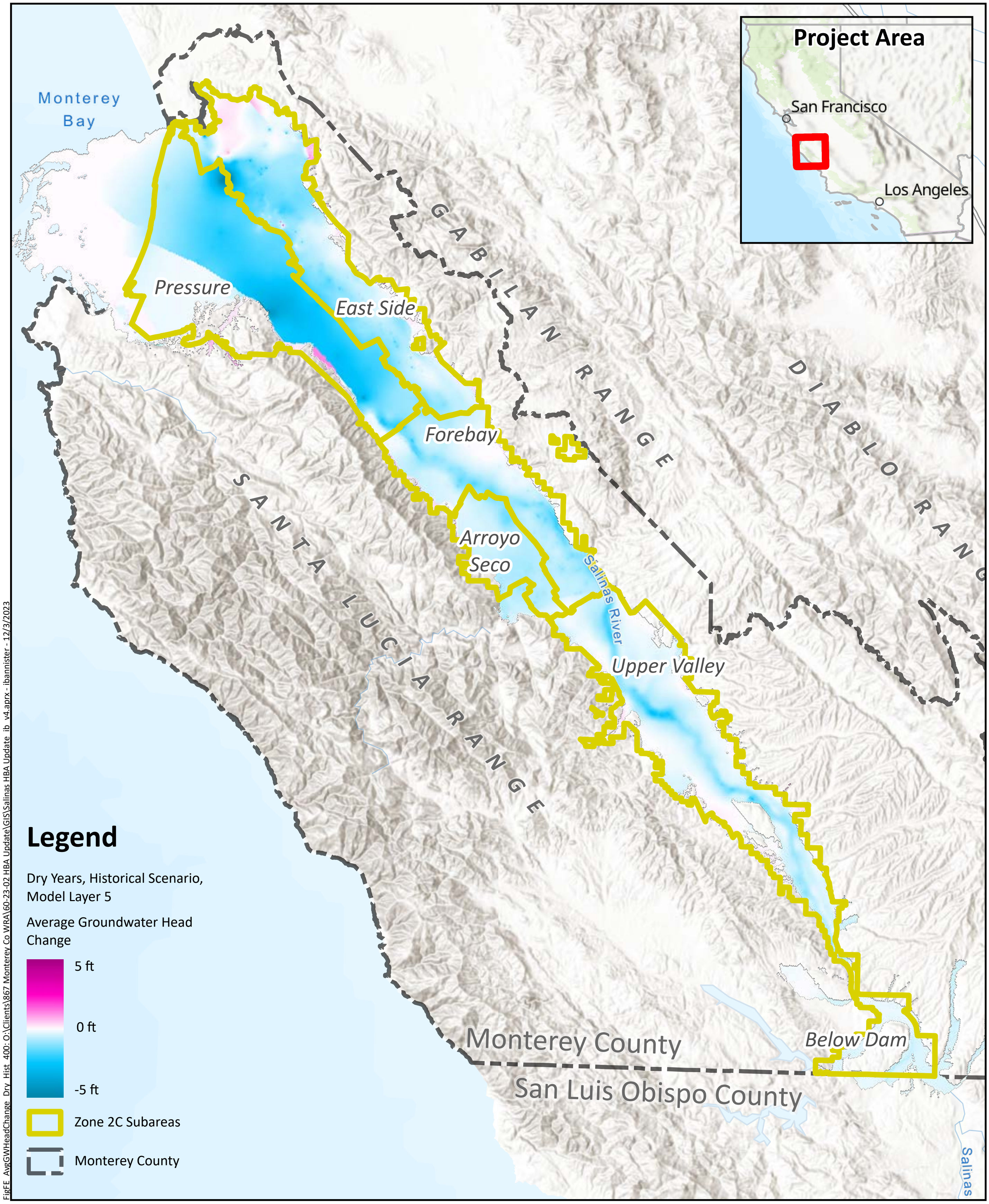
April 2025

Average Annual Groundwater Head Change Historical Scenario, Dry Years
180-Foot Aquifer & Equivalent

Figure A10



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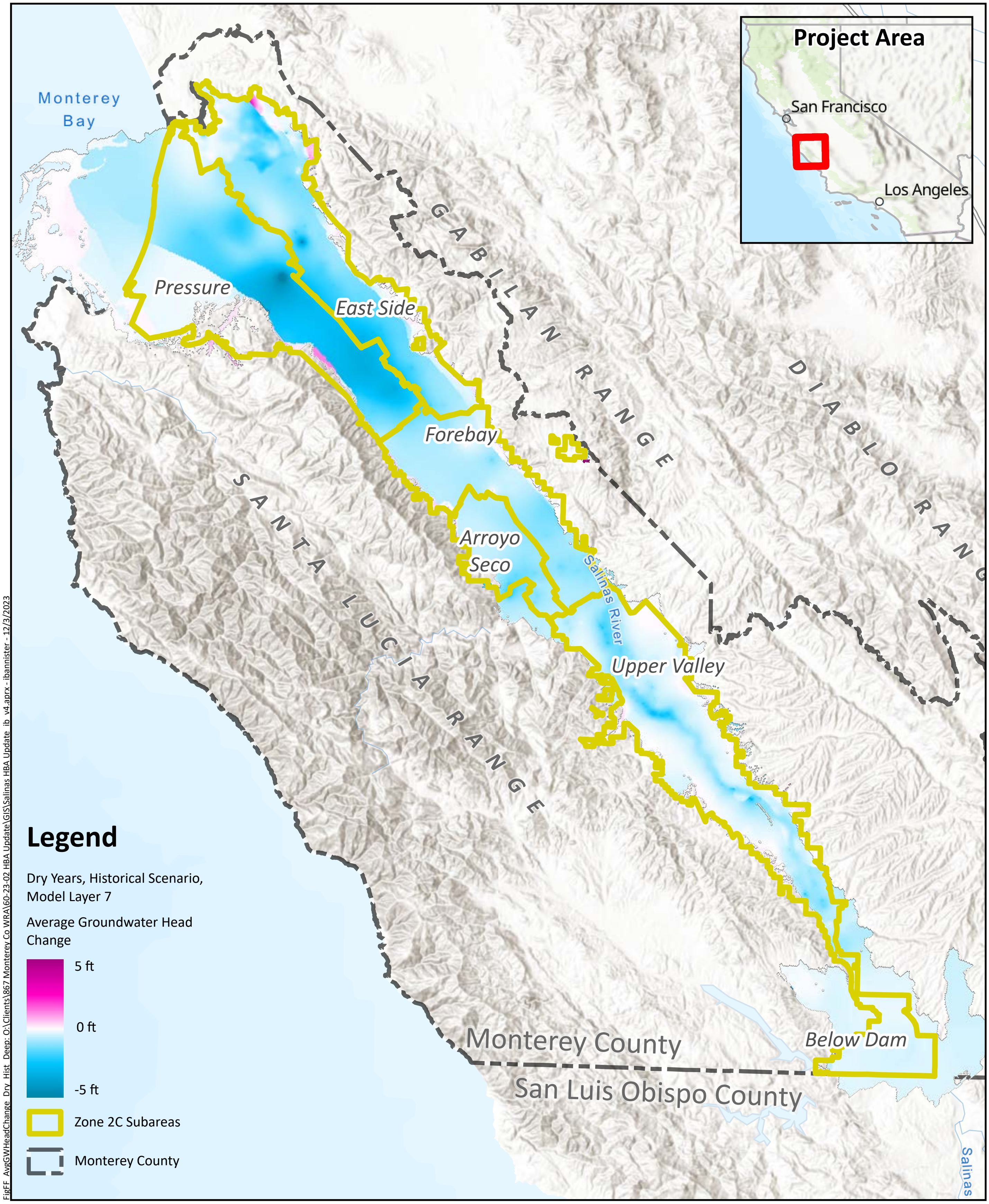
Salinas Valley HBA Update
April 2025

Average Annual Groundwater Head Change Historical Scenario, Dry Years
400-Foot Aquifer & Equivalent

Figure A.20



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Average Annual Groundwater Head Change Historical Scenario, Dry Years

Deep Aquifer

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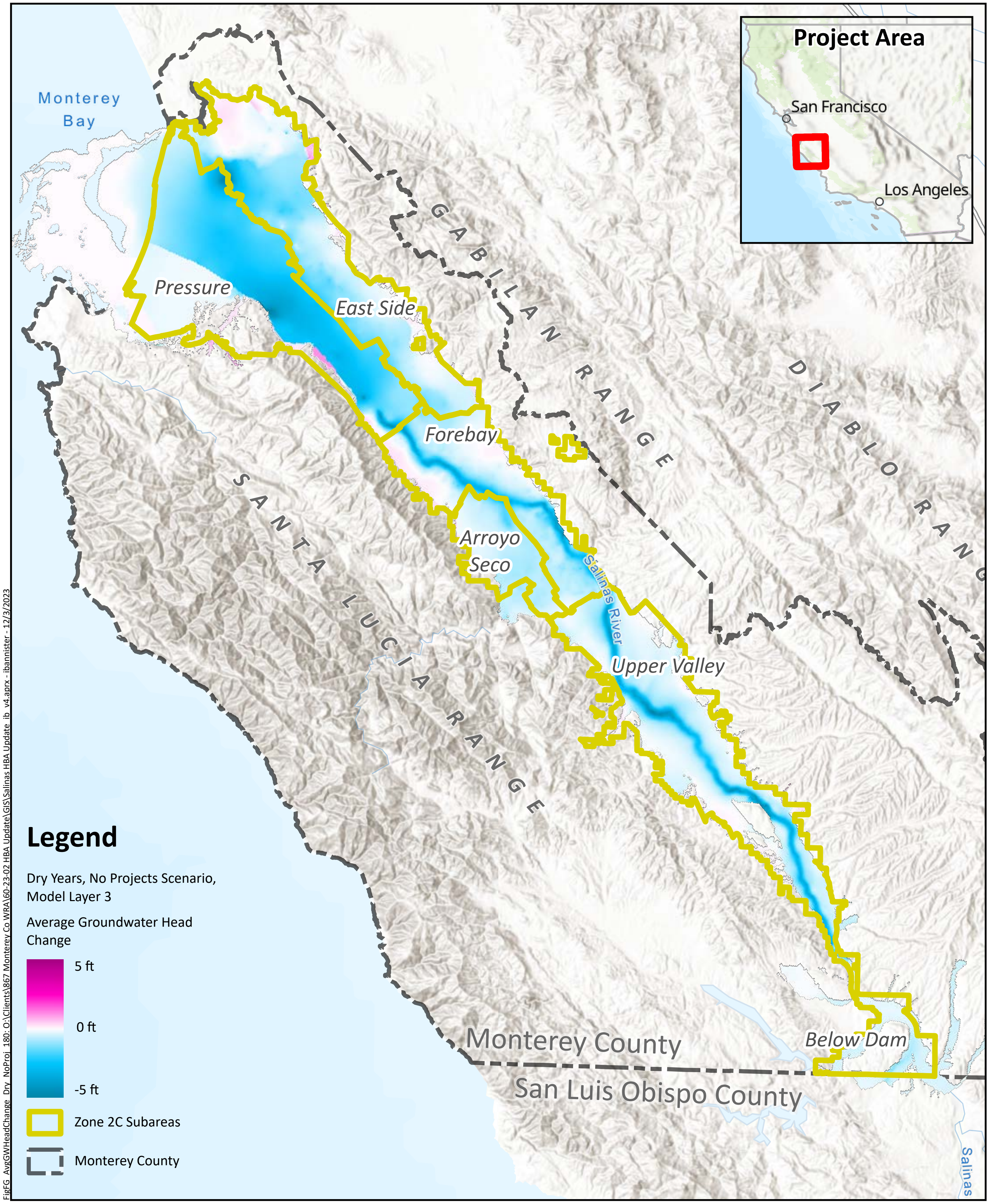
Salinas Valley HBA Update

April 2025

Figure A21



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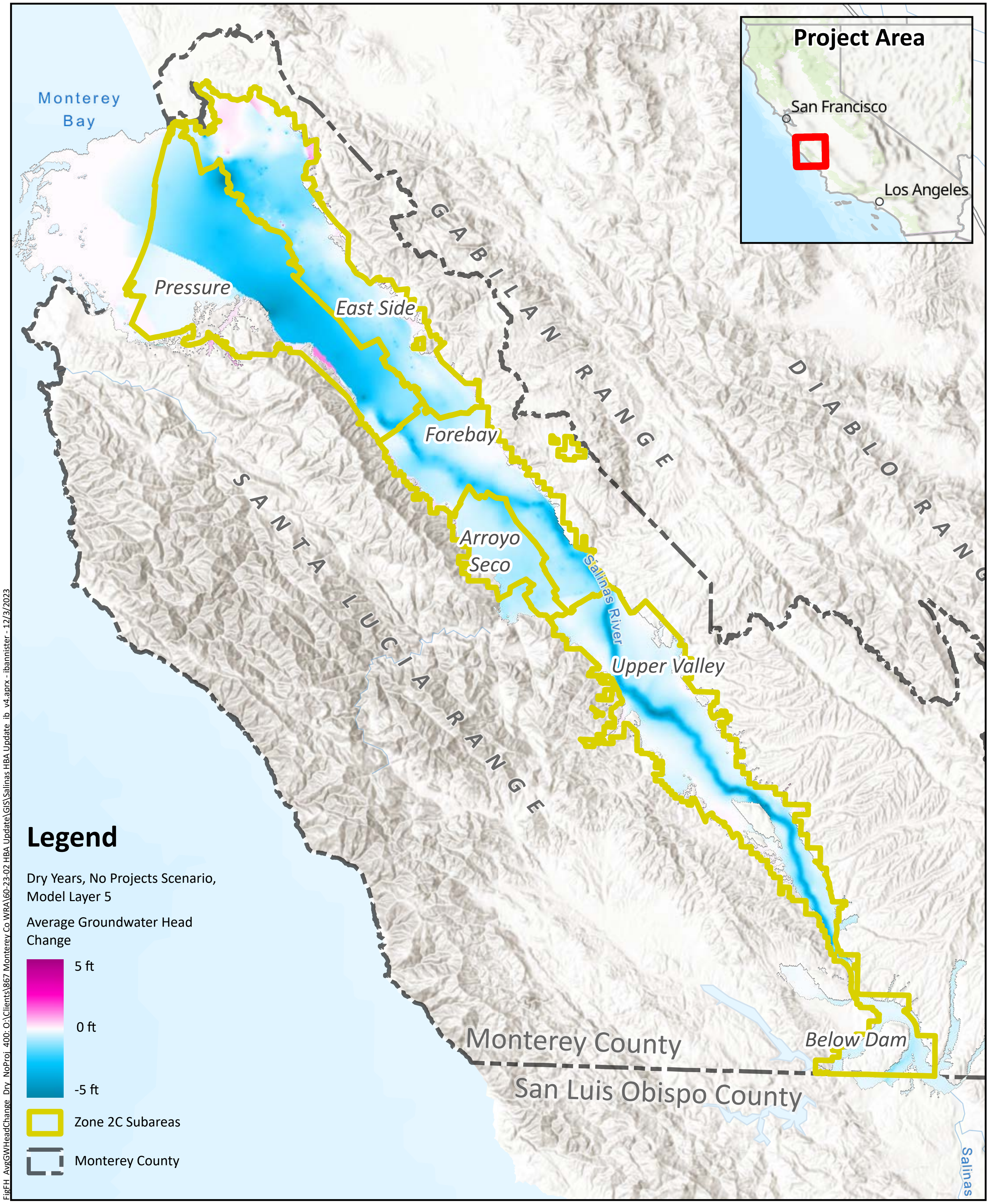
April 2025

Average Annual Groundwater Head Change No Projects Scenario, Dry Years
180-Foot Aquifer & Equivalent

Figure A.??



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Average Annual Groundwater Head Change No Projects Scenario, Dry Years

400-Foot Aquifer & Equivalent

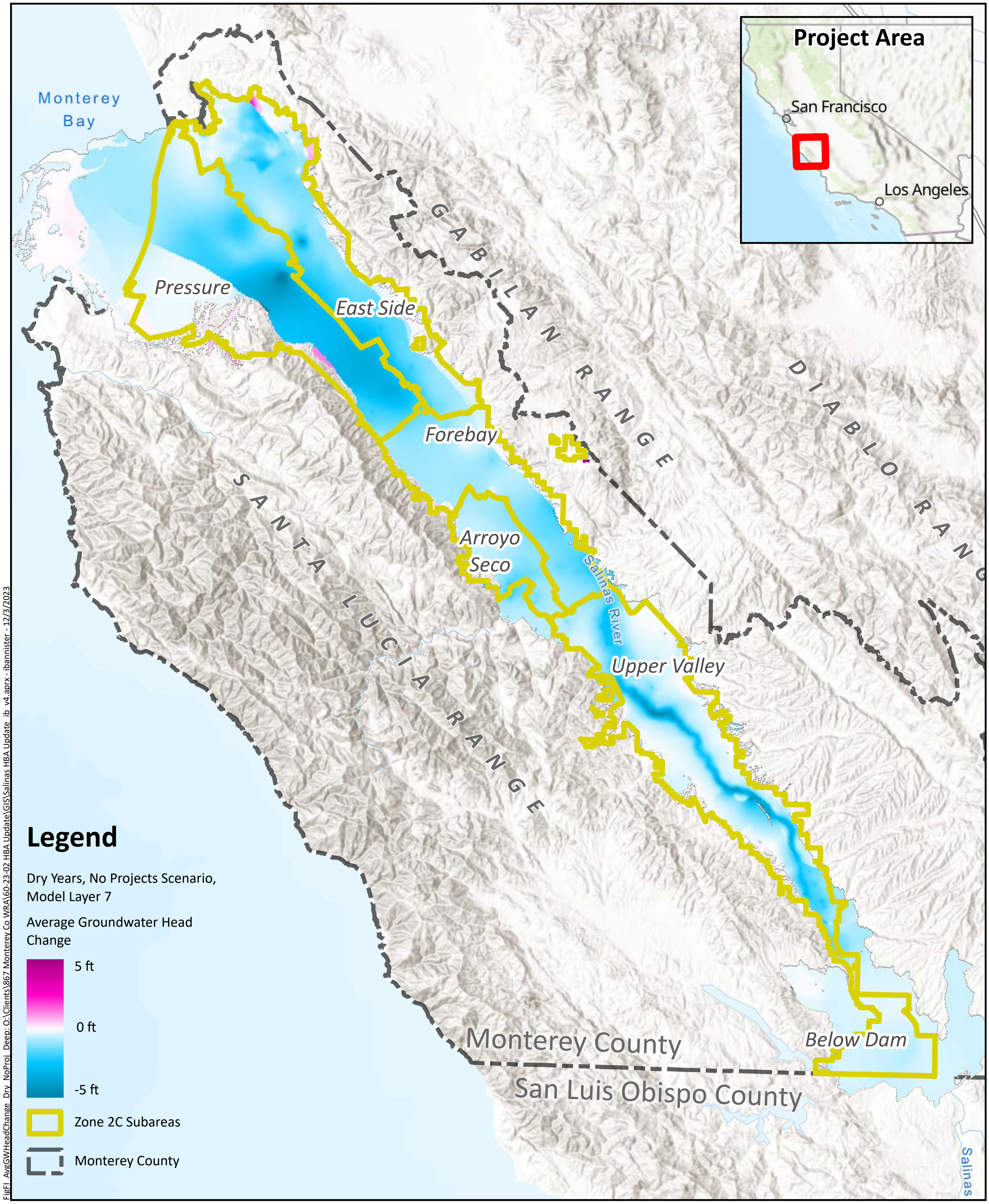
Figure A23

Prepared by: WEST YOST

Miles: 0, 5, 10

Km: 0, 8, 16

Prepared for:
Monterey County Water Resources Agency
Salinas Valley HBA Update
April 2025



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Average Annual Groundwater Head Change No Projects Scenario, Dry Years

Deep Aquifer

Figure A.24

Prepared by:

WEST YOST

0 5 10 Miles

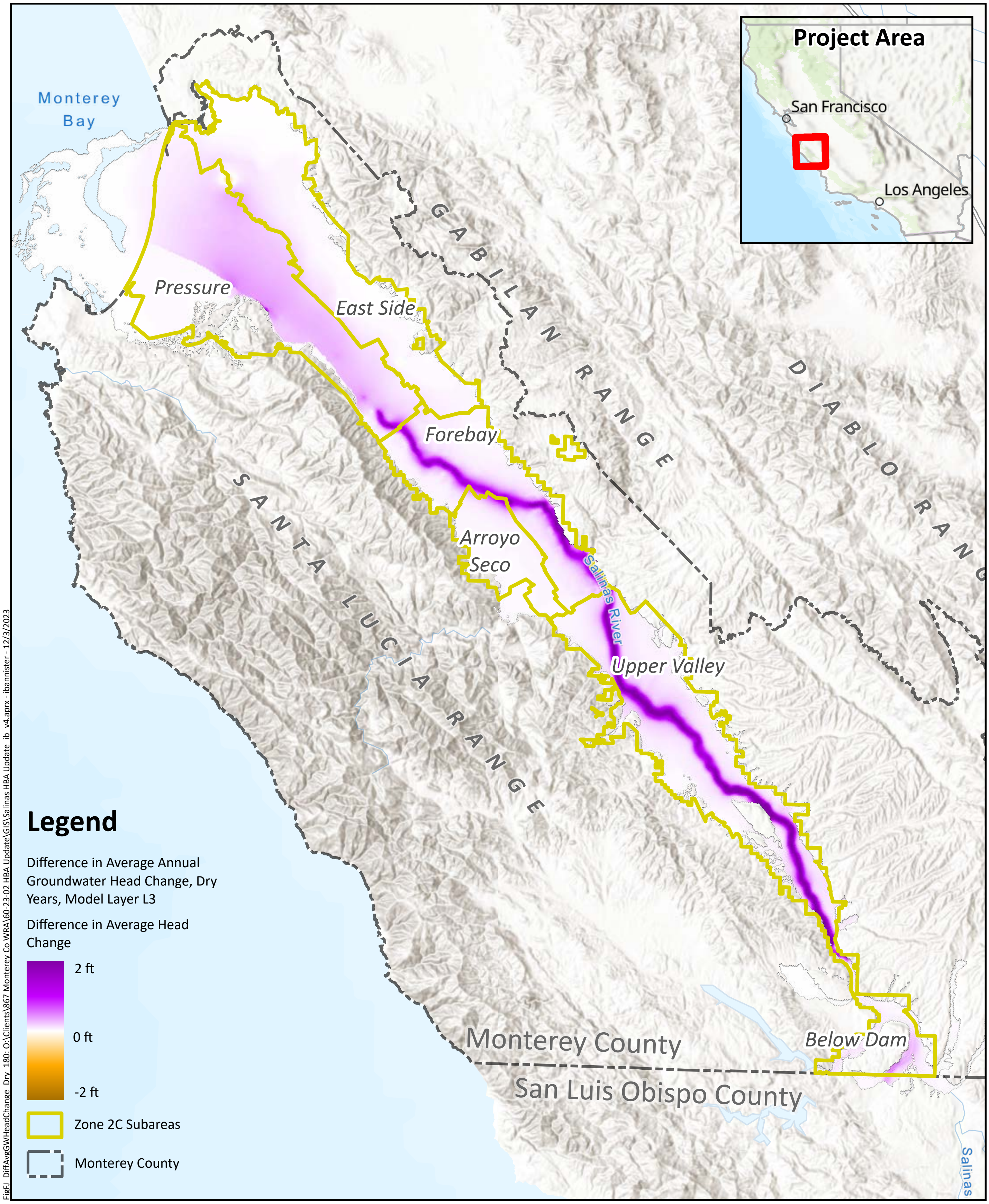
0 8 16 Km

Prepared for:

Monterey County Water Resources Agency

Salinas Valley HBA Update

April 2025



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Prepared by:

WEST YOST

0 5 10 Miles

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Prepared for:

Monterey County Water Resources Agency

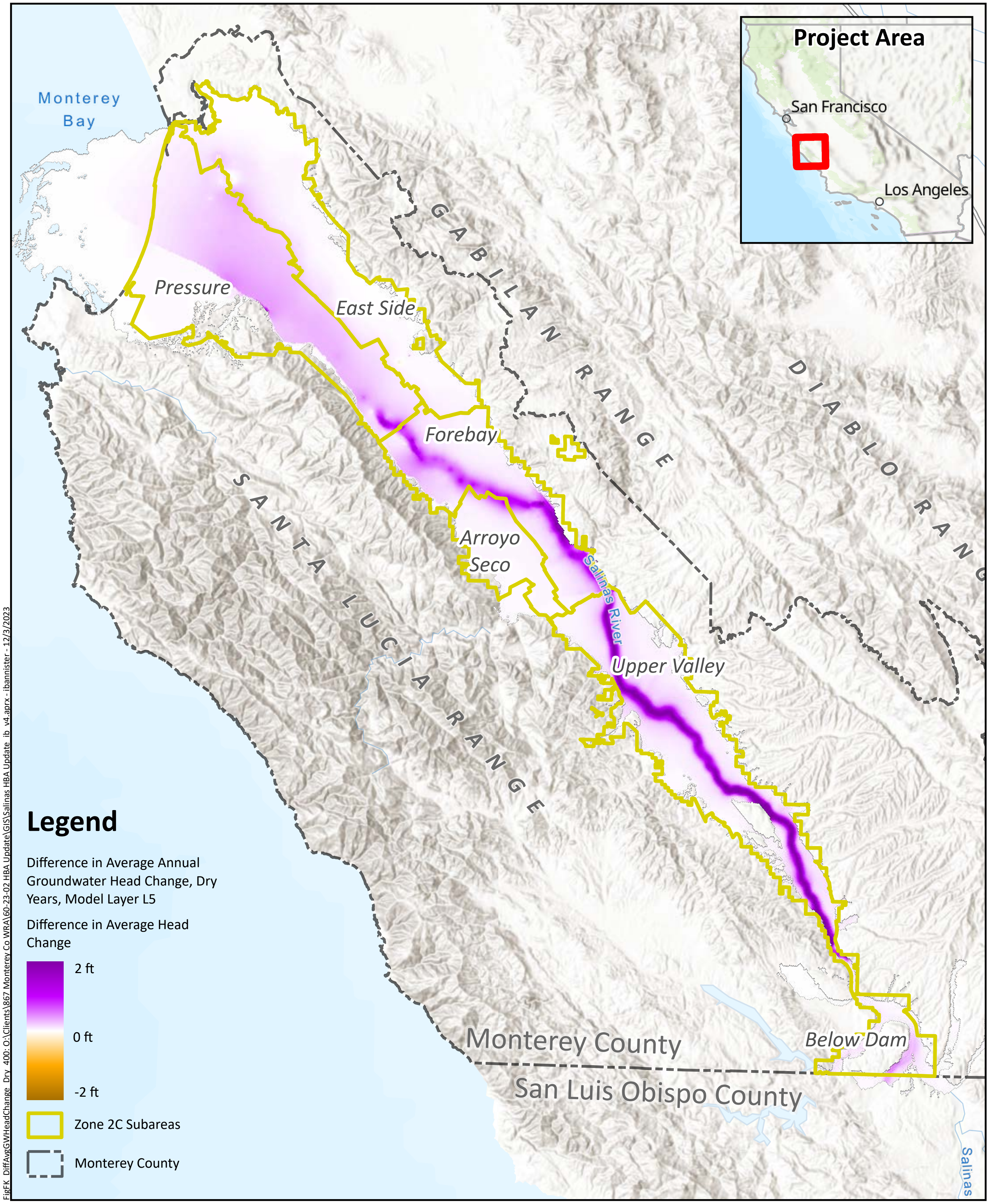
Salinas Valley HBA Update

April 2025

Difference in Average Annual Groundwater Head Change Dry Years

180-Foot Aquifer & Equivalent

Figure A25



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Difference in Average Annual Groundwater Head Change Dry Years

400-Foot Aquifer & Equivalent

Prepared by:

WEST YOST

0 5 10 Miles

0 8 16 Km

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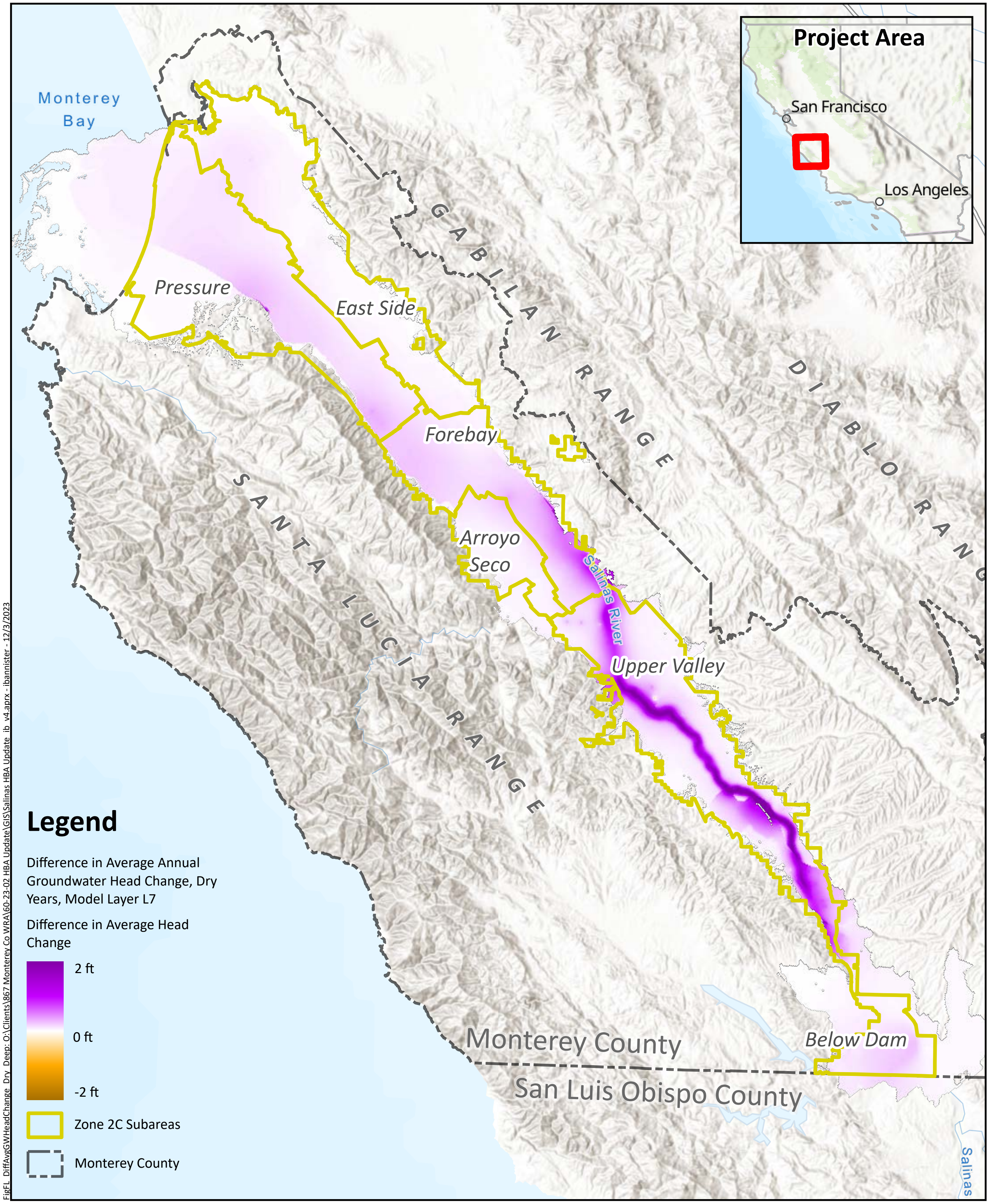
Monterey County Water Resources Agency
Salinas Valley HBA Update
April 2025

Figure A26



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Difference in Average Annual Groundwater Head Change
Dry Years
Deep Aquifer

Figure A27

Prepared by:

WEST YOST

0 5 10 Miles
0 8 16 Km

Prepared for:
Monterey County Water Resources Agency
Salinas Valley HBA Update
April 2025

Appendix B

Streamflow Estimation Approach

One major finding of the 1998 HBA (MW, 1998) was that the reservoirs have reduced the extent of severe flooding occurring along the Salinas River from Bradley to Monterey Bay. That study developed a statistical description of flood flow magnitudes with and without the Nacimiento and San Antonio Reservoirs using a combination of observed and simulated streamflow and accounts of historical flood events. The 1998 HBA presented the extents of the 100-year floods with and without the reservoirs to demonstrate the benefit that stakeholders in the Basin have received due to the reservoirs' flood control operations.

For this HBA Update, some modifications to the 1998 HBA approach were required because of differences in the modeling tools available. The Salinas Valley Integrated Hydrologic Model (SVIHM) was the main tool used to simulate conditions in the Basin for the HBA Update, and simulated streamflow in the SVIHM is only calculated once per 5- to 6-day timestep, with temporal variation in streamflow highly influenced by the use of monthly streamflow values at the stream inflow points along the edges of the SVIHM (i.e., there is little variation in simulated streamflow within each month in the SVIHM). While the SVIHM is useful for understanding seasonal and annual variations in streamflow, it is not appropriate for characterizing the magnitude of peak flows resulting from, for example, individual storm events.

This appendix describes an alternative approach that was created for this HBA Update to develop an estimate of peak flow magnitudes analogous to those analyzed in the 1998 HBA. This approach relies on a combination of observed streamflow data, simulated mean daily streamflow from the USGS Salinas Valley Watershed Model (SVWM), measured daily reservoir outflow, estimated mean daily reservoir inflow, and simulated groundwater-surface water interaction from the SVIHM. The goal of this approach was to estimate the magnitude of peak flows with the information available. The finest temporal resolution available for most of the data sources used for the streamflow estimation is daily (total or average daily flow); instantaneous peak streamflows were estimated from mean daily streamflows based on linear regressions.

The portion of the study area over which this streamflow estimation was performed consists of the active model domain of the SVIHM above the location of the U.S. Geological Survey's Salinas River at Bradley stream gauge along the Salinas River and its tributaries, the Nacimiento and San Antonio Rivers (see Figure 4-3 in the HBA Update). Other tributaries to the Salinas River in this area (e.g., Vineyard Canyon) are relatively minor and are not considered here.

This Appendix includes discussion of results from the SVIHM, which is a preliminary model that has not yet been published and documented by the USGS. Results from the SVIHM until publication are considered preliminary; any use of the SVIHM results before publication of the model must be accompanied by the following disclaimer:

> *Historical SVIHM Model: Unoffical [sic] 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 recieved [sic] 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.

SIMULATED STREAMFLOW IN SVIHM

The SVIHM simulates the routing of streamflow within a defined stream network based on a simplified mass balance approach. The SVIHM takes inflow where streams intersect the edges of the active model domain, or where stream headwaters are located within the active model domain; together, there are about 150 such locations in the SVIHM.

Inflow to the model domain at these locations is provided as an average monthly flow, corresponding to the temporal discretization of the SVIHM. Although model calculations are made on a slightly finer discretization of 5 to 6 days, the values of streamflow within the model depend strongly on the monthly structure of the inflow time series. Figure B-1 shows an example time series of simulated streamflow in the Salinas River at Bradley for the Historical and No Projects Scenarios run for the HBA Update. Although this historical period experienced a very high peak streamflow (observed daily mean streamflow in the Salinas River at Bradley reached a maximum of 14,000 cfs on 3 Jan 1997), streamflow simulated by the SVIHM does not approach the magnitude of the peak daily streamflow.

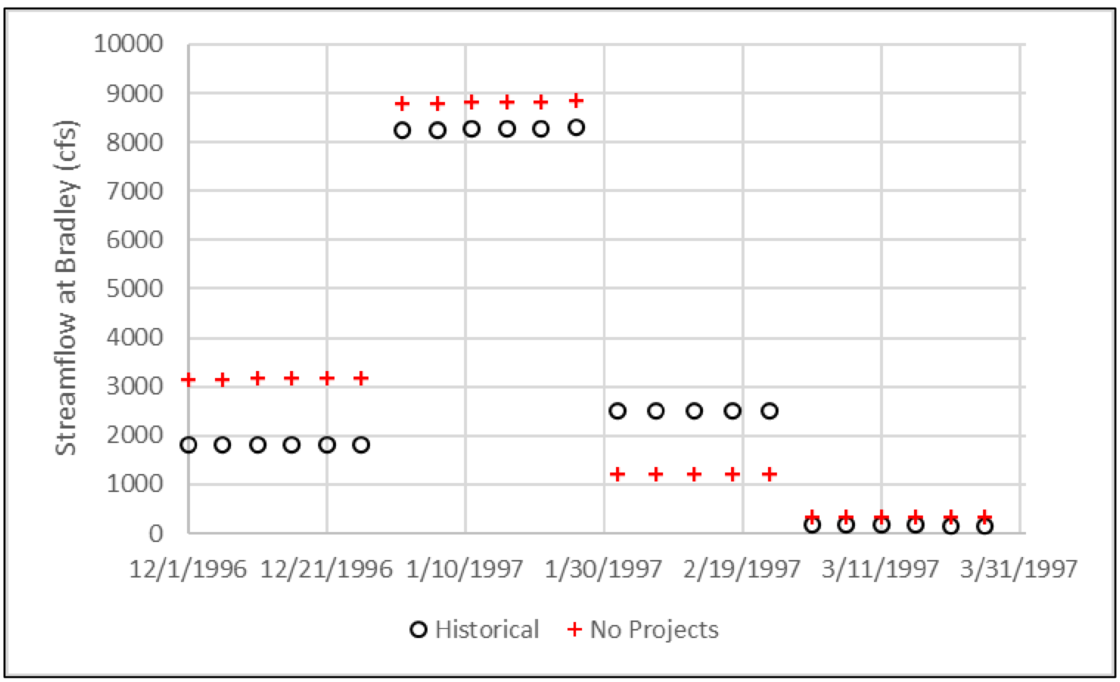

Figure B-1. SVIHM-Simulated Streamflow in the Salinas River at Bradley Showing Monthly Pattern of Streamflow

The monthly structure of simulated streamflow in the SVIHM means that the model results cannot be used directly to quantify the magnitude of peak flow events. Instead, an alternative approach to peak flow estimation was developed that utilized available data sources that could be combined to produce reasonable estimates of instantaneous peak flow magnitudes in the Salinas River at Bradley for the Historical and No Projects Scenarios.

AVAILABLE DATA SOURCES

Streamflow data in the Salinas River and its tributaries, either observed or simulated, are available from various sources. These data sources include:

- Measured mean daily streamflow at the Salinas River at Bradley stream gauge from the USGS (1 Oct 1948 to present)
- Measured instantaneous streamflow (15-minute intervals) at the Salinas River at Bradley stream gauge from the USGS (1 Oct 1988 to present)
- Measured daily release from Nacimiento Reservoir from MCWRA (1 Oct 1958 to present)
- Measured daily release from San Antonio Reservoir from MCWRA (1 Oct 1966 to present)
- Estimated daily inflow to Nacimiento Reservoir from MCWRA (1 Oct 1958 to present)
- Estimated daily inflow to San Antonio Reservoir from MCWRA (1 Oct 1966 to present)
- Simulated mean daily streamflow in the Salinas River near San Miguel (where the Salinas River enters the SVIHM) from the SVWM (1 Oct 1967 to 30 Sep 2018)
- Simulated groundwater-surface water interaction from the SVIHM for the Historical and No Projects Scenarios (1 Oct 1967 to 30 Sep 2018)

Throughout this document, streamflow measurements taken at the USGS gauge at Bradley and dam releases are referred to as “observed” or “measured,” direct model outputs from the SVIHM and SVWM are referred to as “simulated,” and reservoir inflows as well as outputs from the streamflow estimation approach are referred to as “estimated.”

STREAMFLOW ESTIMATION APPROACH

For this HBA Update, the data sources listed above were used to develop time series of estimated mean daily streamflow, annual peak mean daily streamflow, and annual peak instantaneous streamflow for the Salinas River at Bradley under the Historical and No Projects Scenarios. This approach relies on a simple mass balance of the streamflows within the estimation area:

$$S_{Br} = S_{Na} + Q_{Na} + S_{SA} + Q_{SA} + S_S + Q_S \quad (1)$$

where:

- S_{Br} = Mean daily streamflow at the Salinas River at Bradley gauge
- S_{Na} = Mean daily streamflow below Nacimiento Dam (measured, estimated, or simulated)
- Q_{Na} = Simulated groundwater-surface water interaction flux along Nacimiento River between the point where it enters the SVIHM domain and its confluence with the Salinas River (simulated)
- S_{SA} = Mean daily streamflow below San Antonio Dam (measured, estimated, or simulated)
- Q_{SA} = Simulated groundwater-surface water interaction flux along San Antonio River between the point where it enters the SVIHM domain and its confluence with the Salinas River (simulated)
- S_S = Mean daily streamflow in the Salinas River where it enters the SVIHM domain (simulated, from SVWM)
- Q_S = Simulated groundwater-surface water interaction flux along the Salinas River between where it enters the SVIHM domain and the location of the Salinas River at Bradley gauge (simulated)

In this equation, all streamflow variables (S_{Br}, S_{Na}, S_{SA}, and S_S) are available as mean daily flows, whereas all groundwater-surface water interaction flux variables (Q_{Na}, Q_{SA}, and Q_S) are single values for each 5- to 6-day SVIHM timestep. The source of the values of S_{Na} and S_{SA} varies depending on the model scenario being considered. For the Historical Scenario, measured reservoir releases are used. For the No Projects Scenario, the estimated reservoir inflow is used. The equation can be used to estimate streamflow at Bradley for any period where reservoir outflow and Salinas River inflow are known or can be estimated.

Observed versus Estimated Streamflow

Equation 1 was used to calculate an estimated mean daily streamflow for the Salinas River at Bradley for the period of the SVIHM, 1 Oct 1967 to 30 Sep 2018. Figure B-2 shows a time series comparing the observed and estimated mean daily streamflow throughout this period. This figure shows a strong agreement in the overall pattern of streamflow, including the timing of peak flows, between the observed and estimated streamflows. However, the figure also shows that the estimation method under-predicts the magnitudes of many of the highest peaks.

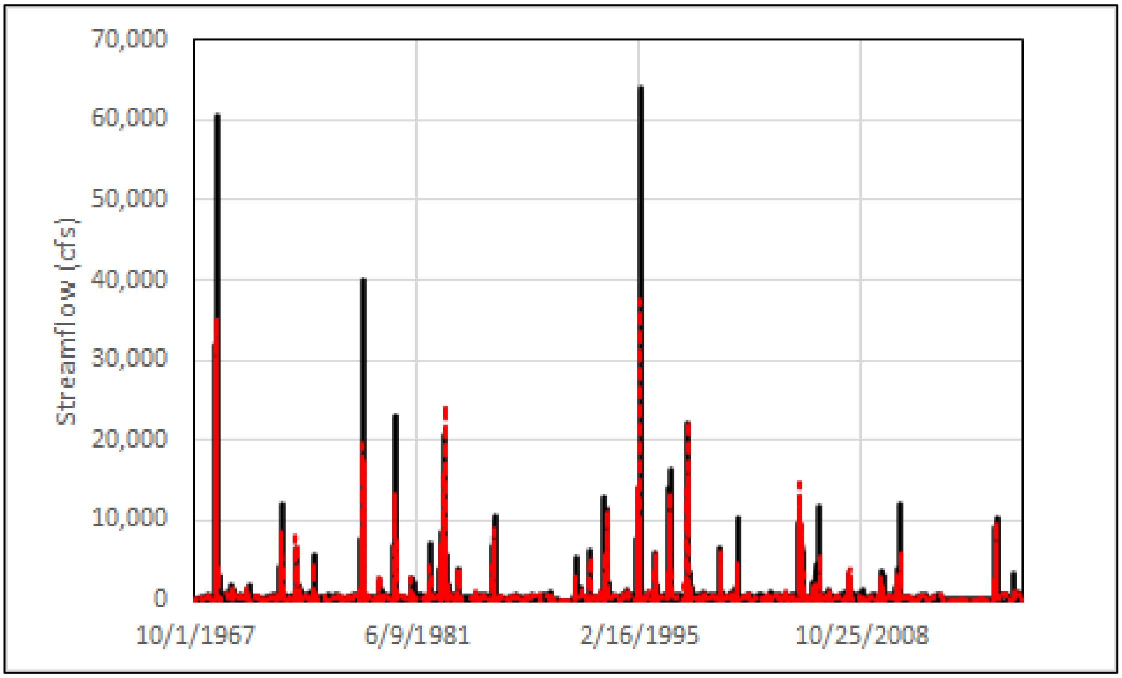

Figure B-2. Observed (black) and Estimated (red) Streamflow in the Salinas River at Bradley

Figure B-3 shows a scatterplot of the observed and estimated mean daily streamflows in the Salinas River at Bradley. Although this plot shows a generally good agreement between observed and estimated mean daily streamflow (as shown by a regression slope of 0.8768 and a regression coefficient, r^2, of 0.8860)[1], the quality of the relationship is noticeably poorer for observed mean daily streamflows above about 32,000 cfs, which are substantially under-predicted by the estimation method.

[1] All linear regressions presented in this document use a forced intercept of (0,0).

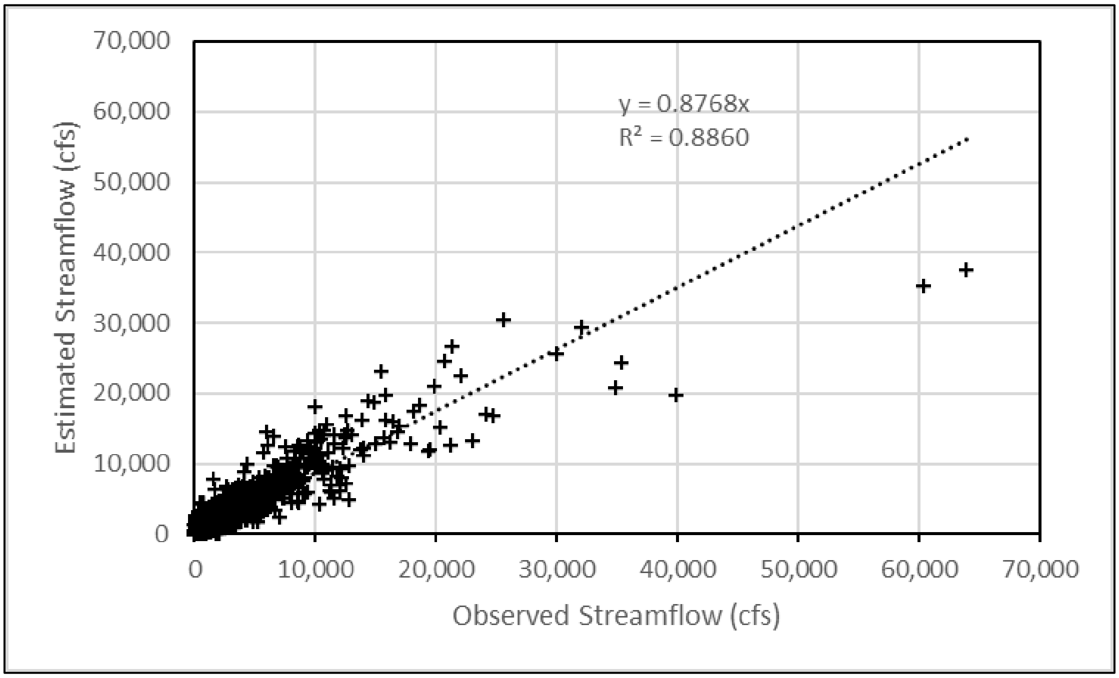

Figure B-3. Scatterplot of Observed Versus Estimated Streamflow Values in the Salinas River at Bradley with Linear Regression

Because the HBA Update is chiefly concerned with the magnitude of peak flows, this regression indicates that the basic streamflow estimation approach cannot be used as-is, and must be modified to provide a more reasonable estimate of mean daily streamflow.

To better understand the under-prediction of the highest streamflows, we looked closer at how well the estimation method matches observed mean daily streamflows above 10,000 cfs (Figure B-4). The linear regression (black line) for the >10,000 cfs events (black circles on Figure B-4) has a slope of 0.7850 and an r^2 of 0.9054. This is not substantially different from the parameters of the linear regression for all of the data (Figure B-3). Figure B-4 further divides the >10,000 cfs mean daily streamflow events into one dataset without the five highest-flow events (green plusses) and another with just the five highest-flow events (purple x's). Each of these subsets exhibits an r^2 significantly closer to a value of 1. For the first subset, the regression (green line) has a slope of 0.9180 and an r^2 of 0.9318. For the second subset, the regression (purple line) has a slope of 0.5859 and an r^2 of 0.9932. The fact that both of these regressions have r^2 values quite close to one indicates that 1) the estimation approach performs very well for flows below 32,000 cfs and 2) the under-prediction of observed mean daily streamflows above 32,000 cfs is fairly systematic, meaning that the degree of under-prediction varies in a predictable way with observed streamflow.

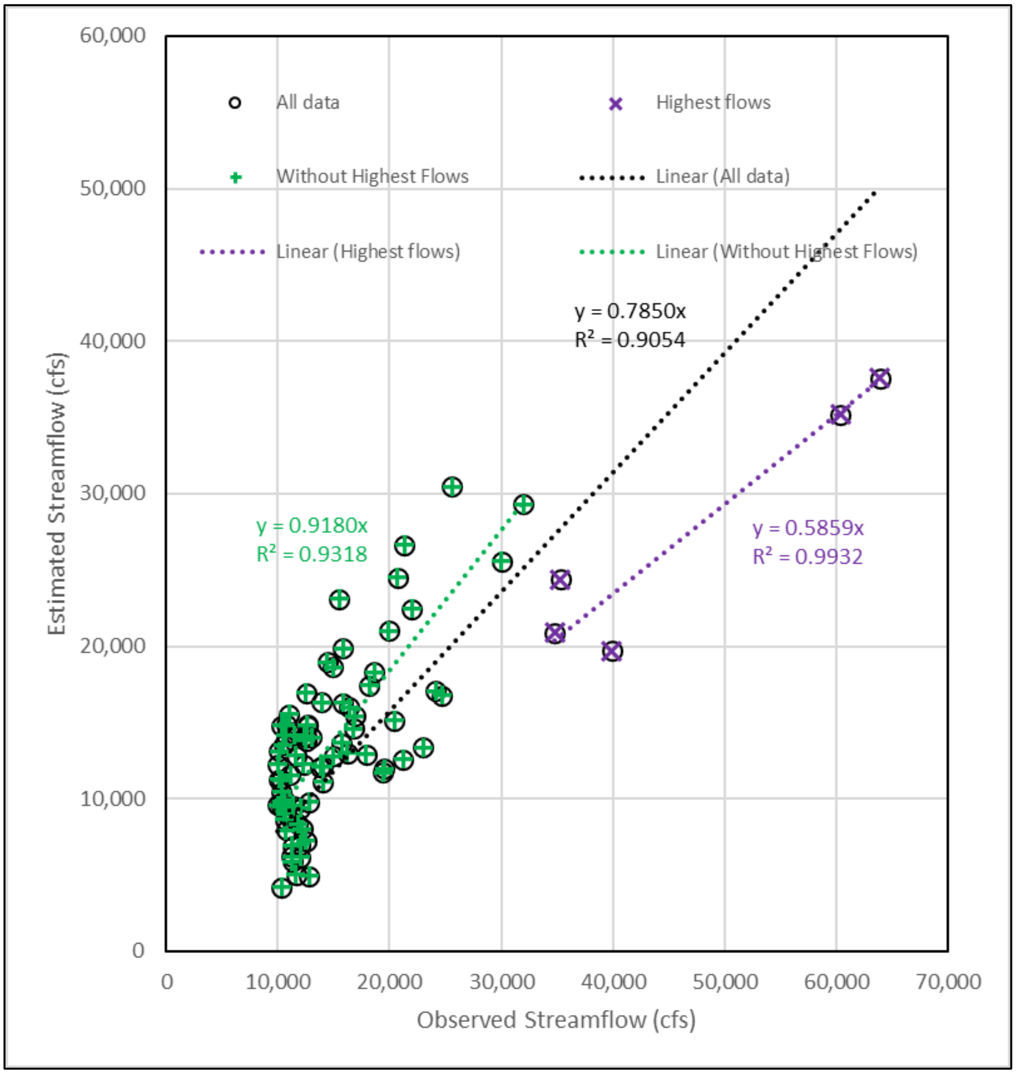

Figure B-4. Scatterplot of Observed Versus Estimated Daily Mean Streamflow in the Salinas River at Bradley for Observed Streamflows of 10,000 cfs or More

Because the sample of observed mean daily streamflows above 32,000 cfs is quite limited, we can take a closer look at those events individually and attempt to ascertain the reason that each is under-predicted. Table B-1 provides the values of all Equation 1 variables for the five highest observed streamflow events, along with the historical date of each streamflow. This table makes it clear that the inflow along the Salinas River (S_S) is by far the largest contributor to the estimated mean daily streamflow in the Salinas River at Bradley for the largest events. This is a strong indication that the under-estimation of these highest peak streamflows may result from under-prediction of the Salinas River inflow for these five events.

Table B-1. Estimated Mean Daily Streamflow (cfs) in the Salinas River at Bradley for Five Highest Flow Days, with Corresponding Observed Mean Daily Streamflow for Comparison									
Date	S_{Na}	Q_{Na}	S_{SA}	Q_{SA}	S_s	Q_s	S_{Br}	Observed	Est/Obs
2/24/69	2,605	-26	0	-1	18,330	-14	20,893	34,800	0.600
3/10/1995	800	-17	10	-1	23,609	-12	24,388	35,000	0.691
2/10/1978	2,580	-25	5	-1	17,158	-11	19,706	39,900	0.494
2/25/1969	5,466	-26	0	-1	29,784	-14	35,208	60,400	0.583
3/11/1995	1,000	-17	10	-1	36,600	-12	37,578	63,900	0.588

Table B-1 also includes the ratio between the estimated (Est) and observed (Obs) streamflow values for these five events, which ranges from 0.494 to 0.691 and average 0.591, quite close to the slope of the linear regression through the five highest-flow events (0.5859).

As stated above, the Salinas River inflow used to estimate mean daily streamflow in the Salinas River at Bradley is derived from the USGS' SVWM, which simulates the generation of streamflow throughout the Salinas River watershed. The SVWM, like the SVIHM, is a preliminary model that has not been published as of the date of publication of this HBA Update, and was not available for assessment as part of this update. This means that any inability for the SVWM to match observed streamflows cannot be investigated or corrected at this stage; the SVWM-simulated streamflow at the Salinas River inflow point represents the best available quantification of streamflow at this location.

Considering the above, the next step in the streamflow estimation approach was to assess the effect of scaling the Salinas River inflow for the five highest-flow events on the match between observed and estimated streamflows.

Modification of SVWM Salinas River Inflows

To improve the ability of the streamflow estimation approach to produce an accurate representation of observed streamflow values, the Salinas River inflow for the five highest-flow events (as measured in the Salinas River at Bradley) was scaled by a factor. Values for the scaling factor of 0.1 to 1.0 were tested and assessed based on the slope and regression coefficient for a linear regression fitted through all observed and estimated streamflow values, as well as the mean and absolute mean residuals for the five highest-flow events (Table B-2; a scaling factor of 1.0 represents no scaling).

Table B-2. Assessment of Application of Scaling Factor for Modification of Highest-Flow Events in the Salinas River Inflow				
Scaling Factor	Regression Slope	Regression Coefficient	Residual Mean, cfs	Absolute Residual Mean, cfs
0.1	2.1229	0.5349	206,561	206,561
0.2	1.4306	0.7512	81,080	81,080
0.3	1.1999	0.8680	39,253	39,253
0.4	1.0845	0.9172	18,339	18,339
0.5	1.0153	0.9815	5,791	7,005
0.54	0.9948	0.9320	2,073	4,304
0.55	0.9901	0.9310	1,228	4,020
0.56	0.9856	0.9613	413	3,814
0.565	0.9834	0.9314	17	3,715
0.57	0.9813	0.9312	-373	3,648
0.575	0.9792	0.9310	-756	3,664
0.5859	0.9747	0.9305	-1,568	3,877
0.6	0.9691	0.9296	-2,574	4,505
0.7	0.9362	0.9209	-8,550	8,550
0.8	0.9114	0.9095	-13,031	13,031
0.9	0.8922	0.8976	-16,517	16,517
1.0	0.8768	0.8860	-19,305	19,305

From Table B-2, it is clear that a range of scaling factors between about 0.5 and 0.6 provide a marked improvement in the overall fit compared to the unscaled estimation. Although various different statistics can be used to identify the optimal scaling factor, the absolute residual[2] mean was relied on most heavily because it provides an indication of the magnitude of the mismatch between observed and estimated streamflows (compared to the residual mean, which can be near the ideal value of zero if large positive and negative residuals balance each other). Based on the absolute residual mean, a scaling factor of 0.57, when applied to the five highest-flow events, provides the best match between observed and estimated mean daily streamflows in the Salinas River at Bradley.

[2] Residual is defined as the difference between an observed and estimated value and is equal to the estimated streamflow minus the observed streamflow. The absolute residual is the absolute value of the residual.

Table B-3 provides the values of the Equation 1 variables for the five highest-flow events (as in Table B-1), with S_S scaled (i.e., divided by 0.57). This table shows that the modified (i.e., scaled) estimated streamflow values produce a much closer match to the observed highest flows compared to using the unscaled flow values.

Table B-3. Estimated Mean Daily Streamflow in the Salinas River at Bradley for Five Highest Flow Days, Using Scaled Values of Salinas River Inflow, with Corresponding Observed Mean Daily Streamflow for Comparison

Date	S_{Na}	Q_{Na}	S_{SA}	Q_{SA}	S_s	Q_s	S_{Br}	Observed	Est/Obs
2/24/69	2,605	-26	0	-1	31,285	-14	33,848	34,800	0.973
3/10/1995	800	-17	10	-1	40,295	-12	41,075	35,000	1.164
2/10/1978	2,580	-25	5	-1	29,285	-11	31,833	39,900	0.798
2/25/1969	5,466	-26	0	-1	50,835	-14	56,259	60,400	0.931
3/11/1995	1,000	-17	10	-1	62,468	-12	63,447	63,900	0.993

Figure B-5 shows the time series of observed and modified estimated streamflow values in the Salinas River at Bradley. Comparison with Figure B-2 demonstrates that the highest peak flows are much better matched with the scaled Salinas River inflows compared to the unscaled inflows. Figure B-6 provides a scatterplot of all observed and modified estimated mean daily streamflows in the Salinas River at Bradley; comparison with Figure B-3 shows that the modification to the Salinas River inflow for the highest-flow events results in a substantially better (i.e., closer to the desired 1:1 line) match to the observed data. A linear regression through these data results in a regression slope of 0.9813 (compared to 0.8768 without scaling) and an r^2 of 0.9312 (compared to 0.8860 without scaling). This scaling factor has no physical meaning, a limitation of this approach. But, because we do not have access to the SVWM to better understand why it may be under-predicting the highest peak flows (and correct the issue), this scaling is considered the best way to reproduce observed streamflow conditions in the Salinas River at Bradley with the available information.

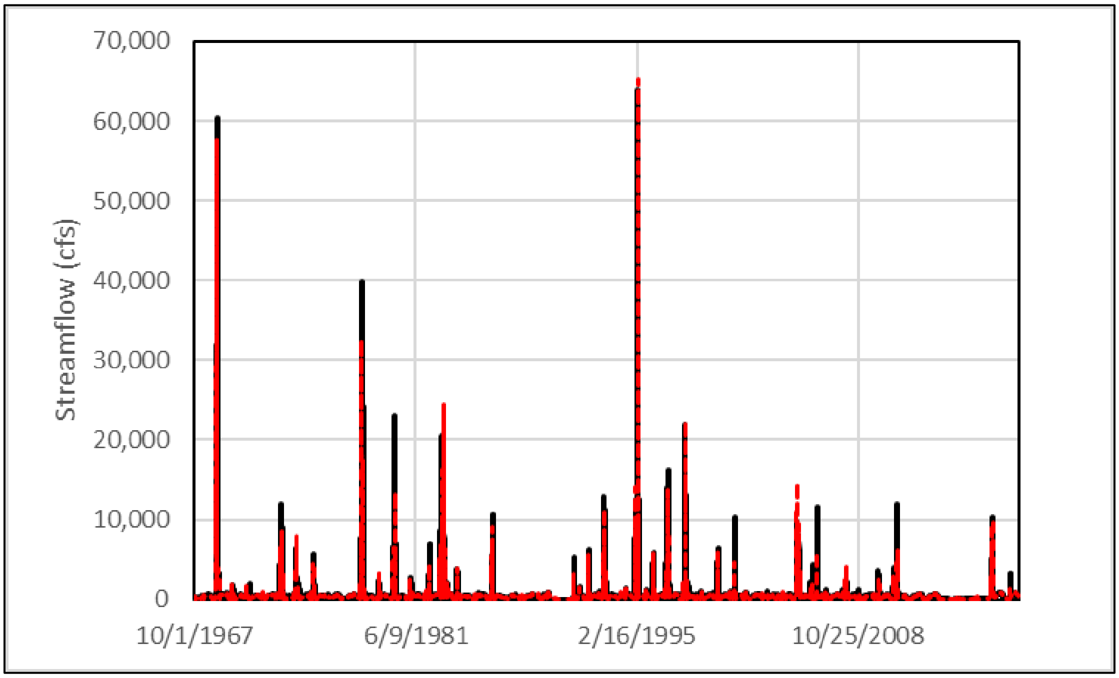

Figure B-5. Observed (black) and Modified Estimated (red) Streamflow in the Salinas River at Bradley, Using Modified Values of Salinas River Inflow for Highest-Flow Events

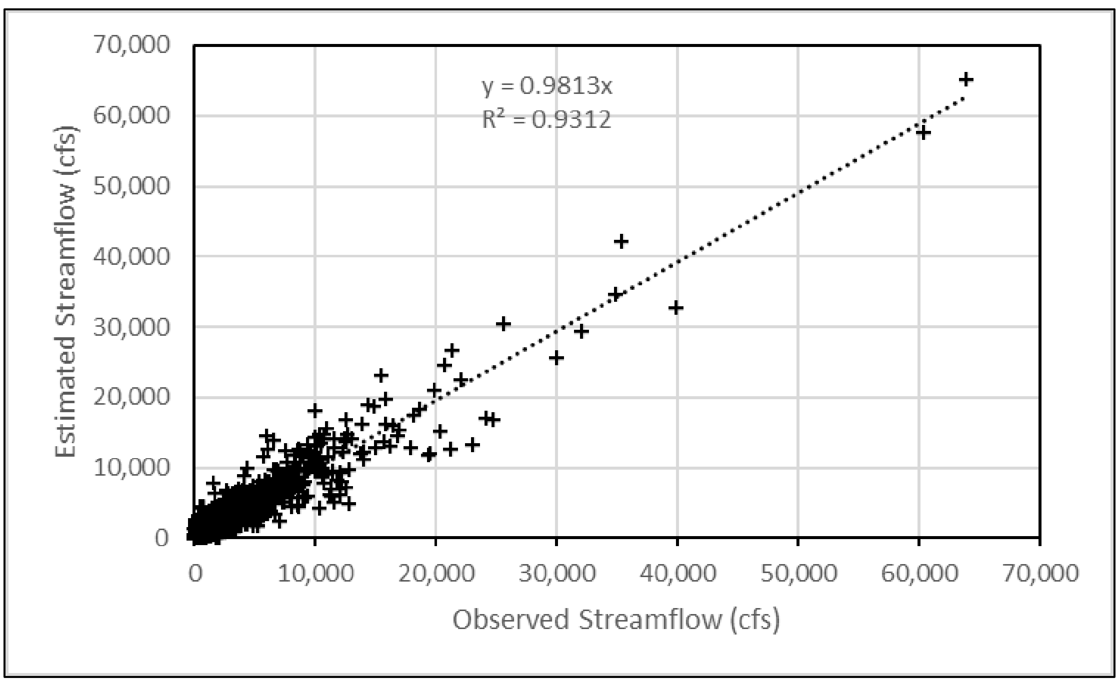

Figure B-6. Scatterplot of Observed Versus Modified Estimated Streamflow Values in the Salinas River at Bradley, Using Modified Values of Salinas River Inflow for Highest-Flow Events (Scaling Factor = 0.57), with Linear Regression

Throughout the remainder of this document, the scaled Salinas River inflows are used to provide the values of S_S to Equation 1 for the characterization of annual peak streamflow in the Salinas River at Bradley.

Modified Estimated Streamflows

Two time series of streamflow were developed using the modified estimation described previously, one representative of historical conditions in the study area and another approximating conditions as if the Nacimiento and San Antonio Reservoirs (and certain related projects and programs; see Section 1.2.4 of the HBA Update). Each uses Equation 1 to calculate mean daily streamflow in the Salinas River at Bradley; the difference lies in the inputs used to calculate the data for each time series.

For the Historical Scenario, the input variables for Equation 1 are as follows:

- S_{Na} = Measured daily releases from Nacimiento Dam (provided by MCWRA)
- Q_{Na} = Simulated groundwater-surface water interaction flux along the Nacimiento River under the SVIHM Historical Scenario
- S_{SA} = Measured daily releases from San Antonio Dam (provided by MCWRA)
- Q_{SA} = Simulated groundwater-surface water interaction flux along the San Antonio River under the SVIHM Historical Scenario
- S_S = Modified estimated mean daily Salinas River inflow
- Q_S = Simulated groundwater-surface water interaction flux along the Salinas River above Bradley under the SVIHM Historical Scenario

This time series of mean daily streamflow is presented in Figure B-5, and the comparison between this time series and the observed mean daily streamflow time series in the Salinas River at Bradley is discussed in the previous section.

For the No Projects Scenario, the input variables for Equation 1 are as follows:

- S_{Na} = Estimated daily inflow to Nacimiento Reservoir (provided by MCWRA)
- Q_{Na} = Simulated groundwater-surface water interaction flux along the Nacimiento River under the SVIHM No Projects Scenario
- S_{SA} = Estimated daily inflow to San Antonio Reservoir (provided by MCWRA)
- Q_{SA} = Simulated groundwater-surface water interaction flux along the San Antonio River under the SVIHM No Projects Scenario
- S_S = Modified estimated mean daily Salinas River inflow
- Q_S = Simulated groundwater-surface water interaction flux along the Salinas River above Bradley under the SVIHM No Projects Scenario

For the No Projects Scenario mean daily streamflow time series, the use of reservoir inflows rather than releases as the inputs to the Nacimiento and San Antonio Rivers approximates the flows along those rivers that would have occurred had the reservoirs not existed. There is no equivalent observed time series against which these streamflow estimates can be compared for verification.

Without the reservoirs in place, one would expect the streamflow in the Salinas River at Bradley to be somewhat more variable compared to the observed streamflows, as flood events in the Nacimiento and San Antonio River watersheds would be passed directly into the Salinas River without the possibility of storage within the reservoirs. Table B-4 provides a selection of statistics for the observed and estimated mean daily streamflow time series. The statistics for the Historical Scenario time series compare very favorably with those of the observed dataset. The average No Projects Scenario mean daily streamflow is very similar to that of the observed data, but the median streamflow is substantially lower, the maximum streamflow is higher, and the standard deviation is larger, a demonstration of the increased variability of streamflow without the reservoirs.

Table B-4. Statistics of Streamflow Time Series for Observed and Estimated Mean Daily Streamflow in the Salinas River at Bradley, cfs

	Observed Streamflow	Historical Scenario Modified Estimated Streamflow	No Projects Scenario Modified Estimated Streamflow
Average	502	506	536
Standard Deviation	1,479	1,506	2,547
Minimum	0	-20	-30
10th Percentile	32	26	-1
1st Quartile	76	66	-1
Median	299	293	16
3rd Quartile	498	489	178
90th Percentile	661	648	891
Maximum	63,900	65,190	105,374

This table indicates that the estimation method described in this appendix results in many negative streamflow estimates. This is obviously not representative of reality; negative streamflow is physically meaningless. Negative mean daily streamflow values in the estimated streamflow time series demonstrate the uncertainties involved in the streamflow estimation, and in part result from the fact that the simulated groundwater-surface water interaction fluxes from the SVIHM are averaged over a 5- to 6-day timestep, while the stream inflow time series have a daily timestep. The simulated groundwater-surface water fluxes also take into account land surface runoff and tributary inflow that enter the stream network between where the stream inflow points are located and the location of the Salinas River at Bradley gauge. When considering the effect of these negative estimated streamflows, it is worth keeping in mind that the flood flow frequency analysis built from these streamflow estimates is largely focused the highest flows in the system and is insensitive to the accuracy of estimates of low flows.

Annual Peak Flows

For a sufficiently long period of record, the characterization of peak flow magnitudes for different return periods (e.g., the 100-year flood) can rely solely on a time series of annual[3] peak flows (i.e., the largest streamflow observed during the year). The 1998 HBA utilized datasets of:

- instantaneous peak flow (i.e., the largest observed or estimated streamflow that occurred each year),
- 1-day flow (i.e., the highest mean daily streamflow each year),
- 3-day flow (i.e., the highest 3-day average of mean daily streamflows each year), and
- 5-day flow (i.e., the highest 5-day average of mean daily streamflows each year).

For this HBA Update, equivalent datasets were developed. The annual peak 1-day flows were derived directly from the results of the streamflow estimation approach, as described above. The annual peak 3-day and 5-day flows were calculated from the time series of estimated mean daily flow by calculating the running 3-day and 5-day average streamflow in each streamflow time series (observed, Historical Scenario modified estimated, and No Projects Scenario modified estimated) and identifying the highest value occurring each year.

Figure B-7 shows the time series of annual peak mean daily streamflow for the observed and Historical Scenario modified estimated streamflow data. Figure B-8 shows a scatterplot of the same data; a linear regression between the annual peak mean daily observed and modified estimated streamflow has a slope of 0.9346 and an r^2 of 0.9742 (compared to a slope of 0.9813 and an r^2 of 0.9312 for all of the streamflow data), demonstrating that the streamflow estimation approach does at least as good a job of replicating the subset of annual peak flows as it does with the entire mean daily streamflow dataset.

[3] For this study, annual peaks are identified based on the water year (WY), which lasts from 1 October to 30 September.

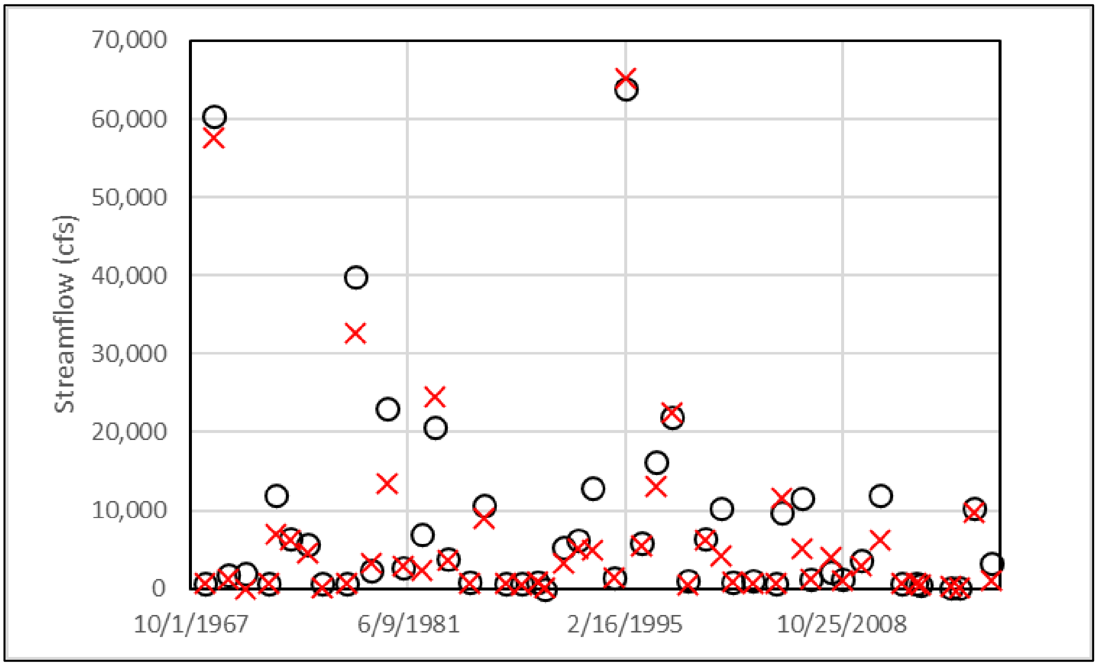

Figure B-7. Observed (black) and Modified Estimated (red) Annual Peak Mean Daily Streamflow in the Salinas River at Bradley

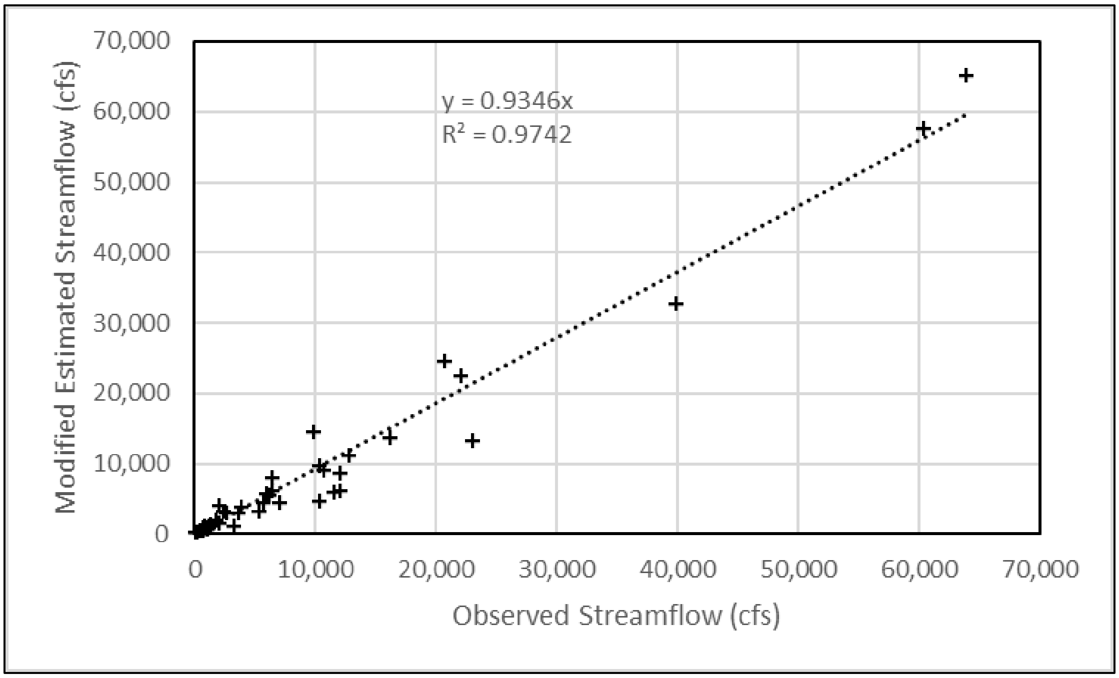

Figure B-8. Scatterplot of Observed Versus Modified Estimated Annual Peak Mean Daily Streamflow Values in the Salinas River at Bradley with Linear Regression

Identification of the annual instantaneous peak flow requires streamflow data on a sub-daily temporal resolution. The USGS makes available streamflow measurements on a 15-minute interval for the Salinas River at Bradley gauge for a limited portion of the study period (i.e., WY 1989 to 2022). However, sub-daily streamflow data are not available for any of the inputs to Equation 1, meaning that the estimation method cannot be used directly to develop a time series of annual instantaneous peak streamflow.

Next, we consider the relationship between annual peak 15-minute streamflow and annual peak mean daily streamflow for the Salinas River at Bradley gauge over the 34-year period when 15-minute data are available. Figure B-9 shows a scatterplot of the annual peak instantaneous streamflow against the annual peak mean daily streamflow for the Salinas River at Bradley over the period from WY 1989 to 2022. A linear regression through these data has a slope of 1.7515 and an r^2 of 0.9819.

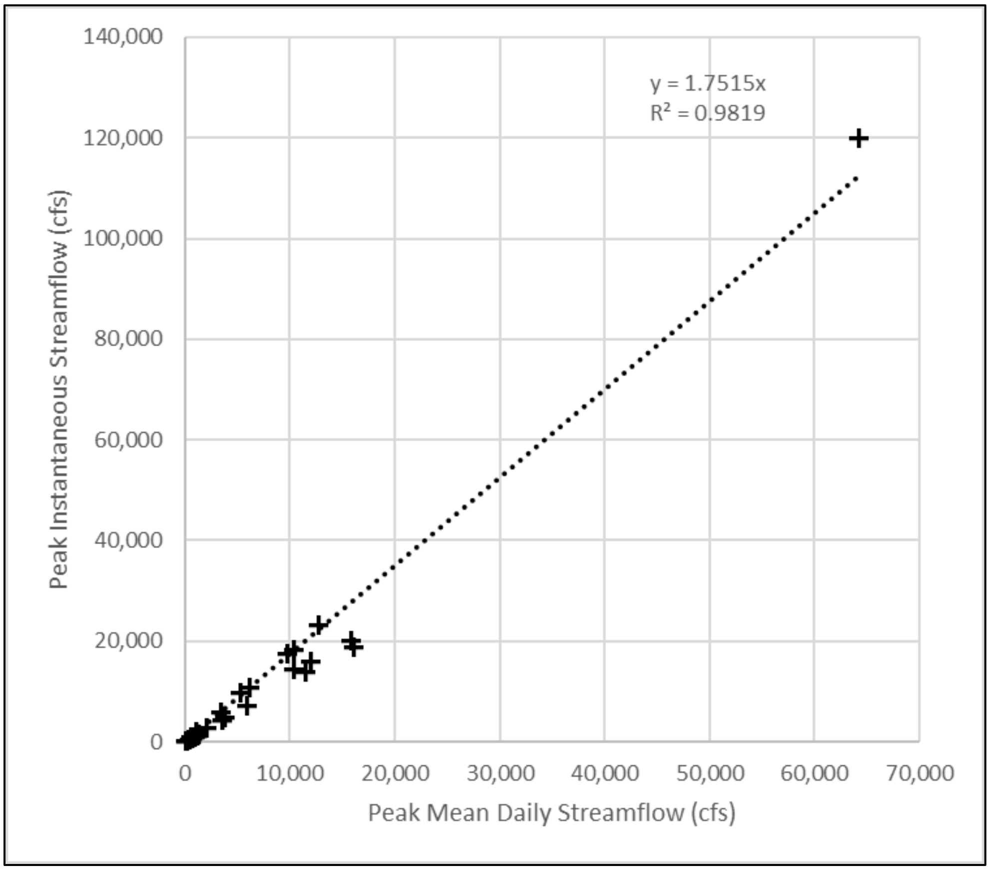

Figure B-9. Scatterplot of Annual Peak Mean Daily Streamflow Versus Annual Peak Instantaneous Streamflow in the Salinas River at Bradley with Linear Regression

The quality of the fit between these two datasets suggests that the annual peak mean daily streamflow time series developed for the entire period of the analysis (WY 1968 to 2018) can be used to calculate an equivalent annual peak instantaneous flow for each year. The slope of the regression (1.7515) can be used to scale the annual peak mean daily streamflows derived from the streamflow estimation approach. Table B-5 provides the annual peak instantaneous, 1-day, 3-day, and 5-day streamflows in the Salinas River at Bradley for the observed, Historical Scenario modified estimated, and No Projects Scenario modified estimated datasets.

Table B-5. Annual peak streamflow values for observed and estimated streamflow datasets (in cfs)

WY	Observed				Historical Scenario Modified Estimated				No Projects Scenario Modified Estimated			
	Instant	1-Day	3-Day	5-Day	Instant	1-Day	3-Day	5-Day	Instant	1-Day	3-Day	5-Day
1968	1,131	646	621	609	1,174	670	666	649	3,148	1,797	1,172	849
1969	105,791	60,400	40,267	29,440	101,021	57,677	40,957	31,136	120,139	68,592	55,496	40,423
1970	3,240	1,850	1,750	1,622	3,438	1,963	1,721	1,536	25,865	14,767	7,520	5,307
1971	3,485	1,990	1,322	848	2,910	1,661	1,402	1,167	17,493	9,988	6,057	5,213
1972	1,279	730	691	675	1,655	945	703	639	9,668	5,520	4,155	3,296
1973	21,018	12,000	8,667	6,700	15,072	8,605	6,953	6,799	38,845	22,178	15,716	13,873
1974	11,192	6,390	6,140	5,630	13,963	7,972	6,971	6,193	39,872	22,764	13,946	10,226
1975	10,071	5,750	5,387	4,778	7,965	4,547	4,431	4,185	41,150	23,494	12,819	8,745
1976	1,130	645	638	632	1,103	629	628	628	1,783	1,018	861	669
1977	1,193	681	680	673	1,229	702	700	698	1,426	814	405	343
1978	69,885	39,900	25,133	23,380	57,187	32,650	22,118	19,823	72,925	41,635	33,892	28,434
1979	4,151	2,370	2,367	2,276	5,755	3,286	3,126	2,939	13,195	7,533	5,469	4,274
1980	40,285	23,000	21,200	18,760	23,410	13,366	12,669	12,571	48,061	27,440	26,980	24,642
1981	4,729	2,700	2,617	2,001	5,152	2,941	2,739	2,253	11,548	6,593	4,568	4,055
1982	12,261	7,000	6,067	5,424	7,821	4,465	3,605	3,339	45,355	25,895	14,763	10,771
1983	36,256	20,700	18,167	15,270	42,883	24,484	20,809	18,393	83,525	47,688	37,065	28,954
1984	6,761	3,860	3,780	3,708	6,715	3,834	3,825	3,817	19,005	10,851	6,378	4,543
1985	1,356	774	757	743	1,946	1,111	783	657	8,303	4,741	3,321	2,286
1986	18,741	10,700	9,730	7,756	15,793	9,017	7,818	6,573	41,590	23,745	19,594	18,198
1987	1,119	639	614	602	1,047	598	598	598	13,534	7,727	3,387	2,192
1988	1,142	652	628	603	1,266	723	661	628	5,708	3,259	2,153	1,547
1989	1,664	950	928	926	1,578	901	901	901	9,057	5,171	2,517	1,730

Table B-5. Annual peak streamflow values for observed and estimated streamflow datasets (in cfs)												
	Observed				Historical Scenario Modified Estimated				No Projects Scenario Modified Estimated			
WY	Instant	1-Day	3-Day	5-Day	Instant	1-Day	3-Day	5-Day	Instant	1-Day	3-Day	5-Day
1990	51	29	27	25	474	270	128	86	2,838	1,620	1,134	807
1991	9,353	5,340	4,377	2,825	5,603	3,199	2,917	2,353	32,767	18,708	8,216	6,265
1992	10,772	6,150	4,923	4,398	9,753	5,568	4,962	4,755	25,091	14,325	9,654	10,121
1993	22,419	12,800	9,727	8,598	19,661	11,225	9,248	8,414	63,238	36,105	21,840	18,350
1994	2,365	1,350	1,347	1,278	2,430	1,387	1,387	1,327	9,491	5,419	3,399	2,624
1995	111,921	63,900	40,167	27,306	114,180	65,190	44,673	32,955	184,563	105,374	74,868	51,024
1996	10,404	5,940	5,567	5,472	10,232	5,842	5,472	5,281	23,972	13,687	11,575	9,147
1997	28,374	16,200	14,000	12,426	23,928	13,661	12,646	11,389	37,972	21,680	18,630	15,020
1998	38,533	22,000	17,400	14,600	39,344	22,463	20,426	17,918	85,785	48,978	31,840	26,356
1999	1,979	1,130	1,007	954	1,744	995	970	907	7,590	4,333	2,727	2,058
2000	11,210	6,400	5,660	4,822	10,783	6,156	5,945	5,305	28,595	16,326	10,755	8,479
2001	18,040	10,300	7,657	5,380	8,294	4,736	3,841	3,033	26,261	14,993	10,649	8,323
2002	1,461	834	827	826	1,682	960	936	918	11,612	6,630	3,822	2,569
2003	1,874	1,070	726	636	1,396	797	628	625	18,697	10,675	5,367	4,499
2004	1,223	698	693	686	1,819	1,038	781	689	15,318	8,746	5,763	4,008
2005	17,147	9,790	7,457	7,028	25,609	14,621	13,640	11,734	53,909	30,779	19,843	18,278
2006	20,317	11,600	10,100	8,386	10,305	5,883	5,358	5,052	22,279	12,720	11,016	8,876
2007	2,154	1,230	1,170	1,044	2,172	1,240	1,240	1,120	3,465	1,978	1,037	718
2008	3,661	2,090	1,690	1,415	7,165	4,091	3,507	3,087	18,166	10,372	9,505	8,370
2009	2,102	1,200	1,180	1,168	1,725	985	985	985	8,139	4,647	2,936	2,198
2010	6,288	3,590	2,907	2,093	5,210	2,974	2,589	2,119	24,383	13,921	11,097	9,031
2011	21,018	12,000	7,920	6,496	10,804	6,168	5,520	4,713	40,700	23,237	14,197	12,473

Table B-5. Annual peak streamflow values for observed and estimated streamflow datasets (in cfs)

WY	Observed				Historical Scenario Modified Estimated				No Projects Scenario Modified Estimated			
	Instant	1-Day	3-Day	5-Day	Instant	1-Day	3-Day	5-Day	Instant	1-Day	3-Day	5-Day
2012	1,124	642	614	614	1,223	698	637	634	5,806	3,315	2,201	1,677
2013	1,287	735	716	707	1,368	781	690	676	16,464	9,400	5,272	3,880
2014	870	497	500	499	915	522	520	517	2,773	1,583	1,246	937
2015	361	206	186	171	730	417	232	208	6,843	3,907	3,131	2,279
2016	254	145	135	124	726	415	341	283	12,936	7,386	5,152	3,598
2017	18,040	10,300	9,337	8,410	17,169	9,802	9,131	8,451	37,792	21,577	15,868	14,648
2018	5,780	3,300	1,772	1,296	2,194	1,253	947	812	20,132	11,494	6,148	4,306

Figures B-10 through B-13 show time series of the annual peak instantaneous, 1-day, 3-day, and 5-day streamflows, respectively, for the observed, Historical Scenario modified estimated, and No Projects Scenario modified estimated datasets. These figures show the excellent agreement between the observed and Historical Scenario modified estimated peak flows, as well as the noticeable difference form the No Projects modified estimated peak flows, which tend to be substantially higher.

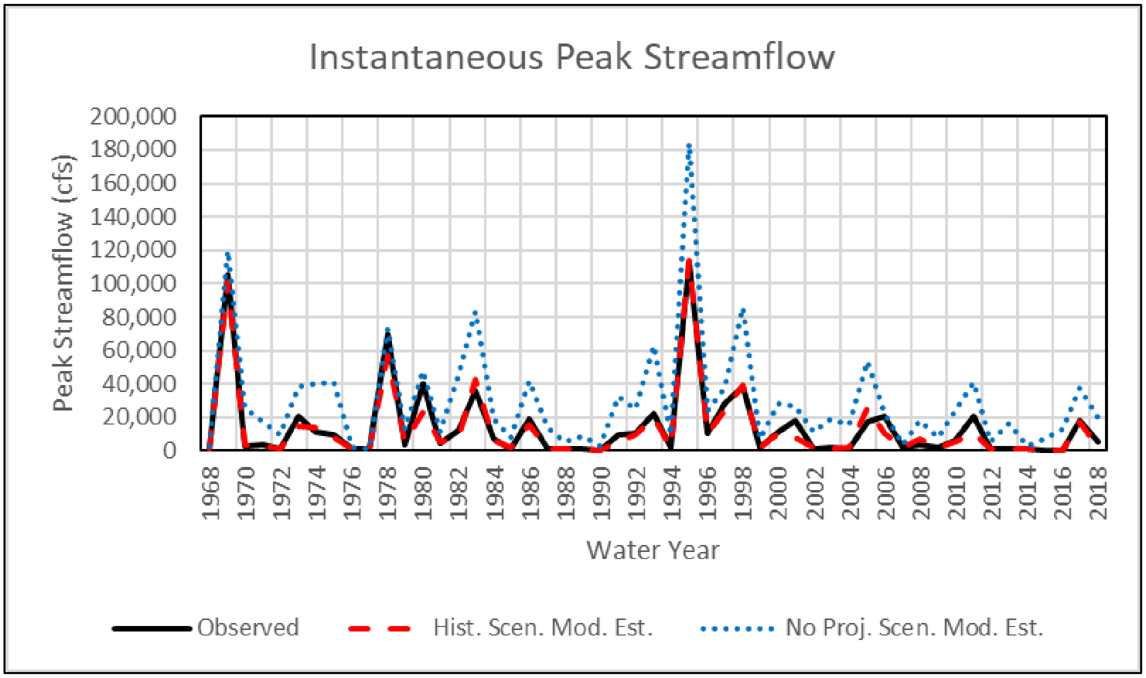

Figure B-10. Annual Peak Instantaneous Streamflow (in cfs) for Observed, Historical Scenario Modified Estimated, and No Projects Scenario Modified Estimated Datasets

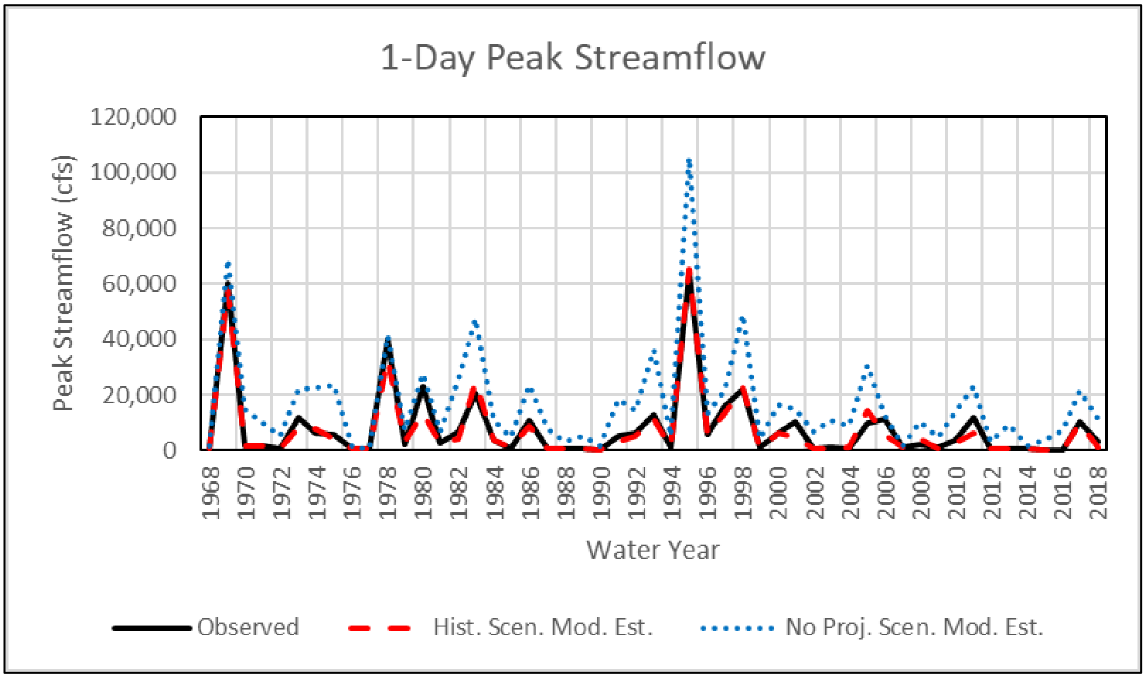

Figure B-11. Peak 1-Day Streamflow (in cfs) for Observed, Historical Scenario Modified Estimated, and No Projects Scenario Modified Estimated Datasets

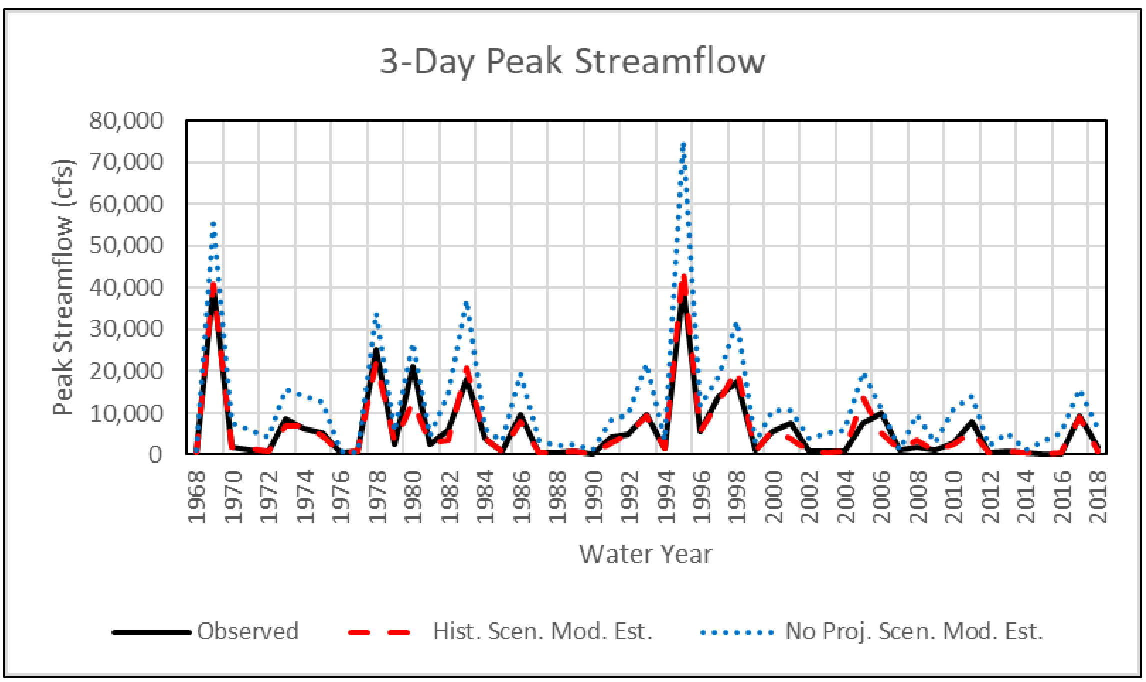

Figure B-12. Peak 3-Day Streamflow (in cfs) for Observed, Historical Scenario Modified Estimated, and No Projects Scenario Modified Estimated Datasets

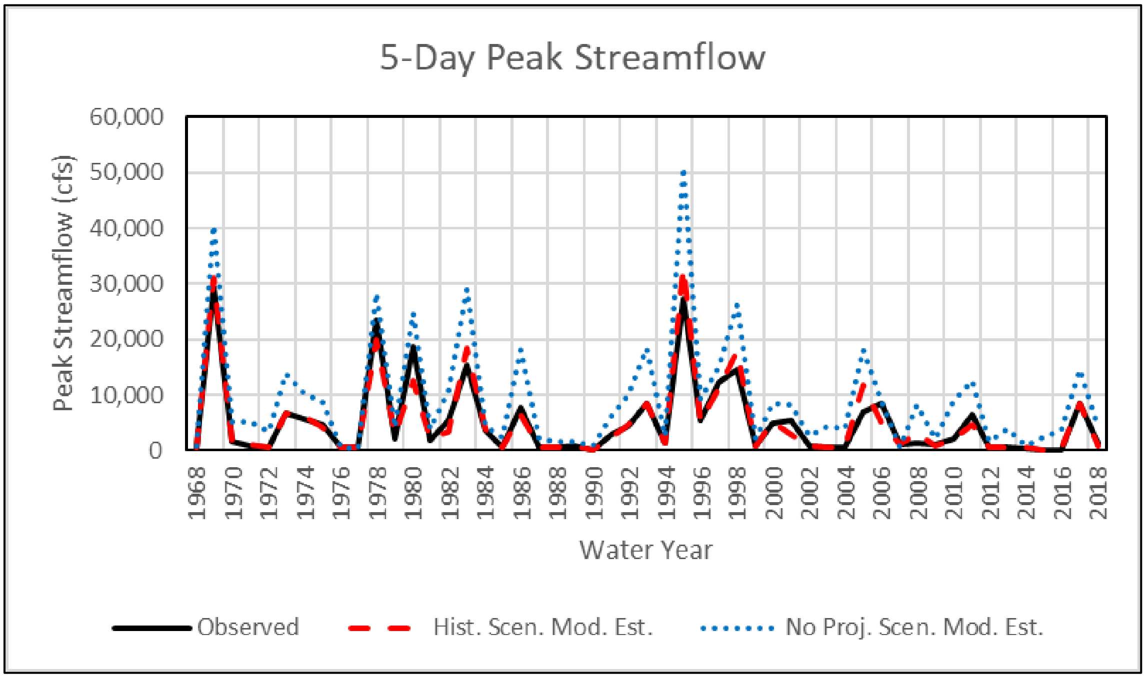

Figure B-13. Peak 5-Day Streamflow (in cfs) for Observed, Historical Scenario Modified Estimated, and No Projects Scenario Modified Estimated Datasets

FLOOD FLOW FREQUENCY ANALYSIS

As stated at the beginning of this appendix, one important conclusion of the 1998 HBA was that the reservoirs have substantially reduced the magnitude of the 100-year flood in the system. This was determined by characterizing the statistical distribution of annual peak flows with and without the reservoirs, then simulating of the effects of these peak flows on the system using a hydraulic model of the Salinas River. This HBA Update reproduces the analysis of the benefits that the reservoirs and related projects and programs have had in terms of their effect on the magnitude of peak flows in the system. Following the approach used for the 1998 HBA, we developed a statistical characterization of the distribution of peak flows in the Salinas River at Bradley, and used a selection of peak flows to investigate the extent of inundation in the Salinas River floodplain using an existing HEC-RAS 2D model of the Salinas River and its floodplain (FlowWest, 2015).

The characterization of the magnitude of peak streamflows relies on the fact that annual peak streamflows in natural systems generally follow a well-defined statistical distribution. England et al. (2019) describe the approach employed here for performing a flood flow frequency analysis using time series of annual peak flows. In brief, the flood flow frequency analysis relies on fitting a log-Pearson Type III distribution to the annual peak flow data. The probability distribution function of a log-Pearson Type III distribution is defined based on certain parameters (location parameter, shape parameter, and scale parameter) the values of which can be estimated for a flood flow frequency analysis from the values of the moments (mean, standard deviation, and skew coefficient) of the dataset of annual peak flows (England et al., 2019).

Various automated programs have been developed for performing flood flow frequency analyses; this study utilizes the USGS software PeakFQ (Flynn et al., 2006). Based on user inputs, PeakFQ estimates the parameters of the statistical distribution for an annual peak flow dataset; it can automatically identify and remove outliers and other problematic data.

In PeakFQ, the third moment of the probability distribution (the skew coefficient) can be calculated directly from the dataset of annual peak flows, but England et al. (2019) recommend using a regional skew coefficient determined independently. For this analysis, California-specific skew coefficients (Parrett et al., 2011) were consulted to identify an appropriate value of the skew coefficient. Although skew coefficients are not published for stream gauges that are highly impacted by surface water regulation (such as the Salinas River at Bradley), other nearby gauges located within the Salinas River watershed from Paso Robles north have skew coefficients ranging from -0.442 to -0.577 (Parrett et al., 2011); a skew coefficient of -0.5 was selected for this study to fit within the range published for nearby gauges.

PeakFQ can also provide confidence limits on the estimation of the flood flow frequency curve if the skew coefficient is accompanied by an estimate of the mean standard error. Parrett et al. (2011) indicated a mean standard error of 0.13 for all of the gauges in the Salinas River watershed.

The output from PeakFQ is a set of flow magnitudes corresponding to various annual exceedance probabilities (AEPs), which is the probability that the corresponding peak flow magnitude will be exceeded each year. For example, a peak flow with an AEP of 0.1 has a 10 percent chance of being exceeded each year. In standard parlance, the inverse of the AEP is referred to as the return period; for example, a peak flow with an AEP of 0.01 is generally referred to as the 100-year flood. The return period should not be taken as an indicator that a given flood should be expected to occur once during the duration of the return period (i.e., that the 100-year flood will happen once per century). In reality, the 100-year flood can happen several times during a given 100-year period, or not at all. The AEP is a more precise way of describing the expected frequency of floods in a system but, because the return period is the more typical way of discussing floods among the general public (e.g., this is the terminology used in flood insurance studies), this study presents peak flows along with their corresponding AEPs and return periods.

Flood Flow Frequency Curves

For this study, flood flow frequency curves were developed for the observed streamflow, Historical Scenario modified estimated streamflow, and No Projects modified estimated streamflow time series (all covering the 51-year period from WY 1968 to 2018). Although observed annual peak streamflows are available for the Salinas River at Bradley from WY 1949 to 2022, the time series analyzed was limited to the same period simulated by the SVIHM. This avoids the complication of analyzing a dataset that is highly non-stationary (because of the construction of the reservoirs).

Table B-6 provides the magnitude of peak flows (instantaneous, 1-day, 3-day, and 5-day) for each of the datasets (observed, Historical Scenario modified estimated, No Projects Scenario modified estimated) for a selection of AEPs and return periods. Figures B-14 through B-16 present the flood flow frequency curves for the observed streamflow, Historical Scenario modified estimated streamflow, and No Projects Scenario modified estimated streamflow, respectively. These data demonstrate the reduction in the magnitude of flood flow events in the Basin that has occurred due to the presence of the reservoirs (and related projects and programs).

Table B-6. Peak Flow Magnitudes (in cfs) for the Observed, Historical Scenario Modified Estimated, and No Projects Scenario Modified Estimated Streamflow Time Series for Selected AEPs

Annual Exceedance Probability	0.5	0.2	0.1	0.04	0.02	0.01
Return Period, Years	2	5	10	25	50	100
Observed Data (WY1968-2018)						
Instantaneous	5,423	19,330	35,650	65,900	96,020	132,900
1-Day	3,096	11,040	20,350	37,620	54,810	75,850
3-Day	2,700	8,956	15,840	27,920	39,390	52,920
5-Day	2,388	7,566	13,060	22,400	31,050	41,050
Historical Scenario Modified Estimated Streamflow (WY1968-2018)						
Instantaneous	5,007	15,740	28,480	53,360	79,880	114,600
1-Day	2,858	8,985	16,260	30,470	45,610	65,450
3-Day	2,526	7,856	13,980	25,510	37,370	52,430
5-Day	2,308	7,028	12,290	21,940	31,600	43,600
No Projects Scenario Modified Estimated Streamflow (WY1968-2018)						
Instantaneous	19,360	45,170	67,600	100,900	128,800	158,700
1-Day	11,050	25,790	38,600	57,640	73,530	90,630
3-Day	7,283	17,740	27,250	41,960	54,670	68,730
5-Day	5,669	14,220	22,180	34,660	45,590	57,780
Difference Between Scenarios (No Projects Scenario minus Historical Scenario)						
Instantaneous	14,353	29,430	39,120	47,540	48,920	44,100
1-Day	8,192	16,805	22,340	27,170	27,920	25,180
3-Day	4,757	9,884	13,270	16,450	17,300	16,300
5-Day	3,361	7,192	9,890	12,720	13,990	14,180

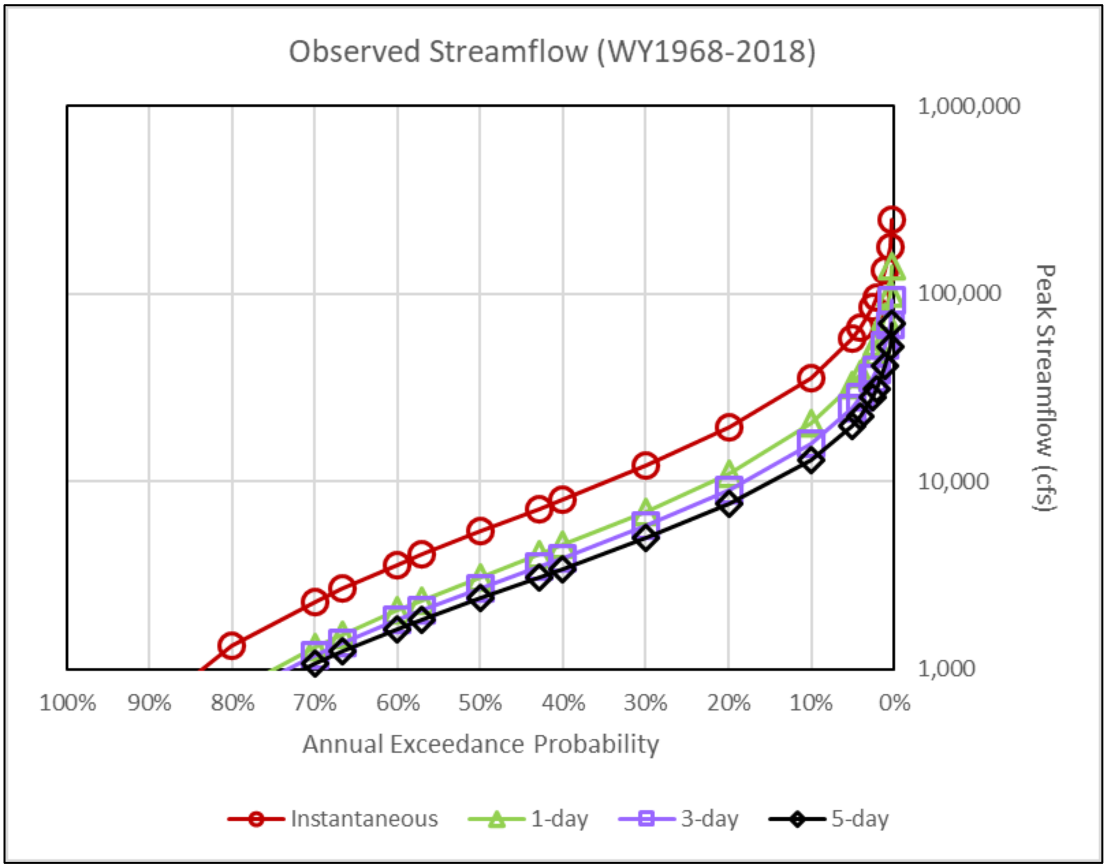

Figure B-14. Flood Flow Frequency Curves for Observed Streamflow for the Salinas River at Bradley

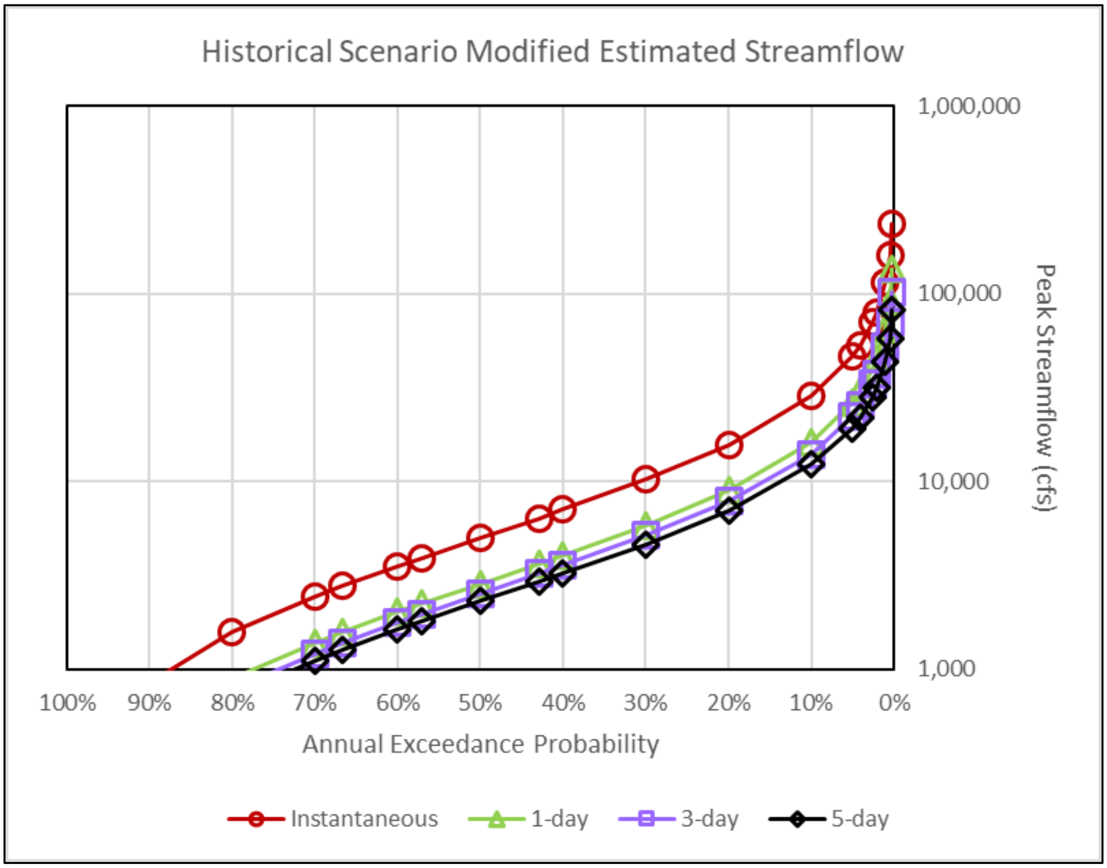

Figure B-15. Flood Flow Frequency Curves for Historical Scenario Modified Estimated Streamflow for the Salinas River at Bradley

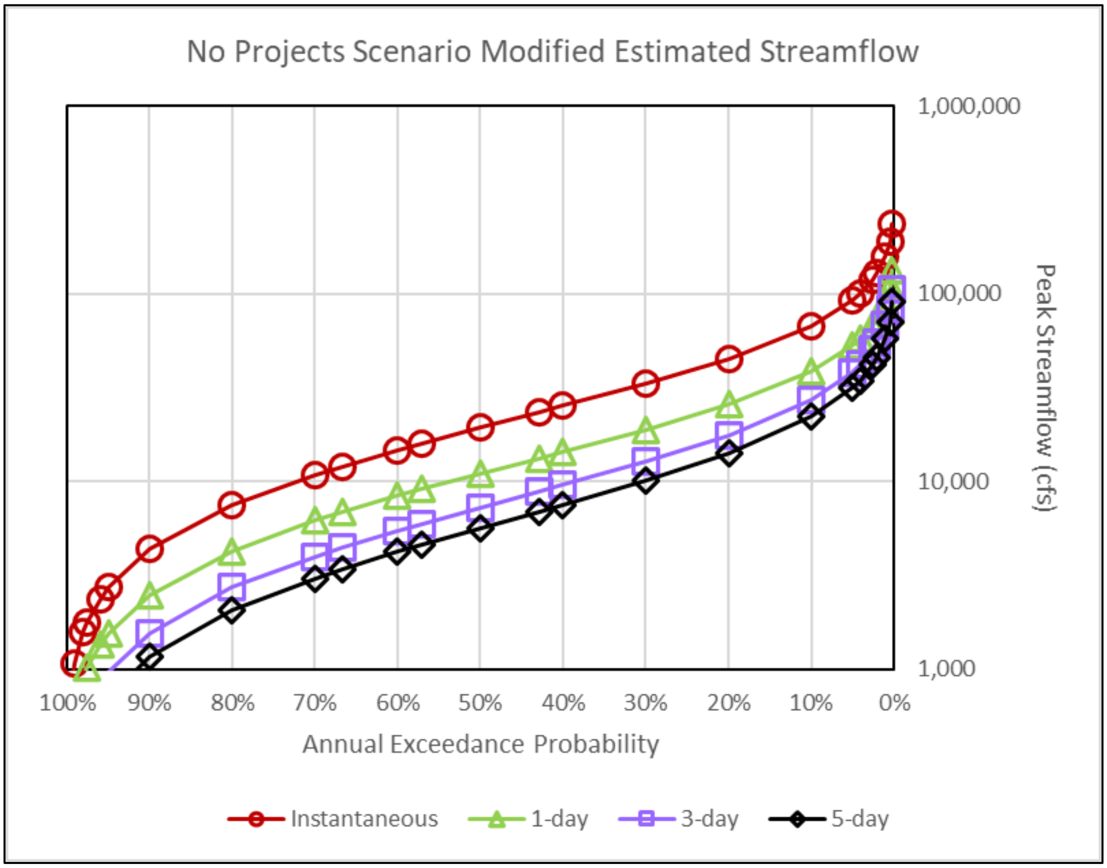

Figure B-16. Flood Flow Frequency Curves For No Projects Scenario Modified Estimated Streamflow for the Salinas River at Bradley

Figure B-17 shows the difference in the flood flow frequency curves between the Historical and No Projects Scenario modified streamflow time series (calculated as the No Projects Scenario curves minus the Historical Scenario curves; this is opposite to the approach used for the groundwater head maps, and is done to avoid negative differences when plotting on logarithmic axes); these differences are also tabulated in Table B-6. These data indicate that the Projects result in a reduction of about 44,000 cfs for the 100-year flood event (AEP = 0.01).

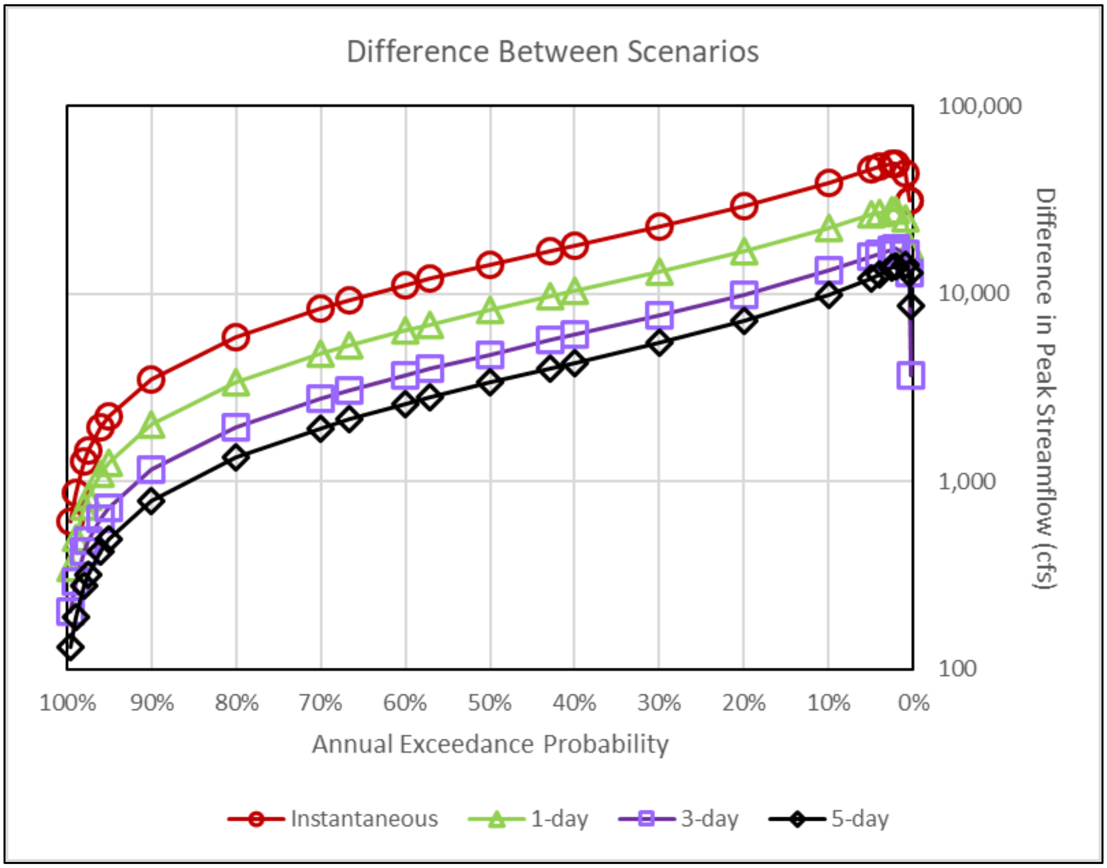

Figure B-17. Difference Between Flood Flow Frequency Curves for Historical and No Projects Scenario Modified Estimated Streamflow

An alternative view providing a more direct comparison between the flood flow frequency curves is provided in Figures B-18 through B-21. Each figure presents the flood flow frequency curves for the observed, Historical Scenario modified estimated, and No Projects Scenario modified estimated streamflows for instantaneous (Figure B-18), 1-day (Figure B-19), 3-day (Figure B-20), and 5-day (Figure B- 21) peak streamflows. These figures show the substantial differences between the flood flow frequency curves estimated for the Historical and No Projects Scenarios.

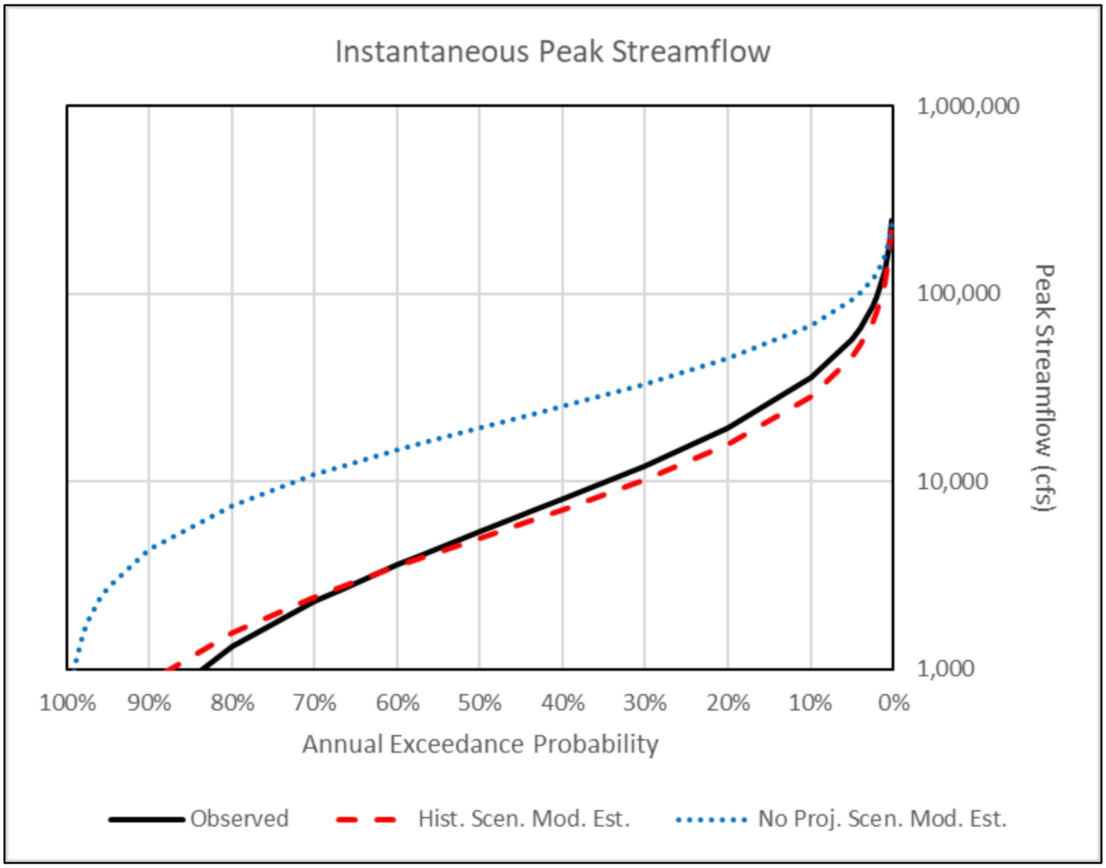

Figure B-18. Flood Flow Frequency Curves for Observed, Historical Scenario Modified Estimated, and No Projects Scenario Modified Estimated Instantaneous Peak Streamflows

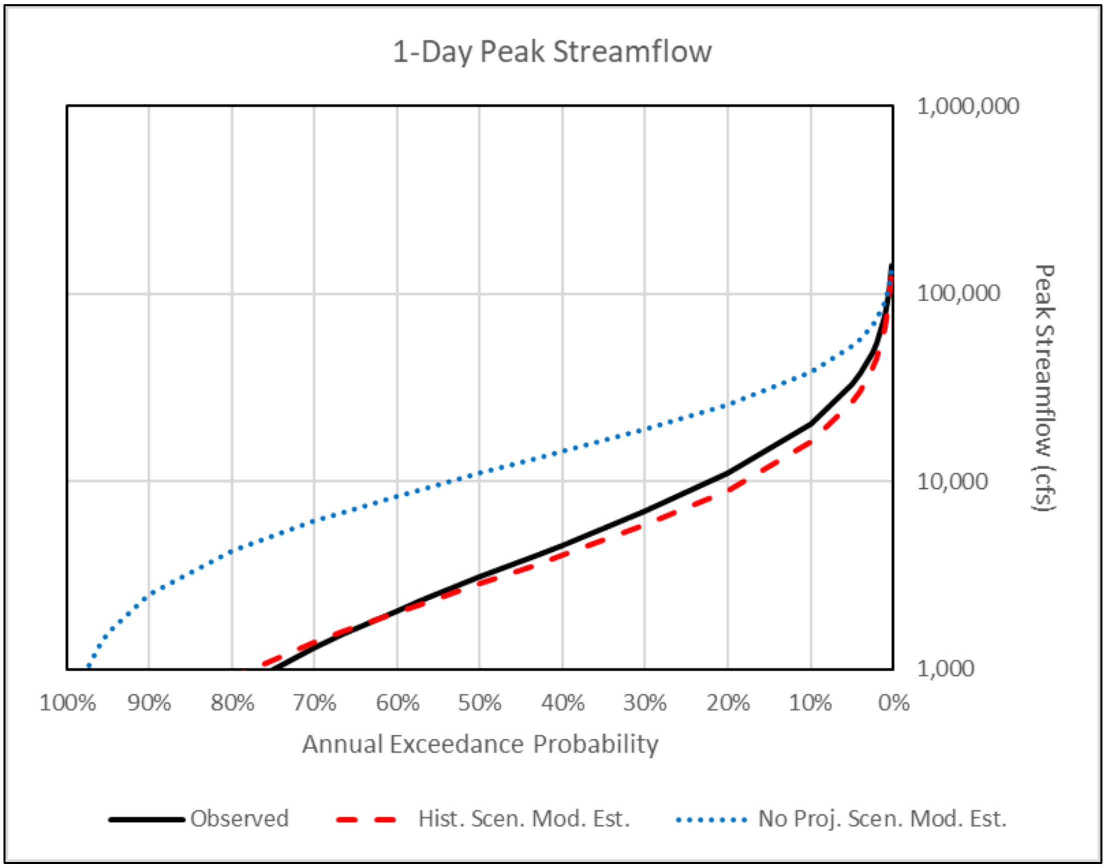

Figure B-19. Flood Flow Frequency Curves for Observed, Historical Scenario Modified Estimated, and No Projects Scenario Modified Estimated 1-Day Peak Streamflows

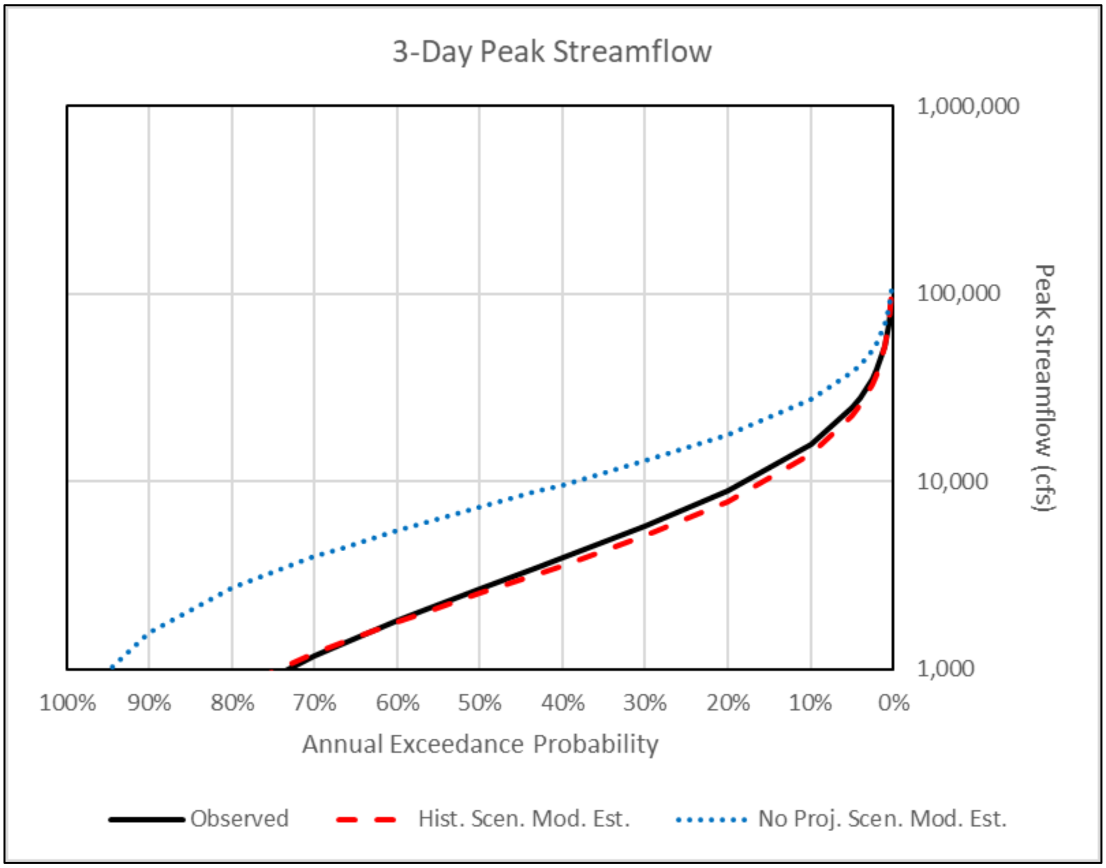

Figure B-20. Flood Flow Frequency Curves for Observed, Historical Scenario Modified Estimated, and No Projects Scenario Modified Estimated 3-Day Peak Streamflows

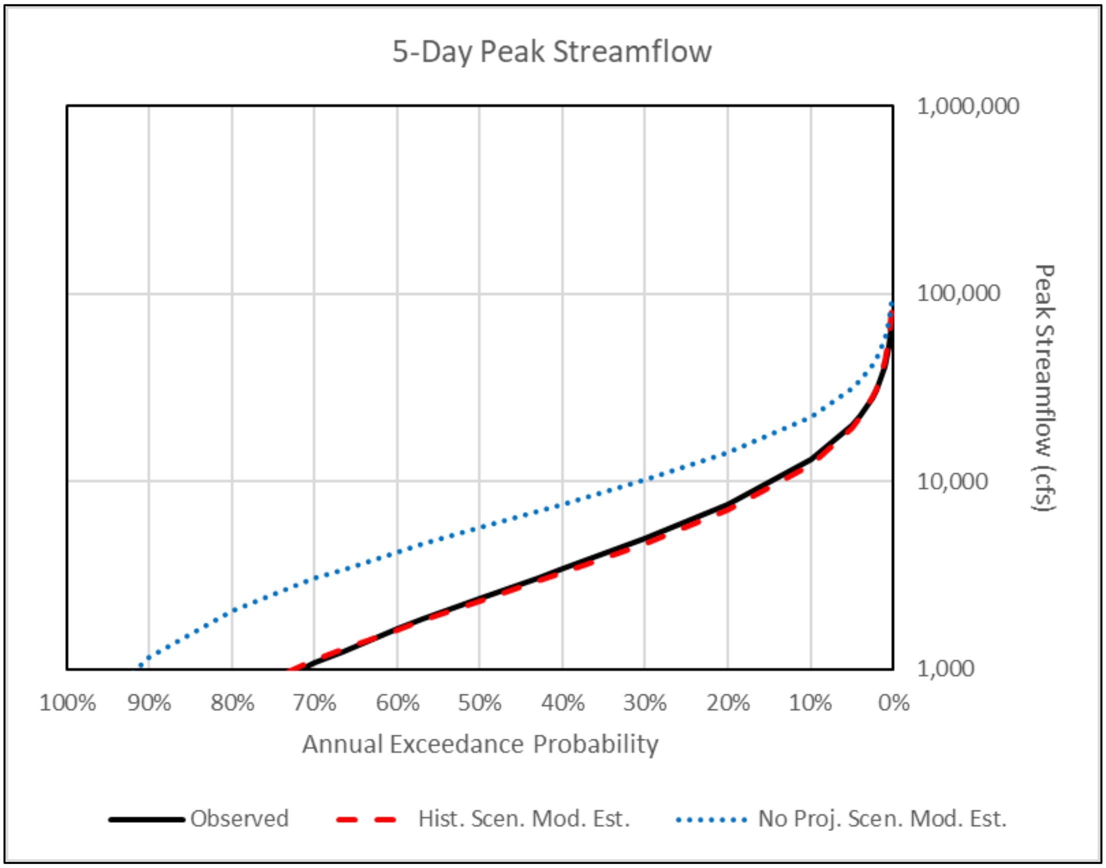

Figure B-21. Flood Flow Frequency Curves for Observed, Historical Scenario Modified Estimated, and No Projects Scenario Modified Estimated 5-Day Peak Streamflows

The peak flow estimates listed above were used as inputs to an existing HEC-RAS 2D model of the Salinas River floodplain (FlowWest, 2015). This model takes as input streamflow in the Salinas River at Bradley and simulates the movement of this flow through the system to Monterey Bay. The model ignores groundwater-surface water interaction. Tributary inflows are limited to Arroyo Seco and San Lorenzo Creek, which are the major gauged tributaries to the Salinas River below Bradley.

Tributary Inflows for HEC-RAS Model

With peak flow values calculated for the Salinas River at Bradley, equivalent tributary inflows had to be developed for Arroyo Seco and San Lorenzo Creek. The Arroyo Seco below Reliz Creek near Soledad gauge (#11152050) has been measuring streamflow since 1 Oct 1994; the San Lorenzo Creek below Bitterwater Creek near King City gauge (#11151300) has been measuring streamflow since 1 Oct 1958. Although the historical record for the USGS gauge present on each tributary could be used to develop flood flow frequency curves, these could only be used as tributary inflows for the HEC-RAS model if it can be shown that the tributary flood with a specific AEP coincides in time with the flood of the same AEP in the Salinas River at Bradley. Instead, peak annual mean daily streamflows in the Salinas River at Bradley were compared to the mean daily streamflow in Arroyo Seco and San Lorenzo Creek for the same dates. Because it can take multiple days for water to flow through the stream network from Bradley to Monterey Bay, the tributary flows for up to two days before and two days after the date of the peak mean daily streamflow at Bradley were also investigated to determine which results in the strongest statistical relationship.

Table B-7 presents the slopes and regression coefficients for the observed peak mean daily streamflow in the Salinas River at Bradley against the mean daily streamflow in Arroyo Seco and San Lorenzo Creek for dates falling two days before to two days after the date of the peak streamflow at Bradley. These results indicate that a strong correlation exists between peak flows at Bradley and streamflow observed in Arroyo Seco and San Lorenzo Creek on the day before the peak flow was observed at Bradley. This indicates that Salinas River tributaries within the study area may react more quickly to storm events compared to the Salinas River at Bradley.

Table B-7. Regression statistics for streamflow in Arroyo Seco and San Lorenzo Creek against annual peak mean daily streamflow in the Salinas River at Bradley

	Arroyo Seco		San Lorenzo Creek	
	Regression Slope	Regression Coefficient	Regression Slope	Regression Coefficient
-2 Days	0.0734	0.3552	0.0109	0.4677
-1 Day	0.2733	0.9166	0.0780	0.8928
Same Day	0.1723	0.7481	0.0333	0.5422
+1 Day	0.0898	0.7148	0.0125	0.6322
+2 Days	0.0658	0.7050	0.0099	0.6123

The high correlation of the observed tributary streamflows to the annual peak mean daily streamflows in the Salinas River at Bradley indicate that observed and estimated streamflows at Bradley could be used to estimate equivalent tributary flows in Arroyo Seco and San Lorenzo Creek. Based on the slopes of the linear regressions, streamflow in Arroyo Seco is about 27 percent of the peak flow at Bradley, and streamflow in San Lorenzo Creek is about 8 percent of the peak flow at Bradley. The peak flows contained in Table B-6 were multiplied by these factors to estimate the equivalent tributary inflows. Note that tributary inflows for No Project Scenario peak flows use the tributary inflows for the Historical Scenario peak flows for the same AEP (e.g., the 100-year flow for the No Projects Scenario uses the tributary inflows from the 100-year flow for the Historical Scenario) because the presence or absence of the Projects has no impact on the amount of flow entering the Salinas River from unregulated tributaries like Arroyo Seco and San Lorenzo Creek.

UNCERTAINTIES AND LIMITATIONS

The analyses presented in this appendix relies on a large number of assumptions and limitations, and they are subject to various uncertainties. This section lists a number of the uncertainties and limitations affecting the estimation of peak flow values in the Salinas River at Bradley and the simulation of the effects of these peak flows. This discussion is not intended to be exhaustive, nor does it cover assumptions inherent to some of the modeling software utilized for this study, except as they may have specific bearing on this analysis.

Any numerical model is an imperfect representation of a natural system, with assumptions and approximations required to simulate conditions within the modeled system with current computing resources. The SVWM and SVIHM, each of which plays a role in developing the estimated streamflows, are both preliminary, unpublished models that are still under development by the USGS (see above for the disclaimer that must accompany the use of any results from the SVIHM prior to publication of its documentation).

As described in this appendix, the development of mean daily streamflows in the Salinas River at Bradley for the Historical and No Projects Scenarios relies on a simplified mass balance approach for calculating streamflow at Bradley. It combines time series of observed, simulated and estimated streamflow from multiple different sources together; each time series has its own associated uncertainty. This approach assumes no lag between the inflow locations (the Salinas River near San Miguel, the Nacimiento River below Nacimiento Dam, and the San Antonio River below San Antonio Dam) and the location of the Salinas River at Bradley gauge. The use of estimated reservoir inflow time series as inputs to Equation 1 further assumes that no lag or interaction would occur between the Nacimiento and San Antonio Rivers and their surrounding environments from the location where the reservoir inflow is estimated (taken to be approximately equivalent to the upstream end of each reservoir) to the location of the reservoir releases.

Equation 1 further utilizes groundwater-surface water fluxes that were simulated based on SVIHM-simulated streamflow conditions which, as described in the HBA Update, are highly affected by the monthly stream inflow boundary conditions. The groundwater-surface water fluxes may be under-predicted during peak flows, as the corresponding SVIHM streamflow (which determines the rate of groundwater-surface water flux) generally represents an average monthly streamflow.

Several components of this analysis rely on linear regressions between different datasets. While many of the regressions demonstrate a high degree of correlation, none is perfect and each regression introduces some error. The regressions are not sophisticated treatments of the data, they do not represent in any meaningful way the complicated physical processes that determine the timing and amount of streamflow, and they cannot be taken to indicate causation.

Similarly, the modification to the streamflow estimation approach described above assumes that the highest-flow events can be scaled in a way that is more representative of actual conditions in the Salinas River. The scaling factor used has no obvious physical meaning, and is included simply to address a clear limitation of the SVWM in terms of its ability to reproduce the highest observed flows. Scaling these high flows was necessitated by the fact that the SVWM itself was not accessible for this study, and therefore the cause of the high-flow mismatch could not be understood or addressed. Although the scaling results in an excellent fit for the linear correlation between the observed and Historical Scenario modified estimated annual peak streamflows, it must be acknowledged as a limitation of the analysis.

The flood flow frequency analysis rests on a number of assumptions. The application of a statistical distribution (the log-Pearson Type III distribution) to the peak flow data assumes that the data are random (that is, a random sampling of the “true” distribution of peak flow events), stationary (i.e., the parameters of the distribution do not change over time), and representative (England et al., 2019). The randomness of the sample can be affected by the presence of extended wet and dry cycles. The stationarity of the peak flow sample is affected by changes to the stream or its watershed above the location of the gauge, including changes in land use and regulation.

The flood flow frequency analysis is not designed for use in settings where regulation of surface water flow (e.g., by reservoirs) substantially alters flood flows (England et al., 2019). This is clearly the case for the Salinas River at Bradley, and it is important to understand that the flood flow frequency analysis is not strictly designed for settings such as the study area. However, the 1998 HBA used the same type of analysis to estimate the magnitude of large peak flows with and without the reservoirs, and its use for this HBA Update provides continuity and comparability with the 1998 HBA.

In terms of stationarity, the period of the flood flow frequency analysis did not include any major changes to the watershed above Bradley, as both Nacimiento and San Antonio Reservoirs were operating at the start of the analytical period (WY 1968). However, there have been various smaller changes that affect the stationarity of the dataset, including the modification of the Nacimiento Dam spillway as part of the Salinas Valley Water Project and various operational changes that have been implemented by MCWRA at the reservoirs over the past decades. The flood flow frequency analysis, as implemented here, assumes that any operational or structural changes that took place during the period of the analysis have been relatively inconsequential to the parameters of the statistical distribution of peak flows. It should be noted that the analytical period used for the 1998 HBA[4] includes periods before and after San Antonio Reservoir began operating, meaning that the sample for that study included a substantial change to the watershed regulation.

Finally, as noted in England et al. (2019), the period chosen for a flood flow frequency analysis has an effect on the results. In a system that is stationary, a longer analytical period theoretically provides a more "representative" sample, with shorter analytical periods potentially impacted by the occurrence (or lack) of very large peak flows. As noted above, the analytical period used for the 1998 HBA was shorter (30 years for the with-dams conditions in the Salians River at Bradley) than the period used for this HBA Update (51 years). While a longer analytical period does not guarantee a "better" result (i.e., closer to the "real" peak flow distribution), it is generally desirable to have a larger sample size than a smaller one.

[4] It is not clearly stated in the 1998 HBA what analytical period was used for characterizing the flood flow frequency curves for the Salinas River at Bradley. However, Figure 15 of Appendix B of the 1998 HBA indicates that the curves were built using 30 years of record, which implies that the analytical period could not have been limited to the period when both reservoirs were operating, as San Antonio Reservoir had been operating for only 27 years by the end of the period of the SVIHM (i.e., WY 1968 to 1994).

SUMMARY

This Appendix presents the analyses that were undertaken to support the development of peak flow estimates in the Salinas River at Bradley for the HBA Update's analysis of the benefits that the Projects have provided in terms of inundation-related damage in the study area. Because the available modeling tools for the HBA Update are not well-suited to directly quantifying the short-term variability in streamflow that would be necessary for characterizing the magnitude of peak flows resulting from storm events, an alternative approach had to be developed that could quantify the expected peak flow magnitudes associated with different return periods (e.g., the 100-year flood). This was done through a simple mass balance approach incorporating various datasets of observed, estimated, and simulated streamflow and groundwater-surface water flux, combined with linear regressions between related datasets.

The results of this analysis indicate that the Projects have substantially reduced the magnitude of flood events passing through the Salinas River at Bradley. This is true for various AEPs (or return periods). For example, the estimated 100-year flood (AEP = 0.01) under the Historical Scenario was about 114,600 cfs, compared to about 158,700 cfs under the No Projects Scenario, a difference of about 44,100 cfs. The difference between the scenarios is slightly larger for the estimated 25-year (about 47,540 cfs) and 50-year (about 48,920 cfs) flood events. This may reflect the fact that the reservoirs are most effective at regulating mid-size floods that they have the available capacity to store fully.

The peak flow magnitudes estimated as outlined in this appendix were used as inputs to a HEC-RAS 2D model of the Salinas River and its floodplain (including tributary inflows from Arroyo Seco and San Lorenzo Creek). The simulation of the effects of these peak flows on the Salinas River floodplain are discussed in the main text of the HBA Update.

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Economic Benefits of MCWRA's Investments in Water Infrastructure Projects for Salinas Valley

Final Report

April 2025

ONEWATER ECON

Contents

Executive Summary

Introduction

This report presents the economic benefits associated with Monterey County Water Resources Agency's (MCWRA's) investments and management of water resource infrastructure in California's Salinas Valley. The analysis presented herein focuses on the economic benefits that have accrued to Salinas Valley stakeholders over a 51-year analysis period (1968 to 2018) from the construction and operation of the Nacimiento and San Antonio Reservoirs, the Castroville Seawater Intrusion Project (CSIP), and the Salinas Valley Water Project (SVWP, collectively, the Projects, Figure ES-1). It demonstrates the important effects that the Projects have had on the system and is intended to inform MCWRA's future assessments on stakeholders within the basin.

Figure ES-1. Summary of MCWRA Infrastructure Projects

MCWRA completed construction of **Nacimiento Dam/Reservoir** in 1957 and **San Antonio Dam/Reservoir** in 1967. The reservoirs retain more water in the Basin by capturing high winter flows and releasing them in the summer when recharge potential along the Salinas River is at its highest. Both facilities provide flood control and recreational benefits, and are operated to ensure adequate instream flows for fish and wildlife habitat. MCWRA also operates a four-megawatt hydroelectric power plant at Nacimiento Dam.

CSIP is a pipeline system that distributes recycled wastewater from the Monterey One Water Regional Treatment Plant, rediverted stored reservoir water, and groundwater to agricultural users. CSIP reduces groundwater pumping by providing an alternative supply, thereby increasing groundwater storage and slowing seawater intrusion. CSIP became operational in 1998.

The **SVWP** included modification of the spillway at Nacimiento Reservoir and installation of an inflatable dam along the Salinas River, the **Salinas River Diversion Facility (SRDF)**. The SRDF began operation in 2010; it allows for the rediversion of stored reservoir water into CSIP for use on irrigated lands, further offsetting the need for groundwater pumping near the coast. CSIP and SVWP provide a water supply that supports agricultural production on more than 12,000 acres of irrigated land.

The economic benefits evaluated as part of this report include:

- Avoided replacement of wells due to depleted groundwater levels and seawater intrusion
- Avoided costs resulting from reductions in overall groundwater pumping and decreased depth to groundwater, which in turn reduces pumping lift requirements (and associated pumping costs)
- Reduced flood risk and associated damages to buildings, structure, and agriculture
- Active and passive reservoir-related recreation opportunities
- Generation of hydropower

This report serves as an update to the "Salinas Valley Historical Benefits Analysis" (HBA), which was developed for MCWRA in 1998 to assess the benefits provided by Nacimiento and San Antonio Reservoirs. Since the original HBA, MCWRA has significantly changed its approach to managing water resources in the Salinas Valley. This has included the development of additional infrastructure and operational changes intended to further stabilize groundwater levels, reduce seawater intrusion, ensure adequate instream flows in the Salinas River for wildlife migration and habitat, and provide enhanced protection from flooding. This updated HBA accounts for the benefits associated with MCWRA's current infrastructure and operations and takes advantage of new tools, data, and knowledge that have been developed over the last 26 years. It also expands the range of benefits evaluated under the original HBA.

One Water Econ conducted this assessment in coordination with MCWRA and West Yost Associates, Inc. (West Yost), a hydrologic engineering consulting firm. West Yost has prepared a separate, complementary report that provides extensive detail on the hydrologic modeling and related physical benefits associated with MCWRA's water resource infrastructure and management. Together, these reports provide a comprehensive update to the 1998 HBA. West Yost's modeling and analysis served as key inputs into this economic assessment.

Study area

The study area for this HBA Update is MCWRA Assessment Zone 2C, which falls within the Salinas Valley in California's Central Coast region between the San Joaquin Valley and the Pacific Ocean. Figure ES-2 shows the MCWRA-defined groundwater subareas that make up Zone 2C. These aquifers serve as the primary source of water supply in the region.

Figure ES-2. MCWRA Zone 2C subareas

Both agricultural and municipal users place heavy demands on groundwater in the Salinas Valley. Agriculture is responsible for the greatest use of groundwater, accounting for approximately 90% of total metered pumping on an annual basis. Over the last several decades, groundwater pumping has exceeded the capability of the natural system to replenish aquifers in some parts of the Salinas Valley, exacerbating seawater intrusion and decreasing groundwater storage. The projects and programs that MCWRA has constructed in the study area have sought to address this imbalance.

Approach

This report compares the effects of the Projects against a scenario in which they had not been constructed. The Historical Scenario represents actual conditions within the Salinas Valley from October 1967 to September 2018. The Historical Scenario models incorporate projects and programs related to the San Antonio and Nacimiento Reservoirs during the period of their operation, with both reservoirs in operation throughout the model simulation period. The effect of raising the Nacimiento Dam spillway elevation (part of the SVWP) is included in the time series of reservoir releases beginning in 2009. Recycled water deliveries through CSIP are modeled beginning in 1998, while SRDF deliveries of rediverted stored reservoir water begin in 2010.

The No Projects Scenario removes the reservoirs and other MCWRA projects and management modifications from the Historical Scenario to simulate "without project" conditions. The difference in outcomes between the Historical and No Projects Scenarios is taken to represent the benefits associated with the construction and operation of the Projects.

Most of the benefits evaluated in this report are closely linked to the hydrologic and flood risk reduction benefits reported by West Yost in the HBA Update and can be monetized using avoided cost analysis. Some benefits, such as recreation benefits, can be more difficult to monetize because they are not bought and sold in a market and therefore do not have a directly observable market price. Economists have developed several methods for valuing these and other "non-market" goods and services. For this analysis, the project team valued non-market benefits using a secondary research approach called benefits transfer. Benefits transfer relies on values reported in the literature from primary or original valuation studies to estimate the potential value of non-market benefits for a specific study site.

Key findings

The HBA Update confirms that the Projects have resulted in significant hydrologic benefits, including increased fresh groundwater storage and reduced flooding across the Salinas Valley. This in turn has resulted in the following economic benefits:

- Higher groundwater levels have reduced the need to replace groundwater wells. This has avoided more than $107.4 million in well replacement costs over the 51-year analysis period (1968 to 2018), for an average annual benefit of $2.1 million.
- Higher groundwater levels have also reduced the energy required to pump groundwater in many areas, and in combination with deliveries from the CSIP and SVWP, have reduced overall groundwater pumping for irrigation. This has saved $67.9 million in groundwater pumping costs over the analysis period, for an average annual benefit of $1.3 million per year.
- The increase in fresh groundwater storage in Basin aquifers has decreased seawater intrusion from Monterey Bay. The HBA Update reports that seawater intrusion has been approximately 1,000 AFY lower in the Pressure Subarea than it would have been without the Projects. Assuming an average applied water rate of 2.0 acre-feet/acre, seawater intrusion under the No Projects scenario would have affected approximately 500 acres of farmland each year, with impacts to crops ranging from $21.7 to $86.9 M. This benefit has largely accrued to growers beginning in 1998, coinciding with deliveries of recycled water from CSIP.

- The reservoirs substantially reduced flooding along the Salinas River floodplain and the land and structures found there. This has resulted in avoided damages to buildings totaling $210.5 million over the study period, $4.1 million per year on average. The value of avoided flood damages to agricultural crops is estimated to be $211.0 million over the 51-year analysis, or $4.1 per year.

In addition to hydrologic and flood risk reduction benefits, the reservoirs have generated close to $800 million in recreational benefits between 1985 and 2018, an average annual benefit of $24 million. Between 1987 and 2018, Nacimiento dam generated 326 MWh of power, for a total value of $59.1 million. The generation of clean hydropower resulted in $16.0 million in avoided health-related costs from 1987 to 2018, an average annual benefit of $500,000. These benefits are further summarized in Table ES-1.

Table ES-1. Summary of Economic Benefits, MCWRA Water Resource Infrastructure and Management

Benefit	Project benefits: Description	Project benefits: Average annual value ($M)	Project benefits: Total value (51-year period, $M)
Water supply			
Avoided well replacement costs	Avoided construction/ replacement of 63 irrigation wells and 6 municipal wells	$2.11	$107.4
Avoided costs from reduced agricultural pumping and pumping lift	Avoided 498,100 AF of groundwater pumping. Increased well groundwater levels for by 4.5 feet on average.	$1.3	$67.9
Reduced seawater intrusion	Decreased seawater intrusion by approximately 68,000 AF.	Mostly occurred after 1998 (CSIP)	$53.6 (with range of $21.8 M to 86.9 M)
Flood risk reduction			
Avoided Damages to Buildings and Structures	Reduced flood damages to buildings, contents, and vehicles. Avoided damages to 210 - 457 buildings for 10- and 100-year flood events.	$4.13	$210.5
Avoided damages to agricultural crops	Reduces inundated acres by up to 16,496 (10-year event), thereby reducing revenue losses, damages, and re-establishment/clean up costs.	$4.14	$211.0
Recreation			
	64 M user days to Nacimiento and San Antonio Lakes, 1985 - 2018	$23.5 (over 34-years)	$797.4

Table ES-1 (continued)

Benefit	Project benefits		
	Description	Average annual value ($M)	Total value (51-year period, $M)
Hydropower			
Power generation	Nacimiento's hydroelectric power plant generated 9,833 MWh per year, 1987 to 2022 (average)	$1.85 (value of hydropower generated).	$59.1 (value of hydropower generated).
Avoided pollutant emissions	Projects avoided emissions of key air pollutants due to cleaner power source: 58 MT of NO_x, 24 MT of SO_2, 6 MT of $PM_{2.5}$, and 79,500 MT of CO_{2e} from 1987 - 2018.	$0.5	$16.0

1. Introduction and Background

This report presents an assessment of the economic benefits provided to stakeholders in California's Salinas Valley from construction and operation of Nacimiento and San Antonio Reservoirs, the Castroville Seawater Intrusion Project (CSIP), and the Salinas Valley Water Project (SVWP). It serves as an update to the "Salinas Valley Historical Benefits Analysis" (HBA), which was developed for the Monterey County Water Resources Agency (Agency, or MCWRA) in 1998 to assess the benefits provided by Nacimiento and San Antonio Reservoirs.

The analysis presented in this report focuses on the economic benefits associated with MCWRA's water infrastructure and management within the Salinas Valley, presenting benefits in monetary terms. One Water Econ conducted this assessment in coordination with MCWRA and West Yost Associates, Inc. (West Yost), a hydrologic engineering consulting firm. West Yost has prepared a separate, complementary report that provides extensive detail on the hydrologic modeling and related physical benefits associated with MCWRA's water resource infrastructure and management. Together, these reports provide a comprehensive update to the 1998 HBA. West Yost's modeling and analysis served as key inputs into this economic assessment.

1.1 Study purpose

Since the original HBA, MCWRA has significantly changed its approach to managing water resources in the Salinas Valley. This has included the development of additional infrastructure and operational changes intended to further stabilize groundwater levels, reduce seawater intrusion, ensure adequate instream flows in the Salinas River for wildlife migration and habitat, and provide enhanced protection from flooding. This updated HBA accounts for the benefits associated with MCWRA's current infrastructure and operations and takes advantage of new tools, data, and knowledge that have been developed over the last 26 years. It also expands the range of benefits evaluated under the original HBA.

Specifically, this report presents the economic benefits that have accrued to Salinas Valley stakeholders over a 51-year analysis period (1968 to 2018) from the construction and operation of the Nacimiento and San Antonio Reservoirs, CSIP, and SVWP (collectively, the Projects). The analysis quantifies and monetizes benefits related to water supply, flood risk reduction, recreation, and hydropower, and identifies to whom these benefits accrue. It demonstrates the important effects that the Projects have had on the system and is intended to inform MCWRA's future assessments on stakeholders within the basin.

1.2 Study area

The study area for this HBA Update is MCWRA Assessment Zone 2C, which falls within the Salinas Valley in California's Central Coast region between the San Joaquin Valley and the Pacific Ocean (Figure 1).

1.2.1 Overview

The Salinas Valley stretches along the Salinas River from its headwaters in San Luis Obispo County to its outlet to the Pacific Ocean at Monterey Bay, approximately 170 miles north near the town of Marina. This study concentrates on the portion of the watershed (known as Zone 2C) located north of San Miguel (near the Monterey and San Luis Obispo County border), where the Salinas Valley narrows after passing through the Paso Robles Basin.

Figure 1. Salinas Valley HBA Update study area

Within the study area, the Salinas River flows north-northwest through a valley between the Gabilan and Diablo Mountain Ranges (on the northeast side) and the Santa Lucia and Sierra de Salinas Mountain Ranges (to the southwest). Major tributaries within the study area include the Nacimiento River (on which Nacimiento Reservoir lies), the San Antonio River (on which San Antonio Reservoir lies), San Lorenzo Creek, Arroyo Seco, Alisal Creek, and El Toro Creek. The study area also includes some areas outside of the Salinas River watershed that are tributary to Elkhorn Slough and Monterey Bay. The Nacimiento and San Antonio Reservoirs are located at the southern end of the study area, within the Santa Lucia range.

Agriculture is the dominant land use within the study area. In 2022, the total value of agricultural production in Monterey County amounted to more than $5 billion, representing the third highest gross agricultural output among California counties. This value includes sales of vegetables and other high value crops from more than 300,000 irrigated acres,[i] much of which is located within the Salinas Valley. In the upstream portion of the study area (closer to the reservoirs), grazing and pasturelands are common, although an increasing amount of this area has been converted to vineyards in recent years. In the lower part of the watershed (closer to the Bay), groundwater is used for agricultural irrigation of lettuce, broccoli, artichokes, strawberries, cauliflower, and other fruits and vegetables.

Cities and unincorporated communities within the study area include Bradley, Castroville, Chualar, Gonzales, Greenfield, King City, Marina, Salinas, San Ardo, San Lucas, and Soledad. The population of these communities totaled approximately 257,900 in 2022, accounting for 60% of the total population in Monterey County.[ii] Salinas is by far the largest city in the study area, with just over 160,000 people. Both agricultural and municipal users place heavy demands on groundwater in the Salinas Valley and it is the dominant source of water in the region. Agriculture is responsible for the greatest use of groundwater, accounting for approximately 90% of total metered pumping on an annual basis.[iii]

1.2.2 Hydrologic setting

According to the California Department of Water Resources (DWR), several groundwater subbasins underlie the study area: the 180/400 Foot Aquifers and East Side Aquifer largely comprise the northern portion, the Forebay Aquifer underlies the central portion, and the Upper Valley Aquifer is located at the southern end. Three small subbasins, Langley Area, Seaside, and Monterey, also underlie portions of the north and northwest study area. MCWRA subdivides the Basin somewhat differently than DWR. Figure 2 shows the MCWRA-defined groundwater subareas that make up Zone 2C, including the Pressure, East Side, Forebay, Arroyo Seco, Upper Valley, and Below Dam Subareas. This HBA Update presents results based on MCWRA's Zone 2C Subarea definitions.

West Yost's accompanying report: *Salinas Valley Historical Benefits Analysis Update (2024)* contains a detailed description of the hydrological characteristics of the study area. In general, the Salinas River loses water to the Basin aquifers throughout the study area. However, natural replenishment of the Salinas Valley's underlying groundwater resources varies depending on location. The northern portion of the study area (lower watershed area) is characterized by a series of confined to semi-confined aquifers.

Figure 2. MCWRA Zone 2C subareas

Aquifers in this region (i.e., the Pressure subarea) are generally replenished by groundwater flows from further up the watershed, which in turn, are heavily influenced by percolation within the channels of the Salinas River and its tributaries. Replenishment of the East Side Subarea comes primarily from percolation of streams on the west side of the Gabilan Range. In the Forebay Subarea, sources of natural replenishment include groundwater outflow from the Upper Valley Subarea and, importantly, percolation from the Salinas River. The Upper Valley Subarea is primarily replenished through stream channel percolation from the Salinas River and its tributaries,[iv] but also receives some runoff from nearby mountain ranges and infiltration from precipitation.

Portions of the Basin have been in a condition of overdraft for decades due to its long history of intense irrigated agriculture, a near-total reliance on groundwater, and its complex hydrogeology. Overdraft has resulted in reductions in groundwater storage, depressed groundwater levels in all major water supply aquifers, and extensive seawater intrusion into the Basin. Manifestations of these issues occur most prominently in the northern part of the Basin, specifically the Pressure and East Side Subareas, where natural replenishment of depleted aquifers from the Salinas River is limited. DWR has categorized the non-adjudicated portions of the Basin as Medium or High Priority, and the 180/400 Foot Aquifer Subbasin as critically overdrafted.[1,v]

1.2.3 Water resources development

The development of water resources in the Salinas Valley has largely been driven by demand from irrigated agriculture, which increased over the course of the 20th century as irrigated acreage significantly expanded. According to West Yost, total groundwater pumping in MCWRA Zone 2C increased from approximately 400,000 acre-feet per year (AFY) in 1949 to a peak of 600,000 AFY by 1959. Declining groundwater levels during this period, especially in the northern part of the Basin, indicated that groundwater pumping was increasing beyond the capability of the natural system to replenish the aquifers, exacerbating seawater intrusion and decreasing groundwater storage. The projects and programs that MCWRA has constructed in the study area have sought to address this imbalance.

MCWRA completed construction of Nacimiento Dam in 1957, impounding the Nacimiento River and creating Nacimiento Reservoir with a maximum storage capacity of 377,900 AF. San Antonio Dam/Reservoir was completed in 1967 and has a maximum storage capacity of 335,000 AF. The reservoirs retain more water in the Basin by capturing high flows behind the dams in winter when they would otherwise flow out to the ocean, and releasing them in the summer when the recharge potential along the Salinas River is at its highest. Both facilities provide flood control benefits and recreation opportunities, and are operated to ensure adequate instream flows for key fisheries. MCWRA also operates a four-megawatt hydroelectric power plant at Nacimiento Dam. The completion of the Nacimiento and San Antonio Reservoirs led to a reversal of groundwater storage losses in the Forebay and Upper Valley Subareas (except during extended dry periods), but not in the Pressure and East Side Subareas. This is largely because of the spatial variability in the connection between the Salinas River and the underlying aquifers (see Section 1.2.2).

To help address seawater intrusion in the northern/coastal portion of the study area, MCWRA constructed the CSIP, a pipeline system that distributes recycled wastewater from the Monterey One Water Regional

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[1] The boundaries of the 180/400 Foot Aquifer Subbasin (classified by DWR) are similar to the boundaries of MCWRA's Pressure Subarea, although they do not fully overlap.

Treatment Plant, rediverted stored reservoir water, and groundwater to agricultural users in the area around the town of Castroville. The intention of CSIP is to reduce groundwater pumping by providing an alternative supply, thereby increasing groundwater storage through in-lieu recharge and slowing the advancement of seawater intrusion. Construction of CSIP started in 1995 and recycled water deliveries started in 1998.

In a continued effort to combat seawater intrusion, the Agency constructed the SVWP, which consisted of modification of the spillway at Nacimiento Reservoir and installation of an inflatable dam along the Salinas River near the City of Marina, the Salinas River Diversion Facility (SRDF). The SRDF began operation in 2010; it allows for the rediversion of stored reservoir water into CSIP pipelines for use on irrigated agricultural lands, further offsetting the need for groundwater pumping near the coast. Together, CSIP and SVWP provide a water supply that supports agricultural production on more than 12,000 acres of irrigated land.

As conditions and infrastructure in the Basin have changed, MCWRA has also modified its approach to operating the Nacimiento and San Antonio Reservoirs. Important alterations have resulted from the infrastructure projects described above and the development of the Salinas Valley Water Project Flow Prescription for Steelhead Trout in the Salinas River (2005), which was required as a condition of the permit for the SVWP. The Flow Prescription focused on modifying operations to support the migration of endangered Steelhead trout and protect critical fish and wildlife habitat below the Nacimiento and San Antonio Dams. It has resulted in an increase in minimum releases from both reservoirs and a change in downstream flow targets, including an increase in total flow rates during the conservation program season.

1.3 1998 HBA

The 1998 HBA investigated the benefits to Basin stakeholders from the construction and operation of Nacimiento and San Antonio Reservoirs starting from when Nacimiento Reservoir first became operational in 1958 to 1994. The study quantified benefits by simulating conditions in the Basin with and without the reservoirs using then-current tools. The 1998 HBA expressed benefits in monetary terms to illustrate the value that Basin stakeholders have received from the reservoirs.

The original HBA reports that from 1958 to 1994, the reservoirs' ability to impound water during the winter wet period and release it during drier periods led to more water being kept within the Basin, increased groundwater recharge and storage, higher groundwater levels, less seawater intrusion, and reduced flooding. This in turn resulted in an estimated $11.8 million per year (1998 USD) in economic benefits to stakeholders in the Basin. In 2024 USD, this amounts to $22.7 million per year.

Specific findings from the 1998 HBA economic assessment include:

- Higher groundwater levels resulting from the increased freshwater storage lessened the need for the replacement or modification (e.g., deepening) of extraction wells in the Basin, particularly in the Upper Valley Subarea. This resulted in approximately $1.5 million per year in reduced pumping costs and $89,000 per year in reduced well modification costs. In 2024 USD, these values amount to $2.8 million and $172,000, respectively.
- The decreased extent of seawater intrusion prevented the salinization of dozens of extraction wells in the coastal area, which otherwise would likely have needed to be replaced with deeper

wells. This resulted in $241,000 ($465,000 in 2024 USD) per year in avoided well replacement costs.

- The reservoirs substantially reduced flooding along the Salinas River floodplain and the land and structures found there. This resulted in approximately $5.5 million per year in increased crop income and reduced repair costs, and $4.5 million per year in reduced damages to structures and buildings, on average. In 2024 USD, these benefits total $19.2 million.

Since the original HBA was published, new infrastructure projects and operational changes have improved water resource management within the study area. There have also been substantial improvements in MCWRA's understanding of the Basin, additional data collection, and improvements to the computational tools necessary for conducting this type of analysis. This HBA Economic Assessment Update relies on these improvements and updates to provide a revised characterization of the economic benefits of MCWRA's investments for Basin stakeholders.

2. Approach and Methods

This chapter describes the methods and approaches used to perform the HBA Economic Analysis Update. First, we describe the "with" and "without" project scenarios that serve as the basis for the analysis. We then provide an overview of the inputs and economic methods used to quantify and monetize the benefits of the Projects. Additional detail on methods and assumptions related to specific benefits of the Projects are provided in relevant Chapters 3 through 7.

2.1. Analysis scenarios

An initial step to undertaking any economic analysis is defining the relevant baseline. The baseline represents "without project conditions" which, in this instance, allows for a comparison of the effects of the Projects against a scenario in which they had not been constructed. Basing this HBA update analysis on a comparison of "with and without project" conditions aligns with the methodology utilized in the 1998 HBA. Consistent with West Yost's approach for Salinas Valley HBA Update (hereinafter referred to as the HBA Update), this HBA Economic Assessment Update refers to the "with" and "without" project scenarios as the Historical Scenario and the No Projects Scenario, respectively.

2.1.1 Historical Scenario

The Historical Scenario represents actual conditions within the Salinas Valley from October 1967 to September 2018, the period for which available modeling tools were calibrated at the time of this study. To simulate historical hydrologic and flood conditions over the analysis period, the HBA Update used the Salinas Valley Integrated Hydrologic Model (SVIHM, developed by the United States Geological Survey, USGS) and the U.S. Army Corps of Engineer's (USACE's) Salinas River HEC-RAS model (Hydrologic Engineering Center River Analysis System) model, with some modifications and additions.

The Historical Scenario models incorporate projects and programs related to the San Antonio and Nacimiento Reservoirs during the period of their operation, with both reservoirs in operation throughout the model simulation period. The effect of raising the Nacimiento Dam spillway elevation is included in the time series of reservoir releases beginning in 2009, when the spillway modifications were completed as part of the SVWP. Recycled water deliveries from the Monterey One Water Regional Treatment Plant through CSIP are modeled beginning in 1998, while SRDF deliveries of rediverted stored reservoir water begin in 2010.

2.1.2 No Projects Scenario

The No Projects Scenario fulfills the same purpose for the HBA Update as did the "without reservoirs" scenario used for the 1998 HBA. It includes the following modifications to the Historical Scenario model:

- **Removal of the reservoirs:** The Historical Scenario uses historical reservoir releases (reported by MCWRA) as the streamflow inputs for the Nacimiento and San Antonio Rivers. For the No Projects Scenario, the streamflow inputs at these locations are replaced by estimated historical reservoir inflows, which are based on streamflow data from USGS gages upstream of the reservoirs.

- **Removal of recycled water deliveries to CSIP area**: The SVIHM simulates recycled water deliveries to satisfy crop demands within the CSIP area. The volume of delivery, which began in 1998, is based on historical records provided by MCWRA. The No Projects Scenario sets these deliveries to zero.

- **Removal of increased Nacimiento Dam spillway elevation (part of SVWP)**: The modification of the Nacimiento Dam spillway was completed in 2009. The impact of raising the spillway crest elevation is incorporated into the reservoir release time series for the Historical Scenario input. The use of reservoir inflows as the stream inflow inputs to the SVIHM in the No Projects Scenario removes the effect of the spillway raise.
- **Removal of SRDF operations (part of SVWP**): As with the recycled water deliveries, the SVIHM makes rediverted water from the SRDF available to satisfy crop demands in the CSIP area. The volume of delivery, which began in 2010, is based on historical records provided by MCWRA. The No Projects Scenario sets these deliveries to zero.

The difference in outcomes between the Historical and No Projects Scenarios is taken to represent the benefits associated with the construction and operation of the Projects. Throughout this report (unless stated otherwise), this difference represents the Historical Scenario minus the No Projects Scenario, such that positive numbers represent a benefit of the Projects, and negative numbers represent a negative outcome (i.e., a cost) relative to without project conditions.

2.1 Economic Analysis Methods

The economic benefits associated with MCWRA's water infrastructure investments include:

- Avoided replacement of wells because of depleted groundwater levels and seawater intrusion
- Avoided costs resulting from reductions in overall groundwater pumping and decreased depth to groundwater, which in turn reduces pumping lift requirements (and associated pumping costs)
- Reduced flood risk and associated damages to buildings, structure, and agriculture
- Active and passive reservoir-related recreation opportunities
- Generation of hydropower

Most of these benefits are closely linked to the hydrologic and flood risk reduction benefits reported by West Yost in the HBA Update and can be monetized using avoided cost analysis. For example, as described in more detail in Chapter 3, output from the SVIHM allowed us to compare groundwater pumping volumes and depth to groundwater for individual wells under the Historical and No Project Scenarios based on time series hydrological data (e.g., pumping volume, depth to groundwater) and information on the characteristics of each well. We applied costs per AF to pump groundwater over different depths to estimate total pumping costs over time across all wells. Total costs were greater under the No Projects scenario, meaning that the Projects resulted in reduced (avoided) pumping costs for growers.

Some benefits, such as recreation and environmental benefits, can be more difficult to monetize because they are not bought and sold in a market and therefore do not have a directly observable market price. Economists have developed several methods for valuing these and other "non-market" goods and services (Figure 3). For this analysis, the project team valued non-market benefits including recreation benefits, using a secondary research approach called benefits transfer. Benefits transfer relies on values reported in the literature from primary or original valuation studies (e.g., a stated or revealed preference study) to estimate the potential value of non-market benefits for a specific study site. Benefits transfer is commonly used in economics, and there is a well-developed literature on how to correctly apply this method.[vi] When implemented correctly, with the recognition that the estimates are not intended to be precise, benefits transfer is accepted as a suitable method for estimating non-market benefits in various contexts.[vii]

2.2 Key Data Sources

As noted above, this study relies on inputs from the HBA Update to estimate the avoided costs resulting from increased groundwater levels, reduced groundwater pumping, and avoided flood damages under the Historical Scenario. Data from SVIHM included groundwater head elevations and pumping volumes under the Historical and No Project Scenarios, in addition to well characteristics (e.g., elevation of the top and bottom of the well intake screen, general well location, top of well elevation) for the 2,375 agricultural, municipal, and industrial wells within the study area. This data was provided in five-day time steps over the 51-year analysis period.

West Yost also provided outputs from the Salinas Valley HEC-RAS model related to the extent and depth of flooding under various storm return intervals (i.e., 100-year, 50-year, 25-year, and 10-year storm events). We combined this information with agricultural crop data from USGS, Monterey County, and the University of California Davis, with data on the location and characteristics of structures within the floodplain to estimate the avoided flood damages resulting from the Historical Scenario.

We supplemented data from the HBA Update with information gleaned from interviews with regional well drilling experts and local government staff, as well as information from published literature and reports. Additional detail on sources and data used value benefits is provided in the following chapters specific to each benefit.

Figure 3. Primary Nonmarket Valuation Approaches

Research approaches to estimate the value of non-market benefits, such as recreation and habitat improvements, include:

Stated Preference methods rely on survey questions that ask individuals to make a choice, describe a behavior, or state directly what they would be willing to pay for a non-market good or service. They are based on the notion that there is some amount of market goods and services that people would be willing to trade off so they can benefit from a non-market good. Stated preference studies typically yield average per-person or per-household willingness to pay (WTP) estimates for survey respondents. These estimates can be extrapolated to the wider study population to provide an indication of the total value of non-market benefits.

Revealed Preference methods: estimate WTP using data gathered from observed choices that reveal the preferences (i.e., WTP) of individuals for nonmarket goods and services. The most common revealed preference methods are the hedonic pricing (statistical analysis to estimate the influence of different factors on observed market prices), travel cost (economic demand functions for recreation based on the choices people make to travel to a specific location), and averting behavior (infers values from defensive or averting expenditures) methods.

3. Avoided Well Replacement and Pumping Costs

This section describes the benefits to agricultural growers associated with the increase in fresh groundwater storage that the Projects have collectively provided over the study period. As noted above, this assessment relies on results from the HBA Update hydrologic benefits analysis, which are first summarized here.

3.1 HBA Update: Hydrologic Benefits Analysis Results

Results of the HBA Update confirm that the Salinas Valley has experienced an overall increase in fresh groundwater storage in Basin aquifers because of the Projects. This has manifested as increased groundwater head (i.e., increased groundwater levels in the well) and decreased seawater intrusion from Monterey Bay relative to the No Projects Scenario.[2]

The HBA Update indicates that higher groundwater heads are concentrated in two portions of the study area: the area between Castroville and Salinas (northern part of the study area) and the area adjacent to the Salinas River near Bradley downstream to Gonzales. By the end of the model period (September 2018), head was as much as 67 feet higher in portions of the Pressure Subarea in the area between Castroville and Salinas. Along the Salinas River, head was approximately 15 feet higher. While head in much of the study area was lower at the end of the model period compared to the start, this decline was substantially smaller than it would have been without the Projects. Head declined by up to approximately 3.0 feet per year in the area between Castroville and Salinas with the Projects, while the average annual head decline was approximately 3.3 feet per year in the same area without the Projects.

Increased groundwater heads reflect an increase in groundwater storage resulting from additional water entering the groundwater system and/or less water leaving the system. The HBA Update shows that the Projects have increased groundwater recharge from the Salinas River and its tributaries to the study area aquifers by 72,000 AFY, with most of this transfer occurring in the Upper Valley Subarea and the Forebay Subarea (southern/upstream portion of the study area). Higher head values have resulted in an increase in discharge to agricultural drains and a decrease in net recharge of approximately 45,000 AFY and 14,000 AFY, respectively, also mostly in the Upper Valley and Forebay Subareas. This means that under the Historical Scenario, groundwater heads in these areas are closer to the elevations of agricultural drains and close enough to the land surface to contribute significantly to the satisfaction of crop water demand.

The Projects have also reduced agricultural pumping by approximately 10,000 AFY, with most of the reduction taking place in the Pressure Subarea. The SVIHM simulates a reduction in agricultural pumping either because head in groundwater wells falls to a level where the well pump can no longer maintain the desired pumping rate, or because the irrigation demand of the crop decreases (e.g., because crops have increased access to groundwater within the root zone). In the Forebay and Upper Valley Subareas, the

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[2] Head is a measurement of the pressure that the water stored in an aquifer is under, referenced to a vertical datum. It is commonly thought of as the elevation to which water would rise in a well or piezometer installed in an aquifer and is used to define groundwater levels. Changes in groundwater head are a proxy for changes in aquifer storage. As storage in aquifers declines, groundwater head declines, while increasing groundwater storage is represented by an increase in groundwater head.

reduction in agricultural pumping is likely a result of increased head levels. The difference in agricultural pumping in the Pressure Subarea mostly occurs from 1998 onward, indicating that the difference is likely due to the recycled water and rediverted surface water deliveries from CSIP. Modifications to reservoir operations resulting from SVWP and associated Flow Prescriptions (i.e., increased minimum flows) have also contributed to increased recharge in these areas.

Overall, the change in inflows and outflows through the groundwater system has resulted in more fresh groundwater storage under the Historical Scenario than there otherwise would have been without the Projects. Although overall storage declined by an average of approximately 11,000 AFY with the Projects, this storage loss would have been substantially greater – close to 31,000 AFY - without the Projects.

As detailed in Chapter 2 of the HBA Update, the SVIHM cannot directly simulate the extent of intrusion of seawater into the freshwater aquifers of the study area. However, the SVIHM-simulated flux of groundwater across the coast can be taken as a reasonable estimate for the rate of seawater intrusion (see Chapter 2 of the HBA Update for additional detail). Applying this approach, the model indicates a that the Projects decreased seawater intrusion by approximately 68,000 AF over the 51-year analysis period. Most of this difference (50,000 AF of the 68,000 AF) occurred in Pressure Subarea, while the remainder largely occurred outside of the Zone 2C impact area. The models also show that the cumulative difference in seawater intrusion across scenarios was minimal prior to 1998 (amounting to approximately 1,000 AF total). This indicates that the CSIP (which began recycled water deliveries in that year) and SVWP have significantly reduced seawater intrusion.

Finally, the analysis of regional groundwater quality impacts in the 1998 HBA was somewhat qualitative; however, it concluded that the reservoirs could be expected to have positive effects on groundwater quality in the Basin because of increased recharge in the riparian area. The HBA Update Hydrologic Analysis does not include a discussion of impacts on regional groundwater quality. They are therefore not valued as part of the economic assessment.

3.2 Economic Study Units

The 1998 HBA summarized the benefits provided by the Nacimiento and San Antonio Reservoirs on a spatial basis using subdivisions referred to as Economic Study Units (ESUs). These units provided a way to group together portions of the study area that experienced similar benefits (as quantified by the average annual groundwater head change). The 1998 HBA divided the hydrologic model into 12 ESUs.

Because the HBA Update utilized a different set of tools to quantify the hydrologic benefits of the Projects, West Yost developed a new ESU map to group portions of the study area together. As with the 1998 HBA, the ESU map is based on the groundwater head difference between the Historical and No Projects Scenarios, in this case using the September 2018 model results. The September 2018 results represent the cumulative difference between scenarios over the entirety of the 51-year simulation period, providing the most detailed understanding of the spatial variation in the benefit of the Projects.

Figure 4 shows the 13 ESUs used for this study. The ESUs follow MCWRA's Zone 2C Subarea boundaries, with subareas subdivided into multiple ESUs as dictated by the head differences between scenarios:

- The East Side Subarea is divided into 3 ESUs (1, 2, and 5)
- The Pressure Subarea is divided into 4 ESUs (3, 4, 6, and 7)
- The Forebay Subarea is divided into 2 ESUs (8 and 9)

Figure 4. Hydrologic Benefits Analysis Economic Study Units (ESUs)

- The Arroyo Seco Subarea is a single ESU (10)
- The Upper Valley Subarea is divided into 2 ESUs (11 and 12)
- Below Dam Subarea is a single ESU (13)

Consistent with the HBA Update, the results of this portion of the economic assessment are presented by ESU and Subarea.

3.3 Economic Benefits

Declines in groundwater head and storage have the potential to negatively affect the ability of groundwater wells to operate, particularly when head falls below the bottom of a well's intake screen or within the "impact zone" between the top and bottom of the screen. Even when this does not occur, decreased groundwater head requires more energy (and increases costs) to pump and lift water from below the ground. By increasing groundwater head relative to the No Project Scenario, the Projects have avoided significant costs for growers associated with these negative effects. The Projects have also reduced overall groundwater pumping in the Basin, further reducing pumping costs. The following sections describe these benefits in turn, including our approach for estimating avoided costs and the resulting monetized benefit estimates.

3.1.2 Avoided well construction/replacement costs

This section presents the avoided costs associated with the effect of the Projects on reducing the number of wells needing replacement due to depleted aquifer conditions. To conduct this analysis, the project team relied on well-level data provided by West Yost from the SVIHM. This data included groundwater head elevations and pumping volumes under the Historical and No Project Scenarios, in addition to well characteristics (e.g., elevation of the top and bottom of the well intake screen) for the 2,356 agricultural and municipal wells in the model. This data was provided in five-day time steps over the 51-year analysis period.

The project team applied a stepwise process to identify wells that would need replacement under the Historical and No Project Scenarios. First, we identified wells where groundwater head fell below the bottom of the well screen more than 20% of the time in a given year. The first year this occurred, we assumed the well was replaced and that the replacement well would continue to pump at levels identified in the database. Next, we identified wells where groundwater head fell within the "impact zone" defined by West Yost. The impact zone represents the area between the bottom of the well screen and ten feet below the top of the well screen. In the third year if groundwater head fell within the impact zone of a well more than 50% of the time, it was flagged for replacement. This is because some pumping can continue to occur when head falls within this zone, and it would not be immediately replaced.

To estimate the cost of replacing a well, the project team conducted interviews with well drilling experts in the region. This allowed us to better understand the various factors that affect when a well would be replaced and well replacement costs (e.g., depth, size, materials, how they vary across study area). Input from the interviewees informed the development of estimates for well replacement costs by ESU, as shown in Table 1. These differences are largely driven by the depth of the well necessary for continued pumping.

Table 1. Estimated well replacement costs by ESU (2024 USD)

	ESU 1-4	ESU 5-7	ESU 8-12
Removal/decommissioning of existing well	$40,000	$30,000	$20,000
Well construction	$1,500,000	$600,000	$175,000
Pump and installation of related equipment	$400,000 - $2,400,000	$275,000	$65,000
Total	**$2,940,000**	**$905,000**	**$260,000**

Our analysis indicates that the Projects avoided replacement of 69 wells within the study area relative to the No Projects Scenario. These wells are mostly concentrated in ESUs 3 (26 wells) and 11 (11 wells), with a handful of well replacements in each of ESUs 2, 6 through 9, and 12. Over the 51-year study period, this resulted in $107.4 million in avoided costs, an average of $2.11 million per year. Table 2 shows the distribution of avoided replacement wells and the associated avoided costs by ESU and Subarea. As shown, most wells identified for replacement are agricultural wells, although several are used for municipal purposes.

Table 2. Avoided well replacement costs (2024 USD), by Subarea and ESU, over 51-year analysis period

Subarea/ESU	Avoided well replacements	Avoided well replacement costs
East side		
1		
2	4	$11,760,000
5	-	-
Forebay		
8	5	$1,300,000
9	5	$1,300,000
Pressure		
3	26	$76,440,000
4	-	-
6	6	$5,430,000
7	8 (w/1 municipal)	$7,240,000
Arroyo Secco		
10	-	-
Upper Valley		
11	11 (w/4 municipal)	$2,860,000
12	4 (w/1 municipal)	$1,040,000
Total	**69 (w/6 municipal)**	**$107,370,000**

3.2.2 Avoided costs from reduced agricultural pumping and pumping lift

As described above, the Projects have led to substantially less agricultural pumping, especially in the Pressure Subarea, where there has been 299,000 AF less pumping over the 51-year analysis period than would have occurred without the Projects. Smaller reductions in agricultural pumping have taken place in the Upper Valley (approximately 104,000 AF) and Forebay (approximately 76,000 AF) Subareas. In addition, increased groundwater heads resulting from the Projects have reduced the distance required to lift groundwater to the surface in many areas. This also results in reduced pumping costs.

The dataset provided by West Yost allowed us to estimate total pumping volume and the depth of pumping (elevation at the top of the well minus groundwater head) under No Project and Historical Scenarios for the 2,356 wells included in the dataset. This in turn allowed us to estimate the difference in energy requirements (and associated pumping costs) across scenarios using the following equation:

$$kWh/AF = 1.0241 \times TDH/OPE$$ [3]

Where:

> TDH = total dynamic head, the sum of water level lift (depth to pumping) and pressure converted to lift. Pressure converted to lift = well pressure (50 psi) x 2.31 (conversion of psi to feet of head)
>
> OPE = overall pumping efficiency, assumed to be 0.6 for this analysis

The kWh per AF is multiplied by $0.2 per kWh, the current average price of energy in this region. This yields an estimated cost of pumping per AF per five-day time step over the 51-year analysis period for each well. This cost is multiplied by the total pumping volume to estimate total pumping costs. The difference in total pumping costs between the No Project and Historical Scenarios represents the avoided pumping costs associated with the Projects.

The project team's assessment indicates that the Projects have resulted in approximately 500,000 AF less pumping over the 51-year analysis period and have raised groundwater heads. Table 3 shows the total avoided pumping and total avoided pumping costs by ESU and Subarea, indicating that the Projects have saved growers $67.9 M in pumping costs over the analysis period, or an average of $1.3 M per year.

3.1.3 Seawater intrusion

The Projects have helped MCWRA slow seawater intrusion in the Salinas Valley, thereby reducing adverse effects associated with the loss of agricultural productivity due to impacts from elevated salinity. Elevated levels of salinity can directly impact crop production by inhibiting water and nutrient uptake by plants. Each crop has a salinity tolerance level, meaning salinity can increase to a certain point before crop yield begins to decline. As salinity levels reach the point of tolerance, yield begins to decline at a somewhat linear rate for each crop. While absolute tolerances vary, depending upon climate and soil conditions, the

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[3] Canessa, P., S. Green and D. Zoldoske. 2011. Agricultural Water Use in California. A 2011 Update. Center for Irrigation Technology Staff Report. Accessed October 2024. Available: https://www.waterboards.ca.gov/waterrights/water_issues/programs/hearings/cachuma/exbhts_2012feir/cachuma_feir_mu289.pdf

Table 3. Avoided pumping costs (2024 USD), by Subarea and ESU, over 51-year analysis period

Subarea/ESU	Avoided pumping (AF)	Average difference in head (feet) at end of study period[a]	Avoided pumping costs
East side			
1	0	0.25	
2	7,100	6.4	$1,959,100
5	-	1.1	$1,060,300
Pressure			$-
3	273,100	8.9	$29,984,700
4	-	-0.59	$145,000
6	13,800	1.2	$1,308,100
7	11,600	0.91	$1,603,100
Forebay			$-
8	29,900	3.0	$4,004,800
9	46,400	4.5	$4,862,700
Arroyo Secco			$-
10	11,900	2.0	$1,769,500
Upper Valley			$-
11	56,000	6.4	$10,852,400
12	48,300	8.1	$10,356,700
Total	**498,100**		$67,906,400

a. Represents the average difference in head under No Projects and Historical Scenarios at end of study period (2018)

general relationship between yield and salinity (measured as conductivity) is reflected in the following equation:

$$Y_r = 100 - B(K_e - A)$$ [viii]

Where

Y_r = yield reduction
B = the percent yield decrease per unit salinity increase above the threshold.
Ke = conductivity level (salinity, typically measured in DeciSiemens per meter, or dS/m)
A = salinity threshold

As noted previously in this report, the SVIHM does not directly simulate the intrusion of seawater into the freshwater aquifers of the study area. However, the SVIHM-simulated flux of groundwater across the coast can be taken as a reasonable estimate for the rate of seawater intrusion. Based on this method, seawater intrusion has been approximately 1,000 AFY lower in the Pressure Subarea than it would have been without the Projects, representing a total decrease in seawater intrusion of approximately 50,000

AF over the 51-year analysis period.[4] More than 90% of the difference in seawater intrusion occurred in the 180-Foot and 400-Foot Aquifers, from which most wells within the Pressure Subarea draw groundwater.

Applying some simple assumptions demonstrates the magnitude of impacts that reduced seawater intrusion has had on agricultural productivity. In 2015, the California Central Coast Regional Water Quality Control Board (CCRWQCB) and U.S. EPA Region 9 published an assessment of salt impairments in the Lower Salinas River and Reclamation Canal watersheds.[5][ix] Based on data from various sources spanning 1971 to 2014, this study reports mean groundwater conductivity levels and total dissolved solids of 1.8 dS/m and 2,314 mg/L (equivalent to a conductivity of approximately 3.6 dS/m), respectively, in the coastal portion of the Pressure Subarea. This provides a range of values across which to assess potential salinity impacts on crop production.

Table 4 shows the average proportion of acres by crop type for crops within the coastal portion of the Pressure subarea and specifically, the coastal portion of ESU 3, which the main area of seawater intrusion underlies, over the 51-year analysis period. Lettuce, artichokes, and crucifers (e.g., broccoli, cauliflower) have accounted for most irrigated acres over time. Lettuce is moderately sensitive to salinity, while artichokes are considered moderately tolerant, with a relatively high salinity threshold of 4.9 dS/m. Other crops within the area that are sensitive or moderately sensitive to salinity include celery, cauliflower, onions, and strawberries. Today, pasture makes up a small portion of irrigated acres in this area (less than 1%), but in the early years of the study period accounted for close to 16%.

Assuming an average applied water rate of 2.0 AF/acre,[x] the 1,000 AFY reduction in seawater intrusion under the No Projects Scenario would have affected approximately 500 acres of farmland each year. Assuming the mix of crops, gross output per acre, and salinity tolerance levels shown in Table 4, Table 5 presents the reduction in gross output associated with the range of salinity levels reported by RWQCB and US EPA (2015). For this somewhat simple assessment, we assume that crops classified as “unspecified” or “other” are not impacted by elevated salinity levels.

In total, this assessment shows that impacts could range from $21.7 to $86.9 M over the 51-year analysis period (an average annual value ranging from $425,000 to $1.7 million). Most of this benefit largely accrued to growers beginning in 1998, coinciding with deliveries of recycled water from CSIP. The estimated reduction in output represents the direct impacts associated with reduced agricultural productivity. These direct impacts would result in indirect and induced effects, as the impact of reduced spending by farmers on supplies and labor rippled through the local economy. These impacts are not estimated as part of this study. Finally, this analysis does not account for crop switching or other adaptations to reduce salinity impacts but rather quantifies the impacts associated with reduced yields. For example, if rather than continuing to plant crops affected by salinity, the 500 impacted acres were converted to pasture, reductions in gross output would range from $10.4 to $75.6 million over the study period.

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[4]An additional 18,000 AF reduction occurred outside of the Zone 2C impact area.

[5] This assessment informed the development of salt-related TMDLs by the CCRWQCB and a salt and nutrient management plan for the Salinas Valley aquifers.

Table 4. Crops within ESU 3 (coastal portion) - gross output and salinity tolerance

Crop type	% of coastal ESU 3 acres	Gross output per acre (2022 USD)[a]	Salinity threshold (dS/m)	% decrease in yield per 1-unit increase in salinity
Celery	2%	$18,900	1.8[b]	6%
Lettuce	44%	$14,900	1.3[b]	13%
Crucifers	18%	$9,400		
Broccoli			2.7[b]	9%
Cauliflower			1.8[d]	10%
Onions	0%	$7,600	1.4[c]	19%
Strawberries	2%	$97,200	1.0[b]	33%
Artichokes	19%	$11,200	4.9[c]	11%
Pasture	4%	$445	6.0	N/A
Other	11%	N/A	N/A	N/A

a. UC Davis Crop budgets and Monterey County crop report
b. Amacher et al. 2000
c. Shannon and Grieve 1999 (USDA)
d. Salinity thresholds for cauliflower are not available, set to threshold for cabbage because they are both brassicas and both classified as moderately sensitive to salt (UC Davis 2015)

Table 5. Benefits resulting from reduced seawater intrusion from Projects (avoided reduction in gross output, 1,000s $ over 51-year analysis period, 2022 USD)

Crop type	Salinity levels (dS/m)		
	1.8	2.7 (mid-point of range)	3.6
Celery	$ -	$412	$815
Lettuce	$9,472	$25,823	$42,175
Broccoli	$ -	$29	$1,529
Cauliflower	$36	$1,652	$3,267
Onions	$48	$150	$252
Strawberries	$12,194	$25,543	$38,893
Artichokes	$ -		
Pasture	$ -		
Total	$21,750	$53,610	$86,930

4. Flood Control Benefits

This section describes the flood control benefits associated with the construction and operation of the San Antonio and Nacimiento Reservoirs over the study period, including avoided damages to structures and agricultural resources (crops and soils). This assessment relied on results from the HBA Update flood control benefits analysis, which are first summarized here.

4.1 HBA Update: Flood Control Benefits Analysis Results

Results of the HBA Update show that the Projects have resulted in a decrease in the frequency and magnitude of flooding events along the Salinas River. The Nacimiento and San Antonio Reservoirs have provided this benefit by storing high flows during wet winter periods and releasing flows during drier parts of the year. The reservoirs act to attenuate flood peaks generated in the Nacimiento and San Antonio River watersheds rather than passing them directly to the Salinas River.

Flood Frequency Curves for the Salinas River at Bradley (located just downstream of the dams) indicate that the reservoirs reduce peak flows associated with the 100-year flood event by 28% - from approximately 159,000 cubic feet per second (cfs) without the Projects to 115,000 cfs with the Projects in place. For more frequent events, the Projects achieve larger proportional reductions; for example, the Historical Scenario shows a 58% reduction in the magnitude of peak flows associated with the 10-year event compared to No Projects (from 68,000 cfs to 28,000 cfs). This is because the reservoirs cannot capture the entirety of the highest flow events when reservoir capacity is not sufficient to fully store the event inflow.

The reduced magnitude of peak flows has resulted in less inundation of the Salinas River floodplain than would have occurred had the Projects not been in place. Without the projects, the 100-year flood would inundate 65,000 acres, compared to 60,000 acres with the Projects. Again, benefits are greater for more frequent events; results from the HBA Update indicate that the 10-year event would inundate 48,000 acres without the Projects and 32,000 with the Projects.

In addition to decreasing the extent of inundation, the Projects, by reducing the magnitude of peak flows, result in lower streamflow velocities in the Salinas River floodplain. This in turn decreases potential for erosion in the floodplain. For the 100-year flood, the area of high potential for erosion was estimated to be 11,000 acres with the Projects and 17,000 without.

4.2 Flood Study Units

The 1998 HBA summarized the flood risk reduction benefits provided by the Nacimiento and San Antonio Reservoirs on a spatial basis using subdivisions referred to as Flood Study Units (FSUs). These units reflect the portions of each ESU (i.e., the Economic Study Units described in the previous section) that are covered by the HEC-RAS flood model. While it does cover the floodplain, the HEC-RAS model does not cover the entire area of Zone 2C, and therefore some ESUs (i.e., 1 and 13) do not have corresponding FSUs. Consistent with the 1998 HBA and West Yost's HBA Update, this economic assessment presents results by FSU. Figure 5 shows the extent of FSUs across the study area.

Figure 5. HBA Update Flood Study Units (FSUs)

4.3 Avoided Damages to Buildings and Structures

4.3.1 Modeling approach and inputs

The project team estimated avoided flood damages to structures resulting from the Projects using USACE's HEC Flood Impact Analysis (HEC-FIA) software. HEC-FIA combines hydrologic modeling results with a terrain model that contains ground surface elevations to determine the depth of flooding for an inventory of structures in the flood area. The model then calculates damages to structures and structure contents using depth-to-damage functions specific to different structure types.

To estimate flood damages under the No Project and Historical Scenarios, we relied on hydrologic modeling results from HEC-RAS (provided by West Yost), including flood depth spatial layers for the 10-, 25-, 50-, and 100-year flood events with and without the Projects. Additional inputs included the terrain model that West Yost used in HEC-RAS for the HBA Update and USACE's 2022 National Structure Inventory (NSI). The NSI combines data from various sources to create a spatial layer with attributes for individual structures in the study area, including occupancy type (residential, commercial, industrial, public), building replacement value, ground elevation, foundation height, and other variables. The NSI indicates that in 2022, there were 17,074 structures within the study area FSUs. As shown in Table 6, FSU 3 has the most structures (9,830) followed by FSU 11 (3,085) and FSU 9 (2,698). The remaining FSUs have relatively few structures, ranging from 6 in FSU 2 to 538 in FSU 6.

Table 6. Number of structures in the 2022 National Structure Inventory for the Salinas River Valley, by building occupancy type and FSU

FSU	Commercial*	Industrial	Public	Residential	Total
2	1	4	0	1	6
3	1,430	256	113	8,031	9,830
4	19	5	0	262	286
6	40	25	4	469	538
7	11	28	0	50	89
8	12	30	1	71	114
9	189	35	26	2,448	2,698
10	4	7	2	75	88
11	316	108	38	2,623	3,085
12	71	20	5	244	340
Total	2,093	518	189	14,274	17,074

*The commercial occupancy category includes agricultural buildings.

Flood control benefits were estimated by comparing average annual flood-related damages under the No Projects and Historical Scenarios across flood event types. HEC-FIA calculates expected annual damages (EAD) from flooding based on the value of structures, their contents, and the estimated number of vehicles located on properties at the time of flooding. EAD is a metric that combines the likelihood of flood events (e.g., the 1% probability of a 100-year flood occurring each year) with the damages expected from each event. It reflects potential damages from flooding across all storm events based on damage calculations for specific events (i.e., the 10-, 25-, 50-, and 100-year events), extrapolating across the hydrograph.

To estimate the number of structures located in each FSU for each year of the 51-year study period, we analyzed population changes by Census tract for the Census tracts that intersect each FSU. Population data is available at the Census tract level from 1970 to 2020, with some cross walking necessary to match population data from 1970 to 1990 to population data from 1990 to 2020 at this geographic scale. We used this information to calculate an average annual growth rate by FSU, equating percent changes in population to percent changes in structures. For the extremely small FSUs (i.e., 2, 4, and 5) we assumed an average growth rate equal to the adjacent FSU because Census tract data is not granular enough to adequately estimate populations in these areas. Table 7 shows the average annual growth rate assumed for each FSU over the analysis period.

Table 7. Estimated average annual population growth rate by FSU, 1968-2018

FSU	Assumed average annual growth rate (%)
2	1.17%
3	1.17%
4	1.17%
5	1.11%
6	1.11%
7	-0.06%
8	-0.08%
9	5.30%
10	1.17%
11	0.36%
12	-0.15%
Weighted average	1.10%

4.3.2 Value of avoided damage to buildings and vehicles

Tables 8 and 9 show the estimated avoided flood damages that have resulted from the Projects by FSU, including average annual and cumulative damages avoided over the 51-year analysis period, respectively. The model indicates that over the analysis period, FSU 3 experiences the most damages across flood event types, accounting for 70% of total damages under the No Projects scenario, 77% under the Historical Scenario, and 65% of total avoided damages resulting from the Projects (No Project minus Historical Scenario). FSU 6 accounts for most of the remaining flood damages, with 26% under the No Projects Scenario, 18% in the Historical Scenario, and 31% of the avoided flood damage to structures resulting from the Projects.

Table 10 also shows the average annual damages that the Projects have avoided, but by building occupancy type rather than FSU. As shown, residential buildings account for the greatest percentage of total damages, followed by commercial structures.

Table 8. Average annual avoided flood damages by FSU, 1,000's of dollars (2024 USD)

FSU	Structural Damage	Contents Damage	Vehicle Damage	Total Avoided Damage
3	$1,380	$1,122	$170	$2,672
4	$1	$-	$-	$1
6	$954	$327	$8	$1,289
7	$2	$1	$-	$4
8	$1	$5	$1	$7
9	$6	$12	$2	$20
10	$22	$35	$3	$60
11	$-	$-	$-	$-
12	$25	$46	$4	$75
Total	$2,393	$1,548	$188	$4,128

Table 9. Avoided flood damages by FSU over 51-year analysis period, 1,000's of dollars (2024 USD)

FSU	Structural Damage	Contents Damage	Vehicle Damage	Total Damage
3	$70,399	$57,210	$8,650	$136,260
4	$43	$-	$-	$43
6	$48,679	$16,661	$392	$65,732
7	$120	$60	$-	$181
8	$61	$242	$61	$363
9	$313	$609	$104	$1,026
10	$1,113	$1,799	$171	$3,083
11	$-	$-	$-	$-
12	$1,297	$2,348	$185	$3,830
Total	$122,026	$78,929	$9,563	$210,517

Table 10. Average annual flood damages by building occupancy type and analysis scenario, 1,000's of dollars (2024 USD)

FSU	No Projects Scenario (NP)	Historical Scenario (Hist)	Avoided Damage (NP – Hist)
Commercial[a]	$1,428	$435	$993
Industrial	$115	$31	$83
Public	$19	$-	$19
Residential	$5,278	$2,187	$3,092
Total	$6,840	$2,653	$4,187[b]

a. The commercial category includes damage to agricultural buildings.
b. Total avoided damages do not exactly match those reported in Table 8 due to rounding.

As shown in Tables 8 and 9, structural damage to buildings constitutes the largest damage category, with building contents and vehicle damage accounting for a much smaller percentage of total damages from flooding. The average ratio of contents damage to structure damage is 60% across flood events, although this varies across structure and occupancy type. This ratio is typical when a large proportion of the flood damage is in the residential sector. Table 11 shows the difference in number of buildings flooded with and without the Projects, by building occupancy type and flood return interval.

Table 11. Avoided number of buildings flooded under various flood return periods, building occupancy type, No Project minus Historical Scenario

	Flood return period			
Building Occupancy Type	10-Year	25-Year	50-Year	100-Year
Commercial	33	21	30	24
Industrial	6	1	8	8
Public	1	1	1	4
Residential	170	89	167	420
Total	210	114	207	457

4.4 Avoided damages to agricultural crops

4.4.1 Modeling approach and inputs

To assess avoided damages to agricultural crops, we relied on data from HEC-RAS (provided by West Yost) on the depth and extent of flooding for the 10- , 25- , 50- and 100-year events under the No Project and Historical Scenarios. Table 12 shows the difference in total acres flooded by FSU for different flood return periods (this data includes all land use categories including non-agricultural acres). Consistent with findings from the HBA Update, it shows that in general, the greatest reductions in acres flooded occur for the smaller return period events (i.e., the 10- and 25-year events). This is because reservoir capacity (when partially full) is not sufficient to fully store inflows from the larger events.

Table 12. Difference in Inundated Acres, No Projects and Historical Scenarios, by flood return period

	Flood return period			
FSU	10-Year	25-Year	50-Year	100-Year
3	6,345	3,500	2,268	1,450
4	116	37	23	57
6	1,000	570	611	848
7	810	190	178	316
8	1,640	483	241	341
9	1,780	1,207	536	226
10	523	317	251	183
11	1,571	1,410	1,421	927
12	2,712	3,402	1,632	599
Total	16,496	11,116	7,161	4,947

Given the extent and depth of flooding by FSU, we used land use data for the Salinas Valley to determine which crops would be affected by flooding with and without the Projects. We relied on data developed by USGS for the SVIHM; this data contains 56 specified land use categories including both agricultural crops and non-agricultural uses (such as urban, riparian or woodlands). For each model year, USGS generated land use maps using a composite of available land use data from California DWR, Monterey County, and the National Land Cover Database (NLCD, USGS 2014) and a newly developed method that leverages the California Pesticide Use Reporting (CalPUR) database.

The CalPUR method provides greater detail for the identification and distribution of crops in the Salinas Valley than was previously available. In the past, row crops have often been only been identified under a general category such as "truck and vegetable crops" but are now identified in more detail by their specific crop type (e.g. lettuce or crucifers) – although an "unspecified" category is still used after applying the CalPUR method for row crops that cannot be identified. In the SVIHM model, these data are linked to individual model cells to provide water demand and other water use data in the spatial detail necessary for model runs. The data have now been released as spatial layers by the USGS and that can be used outside of SVIHM model calculations. Figure 6 shows the 2017 land use spatial data layer for SVIHM.

4.4.2 Crop data for calculating loss

To value crop losses associated with flooding, we calculated lost revenues minus variable costs already expended, re-establishment costs (if any), and land cleanup and rehabilitation costs resulting from the flood. We followed an approach developed by USACE in its 2002 Sacramento and San Joaquin River Basins Comprehensive Study;[xi] this approach was also applied in the Flood Rapid Assessment Model (FRAM) used by the California DWR to assess avoided flood damage benefits in applications for state grant funding (URS 2008). We updated crop returns (revenues minus variable costs already expended) and crop reestablishment costs in the FRAM model with available crop budget data from UC Davis (UC Davis, 2024), supplemented by Monterey County Crop Report data by for corroborating information on average returns per acre by crop. We then used the updated FRAM model to estimate the value of avoided flood damage by crop type.

Net revenue per acre is calculated as revenue minus variable costs expended prior to the month of the flood. Variable costs over a year are calculated as the weighted average of costs by month from the crop budget using the probability of flooding by month[6] – this means that costs expended in more frequent flood months (winter months) are weighted more heavily than costs in other months before the months of typical harvest. Based on this methodology, Table 13 shows per acre values by crop for net revenue and reestablishment costs.

[6] Used the probability of flooding by month for the Sacramento region due to lack of similar information for Monterey County

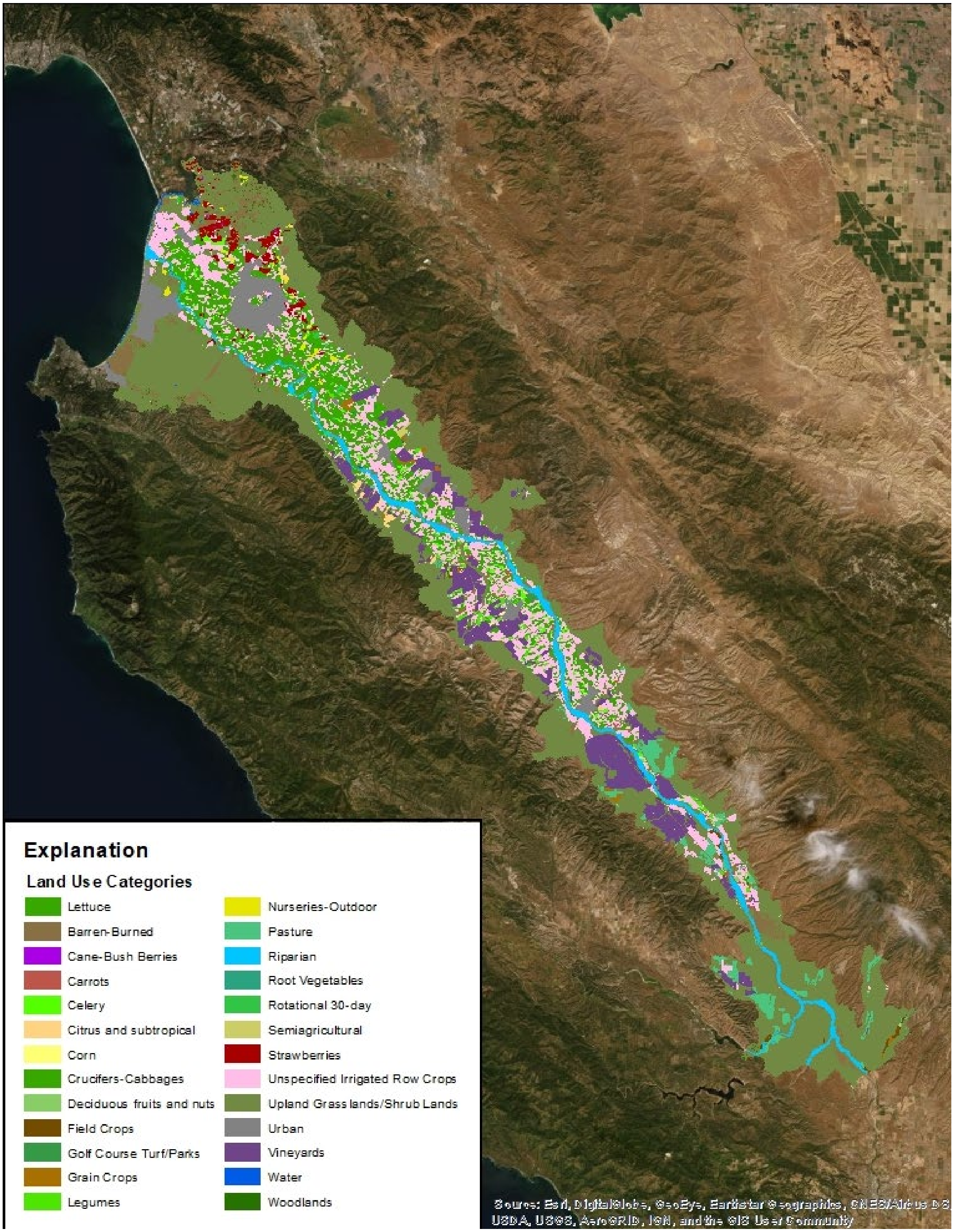

Figure 6. 2017 Land Use GIS Layer for Salinas Valley Integrated Hydrologic Model

Table 13. Crop flood damage estimate components, 2024 USD

Irrigated Crop	Net Revenue Per Acre ($/acre)	Re-establishment Cost ($/acre)[a]
Celery	$6,727	-
Legumes	$208	-
Lettuce	$4,575	-
Rotational*	$3,323	-
Crucifers	$2,072	-
Unspecified*	$3,323	-
Carrots	$2,874	-
Strawberries	$15,316	-
Artichokes	$8,689	-
Field	$299	-
Grain	$414	-
Deciduous	$3,530	$7,870
Vineyards	$5,247	$9,567
Pasture	$54	-
Tomato	$1,481	-
Onion	$4,248	-
Citrus	$10,962	$8,674

a. Annual crops do not have re-establishment costs

b. Rotational and Unspecified categories were valued at the average net revenue per acre of lettuce and crucifers (broccoli and cauliflower)

FRAM uses a threshold for the duration of flooding to determine whether crop re-establishment costs should be included in the damage estimate. If inundation lasts less than five days, only net revenue per acre and land cleanup and rehabilitation costs are included. If inundation lasts five days or longer, then re-establishment costs are also included. Re-establishment costs are only assumed for perennial crops in the Deciduous, Citrus, and Vineyard categories. The hydrologic analysis provided by West Yost does not calculate the duration of flooding, since the Salinas River HEC-RAS Model was run in a quasi-steady state to only represent the conditions under the peak flow magnitude. As a proxy, we assumed that flood depths of equal or greater than five feet would take more than five days to recede, while depths less than five feet would not. Note that flooding duration is not the same as the delay before farming operations can resume, which is often at least 1 to 2 months, including time needed for soil testing to assure that replanting is safe for human consumption.

Next, we used data provided by West Yost on soil erosivity by FSU to calculate land cleanup and rehabilitation costs. The original HBA expressed these costs by FSU as a function of soil erosivity. West Yost calculated soil erosivity by FSU in the same manner for the No Projects and Historical Scenarios. Thus, to estimate clean up and rehabilitation costs for this assessment, we updated these costs from the original HBA by FSU and erosivity category (low, medium, or high) to 2024 dollars. Updated costs are shown in Table 14.

Table 14. Land cleanup and rehabilitation cost, 2024 USD

Erosion Potential	Land Cleanup and Rehabilitation Cost Updated to 2024 Dollars ($/acre)
Low	$405
Medium	$1,773
High	$11,565

We applied the percentage of total acres in each erosion potential category by FSU to calculate the difference in weighted average land cleanup and rehabilitation costs for the No Projects Scenario and the Historical Scenario. Table 15 shows the difference in land cleanup and rehabilitation costs by FSU.

Table 15. Difference in land rehabilitation and cleanup costs, 2024 USD

FSU	Difference in Land Cleanup and Rehabilitation Cost (No Projects – Historical), ($/acre)
3	$597
4	$558
6	$1,120
7	$769
8	$933
9	-
10	$1,031
11	$765
12	$1,296

4.4.3 Avoided agricultural flood damages

For the study period (1968 to 2018), we estimated cumulative avoided agricultural flood damages using the USGS land use GIS data for the years 1992, 1997, 2002, 2007 and 2017. This allowed us to understand how crop damage from flooding in the Salinas Valley changes over time due to changes in the mix of crops each year. Table 16 shows the total acres flooded across all FSUs by land use type for 2017, as a percentage of the total acres flooded. Other years have a similar mix of acres flooded by land use type. Across all land uses, riparian acreage is the largest percentage of the total. Unspecified row crops are the highest percentage of agricultural acreage, followed by lettuce, crucifers (broccoli and cauliflower), and celery.

The difference in flooded agricultural acres based on 2017 land uses varies throughout the valley, based on a sampling of FSUs – FSU 3 closest to the coast, FSU 6 as the next major FSU down the valley from FSU 3, and FSU 11, which is higher in elevation and closer to the reservoirs. In almost all FSUs, the Projects avoid a significant amount of flooding of lettuce, crucifers, and unspecified row crops. In FSUs 3 and 4, a relatively large amount of acres planted in strawberries is not flooded as a result of the Projects; the

Projects reduce the greatest amounts of flooding of vineyard acreage and pasture in FSUs 11 and 12, respectively.

Table 16. Acres flooded by 10- and 100-year storm return period by crop type using the 2017 land use layer, as a percentage of the total acres flooded

Land Uses	10-Year Historical	10-Year No Project	100-Year Historical	100-Year No Project
Celery	1%	2%	2%	2%
Legumes	1%	1%	1%	1%
Lettuce	15%	19%	20%	21%
Crucifers	7%	9%	9%	9%
Unspecified	20%	25%	26%	26%
Carrots	1%	1%	1%	1%
Vineyards	0%	0%	1%	3%
Pasture	0%	1%	1%	1%
Urban	1%	1%	1%	1%
Riparian	43%	31%	26%	24%
Upland	9%	9%	9%	9%
Barren	0%	0%	1%	1%
Other	2%	1%	2%	1%
Total	100%	100%	100%	100%

Table 17 shows the total avoided agricultural crop damage by FSU for selected years, calculated based on the expected annual damage by scenario and across storm return periods, and accounting for the mix of crops for which flooding was avoided in that year. The USGS land use GIS data for 1997 are the same as the year 1992, so results for 1997 are omitted in this table for brevity.

Table 17. Avoided flood damages by FSU and selected year, 1,000's of dollars, 2024 USD

FSU	1977	1987	1992	2002	2007	2017
3	1,785	1,869	1,826	1,683	1,692	1,692
4	11	23	24	23	23	23
6	384	451	333	316	318	317
7	148	151	152	141	141	141
8	268	291	328	280	280	280
9	220	284	319	253	254	254
10	102	118	131	122	122	122
11	321	419	470	442	423	423
12	517	779	940	859	861	863
Total	3,756	4,385	4,523	4,116	4,112	4,114

Years in the GIS data before 1990 did not have the same row crop detail as years from 1990 and later. We used a summary of data by FSU and land use category from the SVIHM to allocate the difference in flooded agricultural acres from 1992 according to the crop mix in the SVIHM data for the years 1977 and 1987. Avoided crop losses for years in the study period not shown in Table 17 are assumed to be equal to the latest year in interval of years from that period (e.g. losses for each year from 1968 to 1976 are assumed to be equal to the losses estimated for 1977; losses for each year from 1978 to 1986 were assumed to be equal to the losses estimated for 1987).

In total, the value of avoided agricultural flood damage over the 51-year analysis period amounts to $211.0 million in 2024 USD.

5. Recreation benefits

This section summarizes the recreational benefits associated with Nacimiento and San Antonio Reservoirs, which both offer a range of recreational opportunities for residents of Monterey County and the broader region. First, we describe the recreational activities available at each reservoir and provide a summary of the approaches we used to value recreational benefits.[7] Limited data on historical revenues and visitation restricted the ability to estimate benefits prior to 1985 (see Section 5.2.1 for additional detail).

5.1 Overview of reservoir recreational activities

5.1.1 Nacimiento Reservoir

The Nacimiento Dam and Reservoir, located in northern San Luis Obispo County, was completed in 1957. The reservoir is 18 miles long with 165 miles of shoreline and a surface area of more than 7,000 acres at full storage capacity. Recreational opportunities at this reservoir include power boating, water sports (water skiing, wake boarding, tubing), kayaking and paddleboarding, camping, fishing, swimming, wildlife viewing, and picnicking. This reservoir has been operated by a concessionaire on behalf of Monterey County Parks since 2011, and the facilities have been branded as Lake Nacimiento Resort (the Resort).

By 1960, Nacimiento Reservoir had a small marina at the North Shore, along with two boat launch ramps, access roads and parking areas. The South shore was also outfitted with a store, marina, gas stations, campground and patrol boats. Over the years, these facilities have been upgraded. The Resort rents boats, water sports equipment and fishing gear at a 100-slip marina that was renovated in 2004. There are now five distinct campgrounds with more than 350 campsites, some with recreational vehicle (RV) water and electricity hookups. The Resort also provides fully furnished lodging accommodation options and RV rentals. The general store on site is open to guests year-round. For boating, Nacimiento is unrivaled in the region, offering many canyons that form lake fingers that can be explored by boat. The surrounding shorelines are heavily wooded with oak trees and provide habitat for golden and bald eagles, hawks, falcon, deer, wild pigs, and turkeys.

The reservoir is also home to many private boat docks located at homes and other buildings surrounding the reservoir. These docks provide direct access to the recreation opportunities described above and offer considerable benefits to the residents of Nacimiento. The number of private docks has increased over time – MCWRA reports that 261 private docks were registered in 1971, while 415 docks were registered as of 2023.

5.1.2 San Antonio Reservoir

Construction of San Antonio Dam and Reservoir was completed in 1965 and the recreation area opened to the public in the summer of 1967. At full capacity, the reservoir is 16 miles long with approximately 100 miles of shoreline and a surface area of 7,500 acres. This reservoir is managed by the Monterey County Parks Department (Parks), and features two main park areas, North Shore and South Shore. In 1990, eagle-watch tours were initiated at San Antonio Reservoir, and Parks added a Visitor Center in 2001. Year-round

[7] Note that this analysis focuses on recreational opportunities that are publicly available. Communities along the shores of Nacimiento also have access to shorelines with private boat ramps. These recreational users are not included in available user counts and are therefore not included in this analysis.

activities at this lake include picnicking, camping, fishing, hiking, swimming, boating, water sports, and horseback riding.

Recreational use at San Antonio Reservoir is dominated by camping. The South Shore is similar to Nacimiento, offering camping in heavily wooded areas with opportunities for wildlife viewing. There are approximately 400 sites with more developed camping amenities, such as bathrooms and hookups for RVs. The North Shore is more open and arid and offers shoreline camping and swimming opportunities that are not available at other locations. With only about 200 camp sites and fewer amenities, the North Shore draws recreational users looking for more peaceful and dispersed experiences. Additionally, an equestrian facility on the northeast side of the lake provides paddocks, camping, and a trail system for horseback riding.

Recreation at San Antonio Reservoir seems to be more susceptible to drought than recreation at Nacimiento Reservoir. From 1989 to 1992, the North Shore area was closed due to drought conditions, and park visitation is still recovering from closures and impacts associated with California's 2014 drought. In this more recent drought, the water storage at San Antonio Reservoir dropped to just 3% of its total capacity, and boats could no longer access the reservoir. A marina, lodging units, and stores on both the North and South Shores closed, and Park staff declined from 60 to just three full-time positions. This major drought also caused a sharp decline in the striped bass population, which was a major draw for recreational fishing at this lake. Additionally, the plants that grew in the absence of the lake during the drought are now covered with water, increasing nutrients and contributing to toxic algal blooms that have been reported most summers since 2014. The reservoir has started to recover from this period of drought, but fluctuations in water levels and algal bloom notifications have impacted lake visitation.

5.2 Methods and inputs for valuing recreational benefits

Individuals participate in recreation for physical activity and associated health benefits, leisure, improved mental health, and for building social capital. Because these benefits are not traded in the market, it can be difficult to establish the values associated with them. However, many researchers have conducted willingness-to-pay (WTP) surveys or revealed preference studies to estimate the value of a recreational experience across a range of activities. These studies yield what economists refer to as *direct use values*. Direct use values reflect the full amount (i.e., beyond any entrance fees) that individuals would be willing to spend to participate in a recreational activity.

Total benefits associated with participation in recreational activities are a function of direct use values and the recreational trips (often referred to as "user days" or visitor days) taken to each site. Direct use values can range significantly depending on the availability of similar recreation opportunities nearby, the type of recreational activities offered at a given location, the amount and quality of the recreational space, and other local conditions. To account for these various factors, this assessment relies on the USACE's Unit Day Value (UDV) method to estimate direct use values for the different activities available at the reservoirs. This method is explained in more detail below.

5.2.1 Visitation (user day) estimates

Recreational benefits depend on the annual number of recreational visits to the reservoirs, as well as the primary activities in which visitors participate. Annual visitation is calculated based on "user-days," which is defined as park use by one visitor for one day. For example, a family of four camping for two nights would count as eight user days. The value of one user-day depends on the primary recreational activities that visitors engage in during their time at the reservoirs.

As a first step to this assessment, we reviewed entry fee revenue data provided by Park staff for boating, camping, day use vehicle permits, and annual passes from July 2022 to June 2023 (FY2023) to better understand overall visitation patterns. At both reservoirs, all vehicles must purchase either a day use or per-night camping permit or use their annual pass to enter the parks. Visitors that intend to boat must purchase a boating permit in addition to a camping or day use pass. Passes are sold per vehicle, not per user. For the purposes of this report, a vehicle entry indicates one vehicle for one day. Because vehicles typically carry multiple people, we estimated the average persons per vehicle to calculate total user-days.

To estimate average persons per vehicle, we relied on a 2003 study by USACE that estimated average party size for different recreational activities.[8] This study was based on survey data from Lake Sonoma in Northern California, along with other USACE-operated lakes across the U.S. The average party size for visitors participating in both camping and boating was 3.5; for all other non-boating activities, the average party size was 2.8. Annual pass holder daily entry data from Lake Nacimiento Resort informed an average user day estimate for visitors with annual passes. We applied these estimates to the FY 2023 vehicle pass revenue data to generate approximate FY 2023 visitation estimates, as shown in Table 18.

Table 18. Visitation estimates for recreational users, by activity type, FY2023

Reservoir	Activity	User day estimates	% of total participation
Nacimiento Reservoir	Day use (no boat)	135,290	28%
	Camping (no boat)	195,357	40%
	Day use + boat	57,020	12%
	Camping + boat	102,920	21%
	Total boating	159,940	33%
	Total Visitors – Nacimiento	**490,586**	
San Antonio Reservoir	Day use (no boat)	27,017	61%
	Camping (no boat)	14,100	32%
	Day use + boat	2,035	5%
	Camping + boat	1,370	3%
	Total boating	3,405	8%
	Total Visitors – San Antonio	**44,522**	
Total visitors (both lakes)		**535,108**	

Nacimiento supported significantly higher recreational visits in FY2023, making up 92% of total visits at the reservoirs. This difference can be attributed in large part to the more developed nature of Nacimiento, as well as the decline in visitation that San Antonio has struggled with since the 2014 drought. The closure of lodgings, the marina, and a general store, along with persistent toxic algal blooms, continue to impact visitation to this day.

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[8] Chang, W., D. B. Propst, D. J. Stynes, and R. S. Jackson. 2003. *Recreation Visitor Spending Profiles and Economic Benefit to Corps of Engineers Projects*. US Army Corps of Engineers: Recreation Management Support Program. ERDC/EL TR-03-21. One party was assumed to equal one vehicle for the purposes of this report.

Unfortunately, there is no comprehensive dataset that provides reservoir visitation by activity type over the analysis period. To estimate historical visitation, we applied a variety of methods, first using annual entry fee revenues to estimate the number of vehicles entering each park, and then converting vehicle counts to annual visitation numbers. We relied on input from park staff and other available resources to estimate participation in various activities at each reservoir.

We collected data from multiple sources for different years, as available:

- Revenue data for Nacimiento from 2010-2023, and for San Antonio for 2010-2020, and 2023, provided by Monterey Parks Department
- Revenue estimates for 1985 to 1993 for both reservoirs combined, from the SVWP Draft Environmental Impact Record (DEIR, 2001)[9]
- "Visitation units" for 1985 to 1994 for each reservoir from the SVWP Draft Economic Impact Report (DEIR, 2001)[10]
- Water elevation on July 1 for both lakes from 1967 to 2023, provided by MCWRA
- Nacimiento vehicle entries for 1994 to 2001, Nacimiento Water Supply Project Report on Recreational Use (NWSPR, 2002)
- 2006 visitor estimates for both lakes from the San Antonio and Nacimiento Rivers Watershed Management Plan (WMP, 2008)

As noted previously, revenue or visitation data are not available for either of the lakes prior to 1985; thus, the benefits analysis is limited to this period. Given available data, our first step was to project annual park entry fee revenues for each year from 1985 to 2018. Revenues at the parks mirror water levels in the reservoirs: when water levels decline, revenues (and visitors) also decline.[11] Water level data for both reservoirs are available for every year of the analysis period. Given that revenues and water levels are the most complete datasets obtained for this analysis, and that they are intricately tied, we developed regression equations to estimate revenues for years with missing revenue data.

Specifically, we applied three simple regression equations (one for Nacimiento and two for San Antonio) using data from years for which both entry fee revenues and water level data were available (applying updated 2022 USD revenue values for consistency). Because of the dramatic changes in revenues and activities at San Antonio associated with the drought, we divided the regression analysis for this reservoir into pre- and post-2014 drought. See Appendix X for additional detail on this estimation.

Next, we converted entry fee revenues to vehicle counts. For Nacimiento, the NWSPR provides vehicle entry estimates from 1994 through 2001. Additionally, the WMP provides visitation estimates for both

[9] The SVWP DEIR (2001) reports combined revenues for 1985-1994 for recreation activities at both reservoirs. To differentiate between the reservoirs, we applied the ratio of 'visitation units' from each park to the reported combined revenue to arrive at each reservoirs revenues.

[10] The SVWP DEIR records the number of visitation units sold and associated revenues for Nacimiento and San Antonio reservoirs. A unit is defined as either 1 overnight camping fee, 1 day use fee for either a vehicle or a boat, 1 yearly boat permit, or a set dollar amount of concession intakes. For the year 1994, we have both visitation estimates for Nacimiento from the NWSPR as well as unit estimates from the DEIR, allowing for an estimated conversion from units to visitation. This conversion factor is approximately 5.3 visits per recorded unit. This conversion was applied to the units to arrive at approximate visitation.

[11] Information gathered from interview with Parks official Nathan Merkle, October 2023.

lakes for 2006. Revenue to vehicle conversions were therefore only necessary from 2002 through 2005, and for 2007 to 2018 at Nacimiento and 1995 to 2018 (except 2006) for San Antonio. This was done using an average ratio of vehicle entries to revenues.

For Nacimiento, the average ratio of revenues to vehicle entries is approximately 0.22, meaning that every $100 in revenues represented 22 vehicles. This ratio was multiplied by revenues to arrive at an estimated count of vehicle entries. For San Antonio, the average ratio from pre-drought years (1995-2013) was 0.27; for post-drought years, the ratio of vehicle entries was 0.3, which was applied to years 2014 through 2018. This lower ratio likely indicates higher costs of vehicle entry.

Figure 7 shows estimates of revenues over time at both reservoirs in 2023 USD; this includes revenue data provided by various sources, as described above. The precipitous declines in revenues at San Antonio from 1989 to 1992, and starting again in 2014, coincide with periods of severe drought that caused parts of the recreation area to close. The Nacimiento revenue data from 2011 onwards were provided to Parks by the concessionaire, so spikes and drops in revenue are less well understood.

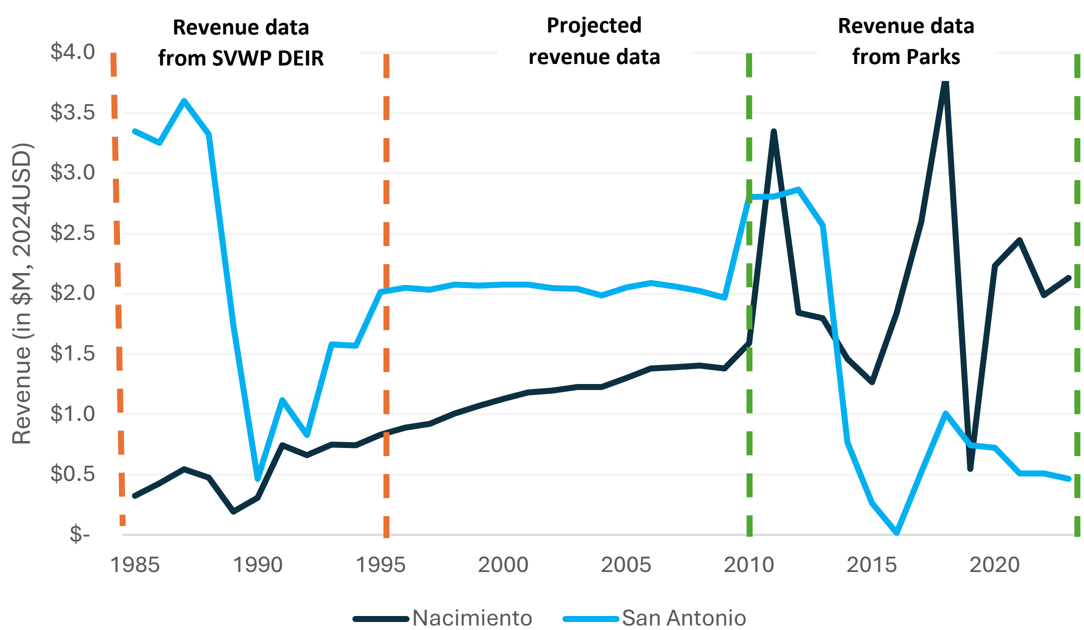

Figure 7. Revenues over time at Nacimiento and San Antonio Reservoirs, 2024 USD
Source: Revenue records from Monterey County Parks, SVWP DEIR (2001), and projections

The final step was to convert vehicle counts to user-day estimates by activity type. Here again we relied upon the USACE study (2003) to determine average visitors per vehicle. In that study, party size is differentiated based on activity. Using proportional activity estimates inferred from interviews with park staff (Tables 19 and 20), we multiplied the percentage of visitors participating in different activity categories, by the total estimated number of vehicles, and then again by the visitors per vehicle by activity type from the USACE study (2003). This yields an estimate of user-days by primary recreational activity. As discussed in the next section, this distinction in activities is important for valuing the user-days.

Table 19. Percent of activities by different types of users at Nacimiento Reservoir

Activity	Day Use Vehicles (28%)^	Day Use Boating (12%)	Camping & Boating (21%)	Camping (No Boating) (40%)
Fishing	10%	20%	10%	10%
Boating & swimming		30%	40%	
Shoreline swimming & picnicking	70%			60%
Paddleboarding & kayaking	10%			
Hiking & wildlife viewing	10%			
Boating water sports*		50%	50%	20%
Just camping				10%

^Percentages in the top row reflect proportion of total visitation

*Sports include water skiing, wake surfing, and wakeboarding

Table 20. Percent of activities by different types of users at San Antonio Reservoir

Activity	Day Use Vehicles (41%)^	Day Use Boating (15%)	Camping & Boating (13%)	Camping (No Boating) (32%)
Fishing	50%	55%	55%	35%
Boating & swimming	40%	20%	30%	
Shoreline swimming & picnicking				30%
Paddleboarding & kayaking				
Hiking & wildlife viewing	10%			
Boating water sports*		25%	15%	
Just camping				35%

^Percentages in the top row reflect proportion of total visitation

*Sports include water skiing, wake surfing, and wakeboarding

Adjustments to the tables above were made to estimate user-days by activity at San Antonio Reservoir after the 2014 drought based on communication with Parks officials. Prior to the drought, most visitors went to San Antonio for striped bass fishing. After the drought, declines in fish populations and water quality issues resulted in significantly fewer boaters visiting the lake. We therefore decreased the proportion of fishing visits to San Antonio across all permit categories (e.g., day use vehicles, day use boating, etc.) so that they accounted for less than half of all visitor activities.

5.2.2 Day use values

To estimate the economic benefits of recreational opportunities at San Antonio and Nacimiento, each visitor-day was valued using USACE UDVs for Recreation (FY 2023). The UDV method includes five criteria by which to judge the quality and value of recreational experiences, as summarized in Table 21. Each criterion is evaluated based on characteristics of the recreational site and assigned a point value according to local expert opinion. The point values are then summed and converted to dollar values (see Table 22), which are updated annually by USACE based on the category of recreation day.

At these two reservoirs, there are two categories of relevant recreation days according to the UDV method: *general recreation* and *general fishing recreation*. The general recreation and general fishing recreation categories both involve activities that are accessible and attractive to outdoor recreational users broadly. General recreation includes boating, water sports, kayaking and paddleboarding, swimming, hiking, camping, wildlife observing, and equestrian activities. General fishing recreation additionally includes fishing from the shore and from boats.

Table 21. USACE Unit Day Value Ranking, adapted from USACE (2023)

Criteria	Judgement factor	Total possible points
Recreation Experience	Count of general (camping, hiking, riding, cycling, fishing, boating) and high quality (uncommon activities) activities: minimum to numerous	30
Availability of opportunity	Count of the alternative options that are readily available: several within a short travel time to none within a 2-hour travel time	18
Carrying capacity	Quality and capacity of facilities and their impact on the natural resources: minimum facility for development to ultimate facilities	14
Accessibility	Ranking of quality of site and facility access: limited access to high standard good access	18
Environmental Quality	Rating of aesthetic quality and factors that could limit aesthetics: low to outstanding aesthetic qualities	20
Total possible points		100

Nacimiento Reservoir

Based on input from park staff, the project team assigned general recreation a point value of 63 out of 100 for Nacimiento Reservoir. This value considers the variety of available activities at Nacimiento, such as fishing, swimming, kayaking and paddleboarding, boating and water sports, and camping. Nacimiento scored highly based on the limited availability of other water sport amenities within an hour drive, and the adequate facility amenities such as a general store, lodging, and a marina for renting boats and other equipment. Scoring also reflects good accessibility to the site, and reasonable access to the lake, as well as aesthetic environmental qualities of the area. Nacimiento's carrying capacity was rated below average due to crowding during peak season, and the environmental quality category was impacted by the homes and private facilities visible from the lake. We also assigned general fishing recreation a point value of 63 out of 100 for many of the same reasons. This scoring yields a unit day value (or direct use value) of $12.00 for general recreation and $13.13 for general fishing.

Table 22. USACE use values by point value and recreation category (FY2024)

Point values	General recreation values ($)	General fishing and hunting values ($)
0	$5.05	$7.26
10	$6.00	$8.21
20	$6.63	$8.84
30	$7.58	$9.79
40	$9.47	$10.73
50	$10.73	$11.68
60	$11.86	$12.94
70	$12.31	$13.57
80	$13.57	$14.52
90	$14.52	$14.84
100	$15.15	$15.15

San Antonio Reservoir

San Antonio Reservoir day use values for the recreational amenities prior to 2014 drought were evaluated separately from the period from 2014 through 2018. For pre-drought points, San Antonio scored 64 out of 100. This score reflects the high-quality boating and fishing that attracted much higher visitation, as well as the variety of other available activities at San Antonio Reservoir, such as fishing, swimming, kayaking and paddleboarding, equestrian facilities, and camping equestrian trails. San Antonio Reservoir scored highly based on the limited availability of other shoreline camping opportunities nearby and the marina and lodging amenities that were open prior to 2014. This scoring yields a unit day value (or direct use value) of $12.04 for general recreation and $13.19 for general fishing.

As described previously, the recreational experience and available amenities declined after the drought in 2014. For this period, general recreation and general fishing were assigned a point value of 51 out of 100 for recreation unit day values at San Antonio. Scoring reflects the limited carrying capacity due to the marina and lodging closing after the drought. The aesthetic value declined post drought given the annual toxic algal blooms that impact recreational opportunities every summer since 2014. This scoring yields a unit day value of $10.35 for general recreation and $11.44 for general fishing per visit.

5.3 Value of recreational benefits

To value the benefits of recreation, we applied the unit day values summarized above to the visitation estimates described in Section 5.1. The unit day value ratings are broken out by general recreation and general fishing, so it was necessary to estimate the number of visitors in each category (day use, camping and boating) whose main recreational activity during their trip to the lake included fishing. Here we applied the activity estimates provided by Parks officials based on recent visitation. Figure 8 shows the breakout of general recreation and general fishing across both reservoirs.

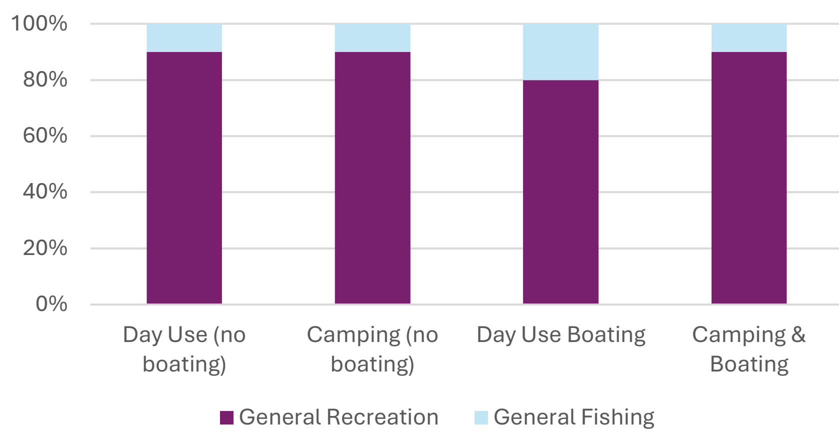

Figure 8(a). Visitation for recreation and fishing at Nacimiento Reservoir, 1985 - 2018

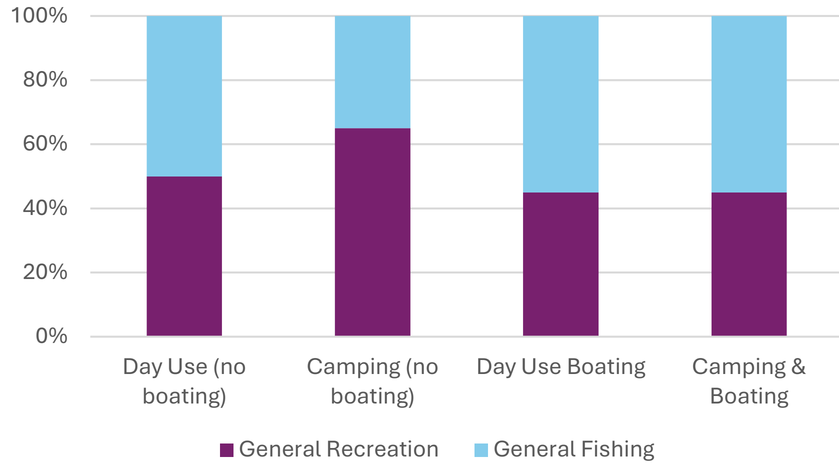

Figure 8(b). Visitation for recreation and fishing at San Antonio Reservoir, 1985-2013

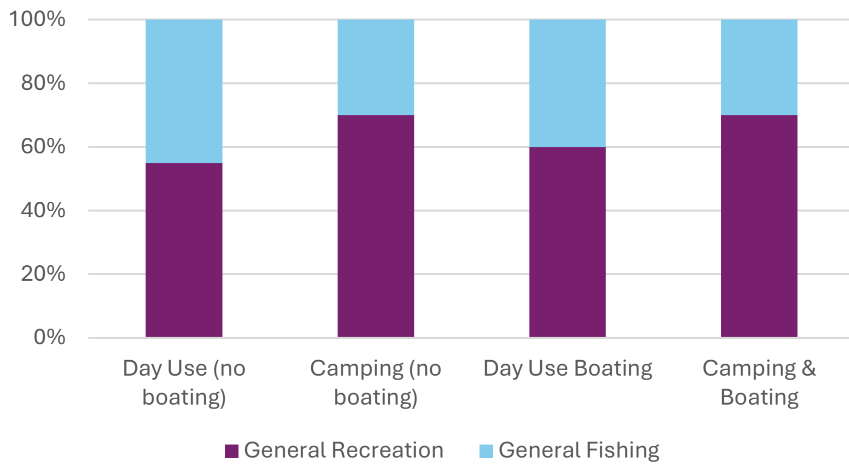

Figure 8(c). Visitation for recreation and fishing at San Antonio Reservoir, 2014-2018

Despite the loss of striped bass after the 2014 drought, fishing remains a primary draw for visitors at San Antonio Reservoir. Only 10% to 20% of visitors at Nacimiento participate in fishing, while 30% to 40% of visitors at San Antonio Reservoir are primarily there to fish. Unit day values for general fishing are higher at both lakes than those for general recreation. Despite lower unit day values generally for San Antonio compared with Nacimiento, the higher fishing values at San Antonio combined with the higher proportion of visitors participating in recreation make this a valuable recreational asset.

From 1985 to 2018, we estimate that the two reservoirs combined hosted over 64 million visitor days (Table 23). Most visitor-days at San Antonio occurred prior to the drought, when the reservoir hosted a significantly greater number of recreators who were attracted to the park's high-quality fishing, camping, and lodging amenities. In total, the reservoirs generated $797,450,000 in estimated recreational benefits for users during the period 1985-2018, an average annual benefit of more than $24 million.

Table 23. Total Recreational Benefits of Nacimiento and San Antonio Reservoirs, 1985-2018 (2024USD)

Reservoir	Category	Unit Day Value (per visit)	Total Visitor Days	Total Value
Nacimiento	General Recreation	$12.00	16.4M	$196.3
	General Fishing	$13.13	2.1M	$27.0
	Nacimiento Total		**18.4M**	**$223.2**
San Antonio 1985-2013	General Recreation	$12.04	24.3M	$292.0
	General Fishing	$13.19	21.2M	$279.5
	LSA Pre-Drought Total		**45.5M**	**$571.5**
San Antonio 2014-2018	General Recreation	$10.44	149,500	$1.6
	General Fishing	$11.38	97,800	$1.1
	LSA Post-Drought Total		**247,300**	**$2.7**
Total			**64.1M**	**$797.4**

6. Hydro-electric generation

Nacimiento Dam has a 4-megawatt (MWh) hydroelectric power plant that was built in 1987 on the dam's south side. The hydropower generated at Nacimiento is renewable energy that is valuable for its ability to avoid energy generated from other sources, including sources that generate more emissions. This section quantifies the value associated with hydropower generated at Nacimiento and monetizes the value of the related reduction in emissions.

6.1.1 Power generation

Based on data provided by MCWRA, Nacimiento's two-unit hydroelectric power plant generated an average of 9,833 MWh per year from 1987 to 2022. This includes two years of zero power generation from both generating units in 1989 and 1990, and a total of four other years of zero power generation from Unit 1, from 2014 through 2016 and in 2022. Maximum annual power generated from both units combined at Nacimiento was 20,052 MWh in 2005.

To value the hydropower generated, we used the cost of energy to the relevant power customers in California for each year of the analysis period.[12] From 2014 to 2022, power generated at the Nacimiento dam was sold to the Bay Area Rapid Transit (BART) system. To evaluate the cost of alternative power sources during this time, we applied the price of power sold to the transportation sector in California. For the years 1987 through 2013, power generated at Nacimiento Dam was sold to PG&E and distributed through the grid to all sectors. To value power from Nacimiento in these years, we used the average price of power sold in California in each year to all user sectors (residential, commercial, industrial, and transportation), weighted by the amount of power consumed by each sector in each year. Prices from each year were inflated to 2024 dollars using the Consumer Price Index (CPI) for energy expenditures.

Based on these assumptions, the total value of power generated at Nacimiento from 1987 to 2018 was $59.1 million. This represents the value of power generated, rather than an avoided cost (i.e., BART and PG&E would have purchased power from elsewhere if not from MCWRA).

6.1.2 Avoided power generation emissions

The hydropower generated at Nacimiento is also valuable for the air quality emissions it avoids. Avoiding power generation supplied through the electric power grid means avoiding emissions from the mix of fuels used at California power plants (and any imported power) over time. The mix of energy generation fuel sources has changed over time, as baseload power generation has shifted away from coal to natural gas and some renewables. The value of avoided emissions from non-renewable energy sources can be calculated based on the avoided health care costs associated with pollution from those emissions.

To estimate the benefit of reduced air pollutants, the project team used annual air quality emission rates (pound of pollutants per MWh of energy produced in California), available from the U.S. EPA's EGRID database (Emissions & Generation Resource Integrated Database) and EPA's AVERT (Avoided Emissions and geneRation Tool) model.[xii] Emissions reported in EGRID and AVERT include nitrogen oxides (NO_x), sulfur dioxide (SO_2), particulate matter 2.5 ($PM_{2.5}$) and carbon dioxide (CO_2). California emissions rates are

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[12] Data on historical energy prices by use sector came from the Energy Information Administration, Form HS861. Energy Information Administration. 2023. Annual Electric Power Industry Report, Form EIA-861 detailed data files. https://www.eia.gov/electricity/data/eia861/ Accessed: November 6, 2023

reported in EGRID from 1996 to 2021 and in AVERT from 2007 to 2018. EGRID data are not collected every year; to accommodate these data gaps, we applied a year's value in every subsequent year until a new value was available. An average of five years of emission rates from 1996 to 2000 was applied every year from 1987 to 1995 for which emission rate estimates were not available. In addition, PM2.5 is the only pollutant for which emission rates are only available in AVERT. To estimate emission rates prior to 2007, we based on the correlation between other emission rates (NO_x) over the analysis period.

To estimate the value of avoided emission-related pollutants (including NOx, SO2 and PM2.5), we used EPA's national benefit-per-ton estimates for reductions in $PM_{2.5}$ and $PM_{2.5}$ precursor emissions (including NOx and SO2) for the electricity generating sector (Table 24).[xiii] These values were created using the air quality valuation model BenMAP (Benefits Mapping and Analysis Program). BenMAP is a software package and database that allows users to estimate the health-related benefits of air quality improvements based on established health impact functions (HIFs). The HIFs are derived from epidemiology studies that relate pollutant concentrations to specific health endpoints (e.g., premature mortality, chronic bronchitis, heart attacks, and other illnesses). Using values from the literature, BenMAP applies estimates of willingness-to-pay to avoid specific adverse health effects and avoided health care cost estimates to calculate benefits in monetary terms.[13]

Table 24. Dollar value per ton of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors reduced from the electricity generating sector
(2024 USD, 3% discount rate[a,b])

Benefit per ton		
NO_x[c]	SO_2	Directly emitted $PM_{2.5}$
$13,262	$87,456	$311,539

Source: U.S. EPA 2018

a. Values updated to 2024 from 2015 USD, using CPI
b. Discount rate is applied because health effects associated with one-ton reduction in emissions do not occur all within the same year. This study assumes is a "cessation" lag between changes in PM exposures and the total realization of changes in health effects as follows: 30% of mortality reductions in the first year, 50% over years 2 to 5, and 20% over the years 6 to 20 after the reduction in $PM_{2.5}$.
c. Estimates for NO_x and SO_2 include a reduction in premature mortality. While these emissions are not directly linked to mortality risk, these estimates reflect the contribution of these gases to PM2.5 and ozone formation, and associated mortality risk.

To monetize the value of avoided carbon dioxide equivalent emissions, we applied the Social Cost of Carbon (SCC) to the CO_{2e} emissions avoided as a result of hydropower production. The SCC was developed by the Intergovernmental Panel on Climate Change (IPCC) Interagency Working Group (IWG) based on models that estimate the global impacts from climate change.[xiv] The SCC represents the damages caused per ton of CO_{2e} emitted, including damages related to illness, property value reductions associated with climate change, agricultural productivity, and environmental remediation related expenditures. The U.S. EPA recently updated the SCC to $146 per metric ton (2024 USD).[xv]

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[13] EPA (2018) notes that care should be taken in applying the national average estimates reported in Table 24 to emission reductions occurring in any specific location. Health outcomes and associated monetary values can range significantly based on the local population, geography, and power generation mix, among other factors. For example, the marginal cost of emitting one unit of SO_2 in a remote area may be lower than the marginal cost of the same unit of pollution emitted in a densely populated area, because emissions in populated areas generate greater health damages.

Table 25 presents the value of avoided emissions associated with the generation of more than 326,000 MWh at Nacimiento dam (over the analysis period, 1987 to 2018). As shown, hydropower generation resulted in $16.0 million in avoided health-related costs from 1987 to 2018, an average annual benefit of $500,000 (from 1987 to 2018).

Table 25. Avoided Emissions from Nacimiento Hydropower Generation, 1987 -2018

	NOx	SO2	PM2.5	CO2
Avoided Emissions (metric tons)	58	24	**6**	79,500
Value (2024$)	766,000	2,139,000	1,514,000	11,576,000

7. Summary

This report presents the economic benefits provided to stakeholders in California's Salinas River Basin from construction and operation of Nacimiento and San Antonio Reservoirs, CSIP, and SVWP (the Projects). It serves as an update to the "Salinas Valley Historical Benefits Analysis" (HBA), which was developed for MCWRA in 1998 to assess the benefits provided by Nacimiento and San Antonio Reservoirs. The HBA Update (developed by West Yost) confirms that the Projects have resulted in significant hydrologic benefits, including increased fresh groundwater storage and reduced flooding across the Salinas Valley. This in turn has resulted in the following economic benefits:

- Higher groundwater levels have reduced the need to replace groundwater wells. This has avoided more than $107.4 million in well replacement costs over the 51-year analysis period (1968 to 2018), for an average annual benefit of $2.1 million.
- Higher groundwater levels have also reduced the energy required to pump groundwater in many areas, and in combination with deliveries from the CSIP and SVWP, have reduced overall groundwater pumping for irrigation. This has saved $67.9 million in groundwater pumping costs over the analysis period, for an average annual benefit of $1.3 million per year.
- Results of the HBA Update confirm that the increase in fresh groundwater storage in Basin aquifers has decreased seawater intrusion from Monterey Bay. The HBA Update reports that seawater intrusion has been approximately 1,000 AFY lower in the Pressure Subarea than it would have been without the Projects. Assuming an average applied water rate of 2.0 AF/acre, seawater intrusion under the No Projects scenario would have affected approximately 500 acres of farmland each year, with impacts to crops ranging from $21.7 to $86.9 M. This benefit has largely accrued to growers beginning in 1998, coinciding with deliveries of recycled water from CSIP.
- The reservoirs substantially reduced flooding along the Salinas River floodplain and the land and structures found there. This has resulted in avoided damages to buildings totaling $210.5 million over study period, $4.1 million per year on average. The value of avoided flood damages to agricultural crops is estimated to be $211.0 million over the 51-year analysis, or $4.1 per year, on average.

In addition to hydrologic and flood risk reduction benefits, the reservoirs have generated close to $800 million in recreational benefits between 1985 and 2018, an average annual benefit of more than $24 million. Between 1987 and 2018, Nacimiento dam generated 326 MWh of power, for a total value of $59.1 million. The generation of clean hydropower resulted in $16.0 million in avoided health-related costs from 1987 to 2018, an average annual benefit of $500,000.

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Monterey County Water Resources Agency

DRAFT

Interlake Tunnel and San Antonio Spillway Modification Assessment Engineers Report

May 29, 2025

BARTLE WELLS ASSOCIATES
INDEPENDENT PUBLIC FINANCE ADVISORS

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Executive Summary

This report serves as the detailed engineer's report required by Section 4(b) of Article XIIID of the California Constitution, Proposition 218, to support the assessments proposed to be levied within the benefit assessment area being established in the County of Monterey, California. This assessment would, if approved and passed, fund Monterey County Water Resources Agency (MCWRA) with the capital costs of the Interlake Tunnel and San Antonio Dam Spillway Modification Project (Project). The discussion and analysis contained within this report constitutes the required nexus of rationale between assessment amounts levied and benefits derived by real properties within the proposed Zone 2E Assessment District.

The proposed assessment is set to recover MCWRA's total Project costs for the construction of the Interlake Tunnel and San Antonio Dam Spillway Modifications needed to:

- Minimize flood control releases through the Nacimiento Dam Spillway and reduce associated downstream flood damage.
- Increase the overall surface water supply available from Nacimiento and San Antonio Reservoirs by maximizing the opportunity for water to be collectively stored in the reservoirs.
- Improve the hydrologic balance of the Salinas Valley Groundwater Basin (Basin) and reduce seawater intrusion.
- Continue to meet downstream environmental flow requirements for south-central California coast steelhead.
- Minimize the impact on existing hydroelectric production.
- Protect agricultural viability and prime agricultural land.

Assessment law does not specify the method or formula that should be used to apportion assessments. Since this Project is still in a preliminary phase, this report provides three options for allocating Project benefits.

This report relies on data provided by the 2003 RMC Engineer's Report, the 2024 West Yost Historical Benefits Analysis Update, and other data provided by MCWRA staff related to this Project.

This Engineer's Report includes the following Parts:

Part I - Project Description: A background of the Nacimiento and San Antonio Reservoirs and Dams, and a general description of the proposed Project and its components.

Part II - Estimate of Costs: An estimate of the costs of the proposed Project including a breakdown of costs for the Interlake Tunnel and the modifications to the spillway.

Part III - Assessment Zone Boundary: A description of the proposed assessment zone boundary.

Part IV - Assessment Methodology: A description of the assessment methodology used to develop the assessment roll for the Proposition 218 Special Assessment election.

Part V - Assessment Roll: The proposed assessment is based on a portion of the costs and expenses of the proposed improvements in proportion to the estimated special benefits to be received by properties within the Assessment District from said improvements. The Assessment Roll also includes the Assessor's Parcel Number corresponding to each property within the Assessment District as recorded in the County of Monterey Assessor's Office.

Pursuant to the provisions of law and the Resolution of Intention, the costs and expenses of the Zone 2E Assessment District have been assessed upon each of the parcels of land benefitted in direct proportion and relation to the estimated special benefits to be received by each of the parcels.

Part VI - Maximum Annual Administration Assessment: A proposed maximum annual administration assessment upon each parcel to pay costs incurred by the Agency resulting from the administration and collection of assessments and/or administration and registration of bonds and other funds, if required.

1 PROJECT SUMMARY

The proposed Project includes the construction of a water conveyance tunnel approximately 2 miles long connecting the Nacimiento Reservoir to the San Antonio Reservoir (Interlake Tunnel) and modifications to the existing spillway at the San Antonio Reservoir (Spillway Modification) to enhance water supply and flood control capabilities. The Project has been under consideration since the late 1970s and was included in MCWRA's July 1991 Water Facilities Capital Plan, as an approach to better manage flood and conservation flows in the Salinas River watershed. More recently, the proposed Project was included in the 2013 Greater Monterey County Integrated Regional Water Management Plan and in May 2014, a group of Salinas Valley growers revitalized the urgency water storage projects due to the ongoing multi-year drought. Additional details on the history of the Project and its description are provided below.

1.1 BACKGROUND

MCWRA is responsible for managing, protecting, and enhancing water supply and quality as well as providing flood protection in the County of Monterey. The Agency was formed under Chapter 699 of the Statutes of 1947 as the Monterey County Flood Control and Water Conservation District. In 1990, MCWRA had its mandate updated: to provide for the control of flood and storm waters, conservation of such waters through storage and percolation, control of groundwater extraction, protection of water quality, reclamation of water, exchange of water, and the construction and operation of hydroelectric power facilities.

Construction of the Nacimiento Dam was completed in 1957 and the San Antonio Dam was completed in 1967. Both dams, and the associated reservoirs, were constructed and are owned by MCWRA and serve as flood control, water conservation, and recreation facilities.

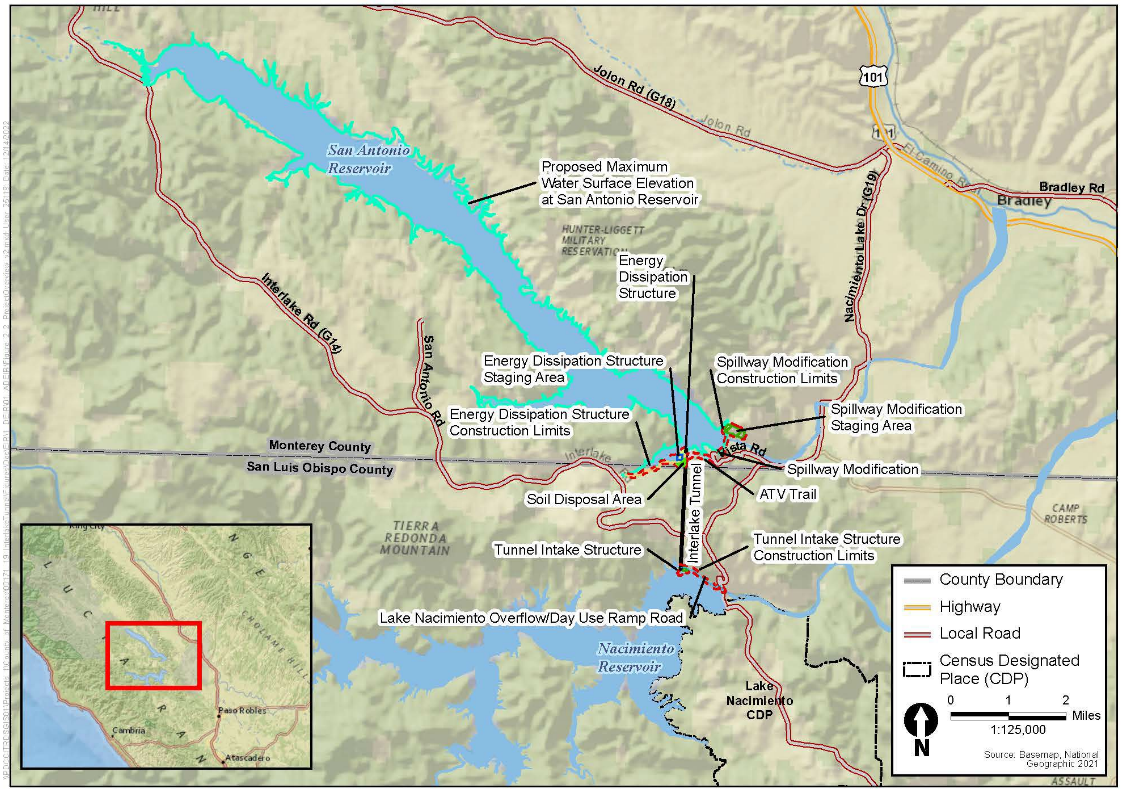
1.2 PROJECT DESCRIPTION

The Nacimiento Reservoir fills approximately three times faster than the San Antonio Reservoir, resulting in the possibility of unused storage in the San Antonio Reservoir when the Nacimiento Reservoir is at capacity and releasing flood spills.

The San Antonio Dam Spillway Modification (Spillway Modification) would include removal and replacement of the existing ogee spillway crest control hydraulic structure with a new labyrinth weir structure. The Spillway Modification would provide an up to 7-foot increase in the reservoir's maximum water surface elevation (WSE), effectively increasing San Antonio Reservoir's storage capacity by up to approximately 41,000 acre-feet without raising the height of the dam itself.

Construction of the Interlake Tunnel connection would provide the conveyance means to transfer water from the Nacimiento Reservoir to the San Antonio Reservoir before it is spilled in a flood release. Additionally, water could be transferred from the Nacimiento Reservoir at appropriate times to maximize the net storage of the combined reservoirs. The Interlake Tunnel would be approximately 11,000 feet (2.06 miles) long and have a minimum inner diameter of 10 feet. Figure 1 shows an overview of the proposed Interlake Tunnel and associated components.

Figure 1: Interlake Tunnel



2 ESTIMATE OF COSTS

MCWRA estimated the Project cost to be $264,580,290 in 2023. The cost breakdown is inclusive of Project development, construction, spillway modification, administrative costs, capitalized O&M costs, capital equipment replacements, financing fees, contingency, and escalation. Using the ENR CCI from December 2023, the Project cost was escalated to 2024 dollars, bringing the total Project cost $271,402,731 in 2024.

The Project assumes 50% grant funding and annual payments reflecting a 30 -year bond with 5% interest for the remaining portion of costs. Table 1 below provides a cost breakdown for each cost component and the annual payment from financing.

Table 1: Total Project Cost with Inflation

Project Cost	2023 Dollars	2024 Dollars[1]
Project Development	$15,064,920	$15,453,383
Construction	160,637,490	164,779,672
Spillway Modification	8,757,450	8,983,269
Management & Administration	21,174,660	21,720,668
Capitalized O&M Costs	23,381,280	23,984,187
Capital Equipment Replacement Fund	6,767,280	6,941,780
Financing Fees	3,388,320	3,475,691
Contingency & Escalation	$25,408,890	$26,064,081
TOTAL	**$264,580,290**	**$271,402,731**
Grant	50%	**$135,701,365**
Debt Funded Amount		$135,701,365
Annual Payment[2]		**$8,827,569**

[1] Escalated to 2024 dollars using ENR CCI 20 Cities, December 2023.

[2] Annual payment reflects financing of 5% interest over 30 years.

3 ASSESSMENT OF ZONE BOUNDARY

The following section provides a description of the assessment zone boundaries, and the potential subareas boundaries, for the proposed Zone 2E Assessment District.

3.1 ZONE 2E ASSESSMENT BOUNDARY

The proposed assessment zone boundary is equivalent to the existing MCWRA assessment Zone 2C boundary.

There are seven distinct subareas within Zone 2E (Figure 2). Six subareas receive benefits from MCWRA Dam Operations; the Above Dam subarea is not included here. These subareas are:

- East Side
- Pressure
- Forebay
- Arroyo Seco
- Upper Valley
- Below Dam

Historical work has shown that each of the subareas identified within the Salinas Valley Groundwater Basin are hydraulically connected, but due to their varying geology and geography they receive varying levels of benefits from the operation of the two Reservoirs. Portions of the upper Arroyo Seco Cone area have been described has predominantly receiving recharge from the Arroyo Seco River.

Figure 2: Map of Zone 2C

4 ASSESSMENT METHODOLOGY

The following section provides an overview of current assessment law and the assessment methodology for the proposed Assessment developed for the Zone 2E Assessment District.

4.1 ASSESSMENT LAW

Projects typically confer a combination of both general and special benefits to properties. Under California law, the only Project costs that can be assessed to properties are those that provide a special benefit to the assessed properties. This means that no assessment may exceed the proportional special benefit conferred on the assessed parcel; and that publicly owned parcels shall not be exempt from the assessment unless clear and convincing evidence demonstrates that such publicly owned parcels receive no special benefits from the improvements for which the assessments are imposed.

General enhancement of property does not constitute special benefit. It is therefore necessary to identify the special benefits that the works of improvement will render to the properties within an assessment district. It is also necessary that the properties receive a special and direct benefit as distinguished from benefit to the general public.

MCWRA's mission is to manage water resources sustainably while minimizing impacts from flooding for present and future generations. The Project will allow MCWRA to operate the Reservoirs at maximum possible capacity, for the primary purpose of providing sustainable water supply and flood protection to parcels within the Zone 2E Assessment District. The MCWRA Board of Supervisors may take final action and establish the Zone 2E Assessment District once all Proposition 218 requirements have been met. Proposition 218 Requirements are listed in the following section.

Assessment law does not specify the method or formula that should be used to apportion assessments.

4.1.1 Proposition 218 Requirements

In November 1996, the California voters approved Proposition 218, the "Right to Vote on Taxes Act", Articles XIII C and XIII D to the California Constitution. Proposition 218 imposes requirements for the levying of assessments. Before a public agency can levy a new or increased assessment, the following requirements must be met:

1) Preparation of a detailed engineer's report by a registered engineer certified by the State of California that calculates the proposed assessment for each parcel.

2) The record owner of each parcel must be given written notice by mail of the proposed assessment, the total amount chargeable to the entire District, the amount chargeable to the

owner's particular parcel, the duration of the payments, the reason for the assessment as a special benefit, and the basis upon which the amount of the proposed assessment was calculated.

3) Notice to the record owner must include the time, date, and location of the public hearing on the assessment. Each notice must also include a summary of the procedures applicable to the completion, return, and tabulation of the ballots, and a disclosure statement that a majority protest will result in the assessment not being imposed.

4) Each notice mailed to parcel owners must contain a ballot including the agency's address for receipt of the completed ballot by any owner receiving the notice. The ballot form must include the owner's name, reasonable identification of the parcel, the amount of proposed assessment, and his or her support or opposition to the proposed assessment.

5) A public hearing to consider protests and tabulate the ballots must be conducted not less than 45 days after mailing the notice to landowners.

6) The agency shall not impose an assessment if there is a majority protest. A majority protest exists if the ballots submitted in opposition to the assessment exceed the ballots submitted in favor of the assessment. In tabulating the ballots, the ballots must be weighted according to the proportional financial obligation of the affected property.

7) The assessment may include an annual adjustment tied to a cost inflator such as the Consumer Price Index (CPI).

The proposed assessment calculated in this engineer's report was developed pursuant to Article XIII D of the California Constitution.

4.2 PROJECT BENEFITS

The proposed assessment examined the benefits resulting from the proposed Project. These benefits are primarily the enhancement of 1.) the water supply and 2.) flood protection within the study area Zone 2E Assessment District. These benefits were found to be a direct result of the Project and would not materialize without construction of the Interlake Tunnel and San Antonio Spillway Modification Project. General benefits identified are not included in the proposed assessments because they are not special benefits to property owners in the Zone 2E Assessment District.

4.2.1 Water Supply Benefits

The Interlake Tunnel and San Antonio Spillway Modification Project increases the reliability and potential amount of water supply. Improved water supply conditions among the reservoirs also allows for heightened water conservation storage. Without Project enhancements, water unable to be stored in the reservoirs, percolate into underlying aquifers, be rediverted at the Salinas River Diversion Facility, or be directly used would otherwise be lost to the Monterey Bay. With the reservoir enhancements in place, additional water supply collected during the wet weather season may be made available for release during the subsequent seasons. The stored water may also be released to increase groundwater recharge in the Salinas Valley. Increase in groundwater recharge would likely result in additional benefits, including increased water supply levels, reduction of seawater intrusion, improved general groundwater quality, drought protection, preservation of aquifer storage, and timing and location of recharge in relation to the timing and location of groundwater pumping.

The Project also provides the benefit of reducing or slowing the advancement of seawater intrusion. Seawater intrusion is considered an extreme event as it can threaten health, crops, and other ecosystems reliant on sources of fresh water supply. Seawater intrusion is the process by which saltwater moves into freshwater aquifers, contaminating groundwater, and potentially making it unstable for drinking and other purposes and is associated with groundwater overdraft and lower water supply levels. The increased water storage resulting from the Interlake Tunnel and the modification of the spillway enhances protection against the likelihood of this event.

4.2.2 Flood Control Benefits

Flood protection is another benefit resulting from the construction and operation of the Project. Increased flood protection is achieved through increased storage of river flows to reduce the peak flows downstream of the reservoirs. The reduction in flows results in decreased frequency and magnitude of flooding events, resulting in fewer inundated acres. Analysis has been performed to quantify the level of flood protection benefit received due to the Project.

4.2.3 General Benefits

The proposed Project also provides additional benefits to the public at large. Both the Nacimiento and San Antonio Reservoirs have provided recreational opportunities to the area since the reservoirs began operation. These recreation and tourism activities provide certain economic benefits to the area. Such activities may increase as a result of the Project.

The Project may also, through the enhancements to water supply sustainability and flood control, impact stream flows throughout the area which support fish and wildlife habitats. Studies are ongoing on how to operate the reservoirs to maximize benefits for fish and wildlife in the area.

These economic and environmental benefits will not provide the study area with additional water supply sustainability or flood control and are therefore considered general benefits and not included as part of the proposed assessments presented in this report. MCWRA intends to evaluate and quantify economic benefits in further detail in an Economics Benefits Analysis.

4.2.4 Benefit Allocation

The are numerous reasonable ways to allocate the benefits of the Project between the three benefit categories identified above. Ultimately, deciding the manner and measure for allocating the benefits will involve a qualitative analysis. The weighting factors identified by the Cost Allocation Committee (CAC) formed by MCWRA for the Zone 2C assessment in 2003 to support the existing infrastructure are one reflection of the portion of benefits because they reflect the importance of each benefit category. As the Project enhances the functions of the existing infrastructure, the 2003 analysis provides a reasonable apportionment of the Project benefits. The Project benefit allocation applied to the Project costs is summarized in the Table below.

Table 2: Cost Allocation

Benefit	Allocation[1]	Allocated Cost
Water Supply	66.7%	$5,885,046
Flood Control	25.0%	$2,206,892
General Benefit	8.3%	$735,631
Total Annual Cost:	100.0%	**$8,827,569**

[1] Based on 2003 RMC Engineer's Report.

4.3 Active/Passive Use of Land

Project benefits were evaluated based on whether the land is actively or passively utilized. The County of Monterey is the jurisdictional agency responsible for designating land use areas within the County. Monterey County has agricultural, residential, commercial, industrial, open space, and other land use designations. These land use areas do not all receive the same benefits from the enhanced operations of the Nacimiento and San Antonio Reservoirs with the Project. For instance, an acre of irrigated agricultural land is expected to have a higher benefit from the enhanced operations of the Nacimiento and San Antonio Reservoirs with the Project than an acre of open space. This is because the irrigated agricultural land is likely to use the water supply that is recharged through flows in the Salinas River and is also likely to maintain infrastructure or crops that could be impacted if flood protection was not provided. Each land use area receives a distinct benefit from the proposed Project and requires an assessment proportional to the benefits that would be received from the Project.

Land use factors are assigned based on whether the land is actively or passively used. Active use of the land means the landowner has put the land to its potential use. The highest potential land uses are considered residential, commercial, industrial, institutional, and irrigated agricultural uses and are assigned a land use factor of 1.0. Dry farming, grazing, vacant lot, lands subject to frequent flooding, and native lands (lands receiving no charge) are lower levels of use of land, or considered more passive uses and are assigned a lower land use factor. This methodology is consistent with the existing and previously assessed methodologies. The passive/active use land factors are summarized in the following table.

Table 3: Proposed Active/Passive Land Use and Weighted Factor

Land Use		Active (A) or Passive (P)	Weighted Factor
Factor A	Irrigated Agriculture	A	1.0
Factor B	Residential (Single Family, Multi-Family)	A	1.0
	Commercial		
	Industrial		
	Institutional		
Factor C	Dry Farming	P	0.1
	Grazing		
	Vacant Lot		
Factor D	River Channels	P	0.01
	Lands with Frequent Flooding		
Factor E	Open Space	P	0.0

The "equivalent acreage" is the product of multiplying the land use factors by the total land use acreage. Calculating the equivalent acreage of each subarea is necessary to assign the assessments per equivalent acre. The table below summarizes the equivalent acreages for each subarea.

Table 4: Total Equivalent Acreages by Subarea

		Land Use Factors				
		0	0.01	0.1	1	
Subarea[1]	Total Acres	*Open Space*	*River Channels, Lands w/ Frequent Flooding*	*Dry Farming, Grazing, Vacant Lot*	*Residential, Commercial, Industrial, Institutional, Irrigated Agriculture*	Total Equivalent Acreages
East Side	16,144	6,351	550	37,486	46,858	50,612
Pressure	29,226	4,134	5,156	43,545	67,256	71,662
Forebay	46,010	430	5,024	15,171	38,375	39,942
Arroyo Seco	36,727	66	255	8,792	18,390	19,272
Upper Valley	44,222	2,053	8,578	42,162	53,889	58,191
Below Dam	21,049	865	3,395	17,918	217	2,043
Total	193,379	13,899	22,957	165,073	224,984	241,721

[1] Source: West Yost "LU by ESU Clean" Workbook.

4.4 ASSESSMENT CALCULATION METHODOLOGY

The are several reasonable approaches to allocating Project benefits between the subareas. Since this project is still in a preliminary phase, this section will explore three assessment methodologies that illustrate the range of reasonable benefit allocations. A brief summary of the three options is provided below.

- Option 1, 2003 Cost Allocation Committee (CAC) weighting: This option allocates the benefits based on the judgement of a committee of experts and stakeholders as developed for the Salinas Valley Water Project. Benefits of this approach are that it reflects qualitative benefits and extreme events, for example seawater intrusion events, which are difficult to measure and can be very costly and difficult to reverse.

- Option 2, Historical benefit weighting, as analyzed by the 2024 West Yost Historical Benefits Analysis Update Report: This option allocates benefits based on the benefits of the existing infrastructure as of 2024. This would reasonably apportion benefits because the Project is an enhancement to the existing infrastructure. This approach reflects the most recent analysis of existing reservoir benefits prepared for the MCWRA by West Yost in May 2024.

- Option 3: Even weighting: Under even weighting, the entire study area is considered a single area of benefit. This methodology reflects that the essence of the Project is to enhance water supply and flood control for the six of the seven Zone 2E subareas. This option is would utilize one proposed assessment for the entire study area and all properties will pay the same annual assessment amount by land use type.

The proposed assessments and full calculations of each of the three methodologies are provided in the following sections of this report.

4.4.1 Option 1: 2003 CAC Weighting

MCWRA previously established an assessment to fund the Salinas Valley Water Project (SVWP). The allocations in their 2003 Engineer's Report were based on the work of the Cost Allocation Committee (CAC) formed by the MCWRA Board. The goal of the CAC was to develop a basis for the assessment of benefits to fully comply with the provisions of Proposition 218. The CAC assigned weighting factors to the identified special benefits received from implementing the SVWP project. Benefit factor rankings were then assigned to each of the SVWP's project components by subarea and multiplied by the weighting factor. The benefit ratios for each subarea are derived by dividing the subarea's total benefit by the total benefit of the subarea with the minimum benefit received. The following table (Table 5), demonstrates that the Arroyo Seco subarea received the lowest benefit factor rankings and was assigned a benefit ratio of 1.0.

Table 5: Weighted Benefits and Benefit Ratio

Benefit[1]	East Side	Pressure	Forebay	Arroyo Seco	Upper Valley	Below Dam
Water Supply	19	25	10	4	9	11
Flood Control	3	15	9	3	9	9
Total	**22**	**40**	**19**	**7**	**18**	**20**
Benefit Ratio[2]	**3.1**	**5.7**	**2.7**	**1.0**	**2.6**	**2.9**

[1] Source: 2003 Engineer's Report, Table 3-6d: Operations Weighted Benefits

[2] Calculated by dividing subarea's total benefit by baseline subarea's (the subarea with the minimum benefit received) total benefit.

A cost allocation percentage for each subarea was determined by multiplying the subarea's total equivalent acreage by the subarea's benefit ratio to determine each subarea's cost share factor (see Table 6). Each cost share factor was then divided by the total cost share factor of all benefitting subareas.

Table 6: Cost Share Factors and Allocation

Subarea	Total Equivalent Acreages	Benefit Ratio	Cost Share Factor	Cost Allocation Percentage
East Side	50,612	3.1	159,065	18.68%
Pressure	71,662	5.7	409,496	48.08%
Forebay	39,942	2.7	108,414	12.73%
Arroyo Seco	19,272	1.0	19,272	2.26%
Upper Valley	58,191	2.6	149,635	17.57%
Below Dam	2,043	2.9	5,836	0.69%
Cost Share Factor			**851,717**	**100.0%**

4.4.2 Option 2: Historical Benefits Analysis Update Weighting

The benefits for water supply and flood control are based on the 2024 West Yost Historical Benefits Analysis Update Report prepared for MCWRA which models the change in water supply and flood inundation due to the construction of the infrastructure subsequent to the 2003 Engineer's Report that affects each subarea. The West Yost Report assessed the difference in the average annual groundwater budget in acre feet per year and the amount of inundated acres between the "historical" scenario (current infrastructure) and the "no projects" (no infrastructure) scenario. Since the Project enhances existing infrastructure, allocating Project benefits based on the modeled changes from the construction of existing infrastructure is an alternative and equally reasonable second option to consider as the methodology for the proposed assessments.

The measurement of inundated acres was used to reflect the benefit to the water supply because it is impacted by changes in surface flows, groundwater levels, and seawater intrusion.

In 1998 the Castroville Seawater Intrusion Project (CSIP) was completed. The change in freshwater storage by subarea as a result of this project provides a comparative estimate of how the water supply of each subarea benefits from the proposed Project. The time period of the water supply comparison in the West Yost report is from the beginning of the 1998 water year to the end of the 2018 water year, to reflect the benefit impact after the existing infrastructure was substantially completed. The HBA Update model simulations conclude in Water Year 2018 due to model calibration constraints at the time this work was completed. The resulting benefit was then allocated to each subarea by dividing the subarea's respective change in water storage by the total change in water storage in the study area.

Table 7: Water Supply Benefit Allocation – Option 2

Subarea	Change in Storage[1]	Allocation Percentage
East Side	3,000	10.7%
Pressure	9,000	32.1%
Forebay	4,000	14.3%
Arroyo Seco	1,000	3.6%
Upper Valley	10,000	35.7%
Below Dam	0	0.0%
Non-Zone	1,000	3.6%
Total	28,000	100.00%

[1] Source: "ESU_NoProjects" and "ESU_Historical" spreadsheets provided by West Yost on 7/19/2024.

As shown in Table 8, the flood control benefit is allocated to each subarea by dividing the subarea's reduction in inundated acres due to the existing infrastructure by the total reduction in inundated acres due to the existing infrastructure in the study area.

Table 8: Flood Control Benefit Allocation – Option 2

Subarea	Reduced Inundation Acres[2]	Allocation Percentage
East Side	0	0.0%
Pressure	4,340	39.0%
Forebay	1,700	15.3%
Arroyo Seco	300	2.7%
Upper Valley	4,800	43.0%
Below Dam	0	0.0%
Non-Zone	0	0.0%
Total	11,140	100.0%

[2] Source: "ESU_NoProjects" and "ESU_Historical" spreadsheets provided by West Yost on 7/19/2024.

4.4.3 Option 3: Even Weighting

Option 3 applies one assessment per equivalent acre to the entire Zone 2E Assessment District rather than by each subarea. This reflects how the purpose of the Project is to enhance the water supply and flood control in the entire Zone 2E Assessment District. Under this option, each equivalent acre in each subbasin will pay the same annual assessment amount.

4.5 ASSESSMENTS

The assessments per equivalent acre for Options 1 and 2 were derived by using the allocation percentage that was calculated in the previous sections, the equivalent acreages of each subarea, and the costs allocated to each benefit. The calculation of proposed assessments under benefit allocation methodology option 1 and option 2 is as follows:

> Assessment per Equivalent Acre by subarea = (Subarea's Allocation Percentage * Cost Allocated to Benefit) / Subarea's Equivalent Acreages

The assessment per equivalent acre for Option 3 was derived by dividing the Project cost allocated to the specified benefit by the total equivalent acreage of the whole basin.

The assessment per acre under all three options is derived by multiplying the assessment per equivalent acre by each land use factor.

The tables below show the assessment per acre by subarea for both the water supply and flood control benefit for all options.

Table 9: Option 1 - Assessment Derivation

Water Supply Assessment

Subarea	Allocation Percentage	Water Supply Assessment *$5,885,046*	Equivalent Acreages	Assessment Per Equivalent Acre	Assessment per Acre / Land Use Factor 0	0.01	0.1	1
East Side	18.68%	$1,099,327	50,612	$21.72	$0.00	$0.22	$2.17	$21.72
Pressure	48.08%	2,829,530	71,662	39.48	0.00	0.39	3.95	39.48
Forebay	12.73%	749,166	39,942	18.76	0.00	0.19	1.88	18.76
Arroyo Seco	2.26%	133,002	19,272	6.90	0.00	0.07	0.69	6.90
Upper Valley	17.57%	1,034,003	58,191	17.77	0.00	0.18	1.78	17.77
Below Dam	0.69%	40,607	2,043	19.88	0.00	0.20	1.99	19.88

Flood Control Assessment

Subarea	Allocation Percentage	Flood Control Assessment *$2,206,892*	Equivalent Acreages	Assessment Per Equivalent Acre	Assessment per Acre / Land Use Factor 0	0.01	0.1	1
East Side	18.68%	$412,247	50,612	8.15	$0.00	$0.08	$0.81	$8.15
Pressure	48.08%	1,061,074	71,662	14.81	0.00	0.15	1.48	14.81
Forebay	12.73%	280,937	39,942	7.03	0.00	0.07	0.70	7.03
Arroyo Seco	2.26%	49,876	19,272	0.00	0.00	0.00	0.00	0.00
Upper Valley	17.57%	387,751	58,191	6.66	0.00	0.07	0.67	6.66
Below Dam	0.69%	15,228	2,043	7.45	0.00	0.07	0.75	7.45

Total Assessment

Subarea	Assessment per Acre / Land Use Factor 0	0.01	0.1	1
East Side	$0.00	$0.30	$2.98	$29.87
Pressure	0.00	0.54	5.43	54.29
Forebay	0.00	0.26	2.58	25.79
Arroyo Seco	0.00	0.07	0.69	6.90
Upper Valley	0.00	0.25	2.45	24.43
Below Dam	0.00	0.27	2.74	27.33

Table 10: Option 2 - Assessment Derivation

Water Supply Assessment

Subarea	Allocation Percentage	Groundwater Assessment *$5,885,046*	Equivalent Acreages	Assessment Per Equivalent Acre	Assessment per Acre / Land Use Factor 0	0.01	0.1	1
East Side	10.70%	$629,700	50,612	$12.44	$0.00	$0.12	$1.24	$12.44
Pressure	32.10%	1,889,100	71,662	26.36	0.00	0.26	2.64	26.36
Forebay	14.30%	841,562	39,942	21.07	0.00	0.21	2.11	21.07
Arroyo Seco	3.60%	211,862	19,272	10.99	0.00	0.11	1.10	10.99
Upper Valley	35.70%	2,100,961	58,191	36.10	0.00	0.36	3.61	36.10
Below Dam	0.00%	0	2,043	0.00	0.00	0.00	0.00	0.00

Flood Control Assessment

Subarea	Allocation Percentage	Flood Control Assessment *$2,206,892*	Equivalent Acreages	Assessment Per Equivalent Acre	Assessment per Acre / Land Use Factor 0	0.01	0.1	1
East Side	0.00%	$0	50,612	$0.00	$0.00	$0.00	$0.00	$0.00
Pressure	39.00%	860,688	71,662	12.01	0.00	0.12	1.20	12.01
Forebay	15.30%	337,654	39,942	8.45	0.00	0.08	0.85	8.45
Arroyo Seco	2.70%	59,586	19,272	0.00	0.00	0.00	0.00	0.00
Upper Valley	43.00%	948,964	58,191	16.31	0.00	0.16	1.63	16.31
Below Dam	0.00%	0	2,043	0.00	0.00	0.00	0.00	0.00

Total Assessment

Subarea	Assessment per Acre / Land Use Factor 0	0.01	0.1	1
East Side	$0.00	$0.12	$1.24	$12.44
Pressure	0.00	0.38	3.84	38.37
Forebay	0.00	0.29	2.96	29.52
Arroyo Seco	0.00	0.11	1.10	10.99
Upper Valley	0.00	0.52	5.24	52.41
Below Dam	0.00	0.00	0.00	0.00

Table 11: Option 3 - Assessment Derivation

Water Supply Assessment

	Groundwater ($)	Equivalent Acreages	Assessment Per Equivalent Acre	Assessment per Acre — Land Use Factor 0	0.01	0.1	1
Whole Basin	$5,885,046	241,721	$24.35	$0.00	$0.24	$2.43	$24.35

Flood Control Assessment

	Flood Control ($)	Equivalent Acreages	Assessment Per Equivalent Acre	Assessment per Acre — Land Use Factor 0	0.01	0.1	1
Whole Basin	$2,206,892	241,721	$9.13	$0.00	$0.09	$0.91	$9.13

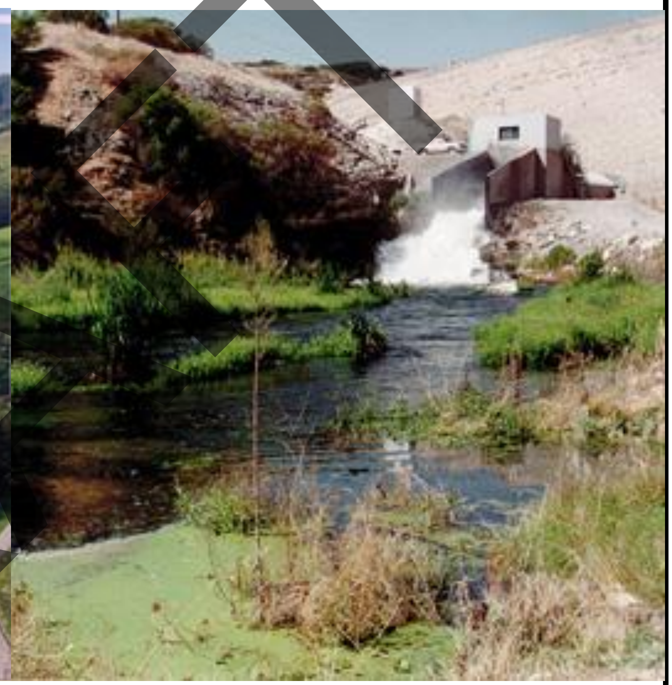
Total Assessment

Assessment per Acre — Land Use Factor 0	0.01	0.1	1
$0.00	$0.33	$3.34	$33.48

APPENDIX A: STUDY TABLES

Monterey County Water Resources Agency

Draft Engineer's Report Tables



October 21, 2024

BARTLE WELLS ASSOCIATES
INDEPENDENT PUBLIC FINANCE ADVISORS

Table 1
Monterey County Water Resources Agency
Monterey Interlake Tunnel Costs - Preliminary Estimates

Project Cost	**2023 Dollars**	**2024 Dollars[1]**
Project Development	$15,064,920	$15,453,383
Construction	160,637,490	164,779,672
Spillway Modification	8,757,450	8,983,269
Management & Administration	21,174,660	21,720,668
Capitalized O&M Costs	23,381,280	23,984,187
Capital Equipment Replacement Fund	6,767,280	6,941,780
Financing Fees	3,388,320	3,475,691
Contingency & Escalation	$25,408,890	$26,064,081
TOTAL	**$264,580,290**	**$271,402,731**
Grant	50%	**$135,701,365**
Debt Funded Amount		$135,701,365
Annual Payment[2]		**$8,827,569**

[1] Escalated to 2024 dollars using ENR CCI 20 Cities, December 2023.

[2] Annual payment reflects financing of 5% interest over 30 years.

Table 2
Monterey County Water Resources Agency
Cost Allocation

Benefit	Allocation[1]	Allocated Cost
Water Supply	66.7%	$5,885,046
Flood Control	25.0%	$2,206,892
General Benefit	8.3%	$735,631
Total Annual Cost:	100.0%	**$8,827,569**

[1] Based on 2003 RMC Engineer's Report.

Table 3
Monterey County Water Resources Agency
Total Equivalent Acreages by Subarea

		Land Use Factors				
		0	0.01	0.1	1	
Subarea[1]	**Total Acres**	*Open Space*	*River Channels, Lands w/ Frequent Flooding*	*Dry Farming, Grazing, Vacant Lot*	*Residential, Commercial, Industrial, Institutional, Irrigated Agriculture*	**Total Equivalent Acreages**
East Side	16,144	6,351	550	37,486	46,858	50,612
Pressure	29,226	4,134	5,156	43,545	67,256	71,662
Forebay	46,010	430	5,024	15,171	38,375	39,942
Arroyo Seco	36,727	66	255	8,792	18,390	19,272
Upper Valley	44,222	2,053	8,578	42,162	53,889	58,191
Below Dam	21,049	865	3,395	17,918	217	2,043
Total	193,379	13,899	22,957	165,073	224,984	241,721

[1] Source: West Yost "LU by ESU Clean" Workbook.

Table 4
Monterey County Water Resources Agency
Weighted Benefits and Benefit Ratio: Option 1, 2003 Weighting

Benefit[1]	East Side	Pressure	Forebay	Arroyo Seco	Upper Valley	Below Dam
Water Supply	19	25	10	4	9	11
Flood Control	3	15	9	3	9	9
Total	**22**	**40**	**19**	**7**	**18**	**20**
Benefit Ratio[2]	**3.1**	**5.7**	**2.7**	**1.0**	**2.6**	**2.9**

[1] Source: 2003 Engineer's Report, Table 3-6d: Operations Weighted Benefits

[2] Calculated by dividing subarea's total benefit by baseline subarea's (the subarea with the minimum benefit received) total benefit.

Table 5
Monterey County Water Resources Agency
Cost Share Factors and Allocation: Option 1, 2003 Weighting

Subarea	Total Equivalent Acreages	Benefit Ratio	Cost Share Factor	Cost Allocation Percentage
East Side	50,612	3.1	159,065	18.68%
Pressure	71,662	5.7	409,496	48.08%
Forebay	39,942	2.7	108,414	12.73%
Arroyo Seco	19,272	1.0	19,272	2.26%
Upper Valley	58,191	2.6	149,635	17.57%
Below Dam	2,043	2.9	5,836	0.69%
Cost Share Factor			**851,717**	**100.0%**

Table 6
Monterey County Water Resources Agency
Assessment Derivation: Option 1, 2003 Weighting

Water Supply Assessment

Subarea	Allocation Percentage	Water Supply Assessment *$5,885,046*	Equivalent Acreages	Assessment Per Equivalent Acre	Assessment per Acre, Land Use Factor: 0	0.01	0.1	1
East Side	18.68%	$1,099,327	50,612	$21.72	$0.00	$0.22	$2.17	$21.72
Pressure	48.08%	2,829,530	71,662	39.48	0.00	0.39	3.95	39.48
Forebay	12.73%	749,166	39,942	18.76	0.00	0.19	1.88	18.76
Arroyo Seco	2.26%	133,002	19,272	6.90	0.00	0.07	0.69	6.90
Upper Valley	17.57%	1,034,003	58,191	17.77	0.00	0.18	1.78	17.77
Below Dam	0.69%	40,607	2,043	19.88	0.00	0.20	1.99	19.88

Flood Control Assessment

Subarea	Allocation Percentage	Flood Control Assessment *$2,206,892*	Equivalent Acreages	Assessment Per Equivalent Acre	Assessment per Acre, Land Use Factor: 0	0.01	0.1	1
East Side	18.68%	$412,247	50,612	8.15	$0.00	$0.08	$0.81	$8.15
Pressure	48.08%	1,061,074	71,662	14.81	0.00	0.15	1.48	14.81
Forebay	12.73%	280,937	39,942	7.03	0.00	0.07	0.70	7.03
Arroyo Seco	2.26%	49,876	19,272	0.00	0.00	0.00	0.00	0.00
Upper Valley	17.57%	387,751	58,191	6.66	0.00	0.07	0.67	6.66
Below Dam	0.69%	15,228	2,043	7.45	0.00	0.07	0.75	7.45

Total Assessment

Subarea	Assessment per Acre, Land Use Factor: 0	0.01	0.1	1
East Side	$0.00	$0.30	$2.98	$29.87
Pressure	0.00	0.54	5.43	54.29
Forebay	0.00	0.26	2.58	25.79
Arroyo Seco	0.00	0.07	0.69	6.90
Upper Valley	0.00	0.25	2.45	24.43
Below Dam	0.00	0.27	2.74	27.33

Table 7
Monterey County Water Resources Agency
Benefit Allocation: Option 2, Historical Benefit Weighting

Water Supply Benefit Allocation

Subarea	Change in Storage[1]	Allocation Percentage
East Side	3,000	10.7%
Pressure	9,000	32.1%
Forebay	4,000	14.3%
Arroyo Seco	1,000	3.6%
Upper Valley	10,000	35.7%
Below Dam	0	0.0%
Non-Zone	1,000	3.6%
Total	28,000	100.00%

[1] Source: "ESU_NoProjects" and "ESU_Historical" spreadsheets provided by West Yost on 7/19/2024.

Flood Control Benefit Allocation

Subarea	Reduced Inundation Acres[2]	Allocation Percentage
East Side	0	0.0%
Pressure	4,340	39.0%
Forebay	1,700	15.3%
Arroyo Seco	300	2.7%
Upper Valley	4,800	43.0%
Below Dam	0	0.0%
Non-Zone	0	0.0%
Total	11,140	100.0%

[2] Source: "ESU_NoProjects" and "ESU_Historical" spreadsheets provided by West Yost on 7/19/2024.

Table 8
Monterey County Water Resources Agency
Assessment Derivation: Option 2, Historical Benefit Weighting

Water Supply Assessment

Subarea	Allocation Percentage	Groundwater Assessment *$5,885,046*	Equivalent Acreages	Assessment Per Equivalent Acre	Assessment per Acre – Land Use Factor 0	0.01	0.1	1
East Side	10.70%	$629,700	50,612	$12.44	$0.00	$0.12	$1.24	$12.44
Pressure	32.10%	1,889,100	71,662	26.36	0.00	0.26	2.64	26.36
Forebay	14.30%	841,562	39,942	21.07	0.00	0.21	2.11	21.07
Arroyo Seco	3.60%	211,862	19,272	10.99	0.00	0.11	1.10	10.99
Upper Valley	35.70%	2,100,961	58,191	36.10	0.00	0.36	3.61	36.10
Below Dam	0.00%	0	2,043	0.00	0.00	0.00	0.00	0.00

Flood Control Assessment

Subarea	Allocation Percentage	Flood Control Assessment *$2,206,892*	Equivalent Acreages	Assessment Per Equivalent Acre	Assessment per Acre – Land Use Factor 0	0.01	0.1	1
East Side	0.00%	$0	50,612	$0.00	$0.00	$0.00	$0.00	$0.00
Pressure	39.00%	860,688	71,662	12.01	0.00	0.12	1.20	12.01
Forebay	15.30%	337,654	39,942	8.45	0.00	0.08	0.85	8.45
Arroyo Seco	2.70%	59,586	19,272	0.00	0.00	0.00	0.00	0.00
Upper Valley	43.00%	948,964	58,191	16.31	0.00	0.16	1.63	16.31
Below Dam	0.00%	0	2,043	0.00	0.00	0.00	0.00	0.00

Total Assessment

Subarea	Assessment per Acre – Land Use Factor 0	0.01	0.1	1
East Side	$0.00	$0.12	$1.24	$12.44
Pressure	0.00	0.38	3.84	38.37
Forebay	0.00	0.29	2.96	29.52
Arroyo Seco	0.00	0.11	1.10	10.99
Upper Valley	0.00	0.52	5.24	52.41
Below Dam	0.00	0.00	0.00	0.00

Table 9
Monterey County Water Resources Agency
Assessment Derivation: Option 3, Even Weighting

Water Supply Assessment

	Groundwater ($)	Equivalent Acreages	Assessment Per Equivalent Acre	Assessment per Acre Land Use Factor 0	0.01	0.1	1
Whole Basin	$5,885,046	241,721	$24.35	$0.00	$0.24	$2.43	$24.35

Flood Control Assessment

	Flood Control ($)	Equivalent Acreages	Assessment Per Equivalent Acre	Assessment per Acre Land Use Factor 0	0.01	0.1	1
Whole Basin	$2,206,892	241,721	$9.13	$0.00	$0.09	$0.91	$9.13

Total Assessment

Assessment per Acre Land Use Factor 0	0.01	0.1	1
$0.00	$0.33	$3.34	$33.48

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