FLOODPLAINS REIMAGINED

2024

FLOODPLAINS REIMAGINED PHASE 1 REPORT

The Landscape Scale Multi-Benefit Floodplain Feasibility Study

Funded by Protecting California's Rivers, Streams and Watersheds Grant Program – Proposition 68

floodplainsreimagined.org

Funding provided by Proposition 68 to improve ecosystem health for the Central Valley salmon, steelhead and other native fish species, through the California Natural Resources Agency's Protecting California's Rivers, Streams and Watersheds grant program.

FORWARD

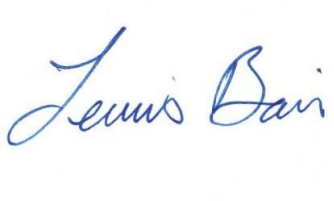
The Sacramento Valley water users have a culture steeped in stewardship, collaboration, and innovation with a drive toward action. The propensity toward problem solving and partnership in this Valley was something I noticed when I first started at RD 108 as an assistant general manager under Lu Hintz almost 30 years ago, and it is something that I have watched grow and flourish exponentially since then. As we grow and evolve together in our stewardship, it is exciting to see these principles applied to our historic floodplains.

Working closely with landowners over the years has proven to me that grassroots, local leadership is essential when it comes to resource management in California. As our State and Federal partners embrace Agreements for Healthy Rivers and Landscapes, landowners finally have the right framework to develop best ecological practices for lands where habitat is carefully integrated with existing land uses.

Reclamation District 108 is committed to landowner success and voluntary actions that support our Valley's stewardship and honor existing land uses. As such, we felt it was important to help provide a platform for exploration of multi-benefit opportunities and science development on our floodplains. To that end, we have been a key collaborative partner and fiscal agent in the facilitation and development of the Floodplains Reimagined program to better assist landowners in achieving their goals.

With landowners primed and supported to pursue multiple-benefit projects through Floodplains Reimagined, we stand at a pivotal moment for progress. We have significant alignment among state and federal agencies, environmental organizations, fishing groups, tribes and farmers who are energized to change the narrative around resource management. The opportunity is now ripe for collective action toward a future where we reimagine a valley serving multiple benefits. Reclamation District 108 is honored to help support this opportunity.

Sincerely,



Lewis Bair

General Manager
Reclamation District 108

ACKNOWLEDGEMENTS

We would like to express our sincere gratitude to the organizations and individuals who offered their invaluable support and collaboration in the development of the Floodplains Reimagined report.

During the development process, stakeholders encountered divergent opinions and perspectives, but through open dialogue, mutual respect, and a shared commitment to a common goal, participants navigated these differences and helped to produce a comprehensive and inclusive document.

We commend each member of the team for their willingness to engage in constructive dialogue, listen to differing viewpoints, and work collaboratively towards our shared objective. The dedication, flexibility, and perseverance of stakeholders have been instrumental in shaping the outcome of the Floodplains Reimagined report. We are proud of what we have accomplished together and grateful for the opportunity to work alongside such a talented and committed group of individuals and organizations.

The following is a list of those whose expertise, guidance, and resources have been instrumental in advancing our understanding of how we can improve floodplain functional connectivity to support salmon, birds, and agriculture in the Mid-Sacramento River valley region. We extend our deepest appreciation to all involved. Without their dedication and contributions, this report would not have been possible.

STAKEHOLDERS

American Rivers
American West Conservation
Audubon California
Basin Irrigation Drainage Authority
Ben King, Landowner
Benden Farms
Berry Creek Rancheria of Maidu Indians
Birdhaven Ranch
Butte Lodge Outing Club
Butte Sink Waterfowl Association
Butte Slough Irrigation District
CA Waterfowl Association
Cal Trout
California Department of Fish and Wildlife
California Department of Water Resources
California Farm Bureau Federation
California Rice Commission
Central Valley Flood Protection Board
Central Valley Project Improvement Act Science Integration Team
Colusa Basin Drainage District
Colusa County
Colusa County Board of Supervisors
Colusa County Resource Conservation District
Colusa Groundwater Authority
Colusa Shooting Club
Colusa Shooting Club
DeWit Farms
Dos Rios Norte
Ducks Unlimited
DWR Flood Management Division
DWR Multi-Benefits Division
Environmental Defense Fund
Estom Yumeka Maidu Tribe of the Enterprise Rancheria
Field and Tule Gun Club
Flyway Farms
Foraker Properties
Glenn-Colusa Irrigation District
Greenhead Hunting Club
Live Oak Gun Club
Lundberg Family Farms
Maxwell Irrigation District
Mechoopda Indian Tribe
Metropolitan Water District
Montna Farms
National Marine Fisheries Services, National Oceanic and Atmospheric Administration
Natural Resources Conservation District
Northern California Water Association
Rancho Llano Seco
Reclamation District 108
Reclamation District 1500
Reclamation District 1660
Reclamation District 70
Reclamation District 1004
River Partners
Sacramento Outing Farms
Sacramento River Settlement Contractors
San Francisco Estuary Institute and the Aquatic Science Center
Sanborn Slough Club
Sutter Butte Flood Control Agency
Sutter Bypass Butte Slough Water Users Association
Sutter Mutual Water Company
The Nature Conservancy
Tisdale Irrigation District
Trout Unlimited
U.S. Army Corps of Engineers Sacramento District
U.S. Bureau of Reclamation
U.S. Fish and Wildlife Service
UC Davis Center for Watershed Sciences
University of California, Davis
Ward Charter Farms
Western Canal Irrigation District
Westervelt Ecological Services
Wild Goose Club
Yocha Dehe Wintun Nation
Yolo County
Yolo Subbasin Groundwater Agency

CONSULTANTS

Downey Brand
Environmental Science Associates
FlowWest
R&F Engineering
Somach, Simmons, and Dunn

STEERING COMMITTEE MEMBERS

- Andy Duffey, Reclamation District 70/1660, Tisdale Irrigation District, Butte Slough Irrigation District
- Bjarni Serup, California Department of Fish and Wildlife
- Brian Ellrott, National Oceanic and Atmospheric Administration/National Marine Fisheries Services
- Carson Jeffres, University of California, Davis
- Denise Carter, Colusa County Board of Supervisors, Mid-Upper Sac RFMP, Colusa Groundwater Authority
- Julie Rentner, River Partners
- Laverne Bill, Yocha Dehe Wintu Nation
- Steve Rothert, California Department of Water Resources
- Virginia Getz, Ducks Unlimited
- Ward Charter, Ward Charter Farms

Our sincerest thanks from the Program and Technical Teams

Reclamation District No. 108, Grant Fiscal Agent

KSN, Inc, Program Manager

Kearns & West

Aquatic Resources Consulting Scientists

cbec eco engineering, Technical Lead

Cramer Fish Sciences

Ducks Unlimited

Point Blue Conservation Science

San Francisco Estuary Institute

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Benden Farms Enhancement Opportunities
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Decision Support Tool for Fish Food Inventory
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SECTION ONE

Phase 1 Report

SECTION 1: INTRODUCTION

Local and Voluntary Watershed Solutions

Since 2021, a consortium of landowners, scientists, government agencies, non-profit organizations and tribal members have been working to prioritize the improvement of historic floodplains for the benefit of salmon, birds, agriculture, and community. While actively participating in pilot programs to increase food availability for native fisheries, the Floodplains Reimagined partnership has also been studying the floodplain lands and adjoining rivers to better understand *how the marriage of water and soil* in the Sacramento Valley benefits the organisms that depend on a healthy watershed.

This expansive historic floodplain, with its mix of agricultural, managed wetlands, and riparian habitat, allows a rare chance to reimagine how healthy rivers and floodplains could thrive in an adaptively managed California. While Floodplains Reimagined is ongoing, this report documents the actions and findings of the first phase of the Program.

Vision

Floodplains Reimagined (Program) is a multi-benefit landscape scale approach to improve California's Sacramento River functional connectivity to historical floodplains while honoring existing land uses and stakeholder engagement. The partnership has coalesced around a common goal of population recovery of the anadromous Chinook salmon (targeted species) while increasing watershed health for the benefit of birds and wildlife. After years of coalition building, stakeholder engagement, technical and scientific data development, and program structure development, the program is now in a position to be a catalyst for transformational improvements to floodplain function for multiple purposes through voluntary collaborative partnerships.

Figure 1.1 / The Floodplains Reimagined Footprint

Need

The introduction of the Swamp Act in the 1850s altered the landscape and future of wildlife in California. The actions spurred by this legislation and the drive to protect life and property while supporting community economic growth, are believed to be contributing factors to the imperilment of native fisheries, especially the Chinook salmon. The Floodplains Reimagined partnership is working together to address declining wildlife populations through restoration of a critical level of function to historic floodplains of the Sacramento Valley.

For the majority of the history of the Sacramento Valley, rivers overflowed their banks each winter and spring transforming the surrounding landscape into a vast shallow inland sea. Populated by native peoples, this seasonally inundated floodplain teemed with native fish and wildlife populations. As rivers swollen with snowmelt overflowed their natural banks and spread slowly across the landscape, solar energy captured by plants and algae supported an abundance of fish food. This food-rich water of the floodplain would gradually recede as the season progressed, draining back into rivers, and carrying food to fish species. Chinook salmon teemed in their migratory waterways: winter-run in the Sacramento River, spring-run in Butte Creek. Billions of birds migrated down the 4,000-mile-long Pacific Flyway, taking advantage of the essential abundance provided by California's natural floodplains. Many other species reliant upon this diverse and complex ecosystem thrived in vast numbers.

Over the last century and a half however, development—primarily for reliable food supply with agriculture and public safety through flood control—has largely cut off Central Valley floodplains from their source rivers. This disconnection of river from floodplain now deprives many Central Valley river ecosystems of the floodplain food web foundation required for native species to thrive.

This disconnection is a contributing factor in the decline of California's native fish populations. As rivers became segregated from their floodplains, so too were species like the Chinook salmon cut off from the food web historically available on the floodplain. Bird species, both nonmigratory and those migrating along the Pacific Flyway, were also left with a fraction of the floodplain habitat on which they had previously relied.

In 2021, Reclamation District 108, acting as fiscal agent for the Program, received a Proposition 68 grant from the California Natural Resources Agency to evaluate the feasibility of reactivating historic floodplains by reintroducing low flows during the agricultural off-season onto lands owned by willing landowners of the Butte Sink, Sutter Bypass and Colusa Basin with the goal of increasing the functional connectivity Sacramento Valley floodplains. This document reports the finding of Phase 1 of that effort which was completed in in early 2024.

Figure 1.2

The 9 Priorities and Objectives:

Floodplains Reimagine was created to improve floodplain function for multiple purposes through voluntary collaborative partnerships with private landowners, sovereign tribal entities, government, and non-government representatives. This dynamic program works in concert with a constellation of efforts underway in the Colusa, Butte, and Sutter Basins, almost ½ million acres in the Mid-Sacramento River Valley region, to improve the floodplain functional connectivity to support salmon, birds, and agriculture.

It is important to note that Floodplains Reimagined is a locally driven program, guided by the landowners, agencies, and tribes it serves. As a collaborative organization, the participants in Floodplains Reimagined continue to develop a shared understanding of each other's interests and have maintained a mutual respect. With this collaborative mindset, stakeholders approved 12 unranked Priorities presented here alphabetically:

- Agriculture
- Ecosystem Health
- Flood Control
- Floodplain Connectivity
- Floodplain Wildlife
- Indigenous Cultural Values
- Recreation
- Water Quality
- Water Supply

Participants also identified the following process priorities:

- Collaboration
- Resiliency and Flexibility
- Urgency

With stakeholder input from interviews and committee meetings, the Program Team compiled the Floodplains Reimagined objectives related to each priority. In the following table, each priority is listed with its corresponding objective(s).

Table 1.1

FLOODPLAINS REIMAGINED MEMBERS ARE GUIDED BY 9 PRIORITIES

in the following sectors to remain focused on our purpose and process.

Agriculture

Evaluation Criteria	Objectives
Landowner Willingness	• Do no harm to existing property and water rights. • Limit actions to voluntary measures.
Agricultural Compatibility Evaluation Criteria	• Maintain planting, growing, and harvest season • Maintain or improve agricultural water supply and quality

Ecosystem Health

Evaluation Criteria	Objectives
Zooplankton Production and Export Evaluation Criteria Juvenile Salmon Habitat Suitability Criteria	Increase the frequency, duration, and spatial extent of inundation within the FR geographic areas to stimulate production of invertebrates to provide habitats for rearing when juvenile salmon are migrating through the area.
	Improve sediment dynamics.
Zooplankton Production and Export Evaluation Criteria	Improve the ecosystem health of the floodplains including riparian habitat throughout the FR geographic area during varying flow conditions, where and when appropriate.
	Decrease invasive vegetation including in channel maintenance areas to prevent fish kills and localized backflow flooding.

Table 1.1

Flood Control

Evaluation Criteria	Objectives
Landowner and Manager Willingness	Respect flood management functions, including operations and maintenance so that scenarios are flood management neutral or flood positive.

Floodplain Connectivity

Evaluation Criteria	Objectives
Juvenile Salmon Habitat Suitability Criteria	Increase hydrologic connectivity between the FR geographic area and the Sacramento and Feather rivers to provide access onto and off-of the floodplain for juvenile salmon.
Various Contributing Evaluation Criteria	Improve long-term, independently sustainable holistic floodplain connectivity.

Floodplain Wildlife

Evaluation Criteria	Objectives
Zooplankton Production and Export Evaluation Criteria	Increase the frequency, duration, and spatial extent of inundation within the FR geographic areas to stimulate production of invertebrates to provide habitats for rearing when juvenile salmon are migrating through the area.
Juvenile Salmon Habitat Suitability Criteria	Improve juvenile access to functional habitat.
	Reduce fish passage impediments to adult fish passage.
Birds Habitat Suitability Criteria Managed Wetland and Waterfowl Hunting Evaluation Criteria	Improve Pacific Flyway bird populations (including waterbirds, shorebirds, and migratory birds) using the floodplain.

Table 1.1

Recreation

Evaluation Criteria	Objectives
Landowner Willingness	• Do no harm to existing property and water rights. • Limit actions to voluntary measures.
Managed Wetland and Waterfowl Hunting Evaluation Criteria	• Maintain or improve recreational hunting opportunities for duck and goose clubs.
	• Maintain or improve public and private access for wildlife viewing and hiking.

Indigenous Cultures

Evaluation Criteria	Objectives
Landowner Willingness	• Improve accessibility for indigenous peoples to grounds for ceremony, as well as the gathering of traditional vegetation and wildlife during desired seasons.
Indigenous Tribes Willingness	• Do no harm to existing property and water rights. • Limit actions to voluntary measures.

Water Quality

Evaluation Criteria	Objectives
	Improve water quality.

Water Storage

Evaluation Criteria	Objectives
Landowner and Manager Willingness	Improve groundwater supply reliability and maintain groundwater supply by diversifying and coordinating regional water supply management.

OUTREACH AND EDUCATION

Stakeholder Support

Stakeholder engagement has been broad across the almost ½ million acres of the footprint (See Figure 1.1). Program partners are landowners, Federal agencies, State agencies, and NGOs. Floodplains Reimagined has a charter and an established outreach and engagement plan. Further, the Program has an expansive database of stakeholders and records of their engagement. Concepts are vetted by landowner groups, the advisory committee, and then approved by the steering committee. The program structure is illustrated and explained in Figure 1.3.

Figure 1.3

PROGRAM TEAM STRUCTURE

in the following sectors to remain focused on our purpose and process.

Program Team

Role

Management of funding and Program

Members

- KSN
- RD 108
- SFEI
- Cramer Fish Science
- Point Blue
- LSWA

Steering Committee

Role

Approval

Members

Landowners or Water Districts Landowners or Water Districts

- Benden Farms
- RD70/ Butte Slough Irrigation Company
- Ward Charter Farms

State and Federal Agencies

- CDFM
- DWR
- USFWS
- NMFS

Conservation NGO's and Academic

- UC Davis
- River Partners
- Ducks Unlimited

Indigenous Tribes

- Yocha Dehe Winton Nation

Advisory Committee

Role

Recommendations to the Steering Committee

Members

- Open Membership Representative of broad interests

Ad Hoc Groups

Role

Makes proposals and provides technical input to the advisory committee

Members

- Technical Staff
- Open Membership Representative of broad interests

Inclusive Planning and Engagement

Floodplains Reimagined is committed to including a diverse group of interested parties to help develop and guide the Program. This is specifically addressed in the Program's charter. It is also how the governing board is formed, with specified seats held for a diverse stakeholder base.

Community Outreach and Education

Floodplains Reimagined has an Engagement and Communications Plan. Additional information is available in the Appendix. Advisory meetings were scheduled to occur quarterly. There is an active website with all chartering, planning, and meeting documents posted (www.floodplainsreimagined.org).

Targeted Briefings and Presentations

During Phase 1, the Program Team coordinated targeted briefings and presentations with key interested groups to ensure coordination with other programs and create implementable (permittable) projects. Regular (bi-annual or quarterly) meetings were held with multiple public partners. Coordination included, but was not limited to the following:

- ***Frequent Multi-Department Briefings with California Department of Water Resources.*** The Department of Water Resources had a sitting member on the Steering Committee. These briefings were a way to engage staff across departments that are stakeholders and partners in potential multi-benefit solutions.
- ***Frequent Multi-Regional Briefings with California Department of Fish and Wildlife.*** The Department of Fish and Wildlife had a sitting member on the Steering Committee. These briefings were a way to engage staff across regions and projects that would be partners in potential multi-benefit solutions.
- ***Presentations to Central Valley Flood Protection Board.*** The Team also provided periodic updates to the broader flood management and natural resource communities to share information and help foster coordination and information sharing between the Management Plan and other relevant projects. This included providing presentations to the Central Valley Flood Protection Board-hosted (CVFPB) Coordinating Committee.

Advisory Meetings with US Bureau of Reclamation Science Integration Team (SIT). To bring the best available science to the evaluation of ecosystem enhancement project concepts and build consensus in the scientific community, the Floodplain Reimagined Technical Team coordinated with a cross-collaborative Science Integration Team (SIT) headed by the US Bureau of Reclamation (USBR) and US Fish and Wildlife Service (USFWS). Reclamation and USFWS seek broad support and buy-in for resource decisions by facilitating stakeholder participation in the SDM process through the SIT. The result was a science-based approach that supports achieving the anadromous fish doubling goal of the Central Valley Project Improvement Act (CVPIA) and documents the current understanding of the science affecting the recovery of Sacramento Valley salmonids. The Program Team will increase this coordination in Phase 2.

Partnership For Watershed Health

Floodplains Reimagined provides a platform to create multi-beneficial opportunities on the floodplains through improving floodplain function and connectivity, increasing abundance of fish and birds, and improving water reliability and quality while honoring existing land uses and voluntary actions. The partnership focuses on cultivating and implementing a shared vision to develop and manage healthy rivers across all interests. Phase 1 of the Program provided a foundation for future exploration of multi-beneficial solutions and vastly increased stakeholder engagement. This report provides a record of the work achieved from mid-2021 through 2023.

Science Report

SECTION TWO

Phase 1 Report

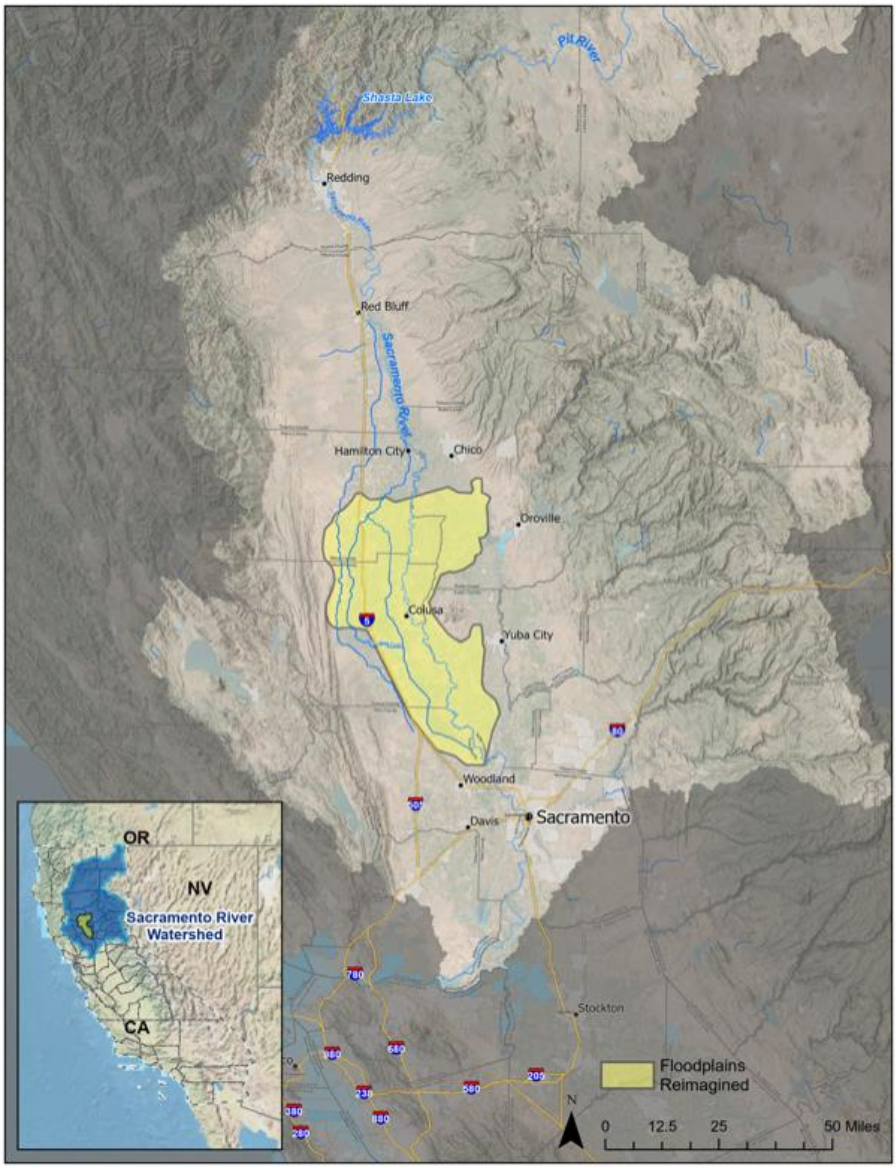
SECTION 2: LANDSCAPE

Study Area Summary Description

Flood Basin vs Floodplain

The footprint of Floodplains Reimagined lies primarily within the flood basins of the Sacramento Valley, which are low-lying areas beyond and parallel to the natural levees of the Sacramento River. Flood basin landforms are unique types of floodplains, a term used broadly by the Floodplains Reimagined Program and within this document. Flood basins are large-scale landscape features and connected at distinct points with the main channel network at intermediate flood levels. Floodplains are immediately adjacent to the river channel with broad longitudinal river connectivity during flood (Whipple et al. 2012). For the purposes of this document, floodplains is used as an all-encompassing term to address the historic floodplains.

Figure 2.1 / The Sacramento River Watershed



Historic Functionality

The Sacramento Valley flood basins reflect the geology, natural physical processes, and geography of the valley. Large-scale depressions formed between alluvial fans extending into the valley and the natural levees built by the Sacramento River since the last glacial period (Atwater 1980). Historically, these basins received, retained, and released peak flood flows of the Sacramento River – at times conveying more water than the main river channel – and also received considerable flow from the many smaller distributary rivers and streams that spread into the valley during the wet season (Gilbert 1917, Bryan 1923).

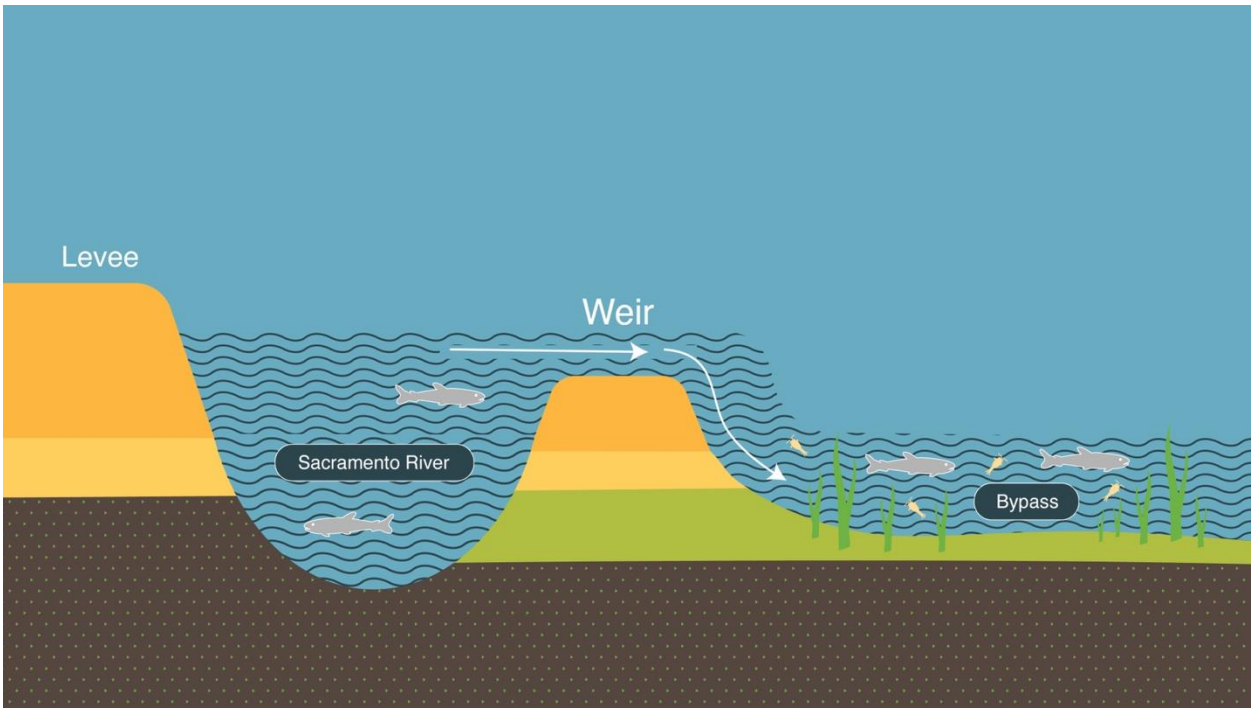
Perennial emergent wetlands dominated the lowest-lying areas of the flood basins, interspersed with sloughs, ponds, and lakes. Along the river side of the wetland margins were the Sacramento River's broad and dense gallery riparian forests. Along the upland margins, perennial wetlands transitioned to complex mosaics of seasonal wetlands, intersected by riparian forest and other habitat types associated with the distributary systems (Whipple et al. 2012).

Understanding Existing Limited Functionality

As Sacramento Valley populations increased so too did a need to protect life, property, and a reliable food supply. Rivers were confined with elaborate infrastructure, resulting in separating rivers from the historic floodplains and disconnecting native fish from critical food-rich habitat.

Flood bypasses and working landscapes are located today in portions of the Sacramento Valley flood basins. The bypasses were constructed as part of engineering efforts to efficiently convey high river flood flows and avoid flooding of other developed urban areas, agricultural land, and flood-vulnerable infrastructure (see Figure 2.2). Dam operations, the flood bypasses, as well as the levees and weirs along the Sacramento River have greatly diminished the extent and duration of inundation within the flood basins and reduced connectivity to the river, within the flood bypasses and most substantially on the dry side of the levees. The structure and management of engineered flood bypasses, along with watershed-scale hydrologic alteration caused by water and drainage management, make them function quite differently from the flood basins of the early 1800s.

Figure 2.2 / Illustration of Bypass Function During Floodflows in the Sacramento River



Section Purpose

The Floodplains Reimagined Program seeks to restore elements of the ecological function and value of floodplains of the Sacramento Valley, much of which are now part of working agricultural landscapes, to benefit wildlife, fish, wetland and riparian ecosystems, and water quality. Management actions would be guided by a conservation framework based on the nascent concept and practices of reconciliation ecology. Reconciliation ecology, a concept proposed by Rosenzweig (2003), acknowledges that humans are an integral part of ecosystems, and for conservation of biodiversity at large scale to ultimately be effective, we can redesign (and operate) human habitats and working landscapes so that their use is compatible with use by a broad array of other species.

It is important to understand the historic and current conditions of the study area to inform the development of future opportunities. Over time, the study area has undergone a transformation that has affected everything from the physical watersheds and the birds and salmon that live within them, to the human endeavors of native peoples, farming, flood control, hunting, and supplying water. This section describes the past and current conditions of ecology and management that are the starting point for the Program's possibilities in the future.

To outline the existing conditions, this section sets the scene with the historical to current transformation of the landscape including the watersheds, topography, and hydrology. Following that, the contents are organized according to the Floodplains Reimagined Phase I Program Priorities.

Historical to Current Transformation of Landscape

The Floodplains Reimagined footprint is an area of nearly half a million acres within the Sacramento River watershed, where wetlands, riverine habitats, farms, and wildlife refuges converge to form a patchwork of land uses. For the purposes of this Program, the footprint was broken into three subregions: Butte, Sutter Bypass, and Colusa. See Figure 1.1 in Section 1.

Sacramento River Watershed

The Program's study area is within the Sacramento River Watershed with subwatershed influences of Butte Creek, the Feather River, Sacramento Valley, and the westside drainage which ends up in the Colusa Basin Drain (See Figure 1.1) The Sacramento River Watershed shapes the area of opportunity for the Floodplains Reimagined program. From its mountainous headwaters in Northern California, the Sacramento River meanders through the valley's broad and relatively flat length on its 247-mile traversal to San Francisco Bay, making it the largest river in California by flow, length, and drainage area. Prior to the creation of engineered levees, the Sacramento River and its tributaries draining to the valley inundated a vast historical floodplain during the wet season, from the Butte Sink in the north to today's Yolo Bypass in the south.

The subwatershed influences of this footprint include:

Butte Creek. Originating in the Butte Meadows (northeast section of the footprint) at an elevation of approximately 7,000-ft. Primarily in Butte County, with a small portion within Tehama Count and the lower portion extending into Sutter, Colusa, and Glenn Counties.

Sacramento Valley. The Sacramento River starts more than 100 miles above Shasta Dam. However, downstream of the dam, the river runs for more than 200-miles mostly through the Sacramento Valley. Flows in the River have contributions from tributary flow and are significantly influenced by Shasta Dam operations for irrigation in the summer and flood control in the winter. The portion of the river through the study area is leveed and primarily runs from Shasta County in the north to Yolo County in the south.

Westside/Colusa Basin Drain. Converging with the Sacramento River at Knights Landing, the Colusa Basin Drain (CBD) is the single largest source of agricultural return flows to the Sacramento River. The drainage for CBD is bounded on the east by the Sacramento River, on the west by the Coast Range and foothills, on the south by Cache Cree, and the north by Stony Creek. Primarily located in Glenn, Colusa, and Yolo Counties.

Feather River.

The lower Feather River watershed starts downstream of Lake Oroville, flowing 60 miles to the Sacramento River. Although this River is not within the study area, water from the Feather River system is diverted into the footprint for the management of agriculture and managed wetlands. The Sacramento River Watershed within this footprint supports diverse ecosystems, a range of wildlife, and critical habitat for salmon and birds. It provides key migratory pathways for fall and

spring-run Chinook adult and juvenile salmon. The Central Valley winter-run (endangered) and spring-run (threatened) Chinook Salmon are listed species under both state and federal endangered species acts (ESAs). The floodplain areas are also within the Pacific Flyway, a major north-south flyway for migratory birds in the Americas, making it an important stopover for these populations. Rice fields and managed wetlands can be resource-rich, offering refueling opportunities and sustaining birds on their long-distance migrations and over the winter. The Floodplains Reimagined area of focus is particularly significant as it contains nearly a third of all California's remaining wetlands in the Central Valley.

From Historical Floodplain to Engineered Corridor

Historically, the Sacramento Valley (northern Central Valley) was a vast mosaic of riparian forest, wetlands, and uplands, supported by the regular meandering and flooding of the Sacramento and San Joaquin rivers and their tributaries, with more than 4 million acres of wetlands estimated (Garone 2006). The Sacramento River and its tributaries would regularly overtop their banks each winter and spring transforming the surrounding landscape into a vast and shallow inland sea. This inundated landscape created an ideal habitat for fish, birds, and other wildlife.

Today, more than 90% of historical wetlands in the Central Valley have been lost, primarily because of land reclamation, the construction of dams and levees for flood control, and conversion of land to intensive agriculture (Frayer et al. 1989; Reid et al. 2018). Inundation of these historic floodplains can be expansive in wet years when rivers flood and the Sacramento River spills over weirs and into the engineered bypasses and overflow areas.

The Program study area was historically part of a large river-wetland corridor that dominated the Sacramento Valley. Infrastructure utilized to protect life and land while developing a reliable food supply for growing communities transformed the valley's naturally functioning floodplains into a highly managed agricultural and flood bypass landscape, limiting the hydrologic connection between river and floodplain and largely eliminating native habitat. This transformation from naturally functioning to engineered system informs opportunities for future transformations and management that could help meet multiple interests.

In the 1800s, communities began engineering infrastructure to constrain the flooding to protect towns and crops. Early drainage of the basin wetlands for agriculture began in the mid to late 1800s and became more organized and extensive in the 20th century. As agriculture expanded and populations grew, engineering efforts to confine rivers and reduce the extent, duration, and frequency of flooding became more organized and extensive.

It is both true that 1) these changes are still vital today for the protection of public safety and food production and 2) the engineering of the complex system of levees, weirs, and drains, separated rivers from their historical floodplains. Within 150 years, a small portion of the historic record, the Valley ecosystems were fundamentally transformed, disconnecting juvenile fish from critical food-rich habitat, and greatly reducing and altering available habitat and food sources for bird populations. This transformation and its resulting existing conditions are the key to understanding the opportunities and constraints for finding new approaches to meet multiple interests.

Topography

The topography of the region defines the water management system and its uses. The region is low-lying and flat with flood basin depressions that collect water.

Elevations range from about 20 to 150 feet mean sea level (MSL). The Holocene basin deposits of silt and clay are covered by mostly fine-textured soils of low permeability. Many areas become inundated during the winter.

The flat, low-lying topography of the region allows precipitation and floodwater to sit on the land in depressions and flats for extended periods. Levees and berms have been engineered to extend the water's residence time on the land and control drainage in certain directions. The topography of levees flanking the Sacramento River drains floodwaters away from the Sacramento River and into the lower Colusa Basin Drain, Butte Creek, and Sutter Bypass with the purpose of conveying floodwaters away from farmlands. A network of canals, ditches, and drainage create a topographical spiderweb of small elevation changes redirecting precipitation and surface water to and away from fields.

The subregions (see Figure 1.1) have defined elements as noted below:

> ***Butte***. The land on both sides of Butte Creek is characterized by low-gradient slopes from the creek that drain precipitation and any field drainage back into the creek. The low-lying marsh and wetlands define the east and to some extent west side of the creek. This area has ecologically variable ground topography so that when water collects it results in a variation of depths. On the west side of Butte Creek, the land is relatively homogenously flat to accommodate rice growing with some exceptions for hunting clubs' wetlands. The Sutter Buttes is a topographic feature of note on its southern boundary.
>
> ***Sutter***. Bounded on the north by the confluency of Butte Creek, Sacramento River, and Sutter Buttes. The topography of the area is comprised of the gentle flatlands of the Sacramento River Valley. The only prominent topographic feature is the Sutter Buttes at its northern boundary, a Pliocene volcanic plug which rises abruptly 2,000-ft above the surrounding valley floor.
>
> ***Colusa***. Precipitation drains from the Cascade Range into the Colusa Basin Drain and Sacramento River. The subregion is generally comprised of low lying flat agricultural lands with managed wetlands.

Hydrology

The hydrology of the region informs how water moves across the landscape and the resulting habitat, species, and activities it supports. The water's magnitude (e.g., flow, depth, velocity), timing, duration, and predictability are all key factors in determining potential opportunities on the landscape. Critically, the flooding regime of the Sacramento River is substantially altered, with both large and intermediate floods now extremely rare. However, the river remains dynamic and variable, and there are different types of flood events which offer opportunities to support enhanced floodplain connectivity through management of flows within the landscape that could be explored for increasing floodplain connectivity.

The hydrology of the Sacramento River Valley is highly variable, as indicated by the large variability in the total volume of water in the system each year. Intra-annual variability, or the variability within a given water year, is characterized by variable flow magnitudes, timing, and durations. Average precipitation ranges from 17 to 21 inches in the study area. Annual rainfall increases across the study area from the southwest to the northeast. (PMC, 1996). Precipitation in the winter and spring contributes to shallow low-lying water in remaining flood basin depressions. Dry periods in summer and fall are characterized by application and drainage of surface water and drainage that contributes to surface water. The rim dams help address the difference in timing between precipitation availability (winter and spring) and demand (summer and fall).

To characterize hydrologic variations more comprehensively within years, (Cordoleani et al. 2021) classified flow events from the 1890s to 2020 into five categories (early small, intermediate, long duration, late small, and ravaging) based on the approach of Whipple (2017) Examples of each flow event category still present in the Sacramento River are shown in Figure 2.3, a conceptual hydrograph.

Figure 2.3 / Floodplains Reimagined Model Boundaries

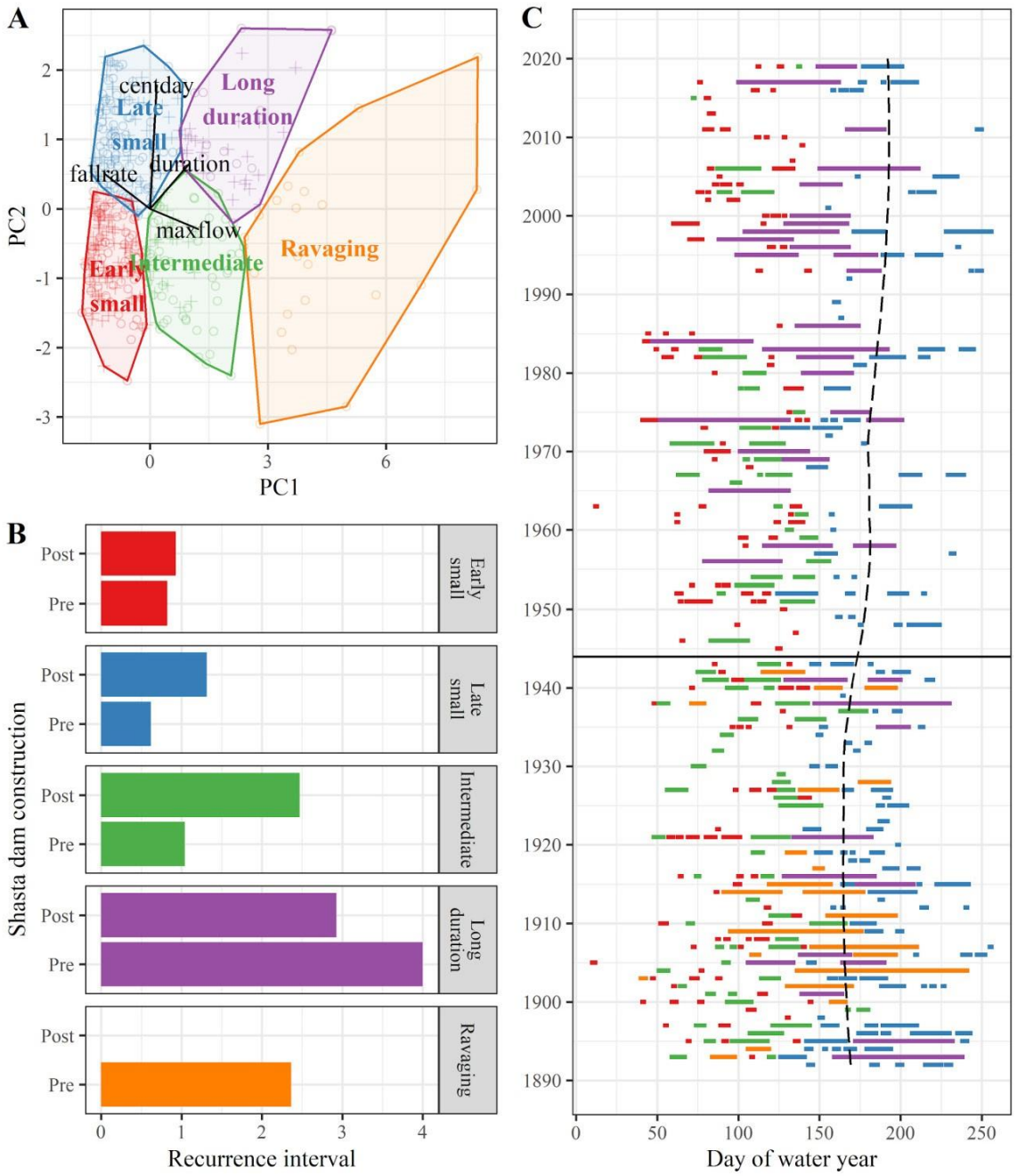


Figure 4. (A) Principal components analysis plot of the first two components (PC1, PC2) grouped by K-means clustering. (B) Recurrence intervals for the five flood types identified by K-means clustering. (C) Historical flood type reconstruction for the Sacramento River at Bend bridge daily flow data. The solid black line represents the construction of Shasta Dam. Dashed line is a smoothed loess line representing the trend in center of mass of annual flow (CT).

Construction of the rim dams, beginning with Shasta Dam in 1943, prevented once common, ravaging flows (large, long duration flows). Regulation of the dams also has recently significantly

reduced intermediate flows, typically at a critical time for juvenile salmon populations (Cordoleani et al., 2022). In general, flows include fewer dynamic events, more often falling into long duration events as well as the early small and late small, categories.

Although intra-annual flow variability has decreased due to regulation, the system is still punctuated by large hydrologic events resulting in flooding throughout the Sacramento Valley. In wetter years there are often multiple and/or large flood pulses. These wetter year flood pulses activate floodplains and associated habitats within the river and the flood basins and bypasses; and present opportunities on the shoulders of flood pulses to enhance river-floodplain connectivity and improve habitat conditions for salmonids and other aquatic and terrestrial species.

Conversely, drier water years typically include short duration flood pulses, while most of the rest of the year is characterized by baseflows in the Sacramento River. In these drier water years, opportunities to enhance river-floodplain connectivity, at the times that juvenile salmon populations are present, can be challenging, especially with the functional loss of intermediate flows. Due to limited water availability in drier years, river-floodplain connectivity becomes more limited in extent and duration, and finding opportunities to enhance river-floodplain connectivity and associated ecological functions becomes especially important.

Historical understanding of hydrology in the study area will likely evolve in the face of climate change. Recent patterns indicate that cycles of wet and dry will become more extreme increasing the need for ecosystem resiliency.

Water Supply

Water supply conditions are a primary component of potential options to re-manage the Butte, Sutter, and Colusa subregions to meet multiple benefits. This section outlines the existing conditions of surface water, groundwater, measurement, and water quality. This section does not address flood control management, which can be found in Section 5, Flood Control.

Floodplains Reimagined participants identified the following objectives to support the Water Supply Priority:

- Maintain or improve water supply and quality for agriculture
- Improve groundwater supply reliability and maintain groundwater supply by diversifying and coordinating regional water supply management
- Improve water quality
- Surface Water Management

Key Features

The management of surface water in the region is characterized by key features that will influence the opportunities for change. First, the system is highly complex, serving multiple decentralized jurisdictions and parties for multiple purposes. It is also characterized by high variability of water delivery rights and agreements. Infrastructure is complex and ranges wildly in condition and adequacy. A wide range of measurement and shared information exists in the system, resulting in varied user predictability. Finally, there is also a range of capacity to

account for and measure water flows and diversions which affects predictability of those same water flows and diversions. However, the larger systems have been operating for over 100 years with experienced understanding of water management within management boundaries.

Distinguishing this region's surface water supplies and strongly influence surface water management in the region include but are not limited to the following: 1) Rice drain water from in-basin and out of basin ; 2) Imported Feather River water from Butte Creek via hydropower and drainage water; 3) Intricacy of infrastructure; 4) Available stored water and flood control capacity which influence river and creek operations; 5) Sacramento River operations and hydrology; 6) Hydrologic year type; and 5) Mix of high-level engineering and controlled surface water management with low-level engineering and less controlled surface water management.

Management of the surface water system includes efforts to clarify challenges around the jurisdiction, authority, and responsibilities including but not limited to distinction between natural and engineered channels, operation of infrastructure, and management of the river and bypass channels. In addition, efforts are currently underway to improve measurement and therefore predictability and accounting of diversions, drainage, and flows.

Challenges within the water supply system due to drought, more extreme hydrologic events, regulation, and other more recent changes have challenged traditional management of the lands in the Valley resulting in negative ecosystem and economic pressures. These conditions have resulted in fallowing of land, decreased agricultural production, increased aquatic invasive species, crop conversion, decreased waterfowl hunting, and decreased flows needed to support adult salmon passage, and decreased floodplain inundation that could support juvenile salmon rearing.

Surface water Infrastructure

This section describes the existing conditions of surface water infrastructure for the primary source basins: 1) Key Functions, 2) Sacramento River, 3) Feather River, 4) Butte Basin, 5) Colusa Basin, and 6) Sutter Basin.

Key Functions

The region is characterized by a complex part-natural and part-engineered system that functions to contain floodwater, move water to users, collect, hold, and then drain water on and off wetlands and fields. The state, private owners, and reclamation districts have developed various canals, sloughs, weirs, and pumping plants to manage surface water. For more detailed information on the infrastructure in the region, please see the Modeling Technical Memorandum in the Appendix.

Surface water infrastructure in this area can be characterized as follows (see Table 2.1 for a list of major management structures):

- A complex system of hydraulic structures that control water diversion and water surface levels as Sacramento River connections and/or in-basin management structures (e.g. natural overflows, weirs, outfall gates, culverts, sluice gates, and dams)

- Infrastructure (e.g. sloughs) may not only convey water delivery, but may also collect field drainage, import water into the basin, and convey floodwater into bypasses/overflows. In some areas of the watershed and depending on the level of floodplain connectivity, salmon may use portions of this system as part of the migration pattern.
- Pumping plants for reclamation and delivery are throughout the system, with the largest ones screened for anadromous fish. Ownership varies between the State (Department of Water Resources) and local water districts/companies.
- Highly coordinated water deliveries and drainage within the watershed between State, Federal, and local water users. Additional information can be found in the Sacramento Valley Regional Water Management Plan (NCWA, 2006) and the Feather River Regional Agricultural Management Plan (NCWA, 2020)

Sacramento River

Sacramento River diversions occur on both the west and east sides of the river. On the west (Colusa Subregion) side, major diversions occur into the Tehama-Colusa Canal at Red Bluff and into the Glenn-Colusa Canal above Hamilton City. These two diversions are the largest on the Sacramento River. The Tehama-Colusa and Glenn-Colusa canal and drainage system in addition to neighboring smaller water systems include well over 1,000 miles of infrastructure. Several additional diversions occur further downstream immediately adjacent to the basin. The diverted water eventually makes its way to the Sacramento River or Colusa Basin Drain, which delivers drainage water back to the Sacramento River at the Knights Landing Outfall Gates or to Yolo Bypass via the Knights Landing Ridge Cut. This is a closed system where flood waters from the river do not enter the subregion. This is colloquially referred to the “dry side” of the footprint. Flooding may occur in this subregion, but it is from precipitation and drainage from the Cascade Ranges.

East (Butte) side diversions occur at M& T Ranch near Llano Seco and the RD 1004 pumping plant. This system is considered the “wet side” of the footprint. Frequent flooding occurs during the winter and spring months due to natural overflows and engineered bypasses.

Colusa Subregion

The Colusa Subregion is an agricultural basin delivering the largest single source of agricultural return flows to the Sacramento River. The basin’s main channel, the Colusa Basin Drain, is supplied by water delivery canals, agricultural drainages, and natural streams. Natural streams include Stone Corral Creek, Powell Slough, Lurine Creek, Salt Creek, Cortina Creek, North Sand Creek, South Sand Creek, Salt Creek 2, Petroleum Creek, Buckeye Creek, Dunnigan Creek, Oat Creek, and Willow Spring Creek.

Flows within the Colusa Drain are managed by three main structures: Davis Weir, Knights Landing Outfall Gates, and Wallace Weir. These control water surface elevations and outflows to the Sacramento River at Knights Landing Outfall Gates and Yolo Bypass at Wallace Weir with support from secondary structures located along the drainage network of the basin.

Feather River

Feather River water is diverted into the Butte Basin at multiple locations for multiple purposes. In the upper watershed, water is diverted from the West Branch Feather River into Butte Creek for hydroelectric power generation as part of PG&E's DeSabla-Centerville Project. Diverted water is run through the powerhouses and released to Butte Creek, thus augmenting its flow. Further downstream, major diversions to the Butte Basin from the Thermalito Afterbay occur via the Western Canal, Richvale Main Canal, and Sutter Butte Canal. These canals provide water to users throughout the basin including several Irrigation/Water Districts, State and Federal managed wetland areas, and privately managed wetlands within the Butte Sink. The diverted water occurring north of the Sutter Buttes eventually makes its way to Butte Creek, Butte Sink, and to the Sacramento River via the Butte Slough Outfall Gates or into Sutter Bypass. Within Butte Sink, which is primarily comprised of privately-owned hunting clubs, diverted water is used to maintain a flow-through system with hydraulic connectivity between clubs managed through a series of weirs, canals, and turnouts that are operated based on agreements amongst the clubs. Several diversions also occur directly from the Feather River downstream from the Sutter Buttes, with this water draining to the East Borrow Canal in the Sutter Bypass.

Sacramento River and Feather River: Butte and Sutter Subregions

Butte Subregion

The Butte Subregion, located to the east of the Sacramento River and upstream of the Sutter Bypass, is a major flood relief basin for the Sacramento River and surrounding area that receives flood flows from natural and engineered flood release structures. The natural overflows include M&T, 3 B's, and Goose Lake Natural Overflow Areas, and the engineered overflows include Moulton and Colusa weirs.

The basin also receives and routes flows via major sources like Little Chico Creek, Butte Creek, Little Dry Creek, and Cherokee Canal. Several sloughs including Angel, Sanborn, and Drumheller sloughs along with a complex agricultural drainage network also convey flows through the basin and into the Butte Sink. Within the Butte Sink, numerous surface water management and conveyance structures divert flows to privately-owned hunting clubs as well as State and Federal wildlife areas. These structures include the Bifurcation Structure, North Weir, End Weir, White Mallard Dam, Morton Weir, Field and Tule Turnout, Mile Canal Turnout, Driver's Cut Weir, and Drumheller Slough Complex.

On the north end of the Sink, the Bifurcation Structure controls the seasonal flow split between Butte Creek and Sanborn Slough. North and End Weirs, located along Sanborn Slough, are used to control the water surface elevation (WSE) in Sanborn Slough and its outflow to Cherokee Canal, and to divert water into the hunting clubs for flooding up the wetlands. White Mallard Dam also controls the WSE for Butte Creek and the Drumheller Slough complex (discharges into Butte Creek) downstream of the Bifurcation Structure. The Morton Weir, Field and Tule Turnout, and Mile Canal Turnout control WSE in Cherokee Canal downstream of End Weir and are used to route water to the hunting clubs in the Sink. The structures also control the outflow from Cherokee Canal into Butte Creek. Driver's Cut Weir serves a similar purpose by managing the drainage of several major hunting clubs back into Butte Creek on the southern end of the Sink.

The surface water control structures are aided by a network of secondary channels and minor infrastructure that enables the hunting clubs and wildlife areas to manage wetland flood up and drawdown seasonally to achieve various goals. These canals include Crosscut Canal, Mile Canal, and North Butte Canal.

Flow-through weirs, between managed fields, provide hydraulic connection throughout the Sink during winter flooding. Diverted flows eventually accumulate downstream within Butte Slough which conveys surface water into the Sutter Bypass or to the Sacramento River via the Butte Slough Outfall Gates.

Sutter Subregion

The Sutter Bypass is a 35-mile-long flood conveyance facility used to divert and convey flood flows from the Sacramento River and surrounding areas. The Bypass also receives and conveys flood flows from natural runoff originating from the Butte Basin. The Sutter Bypass is a man-made channel starting at the south side of the Sutter Buttes, near Highway 20, and continuing south to the Fremont Weir just northeast of the City of Woodland.

Surface water includes Butte Creek, Cherokee Canal, and Butte Slough, as well as drainage from the east near Yuba City through Wadsworth Canal and pumping plants (PPs).

Within the bypass, several structures are used to manage surface water for agricultural purposes during non-flood periods. These structures include Willow Slough Complex, Nelson Weir and Management Unit Culvert, and Weirs 1 –3. Several additional structures include Tisdale Weir and Notch, Weir 4 & 5, East West Diversion Weir, and the Freemont Weir. These are used to aid in flood control through the Bypass during high flow periods.

Table 2.1

FLOOD CONTROL AND SURFACE WATER MANAGEMENT STRUCTURES

Butte Subregion Structure
Flood Control
M & T Natural Overflow Area
3 B's Natural Overflow Area
Goose Lake Natural Overflow Area
Moulton Weir
Colusa Weir
Butte Slough Outfall Gates
Tisdale Weir

Sutter Subregion Structure
Flood Control
Tisdale Weir and Notch
Weir 4
Weir 5
East-West Diversion Weir
Fremont Weir

Butte Subregion Structure
Surface Water Management
Bifurcation Structure
North Weir
End Weir
White Mallard Dam
Morton Weir
Field and Tule Turnout
Mile Canal Turnout
Driver's Cut Outfall
Driver's Cut Weir
Drumheller Slough Complex

Sutter Subregion Structure
Flood Control
Willow Slough Complex
Nelson Weir
Nelson Management Unit Culvert
Weir 1
Weir 2
Weir 3

Colusa Subregion Structure
Surface Water Management
Davis Weir
Knight Landing Outfall Gates
Wallace Weir
Balsdon Weir*

*Not represented in Colusa Subregion Model

Groundwater Management

While surface water (both floodwater and irrigation supplies) contributes the majority of water to the basins, landowners and managers also apply groundwater to irrigated lands, managed wetlands, and for municipal uses. Under the Sustainable Groundwater Management Act (SGMA), multiple Groundwater Sustainability Agencies have been formed to manage groundwater within the Butte, Sutter, and Colusa subregions.

Generally, groundwater is readily available with good water quality. However, there are some areas of concern for overdraft, subsidence, and water quality. Water users are working through goals and targets set in the multiple Groundwater Sustainability Plans that cover this footprint, to develop groundwater and recharge programs that will keep the basins in balance.

In 2022 when surface water supplies were unprecedently limited, the Valley saw dramatic decreases in groundwater availability. However, the aquifers recovered the following winter. The capability of the watershed to develop and implement a conjunctively managed program for all water uses is considered high. More information is available online at

www.colusagroundwater.org

www.suttersubbasin.org

www.yologroundwater.org

www.buttebasingroundwater.org

Water Quality

The Sacramento Valley Water Quality Coalition has been monitoring water quality at various sites throughout the Sacramento Valley from 2005 to present, many of which include water from agricultural runoff. These sampling and analytic methods are approved by the Central Valley Regional Water Quality Control Board. The monitoring complies with the Waste Discharge Requirements for growers within the Sacramento River Watershed, as well as the Pesticides Evaluation Protocol. The monitoring consists of water column and sediment toxicity, physical and conventional parameters in water, organic carbon, pathogen indicator organisms in water, trace metals in water, pesticides in water, and nitrogen and phosphorus compounds in water.

This program and its related monitoring data is representative of over 1.1 million acres of irrigated land supported by more than 8,600 farmers and wetlands managers. The Coalition found that from 2005-2022, 98.0% of all pesticide analyses performed have been below detection; in 2022, 94.6% of pesticide analyses were below detection for all monitored areas; and that the majority of reported water quality concerns for 2022 were physical parameters such as specific conductivity, dissolved oxygen, pH, and E. coli.

Despite the findings of the Sacramento Water Quality Coalition, Floodplain Reimagined participants voiced diverging viewpoints on water quality conditions and their adequacy for

wildlife habitat. Going forward, additional fact finding will be necessary to build a shared understanding of conditions in the study area.

Floodplain Ecology and Wildlife

The existing conditions for three Floodplains Reimagined Priorities are addressed in this section: Floodplain Connectivity, Ecosystem Health, and Floodplain Wildlife. They are presented together due to their inter-relation. First, the section describes the existing conditions of the floodplain connectivity and ecosystem health and then moves on to describe the wildlife supported by the floodplain. The following sections identify the Program's objectives for each priority, discuss the importance of the existing conditions related to the objectives, and outline the existing conditions.

Floodplain Connectivity and Ecosystem Health

Floodplains Reimagined participants identified the following objectives in support of the Floodplain Connectivity Priority:

- Increase hydrologic connectivity between the floodplains and area rivers and streams to provide access onto and off the floodplain for juvenile salmon
- Improve long-term, sustainable floodplain connectivity

Floodplains Reimagined participants identified the following objectives in support of the Ecosystem Health Priority:

- Increase the frequency, duration, and spatial extent of inundation within the FR geographic areas to stimulate production of invertebrates and to provide habitats for rearing when juvenile salmon are migrating through the area.
- Improve sediment dynamics.
- Improve the ecosystem health of the floodplains including riparian habitat throughout the FR geographic area during varying flow conditions, where and when appropriate.
- Decrease invasive vegetation including in channel maintenance areas to prevent fish kills and localized backflow flooding.

The processes and functions supporting Floodplain Connectivity and Ecosystem Health Priorities are critical to making multi-benefit options and they are inextricably interrelated.

The Floodplains Reimagined region's ecological conditions are characterized by disconnection between river corridors and floodplain for most of the flood season and most of the length of the natural stream corridors. The exceptions to this disconnection are Butte Creek's semi-controlled overflow into adjacent wetland management and agricultural properties and its semi-controlled overflow into Butte Sink. Other exceptions include specific parcels where owners have reconnected the Sacramento River to the floodplain or setback levees in a way that increased floodplain function at certain flows.

Variability and complexity in space and time and at multiple scales are defining characteristics of floodplain environments and the opportunities to meet multiple benefits. Variability and complexity are driven primarily by a river's flow regime and floodplain topography. In other

words, the way in which the water moves across the landscape, ponds, and recedes creates a thriving biodiversity where sun, water, and decomposition grow bugs and the bugs become food for fish and birds. There is a great transfer of energy from the sun, earth, and water into the pools of water stretching away from the rivers where birds and fish thrive. As the water recedes, the birds and fish must find their way back into the main river channel or migratory pathway to survive. Highly variable floodplain systems support a thriving web of life.

Flood pulses of a river's flow regime interact with the floodplain landscape and control biological processes, community composition, and life history traits (Junk et al., 1989, Bayley, 1991; Poff et al., 1997, Tockner et al., 2000). Hydrologic connectivity, or the exchange of matter and energy through water, is a representation of that interaction. Connectivity is required for species to enter and exit the floodplain, and species assemblages have been linked to different degrees of connectivity (Tockner et al., 2000). Connectivity also controls residence time, which affects productivity and biogeochemical processing (Grosholz & Gallo, 2006). Macroinvertebrate and fish assemblages and biodiversity patterns have been linked to differences in hydrologic connectivity and other floodplain characteristics (e.g., Andrews et al., 2014; Arthington & Balcombe, 2011; Davidson et al., 2012; Gallardo et al., 2009; Simões et al., 2013; Tockner et al., 2000). Studies widely demonstrate that the shifting mosaics of habitat patches and diverse and interconnected ecosystem processes of naturally functioning floodplains support high levels of biodiversity and productivity (Amoros & Bornette, 2002; Opperman et al., 2017; Tockner et al. 1999; Tockner & Stanford, 2002; Ward et al., 2002; Ward et al., 1999).

Ecosystems are adapted to the associated suite of hydrologic connectivity characteristics (Ward 1989) such that the loss or simplification of flow-landscape interaction results in significant shifts in biota (Bunn and Arthington 2002, Poff et al., 2007). Addressing these challenges should include setting restoration goals for physical processes important to the emergence of the targeted biotic responses (Ward et al. 1999, Opperman et al. 2009), rather than targeting any single species directly.

The extensive water supply and flood infrastructure of the Central Valley and its watersheds make its floodplains globally some of the most highly modified. Though major flood events still inundate substantial portions of the historical extent of floodplain wetland habitats, physical and ecological processes have been profoundly altered, thus affecting overall ecosystem health. As with many systems globally (Dudgeon et al., 2006; Tockner et al., 2010), profound changes in flow regime such as the frequency and duration of inundation due to dams, has translated to an overall loss of ecological diversity and productivity over time (Garone 2006, Whipple et al. 2012, Yoshiyama et al. 1998). Dams, artificial levees, weirs, flood bypasses, canals, and infrastructure that function to rapidly drain water from the landscape have contributed to this reduction in frequency and duration of inundation.

Climate change poses compounding challenges to rehabilitating and sustaining floodplain ecosystems, related to shifting and declining snowmelt regimes, increasing precipitation extremes, and altered land-atmosphere feedbacks (Tockner and Stanford 2002, Beechie et al. 2012).

Meaningful connectivity evaluation is paramount as floodplain habitat is more valuable to birds and fish if they can get on and off the floodplain on their own to continue their migration.

Floodplain Wildlife

The Floodplains Reimagined Program identified the following objectives in support of the Floodplain Wildlife Priority:

- Increase the frequency, duration, and spatial extent of inundation within the Floodplains Reimagined geographic areas to stimulate production of invertebrates to provide high quality habitats for rearing when juvenile salmon are migrating through the area.
- Improve juvenile access to functional habitat, survival, and growth outcomes for juvenile Chinook salmon.
- Reduce impediments to adult fish passage.
- Improve Pacific Flyway bird populations (including waterbirds, shorebirds, and migratory birds) using the floodplain.

Salmon

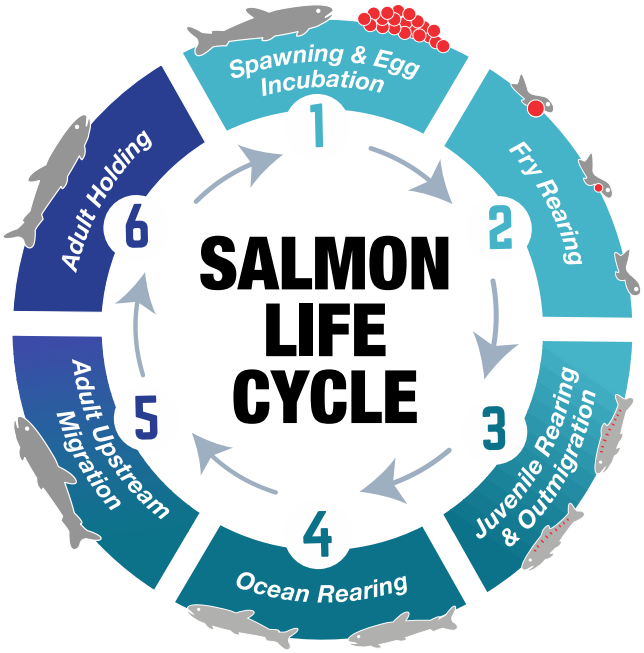
To meet the objectives outlined above, it is important to understand the existing conditions and limiting factors to salmon. Below, the section describes the existing conditions for salmon habitat, populations, fish passage for adults, and food availability and use.

Habitat

Chinook salmon use a wide variety of aquatic habitats to complete their life cycle from headwater streams to the Pacific Ocean. Figure 2.4 shows the salmon life stages. The life stages most likely to interact with floodplains are rearing fry and juvenile rearing and outmigration. Currently, juvenile salmon have an opportunity to access the Butte Basin and Sutter Bypass when one or more of the flood control weirs spills, and juvenile salmon are present at the junction (the Colusa Basin has no access for juveniles). For fish to exit the existing system, they must navigate a series of perennial conveyance canals before exiting through Sacramento Slough and into the Sacramento River just upstream of the Feather River confluence.

Habitat in the bypasses is dominated by agriculture and managed wetlands for waterfowl with remnants of natural wetlands. Flooded habitats can support high productivity of zooplankton that are in turn preyed on by juvenile salmon. The time required for this productivity to develop is dependent on temperature and water residence time. Data from experimentally flooded fields suggest that juvenile salmon can grow well in agricultural landscapes and data from studies with caged fish report the highest growth in wetlands. Currently there is only anecdotal information on the habitat selected by free swimming juvenile fish or their spatial distribution within floodplain environments. Thus, specific habitat conditions that are preferred for rearing and the spatial distribution of juvenile salmon within flooded habitat remains unknown. See also Fisheries Uncertainty Memorandum in the Appendix.

Figure 2.4 / Salmon Life Cycle



Populations

The Sacramento River supports four runs of Chinook salmon including winter run, spring run, fall run and late-fall run. Winter run are listed as endangered under the federal endangered species act (ESA). Currently there is a single population of winter run Chinook that spawns below Keswick Dam and is supported by the Livingston Stone Hatchery. Reintroduction efforts have begun in Battle Creek and the McCloud River above Shasta Reservoir. However, these efforts have not yet established self-sustaining populations. The most recent 5-year review by NMFS ranked the biological risk to this run as “high”.

Spring run Chinook salmon are listed as threatened under the ESA. This run spawns in multiple tributaries to the Sacramento River where summer water temperatures are sufficient for holding prior to spawning in the early fall. Spring run are propagated at one hatchery on the Feather River. The most recent 5-year status reviews classified extinction risks ranging from low to high depending on the specific population.

Fall run Chinook salmon are the most abundant in the Sacramento River and has traditionally supported a commercial and recreational fishery. However, in recent years this run has not supported populations in the wild to meet commercial fishery needs. Fall run spawn in multiple tributaries and the mainstem Sacramento River. This run is supported by five hatcheries with three located in the Sacramento River watershed including Coleman National Fish Hatchery (Battle Creek), Feather River Fish Hatchery (Feather River) and Nimbus Fish Hatchery (American River). Fall run are at risk from an array of stressors including introgression with domestic hatchery stocks, habitat degradation (including flow alterations) and over-harvest.

Late-fall run salmon are closely related to fall-run but spawn later in the year and juveniles over-summer in freshwater and migrate as yearlings. This run primarily occurs in the Sacramento River mainstem but also uses certain tributaries. One hatchery (Coleman National Fish Hatchery) produces late-fall run Chinook salmon.

Food Availability and Use

Juvenile Chinook salmon utilize a variety of invertebrate prey during their freshwater life stages. The specific prey items they rely on change with ontogenetic changes in habitat use and ability to capture and handle invertebrates of varied sizes. In lotic habitat Chinook salmon are primarily feeding on drifting invertebrates. The value of a feeding location is a balance of the energetic cost of holding station in the current and the amount of energy that can be obtained from passing prey items. This also must be balanced with the risk of predation. Chinook salmon are known to set up dominance hierarchies where territories around the most energetically favorable feeding stations are defended by dominant individuals.

Less is known about the feeding ecology of juvenile Chinook salmon in more lentic habitats. However, behavior and habitat use can still be affected by perceptions of risk. The prey items available for consumption depend on the seasonal phenology of invertebrate lifecycles, habitat structure, and location within the watershed (alluvial vs. lowland reaches). Currently, most information on prey communities comes from comparative studies of restored and unrestored habitat in natal habitat and comparative pelagic zooplankton assemblages in floodplain and lowland river habitat. There is little evidence that food resources specifically are currently limiting juvenile production. However, studies in natal habitat have shown that the relative abundance of prey types changes with habitat structure. In addition, in lowland habitat, given enough time, floodplain habitats can develop high concentrations of pelagic zooplankton. Rearing Chinook salmon with access to eating high concentrations of zooplankton achieve higher rates of growth than in the adjacent main channel.

Fish Passage Barriers for Adult Salmon Migration

Fish passage has been a high priority in the watershed since the mid-1990s. The major diversions on the Sacramento River have been screened to protect salmon fry. However, adult fish passage continues to be a major concern for population recovery. Concerns center around issues such as stranding and aquatic invasive weeds blocking migration corridors. Program partners continue to explore understanding and identification of fish passage barriers for adult salmon migration and finding the resources to implement solutions.

Pacific Flyway (Waterfowl, Shorebirds and Cranes)

To improve the Pacific Flyway bird populations using floodplains in the region, it is important to understand the existing conditions for waterbirds, shorebirds, and migratory birds. Currently, the region of focus is vital to the thriving population of many different types of birds that rely on floodplains. This section will discuss populations, habitat, and food availability and use.

The Sacramento Valley provides valuable habitat year-round for millions of birds. Populations include species of conservation concern and numerous species of waterfowl, shorebirds, other waterbirds, riparian landbirds, raptors, and more (CVJV 2020). In Phase 1, Floodplains Reimagined focused on the habitat needs of bird species and groups that rely on wetland habitat and are likely to be affected by changes in the extent, timing, and depth of flooding in the winter and spring, including foraging habitat during the non-breeding season for shorebirds and

waterfowl (emphasizing dabbling ducks), as well as foraging and roosting habitat for Sandhill Crane (*Antigone canadensis*). There are many other bird species and groups that are of conservation interest and could be considered in future phases of the program (discussed further in the next section).

Populations

Millions of waterfowl and hundreds of thousands of shorebirds rely on the Central Valley to provide crucial wetland foraging habitat during migration and over the course of their non-breeding seasons each year, making the Central Valley one of the most important regions for these taxa (Shuford et al. 1998; Reid et al. 2018). The shorebird community includes at least 19 species that commonly use the Central Valley during the non-breeding season (July—mid-May), including 9 species for which the Central Valley population is of primary importance and 12 species with special conservation status in the U.S. Shorebird Conservation Plan (USCPP 2015; Dybala, Reiter et al. 2017).

More than 90% of all ducks in the Central Valley are dabbling ducks, and the Central Valley is responsible for meeting a substantial proportion of the population objectives in the North American Waterfowl Management Plan for 8 species of dabbling ducks, 6 goose and swan species, and 5 species of diving ducks, primarily in the Sacramento Valley (Fleming et al. 2017; CVJV 2020). In addition, two subspecies of Sandhill Crane rely on the Central Valley for wetland roosting habitat with nearby foraging habitat during the winter, and both subspecies are of conservation concern. The Lesser Sandhill Crane (*A. c. canadensis*) is listed as Threatened under the California Endangered Species Act (CDFW 2021), and the Greater Sandhill Crane (*A. c. tabida*) is considered a California Bird Species of Special Concern (Shuford and Gardali 2008).

The Central Valley Joint Venture, a collaborative effort to protect, restore, and enhance habitat for a diverse suite of birds in the Central Valley, has established wetland restoration and enhancement objectives to support long-term goals of increasing the populations of shorebirds, waterfowl, and Sandhill Crane, among many other species (CVJV 2020). Actions to increase hydrologic floodplain connectivity in the Floodplains Reimagined program area could contribute to these conservation objectives.

Habitat

Shorebirds, waterfowl, and Sandhill Cranes are all dependent on wetland habitat during the non-breeding season, and their populations are assumed to have been impacted by the loss of more than 90% of historical wetlands in the Central Valley, primarily as a result of water diversion, the construction of dams and levees for flood control, and conversion to intensive agriculture (Frayer et al. 1989; Reid et al. 2018). Most of the wetland habitat now available to birds in the Central Valley is provided by a network of managed seasonal wetlands on public and private lands, such as wildlife refuges and duck clubs, and agricultural fields that landowners choose to flood post-harvest, especially rice fields (CVJV 2020). However, the Central Valley Joint Venture has identified substantial gaps in habitat availability for shorebirds in the Central Valley during the nonbreeding season, particularly during the fall and spring “shoulder” seasons (CVJV 2020; Dybala, Reiter et al. 2017; Golet et al. 2022).

In addition, winter-flooded rice provides approximately 70% of the energy supply available to waterfowl in the Sacramento Valley (CVJV 2020) and more than 50% of the energy supply available to shorebirds in the Central Valley (Dybala, Reiter et al. 2017). The loss of winter-flooded rice, either due to a shift in post-harvest practices or conversion to other crops, would have a significant impact on waterfowl and shorebird populations in the Central Valley. Moreover, drought is likely to have a long-term impact on winter-flooded rice, increasing waterfowl's dependency on managed wetlands (Petrie et al. 2016)

The Floodplains Reimagined area offers over 50,000 acres of wetlands and over 130,000 acres of rice as a habitat for these bird groups. However, the suitability of these acres for each of these bird groups and species depends on the timing and depth of flooding. Additions or enhancements to the extent of suitable habitat would be valuable to conserving these taxa.

Food Availability and Use

Estimates of the total food supply in wetlands and flooded agriculture inform Central Valley conservation objectives for shorebirds and waterfowl during the non-breeding season (CVJV 2020). For shorebirds, the primary food supply is benthic invertebrates, which are small aquatic animals and the aquatic larval stages of insects that live either on top of or burrowed into the muddy bottom of a water body, which shorebirds reach by probing into the mud. Although information is limited about the abundance and energy content of benthic invertebrates per acre of flooded wetlands, agriculture, and floodplains, previous analyses have estimated higher energy densities (calories per acre) in managed wetlands than winter-flooded rice (Dybala, Reiter et al. 2017).

In contrast, annual wetland plant seeds are the primary source of food for waterfowl in the non-breeding season, including waste grain remaining in rice fields and moist-soil seeds produced in managed wetlands, although their diets shift to include more invertebrates as spring approaches (Fredrickson and Taylor 1982, Euliss and Harris 1987, Heitmeyer 1989). Managed wetlands provide a higher density of food items than winter-flooded rice fields (Naylor 2002, Matthews et al. 2022), and moist-soil seeds also contain essential nutritional components not provided by waste grains (Fredrickson and Reid 1988).

Other Floodplain Wildlife

In phase 1, the Floodplains Reimagined Program focused on a few wildlife species and groups that directly addressed program objectives and were likely to be immediately affected by actions to increase floodplain connectivity in the program area. However, there are many other wildlife species of conservation interest in the area that could be considered in future phases of the program.

Special-status species are those plants and animals listed, proposed for listing, or candidates for listing as threatened or endangered by the U.S. Fish and Wildlife Service (USFWS) under the federal ESA; those listed or proposed for listing as rare, threatened, or endangered by the CDFW under the California Endangered Species Act (CESA); animals designated as "Species of Special Concern," "Fully Protected," or "Watch List" by the CDFW; and plants with a California Rare Plant Rank (CRPR) of 1, 2, 3, and 4. The following are the primary special-status animal species expected to be present within the program area and their special-status designations.

- Valley Elderberry Longhorn Beetle (*Desmocerus californicus dimorphus*) – Federally Threatened
- Green Sturgeon – Southern Distinct Population Segment (*Acipenser medirostris*) – Federally Threatened
- Central Valley Steelhead – Distinct Population Segment (*Oncorhynchus mykiss*) – State Species of Special Concern and Federally Threatened
- Sacramento River Winter-Run Chinook Salmon – Evolutionarily Significant Unit (*Oncorhynchus tshawytscha*) – State and Federally Endangered
- Central Valley Spring-Run Chinook Salmon – Evolutionarily Significant Unit (*Oncorhynchus tshawytscha*) – State and Federally Threatened
- Central Valley Fall/Late Fall-Run Chinook Salmon (*Oncorhynchus tshawytscha*) – State and Federal Species of Special Concern
- Giant Garter Snake (*Thamnophis gigas*) – State and Federally Threatened
- Northwestern Pond Turtle (Actinemys marmorata [= Emys marmorata marmorata]) – State Species of Special Concern
- Swainson's Hawk (*Buteo swainsoni*) – State Threatened
- Tricolored Blackbird (*Agelaius tricolor*) – State Threatened
- Yellow-Billed Cuckoo, Western U.S. Distinct Population Segment (*Coccyzus americanus occidentalis*) – State and Federally Threatened
- Bank Swallow (*Riparia riparia*) – State Threatened
- Burrowing Owl (*Athene cunicularia*) – State Species of Special Concern
- Tule Greater White-fronted Goose (*Anser albifrons elgasi*) – State species of Special Concern

In addition to these special-status species, there are other wildlife species and groups of conservation interest that could be considered in future phases of the program. For example, these include a subset of waterfowl, shorebirds, and other waterbird species that rely on habitat in the program area during the breeding season (especially April–July) and have distinct habitat needs from the non-breeding season habitats considered in Phase 1 (CVJV 2020, Shuford and Dybala 2017, Strum et al. 2017). In addition, there are landbird focal species selected as indicators of ecosystem health that nest in riparian, grassland, and oak savannah habitats which could be affected by more frequent flooding in the program area (CVJV 2020; DiGaudio et al. 2017; Dybala, Clipperton et al. 2017a). Inclusion of more species in future phases would allow a more comprehensive consideration of the effects of actions in the program area.

Land Use

There are three main types of land use in the Butte, Sutter, and Colusa subregions: agriculture, wetlands, and recreation. The three land uses frequently intersect and are compatible in their implementation. This section will outline the existing conditions of each type of land use in the Program footprint.

Within the almost ½ million-acre footprint, the land use is dominated by agriculture (72%) and managed seasonal wetlands (16%). Recreational activities coincide with both agriculture and wetlands. Within the Floodplains Reimagined region, 33% of the lands have recreational hunting on them, and of those recreational hunting lands, rice fields make up 66% and wetlands make up 33%.

Agriculture is comprised of rice (44%), perennial crops (22%), and other various row crops and pasture lands (34%). When comparing the agricultural crops and related water sources in Butte, Sutter, and Colusa basins, Butte Basin and the Sutter Bypass grow a comparatively higher percentage of rice, which is more reliant on surface water supplies. Colusa Basin grows a comparatively higher percentage of perennial crops, which are more reliant on groundwater supplies.

Managed seasonal wetlands include both public and private lands. Public lands include the State Wildlife Areas and National Wildlife Refuges. Private seasonal wetlands include duck and goose hunting clubs and private wetland reserves. These wetlands provide ecological services to various species including salmon and birds. For example, the wetlands provide important foraging habitat for Pacific Flyway populations and habitat for other aquatic and terrestrial species. Similar ecological services for birds are also provided by flooded rice fields in the winter. Managed wetlands are also used for recreational hunting which will be addressed in the recreation section below.

Agriculture

The Floodplains Reimagined participants included the following objectives in support of the Agriculture Priority:

- Maintain planting, growing and harvest seasons
- Maintain or improve agricultural water supply and quality
- Do no harm to existing property and water rights
- Limit actions to voluntary measures

Within the region, preservation of agriculture is important to the livelihood of landowners and land managers and local and state economies. This livelihood can be challenging from year to year and highly variable between and within each subregion due to the frequency, timing, and duration of natural floods; ability to perform needed maintenance activities and timing to start field preparation activities; reliability of water supplies; and changing economics. Frequent and

prolonged inundation from flooding can be problematic for farming, especially late season flooding. Flooding increases the need for maintenance due to sedimentation and colonization of invasive aquatic weeds in canals, erosion of access roads and berms, sedimentation and establishment of woody vegetation within fields, and damage to water control infrastructure. Flooding and inadequate drainage can push planting later into the year, which can result in reduced yields, further compounded by increased risk to crops at time of harvest. There are also concerns that annual flooding can impact soil health and results in the potential for long-term degradation of the microbial community and soil nutrients and thus affect yields. As such, one of the highest priorities stressed by farmers is the importance of being able to get into the field to plant (i.e., having adequate time for the fields to drain and dry before planting).

The Floodplains Reimagined area includes cultivated agricultural land that supports wildlife (e.g., foraging habitat. Phase 1 multi-benefit explorations did not focus on other agriculture types such as orchard and vineyard, which provide lower quality habitat and are less compatible with flooding. Rice is the dominant crop among the multiple crops grown within the program area. Rice is unique among the other major crops in the county because it is grown in flooded fields that resemble and provide some of the same ecological services as a freshwater emergent wetland. Serving as surrogate wetland habitat, rice fields provide breeding and wintering habitat for waterfowl, shorebirds, and other wildlife (CVJV 2020). Rice habitat also provides food resources and habitat cover for some reptiles, amphibians, and mammals. It may also provide food resources for rearing juvenile salmon, depending on juvenile presence, access opportunities, and export conditions.

Depending on the hydrologic year type, rice fields are aimed to be prepared in March and flooded and seeded in April (this schedule may be shifted in the event of a wet spring). From April through August, when most seasonal wetlands in the Central Valley are dry, rice fields continue to hold water, as the rice grows to a height of about 3 feet. In September, the fields are drained, and the crop is harvested; though, some are also flooded after harvest to decompose rice straw (Brouder and Hill 1995). Additionally, the water released from rice fields is reused to flood nearby wetlands (Ducks Unlimited 2017). In total, the rice fields can be flooded for up to 8 months of the year, during which time the fields become temporary wetlands. Consequently, rice fields provide extremely important habitat for several species and provide functions historically offered by historic wetlands.

Other cultivated agricultural land within the Floodplains Reimagined area includes field crops, grain and hay crops, irrigated row crops and orchards. Field crops include irrigated herbaceous crops like safflower, corn, and sunflower, some of which provide important habitat benefits. Grain and hay crops differ from field crops because many, but not all, are not irrigated and they can resemble California prairie in general structure. Grain and hay crops consist of species such as barley, oats, and wheat. Irrigated row crops involve intensive agricultural operations to produce food and landscaping plants. Irrigated row crops are fruits or vegetables that can be planted in rows to grow on a relatively large scale for transport to distant markets. Irrigated row crops include tomatoes, asparagus, melons, squash, cucumbers, onions, strawberries, and peppers. These crop types provide foraging habitat for wildlife species such as the red-winged blackbirds and small mammals.

Wetlands

Much of the wetland habitat remaining in the Central Valley is provided by a network of managed seasonal and semi-permanent wetlands on public and private lands, such as wildlife refuges and duck clubs, supplemented by agricultural fields that landowners choose to flood post-harvest, especially rice fields (CVJV 2020). Most wetlands are managed seasonal wetlands, in which hydrology is managed to provide suitable habitat, especially for waterfowl during the nonbreeding season, access for hunters and wildlife watchers, as well as maximize the production of moist-soil seeds as food for ducks and minimize the growth of unfavorable plants. Managed seasonal wetlands are typically inundated from early fall to late winter or spring, allowing for a dry period over summer during which wetland plants can germinate and grow (Reid et al. 2018). The timing of when water is drained from these wetlands in spring or summer has a major influence on what plant species become established (Heitmeyer et al. 1989).

Recreation

The Floodplains Reimagined participants identified the following objectives in support of the Recreation Priority:

- Maintain or improve recreational hunting opportunities for waterfowl hunting clubs and conditions
- Do no harm to existing property and water rights
- Limit actions to voluntary measures
- Maintain or improve public and private access

This section will outline the private and public recreational hunting conditions in the region. These conditions are the starting point for any potential multi-benefit solutions that could maintain or improve recreational hunting and meet other identified objectives.

Recreational hunting and wildlife habitat within the Central Valley are closely linked since wetlands are often maintained with the intention of providing public and private hunting opportunities. Together, public and private landowners expend a tremendous effort to ensure wetland habitats are productive to support waterfowl and other species, while simultaneously ensuring these areas are accessible to recreational hunters primarily October through January.

Private Wetlands

Private groups currently own and maintain approximately 66% of the Central Valley's 120,000 hectares acres of seasonal wetlands, many of which are used as duck clubs (Gilmer et al. 1982). Much of the public land within the region is also managed to support waterfowl, with both State and Federal lands providing waterfowl hunting and wildlife viewing opportunities (Gilmer et al. 1982; Kramer and Helvie 1983). In addition to managed wetlands, winter-flooded rice fields provide private recreational hunting opportunities through hunting lease agreements. Some private lands are in permanent conservation easements for recreational hunting, while others utilize the land for these purposes only in the non-agricultural season.

Many private wetland owners aim to maximize the benefits their wetlands provide waterfowl to improve hunting opportunities. These efforts have been supported by research examining the effects of wetland management strategies on the production of waterfowl foods, and results

have been distilled into management guidebooks and made available to interested wetland managers (Rollins 1981, Fredrickson and Taylor 1982, Smith et al. 2003). Wetland managers typically combine general management guidelines with the system and conditions their wetlands encounter to build hyper localized best management practices. This process has generated wetland managers with a wealth of experiential knowledge on wetland management within the context of the area they work in.

Public Wetlands

There are six staffed public land areas within the region. Five of these public lands are in the National Wildlife Refuges and one is a designated Wildlife Area. These public lands record waterfowl hunter use, which on average provided 26,782 hunter days each waterfowl season (mean hunter days over a three-year period, 2020-2023).

Current wetland management efforts within the project area allow the region to continue to support goal level populations of ducks and geese or recreational hunting.

The Sacramento National Wildlife Refuge Complex is comprised of five National Wildlife Refuges and three Wildlife Management Areas. These areas provide the public with access to lands for waterfowl hunting, seasonal trails, and limited wildlife viewing, while also supporting wintering populations of more than 175,000 ducks and 50,000 geese (Visit Yuba Sutter 2022). The state of California also manages lands within the project area for fishing, hunting and wildlife viewing, including the Sutter Bypass Wildlife Area, operated by California's Department of Fish and Wildlife.

The Sutter Bypass Wildlife Area was designated as a wildlife area by the Fish and Game Commission in 1968. It consists of the Tisdale Bypass and two long, narrow parcels on either side of the Sutter Bypass, for a total of approximately 3,200 acres. This area is managed by the CDFW for fishing, hunting, and wildlife viewing.

Flood Control

Floodplains Reimagined participants identified the following objectives to support the Flood Control Priority:

- Respect flood management functions, including operations and maintenance so that scenarios are flood management neutral or flood positive

The existing flood control conditions are critical to informing potential multi-benefit options for future management of the region. This section describes key features of flood control management in the region and infrastructure.

Infrastructure

The Sutter Bypass is a major flood relief conveyance facility used to divert and convey flood flows from the Sacramento River and surrounding areas. The Sutter Bypass also receives and conveys flood flows from natural runoff originating from the Butte Sink Overflow Basin (including Butte Creek, Cherokee Canal, and Butte Slough), as well as drainage from the east near Yuba City through Wadsworth Canal and pumping plants. The Sutter Bypass is a man-made channel which overlays historic floodplain areas. It starts at the south side of the Sutter Buttes, near

Highway 20, and continues south to Fremont Weir just north-east of the City of Woodland. The Sutter Bypass is about 35 miles long and spans from about 4,000 feet to 6,200 feet.

The Tisdale Weir is a flood relief structure operated by DWR, which diverts flood flows from the Sacramento River, conveys them east through the Tisdale Bypass, and discharges into to the Sutter Bypass. The Tisdale Weir is located on the east bank of the Sacramento River, between the City of Woodland and the City of Colusa. The Tisdale Bypass is approximately 4 miles long and 1,000 feet wide.

The Sutter and Tisdale Bypasses are part of the Sacramento River Flood Control Project (SRFCP) and therefore considered to be SRFCP facilities. The project is defined in the State Plan of Flood Control Descriptive Document (DWR 2022) as *"Collectively, the facilities, lands, programs, conditions, and mode of O&M for the State- federal flood protection system in the Central Valley."* The SRFCP was originally authorized by the Flood Control Act of 1917. This act made the flood system along the Sacramento River and its tributaries including most of the levees, weirs, control structures, bypass channels, and river channels known as the SRFCP part of the SPFC. These SPFC facilities within the bypasses include levees, channels, canals, sloughs, weirs, water control structures, and several PPs.

The Central Valley Flood Protection Board is the state agency that acts as the non-federal sponsor for the SRFCP and has provided assurance agreements to the federal government to operate and maintain SPFC facilities. More specifically, the Central Valley Flood Protection Board is the governing body and landholder of the Sacramento – San Joaquin Drainage District (SSJDD), responsible for permitting encroachments to the SRFCP facilities[1], and delegated responsibility to operate and maintain facilities to state and local maintaining agencies. Maintaining agencies are responsible for performing routine maintenance, and working with the State and Federal government to take on major repair projects. The O&M of SPFC facilities was divided among state and local maintain agencies, such as Reclamation Districts (RD), and DWR.

The Butte basin serves as a major overflow basin for the Sacramento River during flood flows, with overflows into the basin occurring through a series of natural overflow areas and engineered weirs. These include natural overflow areas M&T, 3 B's, and Goose Lake and engineered weirs at Moulton, Colusa, and Tisdale weirs.

Upstream from the overflows, the Sacramento River has a channel capacity of 260,000 cfs. The channel capacity systematically decreases downstream as water is spilled into the Butte Basin: to 160,000 cfs downstream from the natural overflows, to 135,000 cfs downstream from Moulton Weir, to 65,000 cfs downstream from Colusa Weir, and finally to only 30,000 cfs below Tisdale Weir. The natural overflows have the capacity to spill 100,000 cfs into the Butte Basin, and Moulton, Colusa, and Tisdale weirs have spill capacities of 25,000 cfs, 70,000 cfs, and 38,000 cfs, respectively. Thus, the majority of Sacramento River flood flows are diverted through the Butte Basin and ultimately into Sutter Bypass, which has a channel capacity of 180,000 cfs

[1] In accordance with California Code of Regulations, Title 24

upstream from the Feather River. For further information on facilities and channel capacities, refer to the State Plan for Flood Control Descriptive Document (DWR, 2022).

The overflow weirs begin spilling into the Butte Basin at different flow levels, reflecting the downstream decreases in channel capacity of the Sacramento River. As flows rise on the Sacramento River, weirs begin activating from downstream to upstream, with Tisdale spilling first, then Colusa, then Moulton, and finally the natural overflows, depending on the specifics of the flood hydrograph.

The Colusa Basin does not provide flood release for the Sacramento River and instead collects floodwaters from the westside tributaries and conveys said floodwaters south via the Colusa Basin Drain with support from a SPFC levee on its left bank. At Knights Landing, and when river levels are low, floodwaters can pass back to the Sacramento River via the Knights Landing Outfall Gates (SPFC facility), otherwise they continue down the Knights Landing Ridge Cut (SPFC facility) and through Wallace Weir into the Yolo Bypass.

Bypasses

Both the Sutter and Tisdale bypasses convey flood flows away from agricultural lands, towns, and residences. The bypasses are leveed on either side to provide flood protection to the adjacent lands. The capacity of the Sutter Bypass channel increases from the upstream to downstream end to accommodate the addition of flows from contributing areas as well as overflows from the Sacramento River. The U.S. Army Corps of Engineers requires that channels that are part of the SRFCP pass design flood flows for stages at or below the 1957 Revised Profile Drawings (DWR 2022). California Department of Water Resources Sutter Maintenance Yard is responsible for maintenance of both Sutter and Tisdale Bypasses.

Levees

The Sutter Bypass levees were constructed by excavating material from the adjacent area within the bypasses to provide levee fill material. In general, the levees were constructed by varying local entities (DWR 2022) and have been reconstructed/regraded by the U.S. Army Corps of Engineers to provide six feet of freeboard at the design capacity.

Per the SPFC descriptive document, the State operates SPFC facilities in the Sacramento River Basin based on the design 1957 profile rather than on design flows from the O&M manuals, therefore channel capacity, elevation and freeboard requirements need to be maintained at those levels.

Indigenous Cultural Values

The representatives of the First Nation Tribes who participated in the Floodplains Reimagined Program Phase I, identified the following objectives to support Indigenous Cultural Values:

- Improve accessibility for indigenous peoples to grounds for ceremony, as well as the gathering of traditional vegetation and wildlife during desired seasons
- Do no harm to existing property and water rights
- Limit actions to voluntary measures

It is critical for the First Nation Tribes to understand the current conditions of indigenous cultural resource be able to evaluate improvement in relation to any potential management options. This section describes the existing conditions at a high level. The representatives who participated cautioned that they would like to make their own evaluation of potential benefits and effects in relation to sensitive cultural resources. Should a project be proposed, the First Nation Tribes strongly encouraged any project proponents to enter consultation early.

For time immemorial, California native people have lived with, depended upon, and cultivated salmon as a primary component of an interconnected lifestyle. After a terrible period of forced and often violent removal from ancestral lands and waters, the California native people of the Sacramento Valley do not enjoy their access to ancestral lands. These tribes are contributing to and could contribute further to the stewardship of their ancestral lands and waters.

The Program chose to cast a wide net to notify and invite tribal representatives from tribes with interests in the region. Participating tribal representatives with ancestral lands in the region have included: Yocha Dehe Wintun Nation, Konkow Valley Band of Maidu, and Mechoopda Indian Tribe.

Participating representatives contributed to the development of the objective to improve accessibility for indigenous peoples to grounds for ceremony, as well as the gathering of traditional vegetation and wildlife during desired seasons. This objective underlines the existing condition of limited tribal access and ownership of ancestral lands and river corridors. Tribes shared they do not have access to much of the riparian corridors and lands where some of their traditional practices for gathering, ceremony, and stewardship are rooted. Land ownership and access also affects the authority of the Tribes to collaborate as equal partners. While the Program Team invited Tribes to participate as in the Washington State Yakima Integrated Basin Planning model, the local tribal representatives highlighted that a critical difference is that the Yakima Nation enjoys significant ownership and legal authority in the Yakima Basin. This enables them to lead watershed planning and restoration.

Existing efforts between tribes and non-governmental organizations intend to increase tribes' access for ceremony and gathering, protect cultural resources, and employ indigenous traditional stewardship practices. These efforts could be expanded so that tribes can more fully bring the value of their nation-to-nation partnership and stewardship to the watershed planning efforts.

Priorities for Future Phases

The Floodplains Reimagined Program assessed existing conditions and explored opportunities in relation to the above priorities. The Program Team and participants identified a subset of Priorities to address in future phases. These include:

- Economic Prosperity
- Community Way of Life
- Greenhouse Gas Emissions

Economic Prosperity

The Floodplains Reimagined participants identified the following objectives to support the Economic Prosperity Priority.

- Minimize costs of project
- Reduce cost of future operations and maintenance by reducing human intervention through the utilization of natural infrastructure where possible
- Increase multi-benefit floodplain workforce and scale the flood control and water management workforces appropriately

The region's economic prosperity relies mainly on agricultural rice production, followed by orchards and row crops. Waterfowl hunting clubs provide economic benefit to the county through property taxes, employment, and visitor and resident spending. Financial incentive programs provide income to landowners in return for conservation stewardship practices related to habitat, soil, and wildlife management. The funding sources include federal, state, and non-governmental dollars.

Economic prosperity is driven largely by water supply availability and regulation which are at least somewhat outside of the regional communities' control. These external drivers then affect the priorities of agriculture, recreation, and water supply. Therefore, the Program has chosen to focus on the existing conditions measurement of benefit in relation to those priorities as proxies for the Economic Prosperity Priority.

Community Way of Life

Participants accepted addressing this in future phases. The supporting objective to preserve and build local water management could be strategically developed around any future multi-benefit management options.

Greenhouse Gas Emissions

Participants decided to address this Priority in future phases once they have a better understanding of preliminary concepts that could be evaluated for comparative greenhouse gas emissions.

Conclusion

The Colusa, Butte and Sutter subregions are a complex and interwoven area of nearly half a million acres in size, where wetlands, riverine habitats, farms, and wildlife refuges form a diverse range of land uses. Evaluation of the landscape, management, and uses provides a basis for understanding the Priorities identified by the Floodplains Reimagined participants. Evaluation criteria were developed to measure the potential outcomes of the solutions against Phase I Priorities and related objectives to guide the development of multi-benefit solutions. The process of this development revealed scientific uncertainties and data needs that could significantly inform the measurement of potential outcomes. These will be discussed in Section 3: Exploration of Possibilities. The Program will work towards collaboratively and independently investigating these scientific uncertainties and data needs through analysis and study. The

resulting science will be used to update the Evaluation Criteria and Metrics used to measure the potential outcomes of multi-benefit solutions.

Science Report

SECTION THREE

Phase 1 Report

3

Section 3: Exploration of Possibilities

This section describes the Floodplains Reimagined framework and approach, including the teams that undertook the work. The Program Team is responsible for management. The Technical Team refers to the consultant team of engineers, biologists, and ecologists supporting development and analysis of concepts. The Facilitation Team refers to the independent facilitators who convene and document discussions.

Floodplains Reimagined was developed in recognition that supporting salmon recovery is critical to maintaining local voluntary water management of the region. This region supports the salmon's juvenile rearing life stage, during which young fish need a good place to grow and enough food to eat. The exploration of multi-benefit possibilities focused on two types of concepts to improve the juvenile life stage: 1) juvenile rearing habitat and 2) fish food production. Phase 1 explored the benefit of these concepts for juvenile salmon. It also evaluated compatibility with birds, agriculture, managed wetlands, and recreational waterfowl hunting.

Framework

Priorities and Objectives

The priorities and objectives developed in Floodplains Reimagined Program Phase I are used as an organizing framework for this Phase I Report. The Phase I Priorities are provided in Table 3.1.

Figure 3.1

FLOODPLAINS REIMAGINED MEMBERS ARE GUIDED BY 9 PRIORITIES

in the following sectors to remain focused on our purpose and process.

Agriculture

Evaluation Criteria	Objectives
Landowner Willingness	• Do no harm to existing property and water rights. • Limit actions to voluntary measures.
Agricultural Compatibility Evaluation Criteria	• Maintain planting, growing, and harvest season • Maintain or improve agricultural water supply and quality

Ecosystem Health

Evaluation Criteria	Objectives
Zooplankton Production and Export Evaluation Criteria Juvenile Salmon Habitat Suitability Criteria	Increase the frequency, duration, and spatial extent of inundation within the FR geographic areas to stimulate production of invertebrates to provide habitats for rearing when juvenile salmon are migrating through the area.
	Improve sediment dynamics.
Zooplankton Production and Export Evaluation Criteria	Improve the ecosystem health of the floodplains including riparian habitat throughout the FR geographic area during varying flow conditions, where and when appropriate.
	Decrease invasive vegetation including in channel maintenance areas to prevent fish kills and localized backflow flooding.

Figure 3.1

Flood Control

Evaluation Criteria	Objectives
Landowner and Manager Willingness	Respect flood management functions, including operations and maintenance so that scenarios are flood management neutral or flood positive.

Floodplain Connectivity

Evaluation Criteria	Objectives
Juvenile Salmon Habitat Suitability Criteria	Increase hydrologic connectivity between the FR geographic area and the Sacramento and Feather rivers to provide access onto and off-of the floodplain for juvenile salmon.
Various Contributing Evaluation Criteria	Improve long-term, independently sustainable holistic floodplain connectivity.

Floodplain Wildlife

Evaluation Criteria	Objectives
Zooplankton Production and Export Evaluation Criteria	Increase the frequency, duration, and spatial extent of inundation within the FR geographic areas to stimulate production of invertebrates to provide habitats for rearing when juvenile salmon are migrating through the area.
Juvenile Salmon Habitat Suitability Criteria	Improve juvenile access to functional habitat.
	Reduce fish passage impediments to adult fish passage.
Birds Habitat Suitability Criteria Managed Wetland and Waterfowl Hunting Evaluation Criteria	Improve Pacific Flyway bird populations (including waterbirds, shorebirds, and migratory birds) using the floodplain.

Figure 3.1

Recreation

Evaluation Criteria	Objectives
Landowner Willingness	• Do no harm to existing property and water rights. • Limit actions to voluntary measures.
Managed Wetland and Waterfowl Hunting Evaluation Criteria	• Maintain or improve recreational hunting opportunities for duck and goose clubs.
	• Maintain or improve public and private access for wildlife viewing and hiking.

Indigenous Cultures

Evaluation Criteria	Objectives
Landowner Willingness	• Improve accessibility for indigenous peoples to grounds for ceremony, as well as the gathering of traditional vegetation and wildlife during desired seasons.
Indigenous Tribes Willingness	• Do no harm to existing property and water rights. • Limit actions to voluntary measures.

Water Quality

Evaluation Criteria	Objectives
	Improve water quality.

Water Storage

Evaluation Criteria	Objectives
Landowner and Manager Willingness	Improve groundwater supply reliability and maintain groundwater supply by diversifying and coordinating regional water supply management.

Approach

The Floodplains Reimagined participants established nine Phase I Priorities and related objectives to guide the development of potential multi-benefit solutions. They developed evaluation criteria to measure the potential outcomes of the solutions against these priorities. The process of this development revealed scientific uncertainties and data needs that could significantly inform the measurement of potential outcomes. The Program will work towards collaboratively and independently investigating these scientific uncertainties and data needs through analysis and study. The resulting science will be used to update the Evaluation Criteria and Metrics used to measure the potential outcomes of multi-benefit solutions.

This set of priorities and evaluation criteria informed the Program's measurement of the benefits of existing conditions and a set of preliminary concepts for multi-benefit solutions.

In Phase I, the Floodplains Reimagined Program Team took steps to examine a handful of initial preliminary concepts, potential benefits, and impacts. The team took the following approach to produce the results described in this section:

1. **Priorities and Objectives**
2. **Evaluation Criteria related to Priorities & Objectives**
3. **Baseline Results** — Examination of baseline conditions and identification of key influences on the Program's Priorities
4. **Preliminary Concepts** — Proposed an initial set of preliminary concepts in each basin for exploration of different types of feasibility and benefits. Included concepts study and assessment of potential concepts.
5. **Hydrologic Feasibility** — Examined an initial set of proposed preliminary concepts in each basin for different types of feasibility. Hydrologic feasibility — Analysis of water movement across the landscape and feasibility of preliminary concepts
6. **Landowner Feasibility** — Collected feedback from landowners regarding concepts they are open to exploring.
7. **Benefits Results** — Evaluated the initial set of proposed preliminary concepts in each basin for their benefits to the Program's Priorities and Objectives. This evaluation used the Evaluation Criteria discussed in the next section. This evaluation also included benefits derived from study and assessment of potential concepts.

Engagement

Critical to successful engagement, the Program used a "meet people where they are" approach. The voluntary effort principal necessitated that the Program Team create a forum that fostered collaboration. The landowner willingness principle served as a governing criterion for performance of concepts. The Program Team presented draft concepts and solicited input from a broad array of participants representing a range of interests. They then incorporated and built the evaluation criteria, preliminary concepts, baseline, and evaluation of benefits based on participant input.

The Technical Team began building evaluation criteria based on related efforts. The Ad-Hoc Groups discussed supporting science, refined metrics, thresholds, and weighting. They also identified potential future evaluation criteria, data gaps and uncertainties.

The Technical Team developed the evaluation criteria in the Ad-Hoc Groups in collaboration with subject matter experts and interested participants. The groups compared baseline conditions with the potential benefits and impacts of preliminary concepts on each of the Program's priorities and objectives, and evaluation criteria. The Ad-Hoc Group members shared their expertise to support collaborative formulation of the proposed evaluation criteria. The proposed evaluation criteria were presented to the Advisory Committee for recommendation and the Steering Committee for approval. Though the process produced a high level of collaboration and agreement, the process did not require consensus to advance. The Floodplains Reimagined Program Charter requires the documentation of participants' different viewpoints when they cannot reach agreement.

Tools and Technical Approach

The Technical Team developed a conceptual framework to demonstrate the pathways and connections between the various data, models, evaluation criteria, and metrics. The metrics produced by these tools will be used to understand conditions within the Region for baseline conditions and for future proposed preliminary concepts. The Program developed the evaluation criteria using both qualitative and quantitative approaches.

The models and tools implemented in Phase I of the Program were used to evaluate the existing conditions and preliminary concepts to meet priorities and objectives for 1) baseline key influencing factors, 2) feasibility, and 3) benefits and impacts. The different models' purposes are described below and in further detail in corresponding Appendices of Technical Memoranda.

- Hydrodynamic Model — *The primary tool used to describe the way that water moves through the physical landscape is a hydrodynamic model which produces water depth, velocity, including inundation duration information, in both space and time (Appendix)*
- Salmon Benefits Model — *The model simulates the benefits to salmon. The results from the hydrodynamic model served as inputs for the salmon benefits model (Appendix)*
- Bioenergetics Models — *These models simulate food availability for waterfowl and shorebirds (Appendix)*
- Multiple Hydrospatial [2]Approaches — *Hydrospatial approaches were used in each of the Evaluation Criteria outlined in the next section.*

Evaluation Criteria

The Program developed a suite of Evaluation Criteria to evaluate performance of proposed concepts and scenarios. In particular, the Evaluation Criteria are directed at the landowners,

[2] The term hydrospatial is an adjective whose meaning is about data, information and knowledge in the water and contiguous environment.

water managers, and species managers who need the evaluation of benefits in making decisions about management.

Note the following caveats around the evaluation criteria. These are discussed in more detail in Appendices for the Technical Memoranda on the evaluation criteria.

The following summarizes the Evaluation Criteria developed and approved in Phase I. To review the outstanding divergence of viewpoints around these criteria, please see the Appendices for the Technical Memoranda on the criteria.

It is important to note that at this time, participants are not committing to abide by the boundaries of the criteria; only using the criteria to predict and evaluate benefits. Should such inundation programs be implemented, there may be variation of operational guidelines from the evaluation criteria.

Feasibility criteria are used to establish the feasibility of the concept and include:

- Hydrologic Feasibility – Feasible from an engineering perspective.
- Landowner Willingness – Serves as the governing criteria for opportunities.

Evaluation Criteria measure the benefits and compatibility of concepts in relation to the Program Priorities and Objectives.

- *Juvenile Salmon Habitat Suitability Criteria (Appendix)*
- *Birds Habitat Suitability Criteria (Appendix)*
- *Secondary Productivity (Zooplankton) Production and Export Evaluation Criteria (Appendix)*
- *Managed Wetland and Waterfowl Hunting Compatibility Evaluation Criteria (Appendix)*
- *Agricultural Compatibility Evaluation Criteria (Appendix)*

Juvenile Salmon Floodplain Rearing Suitability Criteria

Juvenile salmon floodplain rearing suitability criteria (Appendix) consider availability of habitat defined by season, depth, velocity, inundation duration, connectivity, and landcover. Seasonality was based on fish run presence in the region. The depth criteria relate to foraging behavior and predator avoidance. Shallow depths (< 7.2 inches) were considered unsuitable, and depths between 7.2 and 10.8 inches were considered sub-optimal suitability. Depths greater than 10.8 inches were given optimal suitability. Diverging viewpoints were documented concerning the possible inclusion of an upper suitability threshold of several feet, as upper depth thresholds are typically used for in-channel environments.

Informed by prior studies, the Technical Team set the velocity criterion at a threshold of 1.5 ft/s, where higher velocities were considered unsuitable (Whipple et al., 2019, DWR and USBR, 2012). Connectivity was an essential criterion for representing juvenile fish, potential ingress into inundated habitats and egress back to adjoining waterways. However, for the current Phase I of Floodplains Reimagined, the approach did not evaluate explicit evaluation of the ultimate connection to the river, and the length and condition of those connections were not evaluated by the app.

Optimal land cover type assumed that more natural landscapes, such as riparian and wetland habitats provide greater habitat complexity and biodiversity as compared to working lands, like

farm fields. In addition, working lands were considered sub-optimal to reflect the inherent challenge of managing for specific ecological conditions when not all variables are well known or easily controlled.

Bird Habitat Suitability Criteria

Bird habitat suitability criteria (Appendix) focused on shorebirds, waterfowl (like dabbling ducks), and Sandhill Crane. The Technical Team identified these as most likely to be affected by efforts to improve floodplain connectivity in the winter and spring. The bird habitat suitability criteria complement the bioenergetics models for waterfowl and shorebirds, allows the inclusion of Sandhill Crane, and facilitate comparisons across bird taxa. For each of these taxa, evaluation criteria were based on suitable land covers, flooding status and depth, and season, with date ranges representing the non-breeding season.

The criteria did not consider flood duration due to lack of information as to how birds respond to short duration inundation. Most of the wetland habitat in the Central Valley region is managed and thus has long inundation duration. The habitat value of short pulses of floodplain inundation is uncertain and may be overestimated.

Land cover criteria were based on studies that show managed and unmanaged wetlands and certain agricultural fields as suitable. All depth criteria for birds were defined as thresholds, meaning there were no marginally suitable depths considered. This decision was intended to avoid misinterpretations when comparing preliminary concepts relative to baseline conditions, such that changes in the amount of optimal habitat available would not be conflated with changes in the amount of marginal habitat.

Depth criteria were based on a combination of prior studies and participant feedback. The Technical Team took a conservative approach when considering multiple depth criteria to ensure that the bird habitat suitability criteria reflected the most optimal depths. Initially the Technical Team considered setting the maximum optimal depth for waterfowl between 10 and 18 inches. However, further evaluation led them to establish 12 inches as the optimal maximum depth because this is preferred foraging depth for dabbling ducks. For shorebirds, although some can forage at deeper depths, 4 inches was selected to represent most shorebird species. Two distinct habitat needs were considered for Sandhill Crane: roosting and foraging. The literature informed the recommendation of an 8-inch maximum for roosting. For foraging, dry and shallow habitats with less than 2 inches were considered, but only within proximity of less than 5km to known roost locations where foraging would occur.

Multi-benefit Relationship between Juvenile Salmon Rearing and Waterfowl Habitat Suitability Criteria

The Technical Team found opportunities for salmon and birds to have suitable habitat at various times at the same location. However, there are limited opportunities for simultaneous mutual benefits for juvenile salmon and birds in the same location, at the same time. Landscape scale multi-benefit solutions can support maximizing potential for different benefits in different locations at different times to improve benefits across the landscape.

The suitable depths for each species are the constraints for achieving suitable habitat at the same time in the same location. The overlap of suitable depths for both juvenile salmon and birds is 2 inches. This is based on maximum suitable depth for waterfowl of 12 inches and the minimum suitable depth for juvenile salmon of 7.2 inches only allows for a 4.8-inch range that is simultaneously suitable for both species. It is important to consider the fact that managed wetlands and winter flooded rice are the dominant land uses within the region. However, these habitats are only suitable for juvenile salmon when they are greater than 10 inches deep to ensure they can be accessed through any outlet structure. This further constraint results in a 2-inch overlap in suitable depths for juvenile salmon and birds. Juvenile salmon access opportunities could be further constrained on managed wetlands and winter flooded rice fields between late October through March.

Agricultural operations would further limit juvenile access opportunities on winter flooded rice from late October through February. The ability to deviate from these constraints depends on landowner willingness to participate in opportunities to achieve multi-species benefits that potentially consider enhancing river-floodplain connectivity or replicating conditions unique to the Butte Sink.

Secondary Productivity and Export Potential Criteria

These criteria address both production and export of food for juvenile salmon. Production refers to the growth of the zooplankton that juvenile salmon eat. Export refers to moving the fish food into the river where the juvenile salmon can eat it.

Secondary productivity refers to the zooplankton production, which is a food source for juvenile salmon, particularly in floodplain environments (Appendix). Floodplain inundation and draining drive productivity and the export of fish food laden waters to nearby waterways. Zooplankton production habitat depends on the presence of inundation, water age or residence time, and landcover.

The Technical Team used velocity and duration as a proxy for water age because the hydrodynamic model does not directly compute water age. The presence of still or slow-moving water for one to three weeks allows ecological and biological processes to establish high prey densities. The Technical Team used 10 days as the threshold between sub-optimal and optimal productivity.

There are diverging views around the comparative productivity of different land covers. There are different viewpoints around whether wetlands and rice fields can produce the same amount and quality of fish food. Studies suggest that wetlands have higher productivity due to the heterogeneity provided. Rice can be managed to obtain similarly high rates of secondary productivity but can require more time to achieve optimum productivity at varying success rates. For this phase of analysis, the Technical Team grouped rice and wetlands together for optimal cover because they are more alike than other cover types for the purpose of differentiating between optimal, sub-optimal, and no productivity.

The Technical Team also analyzed whether the fish food laden waters could be exported from location of origin to the river. Export can happen through the draining of managed wetlands and

winter flooded rice fields or by inundation moving over the landscape and back into the river. The evaluation criteria do not consider the fate of the fish food delivery to juvenile salmon in the Sacramento River. The Fish Food Inventory accounts for lands and their proximity to waterways with juvenile salmon. For more information, see the Studies Findings section of this report.

Agricultural Compatibility Evaluation Criteria

Agriculture compatibility evaluation criteria (Appendix) considered impacts to farming operations, namely the ability for farmers to plant their fields in a timely manner to avoid economic losses due to reduced yields by later planting dates. This necessitates having adequate time for fields to drain and dry in the spring before preparation and planting activities can commence without further disruption to the growing and harvest seasons.

To measure agricultural compatibility of different concepts, the Agricultural Compatibility Evaluation Criteria includes two criteria. These are: 1) cumulative number of wet field days after March 1 for Butte and Upper Sutter Bypass and Colusa, and March 15 for the Lower Sutter Bypass, and 2) the last day a field was considered wet, which is called the Last Day Wet.

The Technical Team based the criteria for agricultural impacts on agricultural economic analyses from previous planning efforts in the Yolo Bypass (Howitt et al., 2013; USBR and DWR, 2019, Appendix) and in the Sutter Bypass (River Partners, 2022). These previous analyses highlighted the importance of minimizing impacts due to late season inundation resulting in later planting dates and lower crop yields (Howitt et al., 2013), while accommodating a 34-day period for field drying and preparation (USBR and DWR, 2019, Appendix). In the Yolo Bypass, landowners selected a date of March 15 to minimize the operational impacts of the Fremont Weir Big Notch Project (USBR and DWR, 2019). In the Sutter Bypass, landowners downstream of Nelson Slough agreed to March 15 (River Partners, 2022), but landowners upstream of Nelson Slough opted for March 1 (RD 1500 and DWR, 2023) based on coordination with the Sutter Bypass Butte Slough Water Users Association (Section 3.2.4.1). Within the remainder of the region (i.e., Butte and Colusa Basins), landowners recommended using March 1.

Waterfowl Hunting and Managed Wetland Evaluation Criteria

Waterfowl hunting and managed wetland evaluation criteria (Appendix) considered impacts to recreational waterfowl hunting on managed wetlands and winter flooded rice, as well as impacts to wetland management after waterfowl season. The Technical Team categorized water depths on managed wetlands and winter flooded rice fields in order of increasing impact: no impact, bird use impact, access impact, and maintenance impact.

When fields were less than 12 inches deep, no impact was assigned since this corresponds to suitable depths for waterfowl (Appendix). When water was deeper than 12 inches, the field was classified as having impact on bird use, but only during the waterfowl hunting season. Access impacts were assigned when water levels exceeded the elevation of the berms surrounding the field units. Finally, maintenance impacts were assigned when water levels exceeded 6 inches above the field perimeter berms to capture the potential for damage to berms, roads, and water control infrastructure. Wetland hunting impact scores were calculated during the waterfowl hunting season. This season is 100 days long, beginning on the fourth Saturday of October and

lasting through two special hunt weekends in February. More heavily weighted impacts were assigned to peak hunting times, comprised of the first two weeks of the season, and December 7 to the end of the primary season. Managed wetland impact scores were calculated from the end of the hunting season to March 31 because the date is representative of the end of drawdown on managed wetlands.

Future Evaluation Criteria

The Floodplains Reimagined Program has identified the following Evaluation Criteria to be developed and updated.

- **[Update] Juvenile Salmon Habitat Suitability Criteria** – This is envisioned to include updates based on new science to resolve outstanding diverging viewpoints surrounding depth criteria and any distinction between land cover suitability.
- **[NEW] Food Web Production and Export Evaluation Criteria** – This is envisioned to include broader criteria for fish food production beyond zooplankton and more of the food web supporting juvenile salmon.
- **[NEW] Fate of Food Web and Benefits for Salmon** – This is envisioned to include criteria for suitable distance, timing, and manner of delivery of fish food. The criteria would address moving the fish food laden waters from off-channel production locations to the Sacramento River at locations and timing when juvenile salmon can eat it.

Salmon and Bird Models

The Program developed two models to further evaluate the benefits of options to juvenile salmon and birds. These include the Salmon Benefits Model and the Bird Bioenergetics Model. These are described in more detail in the technical memoranda in the Appendix.

Salmon Benefits

The Salmon Benefits Model evaluates options in relation to the effects on juvenile salmon. The analysis of effects on adult salmon is only a derivative of the effects on juveniles. The Salmon Benefits Model predicted no discernible change in benefits to juvenile salmon in response to the Moulton and Colusa Weir Operable Gates concepts. While juvenile salmon rearing habitat may be increased, and more overflow from the Sacramento River may create more juvenile rearing habitat, the juvenile salmon may not be present at the weir during overflow and never access the habitat. Accordingly, the model may not discern benefits to juvenile salmon despite the increased juvenile salmon rearing habitat.

Bird Bioenergetics

The Bird Bioenergetics Modeling effort evaluates options in relation to the effects on peak waterfowl food demand. The Program used the following assumptions to evaluate options.

Peak waterfowl energetic demand occurs in late November through early February, while peak food availability occurs in early October. Food resources in rice fields are quickly depleted once fields are inundated. This results in managed seasonal wetlands supporting most waterfowl food needs after mid-December. Natural inundation events can dramatically reduce the ability of the

project area to meet the food needs of waterfowl populations as water depths become too great, preventing foraging access.

Baseline Findings

This section will outline the key findings for baseline conditions which can be compared to estimated outcomes with the application of preliminary concepts. This section is organized by 1) Baseline Primary Influencing Factors and 2) Subregional Findings.

The engagement approach included presenting draft baseline assumptions and soliciting input from participants in various ways. Participants gave input on baseline during Advisory Committee, Ad-Hoc Group meetings, one-on-one meetings, and briefings at water associations and reclamation districts.

Baseline Primary Influencing Factors

Key findings of the existing baseline conditions of inundation patterns, habitat conditions, and land use impacts are outlined below. Understanding these existing conditions was the first step towards measuring potential outcomes.

The analysis showed three important factors influencing inundation patterns, habitat conditions, and land use impacts. The factors include: 1) proximity to primary waterways within the subregions, 2) water management on winter flooded rice and seasonal wetlands, and 3) connection between each field or management unit to the primary waterways.

First, proximity to the primary waterways is a crucial factor in determining inundation patterns, habitat conditions, and land use impacts. Proximity to primary waterways strongly influences depth variability in adjacent lands. Adjacent areas to waterways are typically lower-elevation seasonal wetlands and winter flooded rice fields open for waterfowl hunting. These lands tend to experience more frequent inundation by floodwaters, which results in greater depths being realized more frequently.

Second, greater depths influence habitat conditions. The lower end of the inundation range tends to benefit bird habitat and waterfowl hunting opportunities. Deeper inundation increases suitable juvenile salmon habitat and potential export of fish food to the Sacramento River.

Third, inundation patterns influence land use in that water on the fields can delay preparation of the soil for planting. More frequent flooding and greater depths of inundation decrease agricultural production. This is because prolonged inundation can delay drainage of rice fields when flooding occurs later than March 1 in the water year. March 1 is the general seasonal threshold when growers need to start drying their fields to prepare the soil for planting.

Baseline Subregional Findings

These findings are based on application of the Evaluation Criteria to existing conditions for different year types and each subregion.

Key baseline conditions findings for the subregions include:

1. Butte Basin existing baseline conditions already perform highly for juvenile salmon and bird habitat suitability. Baseline conditions show inundation on lands have variable positive and negative effects on agriculture and recreational waterfowl hunting.

2. Colusa Basin existing baseline conditions perform well for bird suitability habitat and low for juvenile salmon rearing. There are variable existing conditions positively and negatively affecting agriculture and waterfowl hunting.
3. Sutter Bypass Basin existing baseline conditions demonstrate variable bird suitability. There are diverging viewpoints about whether the Sutter Bypass juvenile salmon are limited by habitat availability. Some participants think that improved juvenile salmon habitat in the Sutter Bypass would significantly benefit juvenile salmon while others do not think it would make a significant difference.

Butte Subregion

The Butte basin is the largest of the three subregions. Under baseline conditions, this basin already provides the most suitable habitat for all floodplain wildlife under consideration. It also provides the largest food energy supply across the range of hydrological conditions modeled (Appendix).

Infrastructure in the Butte Sink allows water to flow through across properties downstream in Butte Creek. Water managers inundate a corridor of lands on the east side of Butte Creek and some of the west side. The water sources vary. This “flow-through infrastructure” promotes floodplain connectivity, which is one of the main limiting factors with regards to juvenile salmon floodplain rearing habitat suitability (Appendix).

The flow-through infrastructure and water management approach in the Butte Sink is a potential model for preliminary concepts because this type of water management approach provides the greatest flexibility and opportunity to meet multiple Program objectives. This infrastructure simultaneously provides suitable habitat for waterfowl and high levels of fish food as estimated by secondary productivity export potential. This is because the floodplains are directly hydraulically connected to Butte Creek. However, this high degree of connectivity does make the Butte Sink more prone to flooding, which in turn can negatively impact waterfowl hunting and wetland management. Flows can exceed manageable wetland levels and start to damage roads and infrastructure as well as impede access.

A large proportion of the Butte basin contains winter-flooded rice and public and privately managed seasonal wetlands. The analysis of baseline conditions demonstrated that, regardless of water year type, these land use types are associated with more suitable bird and juvenile salmon habitat and food supplies. Suitable habitat includes: 1) suitable conditions for waterfowl, shorebird, and Sandhill Crane (Appendix) reliable shorebird energy supply (Appendix) fish food as measured by secondary productivity of zooplankton (Appendix).

Comparison of Subregions

The Butte subregion provides the highest suitable habitat among the three basins for floodplain wildlife under evaluation including juvenile salmon and birds. Within the Butte subregion, the Butte Sink contains substantial areas of suitable bird and juvenile salmon habitat. It also provides conditions for fish food production measured by secondary productivity of zooplankton (Appendix). The largest impacts of natural flooding events were seen in the Butte Subregion as exemplified by a (50% reduction in area for foraging after January 2019).

Juvenile salmon

Juvenile salmon habitat enjoys better conditions in wetter years. In wetter years, Sacramento River overflows the weirs and carries juvenile winter-run Chinook into the Butte Sink in Butte Creek watershed. This inundation provides a suitable habitat for winter-run Chinook juvenile salmon to grow and rear in the Butte Creek watershed. In drier years, most of the suitable

habitat for juvenile salmon is confined to areas adjacent to Butte Creek. Note that there is a lack of access to that available habitat in dry years. This is because in dry years, Sacramento River weirs do not overflow and so it does not carry juvenile salmon into the Butte watershed. (Appendix).

Birds

For waterfowl bioenergetics, the Butte basin provides approximately 65% of the total food energy available to wintering waterfowl within the region, and varied less than Sutter, but more than Colusa from year to year (Appendices).

Agriculture

For agricultural impacts, the key factor was the timing of the floods due to the March start date. Greater agricultural impacts occur in years with late-spring/early-summer floods, with little to no agricultural impacts in other years.

Agricultural impacts increased in the direction of Butte Creek and downstream of Moulton and Colusa Weirs. However, the existing land use closest to Butte Creek are predominantly wetlands and thus were not evaluated for agricultural impacts.

Sutter Subregion

Because the Butte Basin drains into the Sutter Bypass, inundation occurs later in the water year, which increases agricultural impacts regardless of hydrologic conditions (Appendix).

Comparison of Subregions

The area within the Sutter Bypass downstream of the Tisdale Bypass is like the Butte Basin downstream of the Colusa Weir in terms of habitat and impact characteristics. These characteristics included increased juvenile salmon habitat suitability and decreased bird habitat suitability. The area also has similar agricultural, wetland, and hunting impacts. Baseline inundation impacts agriculture downstream of the Colusa Weir and the Lower Sutter Bypass. Impacts vary by year depending on the timing of flood pulses.

Like the Butte Sink, the Lower Sutter Bypass is frequently inundated while maintaining floodplain connectivity due to the backwater influence upstream from the confluence of the Sacramento and Feather Rivers and the Yolo Bypass.

Conversely, the Sutter Bypass is inherently different than the Butte and Colusa subregions due to its configuration as a flood bypass channel.

Juvenile Salmon

The flood bypass channel configuration leads to overall lower suitability for birds (Appendix) and higher suitability for salmon (Appendix). In drier years, there is little juvenile salmon rearing suitability because inundation is not maintained at suitable depths. Lands flood quickly and drain without providing extended suitable habitat for juvenile salmon on managed and unmanaged areas alike. The backwater-influenced Lower Sutter Bypass Reach inundates in drier years and provides consistent floodplain habitat for juvenile salmon (SWC, 2019). The habitat is short-lived because the area drains so quickly due to the high topographic relief. Therefore, the area does not sustain long periods of habitat suitability for juvenile salmon.

Fish Food

This configuration also yields greater productive fish food export potential per unit area since the Sutter Bypass inundates more completely during flood events than the Butte and Colusa subregions.

Birds

Like winter managed rice and managed wetlands in Butte and Colusa, managed rice fields in the Sutter Bypass were able to provide some suitable habitat to birds in all years, regardless of hydrologic conditions (Appendix). There were greater variations in habitat suitability, accessible waterfowl food resources, and land use impacts between years in the Sutter Bypass than in the Butte and Colusa Basins (Appendix). While the Sutter Bypass had the least variability in terms of shorebird bioenergetics and total bird-days supported, it was more variable than the other basins in the timing of accessible shorebird habitat throughout the non-breeding season (Appendix).

Recreational Waterfowl Hunting

Flooding events resulted in the largest proportional loss of hunting in the Sutter subregion.

Agriculture

The Lower Sutter Bypass region also experiences greater agricultural impacts due to baseline inundation than other areas in the Sutter Bypass due to backwater-influenced reach and fast draining.

Before the Floodplains Reimagined Program, other efforts already considered multi-benefit management concepts to improve ecological services, agricultural sustainability, and flood functions within the Sutter Bypass (RD 1500 and DWR, 2023; River Partners, 2022). Prior efforts coalesced around a portfolio like the preliminary concepts considered under this Floodplains Reimagined Program but in a manner that is unique to the Sutter Bypass more information is available in the Sutter Basin Butte Slough Water Users Association Management Plan available online at www.floodplainsreimagined.org.

Colusa Subregion

Under existing conditions, inundation of fields outside the river channel is confined to the area along the Colusa Drain, especially South of Highway 20. This Lower Colusa Drain area has high topographic relief, which constrains water laterally adjacent to the Colusa Drain.

Wetter years provided more suitable habitat but also resulted in more land use impacts. Drier years still provided suitable bird habitat and secondary productivity for fish food in managed areas like the Delevan National Wildlife Refuge.

Comparison Analysis

Baseline conditions in the Colusa subregion were like the Butte subregion in terms of variation in bird suitability, land use impacts, and secondary zooplankton productivity for fish food production (Appendix). The range of hydrologic conditions modeled produced similar results.

Juvenile salmon

Juvenile salmon habitat is sub-optimal under baseline conditions. Major investments have been made for several years to keep salmon out of Colusa Drain. Participants have expressed diverging viewpoints about whether the existing infrastructure, water quality, and habitat can or should be changed to support juvenile salmon being present in this basin.

Fish Food

Because the topography of the area tends to constrain inundation adjacent to the Colusa Drain, baseline conditions offer a constrained area of inundation to improve floodplain connectivity and its attendant wildlife. There is a potential to move water further from the channel out onto a larger area of land to increase the area of inundation and corollary benefits.

Birds

For shorebird bioenergetics, the Colusa subregion was the most variable in the number of bird-days supported across water years. This is because of variability in the existence and frequency of any spring flood pulses in different water year types (Appendix). While there was variability for shorebird bioenergetics, the Colusa Basin provided the most stable conditions for foraging waterfowl (Appendix).

Recreational Waterfowl Hunting

The Colusa subregion returned to target water depths following historic flood events slower than the other subregions.

Preliminary Concepts

Opportunities related to the priority of floodplain connectivity are categorized in four types including water's connection point from river to land, water conveyance, field management where the water spreads out, and finally improvement of function in the river itself.

The following describes the four different types of preliminary concepts the Program is exploring.

Preliminary Concept Types

1. **River Connections**
   Modification or addition of connections between the river and the floodplain such as operable gates at weirs
2. **Water Management Conveyance**
   Modification of water management infrastructure including ditches and canals that convey water from the connection from the river to the land
3. **Land Management**
   Management of wetlands and agricultural fields including field checks, boxes, drainage, roads
4. **In-river Function**
   Improve existing floodplain habitats within the river corridor

Enhancement Opportunities

These four preliminary types of concepts can be combined with any enhancement opportunities which could include:

1. Fish passage
2. Riparian habitat conservation and restoration
3. Groundwater recharge

The potential opportunities related to these types of concepts are further outlined in the Opportunities & Constraints Technical Memorandum available in the Appendix.

Phase I Preliminary Concepts

Throughout 2023, the Program Team worked to develop proposed concepts based on stakeholder identification of priorities, objectives, opportunities, and constraints. The engagement approach was for the Program Team to propose some preliminary concepts and

solicit feedback from the Advisory Committee. Then the Program Team would adjust the concepts and proceed through the steps of analysis outlined.

Phase I preliminary concepts explored several individual concepts and the impacts on hydrodynamics, demonstrating an increase in inundation. The preliminary evaluations of benefit suggest that the Program will need to produce a combination of these concepts to address multiple objectives in the same package. These combinations can allow for some areas to serve certain benefits at certain inundation conditions and other areas other benefits. In addition, the preliminary examinations have revealed that some fundamental scientific uncertainties are critical to examine in future phases.

Each concept is summarized in the following table and described further below. For more detail of the hydrologic feasibility and landowner willingness, and benefits of these concepts, please see the following sections.

Guide to Tables

The Phase I Preliminary Concepts are correlated to each of the four Preliminary Concept Types and identified by subregion or river corridor.

Table 3.2 / Phase 2 Preliminary Concepts by Type and Geography

Butte Subregion Colusa Subregion Sutter Subregion

	River Connections	Water Management Conveyance	Land Management	In-River Function
Preliminary Concepts Butte Subregion	Moulton Weir Operable Gate Colusa Weir Operable Gate	None in the Butte Basin at this time	Benden Farms Suite of Concepts: Fish Food Production on Fields	Benden Farms Suite of Concepts: Floodplain and Riparian Restoration
			Benden Farms Suite of Concepts: Juvenile Salmon Rearing on Fields	
			Benden Farms Suite of Concepts: Canal and Access Road Improvements	
Preliminary Concepts Colusa Subregion	New Water Diversion on Sacramento River at Delevan National Wildlife Refuge (NWR)	None in the Colusa Basin at this time	Fish Food Production on Managed Wetlands and Rice Fields	None in the Colusa Basin at this time
	Wallace Weir & Knights Landing Outfall Gates (KLOG) Modifications			
Preliminary Concepts Sutter Subregion	Sutter Bypass Suite of Concepts: Tisdale Weir Operable Gate Re-operation	Sutter Bypass Suite of Concepts: East-West Diversion Weir and Weir 5 Re-operation	Sutter Bypass Suite of Concepts: Juvenile Salmon Rearing on Rice Fields	None in the Sutter Bypass at this time
	Sutter Bypass Suite of Concepts: New Feather River operable gates to Lower Sutter Bypass	Sutter Bypass Suite of Concepts: Willow Slough Weir and Nelson Slough Weir Re-operation	Sutter Bypass Suite of Concepts: Fish Food Production on Rice Fields	

The section below describes each proposed concept for analysis. Concepts are organized by basin and then by the four preliminary concept types. The description includes the elements of the concepts and a brief note on approach for analysis.

Butte Subregion

- **River Connections**
  - **Moulton and/or Colusa Weir Operable Gates** –
    - **Objectives**: To improve opportunities for fish food production and juvenile salmon rearing along with other benefits.
    - **Elements:** Operable gates at Moulton and Colusa weirs to allow water to flow from the Sacramento River to Butte basin at lower river flows. This would include lowering the weir opening and making the gate operable. Applied hydrodynamic modeling to evaluate benefits at different river water levels for each weir independently and in combination.
- **Land Management**
  - **Benden Farms Suite of Concepts**
    - **Objectives:** The Benden Farms suite of concepts was developed with an individual landowner exploring possibilities for floodplain connectivity and wildlife on their own property while maintaining long-term viability of agriculture. The Benden Farms is located immediately downstream from Moulton Weir. It extends into the Sacramento River levee along the river corridor.
    - **Elements:**
      - **Canal and Access Road Improvements** — This concept includes culverts designed to allow for road access across three waterways that inundate and obstruct road access for long durations of time.
      - **Fish Food Production on Fields** — This concept includes overbank winter inundation to produce fish food and export fish food back into Butte Creek for juvenile fish.
      - **Juvenile Salmon Rearing on Fields** — This concept includes inundation from the Moulton Weir overflow onto Benden Farms fields, juvenile salmonids' residence time and growth on inundated fields, and export into Butte Creek.

- **In-River Function**
  - **Benden Farms Suite of Concepts**
    - **Floodplain and Riparian Restoration**
      - **Objectives:** To improve juvenile salmon habitat within the Sacramento River corridor inside the levee.
      - **Elements:** This concept includes land retirement to floodplain and riparian restoration.

Sutter Subregion

Sutter Bypass Butte Slough Water Users Association developed and refined the package, or suite of concepts, as part of the process for development of the Sutter and Tisdale Bypasses

Flood & Multi-Benefit Management Plan (Tisdale Management Plan). While Floodplains Reimagined has not discussed these concepts in the Advisory Committee yet, this report includes them for comprehensive review of the preliminary concepts under development to support salmon and meet multiple benefits.

Sutter Bypass Butte Slough Water Users Association landowners included these concepts in the Tisdale Management Plan and proposed the following concepts to the State of California for coverage under the Voluntary Agreements (RD1500 and DWR, 2023). The concepts are also included in the Lower Sutter Bypass Anadromous Fish Habitat Management Planning Project (River Partners, 2021).

The Tisdale Management Plan formulated and evaluated a suite of concepts integrating: 1) flood system management, 2) ecosystem enhancement, and 3) agricultural viability. The ecosystem enhancement opportunities focused on anadromous salmonids, waterfowl, shorebirds, and other water birds and included similar concept types as those described for the Floodplains Reimagined Program.

The suite of concepts includes river connections, water management conveyance, and land management. The land management concepts in the Sutter Bypass upstream of Nelson Slough depend on the water management conveyance concepts, and both water management conveyance and land management concepts are enhanced by the river connections.

- **River Connections**
  - **Moulton and/or Colusa Weir Operable Gates**
    - **Objectives:** To increase opportunities for increased juvenile salmon access and habitat.
    - **Elements:** This concept includes installing operable gates at Moulton and/or Colusa Weirs.
  - **Tisdale Weir Operable Gate Re-operation**
    - **Objectives:** To increase opportunities for increased juvenile salmon access and habitat.
    - **Elements:** This concept includes allowing operations prior to weir overtopping to augment planned operations post weir overtopping
  - **New Feather River Operable Gates to Lower Sutter Bypass**
    - **Objectives:** To increase opportunities for increased juvenile salmon access and habitat.
    - **Elements:** This concept includes passive and/or operable gates to increase hydrologic connectivity and for juveniles and adult salmon access.
- **Water Conveyance Management**
  - **East-West Diversion Weir and Weir 5 Re-operation**
    - **Objectives:** To increase opportunities for increased juvenile salmon rearing habitat and fish food production.

        - **Elements:** This concept includes redirecting increased flows into the East Borrow Canal or the high side of the Sutter Bypass at the upper end of the Sutter Bypass.
    - **Willow Slough Weir and Nelson Slough Weir Re-operation**
        - **Objectives:** To increase opportunities for increased juvenile salmon rearing habitat and fish food production.
        - **Elements:** This concept includes maintaining higher baseflow water levels at the terminus of the East Borrow Canal and maintaining water delivery and drainage canals in the Lower Sutter Bypass.
- **Land Management**
    - **Fish Food Production on Rice Fields**
        - **Objectives:** To increase fish food production in the Sutter Bypass and export back to the Sacramento River.
        - **Elements:** Various willing landowners are open to inundating their rice fields during winter.
    - **Juvenile Salmon Rearing on Rice Fields**
        - **Objectives:** To increase juvenile salmon rearing habitat.
        - **Elements:** Various willing landowners are open to inundating their rice fields during the winter.

Colusa Subregion

For the Floodplains Reimagined Program, Colusa Drain is being considered for preliminary concepts for fish food production, to be further refined and evaluated in Phase II.

Juvenile salmon rearing concepts are not being considered at this time. The rationale is three-fold: 1) Investment in infrastructure at the bottom end of the system to exclude adult salmon out of the Colusa Drain have been constructed at Wallace Weir and Knights Landing Outfall Gates, 2) lack of existing juvenile access due to lack of river connection connecting the Sacramento River to the Colusa Drain, 3) divergence of viewpoints around water quality in the Colusa Basin and its suitability for salmon.

- **River Connections**
    - **New Diversion on Sacramento River at Delevan National Wildlife Refuge (NWR)**
        - **Objectives:** To increase opportunities to improve fish food production on managed wetlands and rice fields by making connections from the Sacramento River into the Colusa Basin.
        - **Elements:** This includes improving the existing or creating a new point of diversion east of the Refuge and co-located near Maxwell Irrigation District point of diversion.
    - **Knights Landing Outfall Gates Re-operation**
        - **Objectives:** To increase opportunities to improve fish food production on managed wetlands and rice fields by making connections from the Sacramento River into the Colusa Basin.

        - **Elements:** This concept includes improving backflow into the lower Colusa Basin by opening the flap gates when Sacramento River stages are higher than the Colusa Drain. Knights Landing Outfall Gates and Wallace Weir can be re-operated in combination to enhance overbank inundation in the lower Colusa Basin. The flap gates at KLOG can be closed to limit return flows to the Sacramento River at lower river stages or open to at higher river stages. The operable gates at Wallace Weir can be managed to maintain a higher water level.
- **Water Conveyance**
    - **Davis Weir Re-operation**
        - **Objectives:** To increase opportunities to improve fish food production on managed wetlands and rice fields by improving water availability and connectivity within the Colusa Basin.
        - **Elements:** This concept includes re-operating the gates and/or modifying them to maintain higher water levels in the Colusa Basin Drain in the winter months.
    - **Wallace Weir and Knights Landing Outfall Gates Re-operation**
        - **Objectives:** To increase opportunities to improve fish food production on managed wetlands and rice fields by improving water availability and connectivity within the Colusa Basin.
        - **Elements:** This concept includes re-operating the two weirs to enhance overbank inundation in the Lower Colusa Basin with or without a supplemental river connection. The flap gates at KLOG can be closed to limit return flows to the Sacramento River when river stages are lower. The operable gates at Wallace Weir can be managed to maintain a higher water level in Knights Landing Ridge Cut and the lower Colusa Basin. The team modeled results of modifications at each weir together, which would require joint operation at increasing water management levels.
- **Land Management**
    - **Fish Food production on Managed Wetlands and Rice Fields**
        - **Objectives:** To increase fish food production in the Colusa Basin and export back to the Sacramento River.
        - **Elements:** Various willing landowners are open to inundating their rice fields during winter.

Feasibility Findings

The Program applied two feasibility criteria for the preliminary concepts including: 1) hydrologic feasibility and 2) landowner willingness. The hydrologic feasibility is based on an engineering principle. The landowner willingness is based on the Floodplains Reimagined program principle that the effort be voluntary, so landowner willingness governs evaluations of performance against any other criteria.

Hydrologic Feasibility Findings

Overall, the Program found that the preliminary concepts are hydrologically feasible.

The hydrologic feasibility purpose was to examine the changes to water movement across the basins with preliminary concepts compared to baseline conditions.

The purpose of hydrologic feasibility testing on individual preliminary concepts is to promote a better understanding of individual concepts' performance. This can enable further identification of a combination of concepts that could provide a cumulative benefit to all parties. The hydrologic feasibility also can reveal opportunities and constraints for individual property owners, allowing for a better understanding of specific project benefits and/or negative impacts.

Hydrologic feasibility varies by water year type and affects river connections and water conveyance.

Table 3.3 / Preliminary Concepts and Hydrologic Feasibility in Butte Subregion

Butte Subregion | Colusa Subregion | Sutter Subregion

Preliminary Concepts	Hydrologic Feasibility	Hydrologic Feasibility Considerations
Moulton Weir Operable Gate	Hydrologically Feasible	1) An operable gate at Moulton Weir can first activate at river stage and discharge of 61.0 feet and 18,500 cfs with a maximum flow split occurring at 68.8 feet prior to weir overtopping at 76.2 feet. For maximum flow rates of 1,000, 2,000, 3,000 and 6,000 cfs, maximum diversion rates are 3.3%, 6.6%, 10.0%, and 19.9%, respectively. 2) An operable gate has not been paired with other concepts (i.e., water management conveyance or land management) that may provide benefits or limit impacts on surrounding landowners; 3) An operable gate would require a channel within the Sacramento River corridor leading to Moulton Weir 2,840 feet long by 10-15 feet deep with a bottom width of 60 feet requiring 94,700 – 165,700 cubic yards of excavation; 4) An operable gate at Moulton Weir activates when Colusa Weir begins to overtop, and as such, reduces overflows at Colusa Weir
Colusa Weir Operable Gate	Hydrologically Feasible	1) An operable gate at Colusa Weir can first activate at river stage and discharge of 50.0 feet and 16,200 cfs with a maximum flow split occurring at 56.8 feet prior to weir overtopping at 61.2 feet. For maximum flow rates of 1,000, 2,000, 3,000 and 6,000 cfs, maximum diversion rates are 4.3%, 8.6%, 12.8%, and 25.6%, respectively. 2) An operable gate has not been paired with other concepts (i.e., water management conveyance or land management) that may provide benefits or limit impacts on surrounding landowners; 3) An operable gate would require a channel within the Colusa Bypass connecting to Butte Creek 2.8 miles long by 9.0 –12.0 feet deep with a bottom width of 20.0, 50.0, 80.0, 170.0 feet, respectively, requiring 0.4, 0.7, 0.9, and 1.7 MCY, respectively, of excavation; 4) An operable gate at Colusa Weir activates when stage levels are 5.9 ft above the Tisdale Weir crest (44.1 ft NAVD88), and as such, reduces overflows at Tisdale Weir; and 5) The presence of a new channel downstream of the Colusa Weir increases the conveyance capacity of the weir, decreasing local stage levels and routing times for flood waters to Butte Creek.

Table 3.3 / Preliminary Concepts and Hydrologic Feasibility in Butte Subregion

Butte Subregion | Colusa Subregion | Sutter Subregion

Preliminary Concepts	Hydrologic Feasibility	Hydrologic Feasibility Considerations
Moulton & Colusa Operable Gates	Hydrologically Feasible	1) The Colusa Weir operable gate will activate with greater frequency than the Moulton Weir operable gate during the operational period.
Benden Farms Suite of Concepts	Hydrologically Feasible	Hydrologic Feasibility Considerations: 1) All four concepts are compatible with a potential Moulton Weir operable gate • Canal and Access Road Improvements • Fish Food Production on Farm Fields • Juvenile Salmon Rearing on Farm Fields • Floodplain and Riparian Restoration 2) Floodplain enhancement would require ±500,000 cubic yards of excavation.

Table 3.4 / Preliminary Concepts and Hydrologic Feasibility in Colusa Subregion

Butte Subregion | Colusa Subregion | Sutter Subregion

Preliminary Concepts	Hydrologic Feasibility	Hydrologic Feasibility Considerations
New Water Diversion on Sacramento River at Delevan National Wildlife Refuge (NWR)	Hydrologically Feasible	1) A new river connection could be an operable gate through the levee or a pumped diversion. 2) An operable gate can first activate at a river stage and discharge of 61.0 feet and 18,500 cfs with a maximum flow split occurring at 68.8 feet (similar to the Moulton Weir Operable Gate). For maximum flow rates of 1,000 and 2,000 cfs, maximum diversion rates are 3.3% and 6.6%, respectively. 3) A new river connection has not been paired with other concepts (i.e., water management conveyance or land management) that may provide benefits or limit impacts on surrounding landowners. 4) A new river connection would require modifications to existing canal infrastructure to convey flows to the Colusa Basin Drain.
Wallace Weir & Knights Landing Outfall Gates (KLOG) Modifications	Hydrologically Feasible	1) The flap gates at KLOG are at the bottom of the structure or bottom of the water column, so the opportunity to entrain juvenile salmon is limited; 2) Both KLOG and Wallace Weir are equipped with pickets to limit adult salmon passage into the Colusa Basin; 3) Active subsidence in the Lower Colusa Basin may contribute to more frequent overbank inundation.
Fish Food Production on Managed Wetlands and Rice Fields	Hydrologically Feasible	Hydrologic Feasibility Considerations: 1) Re-operation of Davis Weir, Wallace Weir, and Knights Landing Outfall Gates and/or a New Water Diversion on the Sacramento River at Delevan can improve water availability and connectivity within the Colusa Basin. 2) This has not been paired with supplemental water conveyance management concepts that may provide benefits or limit impacts on adjacent landowners.

Table 3.5 / Preliminary Concepts and Hydrologic Feasibility in Sutter Subregion

Butte Subregion | Colusa Subregion | Sutter Subregion

Preliminary Concepts	Hydrologic Feasibility	Hydrologic Feasibility Considerations
River Connections Concepts	Hydrologically Feasible	1) Operable gate in the Butte Basin at either Moulton and/or Colusa Weirs (see above), 2) Re-operation of the planned operable gate at Tisdale Weir to allow it to operate prior to weir overtopping to augment planned operations post weir overtopping. The Sacramento River rises fairly rapidly, so the majority of the flow through the Tisdale Weir operable gate occurs during planned operations; 3) Multiple gates (passive and/or operable) with the Feather River to enhance connectivity into the Lower Sutter Bypass downstream of Nelson Slough.
Water Management Conveyance Concepts	Hydrologically Feasible	1) Re-operation of both the East-West Diversion Weir and Weir 5 at the upstream end of the Sutter Bypass to redirect more Butte Basin outflows into the East Borrow Canal; 2) Re-operation of both Willow Slough Weir and Nelson Slough Weir at the terminus of the East Borrow Canal to maintain higher baseflow water levels in the East Borrow Canal; and 3) Modification of water delivery and drainage canals in the Lower Sutter Bypass.
Land Management Concepts	Hydrologically Feasible	1) Juvenile salmon access and rearing via gravity connections affording volitional ingress to and egress from winter inundated rice fields; and 2) Fish food production and export.

Technical Approach

The hydrologic feasibility's technical approach used hydrodynamic model to quantify changes in floodplain inundation depths and velocities over a range of historic hydrologic conditions. In the first stage, the Program analyzed one water year November 2018 to May 2019. In the second stage, the Program expanded the simulation period to include five water years: 2003 (above normal), 2011 (wet), 2013 (dry), 2015 (critical), and 2019 (wet). This provided a more comprehensive representation of hydrologic conditions.

Landowner Willingness Findings

The Floodplains Reimagined Principles, defined in the Program Charter, state that the Program will be voluntary and respect existing land uses. Therefore, landowner willingness is a governing principle of feasibility of any multi-benefit concept.

The Program Team identified these key takeaways regarding landowner willingness:

- Support improving salmon recovery while respecting existing land uses.
- Support for managed releases rather than uncontrolled flood.
- Request for holistic landscape solutions that protect non-participating neighbors.
- Willing to consider increased frequency and duration of inundation than increased depth of inundation.
- Interest in solutions that avoid potential decreases to 1) land value, 2) recreational hunting opportunities, 3) access, 4) safety, and 5) longevity of infrastructure including roads, buildings, and water conveyance.

Landowner Willingness Phase I Preliminary Concepts

Landowners were open to exploring concepts and contributed a great deal to the evaluation of preliminary concepts. Landowners' willingness to explore options depended on their perspective on threat to their water supply, existing land use, and potential effects on their community way of life and livelihoods.

When Floodplains Reimagined shared the estimated performance of the Moulton and Colusa Operable Gates at a range of overflows and resulting inundation. Several landowners expressed that the range of options did not meet their interests. They were not interested in exploring options that exceeded 2,000 cfs overflows at Moulton and Colusa Weirs due to the predicted decreased agricultural and recreational hunting compatibility. Individually, these concepts decreased existing land uses for agriculture and recreation so much that they were untenable for landowners to consider. The Program responded by putting aside those preliminary concepts that did not meet the criteria for landowner willingness.

The following table summarizes the preliminary concepts performance against the hydrologic feasibility and landowner willingness in relation to the preliminary concepts.

Table 3.6 / Preliminary Concepts and Landowner Willingness

Butte Subregion Colusa Subregion Sutter Subregion

Feasibility and Evaluation Criteria	Hydro Feasibility	Land owner Willingness	Hydrologic Feasibility Considerations
Moulton Weir Operable Gate	Yes	Willing to explore	Operable gate options up to 6,000 cfs were explored as standalone concepts and without consideration for water management conveyance concepts that might otherwise mitigate impacts to unwilling landowners. As standalone concepts, landowners were willing to explore the feasibility of options up to 2,000 cfs. Some landowners have expressed interest in exploring pairing river connection concepts with water management conveyance and land management concepts to protect and bypass unwilling landowners and further explore juvenile salmon rearing and fish food opportunities with willing landowners.
Colusa Weir Operable Gate	Yes	Willing to explore	
Moulton & Colusa Operable Gates	Yes	Willing to explore	
Benden Farms Suite of Concepts	Yes	Willing to explore	Benden Farms has expressed interest in exploring floodplain enhancement as well as juvenile rearing and fish food opportunities on their lands within the Sacramento River corridor and in the Butte Basin (Appendix).
Knights Landing Outfall Gates & Wallace Weir	Yes	Under discussion	Evaluation of land use tradeoffs requires further discussion with landowners directly adjacent to the Colusa Drain. These lands are predominately managed wetlands for waterfowl and waterfowl hunting.
New Water Diversion on Sacramento River at Delevan National Wildlife Refuge (NWR)	Yes	Under discussion	Landowner discussions have started and there are some interested and willing landowners.
Fish Food Production on Managed Wetlands and Rice Fields	Yes	Under discussion	Landowner discussions have started and there are some interested and willing landowners.
Sutter Bypass Suite of Concepts	Yes	Landowners proposed	The Sutter Bypass Butte Slough Water Users Association vetted and adopted the suite of concepts (RD 1500 and DWR, 2023; SBBSWUA TA). The concepts provide habitat benefits to juvenile salmon and birds while minimizing impacts to agriculture and managed wetlands.

Moulton and Colusa Weir Operable Gates

Landowners in the Advisory Committee strongly expressed unwillingness to proceed with exploration of preliminary concepts that would hamper the productivity, access, and use of their lands and potentially cause damage. They objected to the potential concepts proposed at Moulton and Colusa Weir due to potential negative impacts to private property that often occur during weir spills.

Landowners expressed similar concerns around Moulton and Colusa Weir Operable Gates concepts. Landowners downstream of the Moulton Weir expressed concerns about road closures, field access, channel erosion, and undesirable field flooding on winter flooded rice during the waterfowl hunting season. Landowners downstream of the Colusa Weir expressed concerns regarding access to hunting clubs and potential negative impacts to hunting conditions like shooting levels.

Landowner concerns reinforce the need to comprehensively study the downstream impacts of weir overflows and develop comprehensive solutions that will mitigate negative impacts and enhance benefits. Potential solutions include combining floodplain connectivity concepts with other types of preliminary concepts. Combinations of concepts could allow for multi-objective benefits while minimizing land use impacts. For example, combining Fish Food production concepts with water conveyance concepts.

Benefits Findings

This section will describe the preliminary concepts of potential benefits in relation to the evaluation criteria. The purpose was to evaluate the proposed preliminary concepts for benefits in relation to baseline conditions.

Benefits Lessons Learned

1. Optimal Salmon and Bird depths overlap by 2 inches — There is a window of opportunity of 2 inches of depth for meeting both salmon and bird habitat suitability at the same time and place, with the greatest potential to occur in the Butte Sink. However, there are opportunities to meet each habitat suitability at different times and places.

2. Timing influences juvenile salmon access – Juvenile salmon must be present in the Sacramento River to overflow river connections into off-channel habitat.

3. Flow volume influences juvenile salmon access— The number of juvenile salmon that can access the off-channel habitat is directly proportionate to the amount of water overflowing the river connections. The Technical Team assumes a 1:1 ratio. A low overflow from the Sacramento River onto off-channel lands will result in a proportionately low number of juvenile salmon accessing that habitat. A high overflow will result in a proportionately high number of juvenile salmon accessing that habitat.

4. Volume of overflow influences benefits to different salmon runs — Low volume overflows will move a proportionately low volume of Sacramento River winter-run salmon onto off-

channel rearing habitat. High volume overflows will increase inundation in the Butte Basin, which will likely benefit Butte Creek spring-run Chinook juvenile salmon.

5. Hydrologic variability at inter-annual scales had more influence on benefits to salmon and birds than low magnitude overflows from the Sacramento River. The benefits of a wet year and the resulting benefits to floodplain connectivity, salmon, and bird habitat exceed the benefits resulting from low magnitude overflows across multiple year types.

6. River connection concepts could result in increased benefits and landowner willingness if packaged with water management conveyance and land management concepts. These concepts could address tradeoffs, salmon and birds and compatibility with managed wetlands, waterfowl hunting, and agriculture.

Summary of Estimated Potential Benefits for Phase I Preliminary Concepts

Subregional Benefits Summary

1. In the Butte Basin, Moulton and/or Colusa Weirs Operable Gates as standalone concepts could potentially increase habitat suitability for juvenile salmon rearing and increase opportunities for fish food production and export. However, these concepts could decrease suitable bird habitat and waterfowl hunting opportunities due to increased depths on managed wetlands and rice fields.

2. In the Colusa Basin, a new water diversion at Delevan Wildlife Refuge combined with water management conveyance concepts could potentially increase opportunities for fish food production and export. However, there is a potential to decrease suitable bird habitat and waterfowl hunting opportunities due to increased depths on managed wetlands and rice fields.

3. In the Sutter Bypass, a suite of concepts could potentially increase habitat suitability for juvenile salmon rearing and increase opportunities for fish food production and export. Unlike the Butte and Colusa Basins, there could be increased benefits for fish and birds. The concept increases the potential to increase suitable bird habitat by sustaining optimal depths on managed wetlands and rice fields.

The following table summarizes the preliminary concepts in relation to benefits. For the evaluation criteria, the table shows the directionality of an increase or decrease in benefits from baseline. For all these evaluation criteria, there is scientific and modeling uncertainty related to the predicted outcomes. These are explored in the following section on Scientific Uncertainties.

It is important to note that the Technical Team applied the evaluation criteria for habitat suitability for juvenile salmon and birds during a pre-screening of these preliminary concepts. They then inferred the results for evaluation criteria for compatibility with agriculture and waterfowl hunting and managed wetlands.

There are different viewpoints around the significance and acceptability of the increase or decrease of benefits. There are also opportunities to evaluate cumulative benefits of multiple preliminary concepts and try to evaluate and mitigate the tradeoffs between concepts.

Table 3.7 / Estimated Potential Benefits for Individual Preliminary Concepts

Butte Subregion Colusa Subregion Sutter Subregion

Feasibility and Evaluation Criteria	Type of Preliminary Concept	Juvenile Salmon Rearing Habitat Suitability	Fish Food (Zoo-plankton) Production and Export	Birds Habitat Suitability	Agricultural Compatibility	Waterfowl Hunting and Managed Wetlands Compatibility
Description of direction of benefits		Potential for increased benefits	Potential for increased benefits	Potential for decrease benefits	Potential for neutral benefits	Potential for decreased benefits last week of Oct. – mid-Feb (waterfowl hunting season) and Potential for neutral benefits after mid Feb.
Preliminary Concept	Type of Concept	Application of Evaluation Criteria	Based on inference	Application of Evaluation Criteria	Based on inference	Based on inference
Moulton Weir Operable Gate	River Connection Sacramento River into Butte Basin					Decrease last week Oct – mid-Feb Neutral after mid-Feb ↓ =
Colusa Weir Operable Gate	River Connection Sacramento River into Butte Basin	↑	↑	↓	=	Decrease last week Oct – mid-Feb Neutral after mid-Feb ↓ =
Moulton & Colusa Operable Gates	River Connection Sacramento River into Butte Basin	↑	↑	↓	=	Decrease last week Oct – mid-Feb Neutral after mid-Feb
New Water Diversion on Sac-ramento River at Delevan National Wildlife Refuge (NWR)	River Connection Sacramento River into Colusa Basin	↑	↑	↓	=	Decrease last week Oct – mid-Feb Neutral after mid-Feb ↓ =

Table 3.7 / Estimated Potential Benefits for Individual Preliminary Concepts

Butte Subregion Colusa Subregion Sutter Subregion

Feasibility and Evaluation Criteria	Type of Preliminary Concept	Juvenile Salmon Rearing Habitat Suitability	Fish Food (Zooplankton) Production and Export	Birds Habitat Suitability	Agricultural Compatibility	Waterfowl Hunting and Managed Wetlands Compatibility
Wallace Weir &Knights Landing Outfall Gates	Water Management Conveyance within Colusa Basin	Not being considered at this time	Increase ↑	Decrease ↓	Neutral =	Decrease last week Oct – mid-Feb Neutral after mid-Feb
Fish Food Production on Managed Wetlands and Rice Fields	Land Management	For further examination in Phase II				

Technical Approach

The technical approach used the hydrodynamic model output and the evaluation criteria to evaluate changes to the habitat suitability relative for juvenile salmon floodplain rearing and waterfowl. The Program used results from the hydrodynamic model simulations to quantify changes in floodplain depths and velocities in terms of juvenile salmon floodplain rearing habitat suitability for use in the Salmon Benefits Model (SBM) as summarized in the Appendix.

Engagement Approach

The Program Team presented the Benefits findings for Moulton and Colusa Weirs Operable Gates and solicited feedback from the Advisory Committee's in April and May 2023. They also presented and discussed findings at water districts and water associations.

River Connections Benefits Findings

Moulton and Colusa Weir Operable Gates

The primary objective of this analysis was to compare outcomes for juvenile salmon rearing in floodplain and main channel habitats to inform restoration and operational decision making. The Program Team assessed the benefits of modifications to the Moulton and Colusa weirs independently and cumulatively. They used the Salmon Benefits Model to assess the benefits for juvenile Chinook salmon in response to the two concepts.

The secondary objective was to evaluate the accuracy of assumptions, check the predictive accuracy of the model and identify data gaps that could be used to refine understanding.

The Technical Team surmised that the concept of Moulton and Colusa operable gates would allow for increased frequency of inundation of surrounding lands. The analysis demonstrates potential improved benefits to juvenile salmon across a large area downstream of each respective weir. The re-operation of Colusa and Moulton weirs would increase inundation of managed wetlands and agriculture fields downstream of Colusa and Moulton weirs.

Landowners are willing to explore river connections with operable gates producing 1,000 - 2,000 cfs overflow at the Butte Basin weirs. This provides an opportunity for benefiting juvenile salmon by exploring increased duration and frequency of those 1,000– 2,000 cfs weir flows. Accordingly, the Program could explore benefits of increasing the duration and/or frequency of the weir flows at the potentially acceptable magnitude of 1,000–2,000 cfs. The Moulton and Colusa Weirs Operable Gates concept could make overflows at these magnitudes more frequent and last longer. If paired with other protective concepts that meet landowner interest, these overflows may still move many juvenile salmon into beneficial rearing habitat without unacceptable negative impacts to landowners.

Moulton Weir Operable Gate

Modification of only the Moulton Weir produced similar potential benefits for juvenile salmon rearing as modifying both Colusa and Moulton weirs simultaneously. There are two factors at play: 1.) Moulton flow through inundates a larger area than the Colusa Weir and 2) agricultural fields near the Moulton Weir would inundate more frequently than the managed wetlands.

Juvenile Salmon Benefits

Findings show that the concept results in increased juvenile salmon habitat, but no significant benefit to juvenile salmon. Though the habitat may be available at a certain location and time, the juvenile salmon may not be at that same place and time to be able to access it. This results in no discernible benefit to juvenile salmon. The concept offers the opportunity to move more juvenile salmon into that habitat.

All three of these conditions need to be present for a juvenile salmon to move from the mainstem Sacramento River through a weir and into off-channel juvenile salmon rearing habitat:

1. Juvenile salmon need to be present at an entry location (weir)
2. The weir must be actively spilling
3. The fish must move over the weir

There are still scientific uncertainties that need to be resolved around juvenile salmon movement that would help create options to give salmon access to increased rearing habitat (Appendix).

The analysis did produce discernible differences in benefits between drier and wetter year types. To put it simply, an operable gate at Moulton Weir cannot provide the equivalent benefits of a wetter year type. A dry year is still not going to provide good inundation conditions for juvenile salmon to rear in off-channel lands because there is not as much water to inundate the landscape. This means the team may need to look at different concepts that would benefit salmon in different water year types.

Viewed together, the sensitivity analysis indicates that the Salmon Benefits Model predictions of biological metrics are relatively insensitive to the parameters examined for fish entering over Moulton, Colusa, and Tisdale weirs. Continued research, revision and integration of new data will continue to improve the Salmon Benefits Model (Appendix).

Juvenile Salmon Access through Moulton Weir

The magnitude of change in the number of fish that could access the floodplain habitat via the Moulton Weir with an operable gate was not significant enough to affect salmon on a population level. Juvenile salmon entrainment at Moulton Weir was always very low under the baseline conditions for all fish runs analyzed at less than 1%. With an operable gate, entrainment exceeded 5% in one year for one run but was frequently less than 2%. There are different perspectives among the Program participants about the level of benefits that would be significant to improve a salmon life stage, salmon in a certain region, or salmon on a population scale.

Additionally, if more flow and fish are estimated to flow through an operable gate at Moulton Weir, that would reduce entrainment onto the off-channel lands at downstream weirs. If Moulton Weir lets more water go through an operable gate, it is predicted there is less flow and juvenile salmon available for diversion downstream at Colusa and Tisdale weirs.

The conceptual Moulton operable gates could potentially increase inundation of off-channel lands, but the water may not benefit juvenile salmon. Fish must be present at the right time and location at the Moulton Weir to benefit access to the off-channel rearing habitat.

The best information on entrainment indicates juvenile salmon move through a weir in proportion to flow volume. Assuming the Sacramento River is flowing at 30,000 cfs when the gates reach maximum flows prior to Moulton Weir overtopping, the weir flows and related maximum entrainment rates would be: 1,000 cfs weir flow; entrainment rate 3.3% and 2,000 cfs weir flow; entrainment rate 6.7%.

Furthermore, the slight increase in entrainment juvenile salmon through the weirs would occur infrequently and only during wetter years when flows would be high enough to activate the operable gates. Last, the flow to entrainment rates are predicted to decrease as the Sacramento River flows rise and weir flows remain constant.

Benefits to Birds

The Moulton Weir Concept for 1,000 and 2,000 cfs decreased waterfowl habitat suitability due to exceedance of the maximum suitable depth for waterfowl.

Modification to Moulton Weir would result in increased waterfowl suitability in the unmanaged lands downstream of the weir. However, it would also result in decreasing waterfowl suitability on many of the managed winter flooded fields due to depths that exceed the maximum waterfowl habitat suitability criteria of 10 inches.

Benefits to Salmon and Birds

The relationship between the minimum juvenile salmon rearing threshold and the maximum waterfowl suitability threshold leaves a 2-inch depth between 10 - 12 inches. Based on the existing evaluation criteria thresholds, this area of overlap would be considered optimally suitable for juvenile salmon rearing and waterfowl.

The overlap between salmon and waterfowl suitable areas occurred predominantly in the unmanaged fields downstream of Moulton Weir. The managed wetlands and winter flooded rice in this location saw increases in salmon suitability and decreases in waterfowl suitability and recreational hunting access. This area of overlapping benefits presents a next step of investigation since the unmanaged fields were not evaluated for benefits to juvenile salmon rearing or waterfowl. These fields would provide minimal food resources for waterfowl, and likely no hunting opportunities.

Colusa Weir Operable Gates

The addition of Colusa Weir Operable Gate to the Moulton Weir Operable Gate does not significantly increase the benefits to floodplain connectivity or salmon from the Moulton Weir Operable Gate. The Moulton Weir extends the wetted area whereas Colusa Weir Operable Gate does not extend the wetted area as much.

A Moulton Weir Operable Gate results in more benefits to juvenile salmon rearing habitat than modifications at Colusa Weir.

Entraining juvenile salmon through a Colusa Weir Operable Gate results in a lower entrainment rate than Moulton Weir. In other words, the evaluation predicts that adding a Moulton Weir Operable Gate would result in more juvenile salmon accessing the off-channel lands for rearing than a Colusa Weir Operable Gate.

Water Management Conveyance

New Water Diversion on Sacramento River at Delevan National Wildlife Refuge (NWR)

The potential benefits of this concept include potential opportunities for fish food production within the Colusa Basin and eventual export directly to the Sacramento River or delivery through the Yolo Bypass. More specifically, this concept increases opportunities to provide fish food production on managed wetlands within the Delevan NWR and the Colusa NWR by increasing available water to support fish food production, export, and re-inundation of managed wetlands.

The findings show that an operable gate with gravity connection exceeds the Sacramento River with maximum flood capacities of 1,000 and 2,000 cfs. This can exceed the capacity of the upper Colusa Basin Drain and result in potential impacts to existing land uses. Findings predict potential negative impacts to managed wetlands and waterfowl hunting. The next iteration of the concept will include a pump diversion of lesser capacity to minimize negative impacts.

Fish Food Production

The potential to increase opportunities to support fish food production on managed wetlands within the Delevan and Colusa National Wildlife Refuges and export to the Colusa Basin Drain and eventually the Sacramento River can be realized and are inferred based on the ability to improve water availability to support such activities.

Birds

A New Water Diversion Concept for 1,000 and 2,000 cfs decreased waterfowl habitat suitability due to exceedance of the maximum suitable depth for waterfowl, especially on managed wetlands within the Delevan and Colusa NWRs.

Wallace Weir & Knights Landing Outfall Gates

This concept could increase opportunities for fish food production and benefit birds. The analysis of re-operation of Wallace Weir, and Knights Landing Outfall Gates does not yet

consider the effects of subsidence within the Lower Colusa Basin. Future evaluation will need to consider subsidence as part of minimizing impacts to existing land uses, such as managed wetlands, waterfowl hunting, and agriculture.

Fish Food Production

The potential benefits of this concept include increased opportunities for fish food production within the Colusa Basin. Fish food could be exported to the Sacramento River or through the Yolo Bypass. Fish food production could be increased on managed wetlands and winter flooded rice adjacent to the Colusa Basin Drain. Production would require available water to support fish food production, export, and re-inundation of managed wetlands and fields so they may continue to support their intended purposes. The Technical Team inferred these findings based on the ability to increase the flow stages within the Colusa Basin Drain and hence water availability to support such activities.

Birds

Increasing stages in the Colusa Basin Drain via re-operation of the Wallace Weir, and Knights Landing Outfall Gates, in combination with a New Water Diversion at Delevan National Wildlife Refuge decreased waterfowl habitat suitability. The predicted inundation depths exceeded the maximum suitable depth for waterfowl, especially on privately managed wetlands adjacent to the Colusa Basin Drain.

Land Management

Fish Food Production on Managed Wetlands and Rice Fields in Colusa
In Phase II, Floodplains Reimagined will continue to analyze the benefits of fish food production in lands adjacent to the Colusa Drain. This discussion will necessitate shared understanding of water rights and water availability to support the preliminary concepts.

Suites of Preliminary Concepts Benefits Findings

There are two suites of concepts under development that have undergone some level of analysis. The following suites of concepts have been evaluated at various levels to date and will be part of the next steps for Phase II.

- Benden Farms Suite of Concepts
    - Benefits have been inferred from the analyses of the other Phase I preliminary concepts previously discussed
- Sutter Bypass Suite of Concepts
    - Benefits analyzed under the Sutter and Tisdale Bypasses Flood & Multi-Benefit Management Plan with a set of criteria that is close to and served to inform the Floodplains Reimagined Evaluation Criteria

The following table summarizes the potential benefits estimated in relation to these two suites of preliminary concepts. Based on pre-screening analyses of juvenile salmon and bird habitat, the team inferred benefits for evaluation criteria. In Floodplains Reimagined Phase II, the team

intends to continue the work to develop additional suites of preliminary concepts for other subregions and expand the evaluation of benefits for these suites of concepts.

Table 3.8 / Suites of Preliminary Concepts and Benefits

Butte Subregion Colusa Subregion Sutter Subregion

Feasibility and Evaluation Criteria Preliminary Concepts	Type of Concept	Juvenile Salmon Rearing Habitat Suitability	Fish Food Production and Export (Secondary Productivity of Zooplankton and Export of Fish Food)	Birds Habitat Suitability	Agricultural Compatibility	Waterfowl Hunting and Managed Wetlands Compatibility
Type of Analysis		Application of Evaluation Criteria	Based on inference	Application of Evaluation Criteria	Based on inference	Based on inference
Benden Farms Suite of Concepts	River Connection Water Management Conveyance Land Management	Potential for increased benefits	Potential for increased benefits	For future analysis under Floodplains Reimagined Phase II.	Potential for neutral impacts	Potential for neutral impacts
Sutter Bypass Suite of Concepts	River Connection Water Management Conveyance Land Management	Potential for increased benefits	For future analysis under Floodplains Reimagined Phase	Potential neutral impacts on managed wetlands Potential increase benefits on lands managed for juvenile rearing	Potential for neutral impacts	Potential for neutral impacts for managed wetlands after hunting season, mid-Feb.

Sutter Bypass Butte Suite of Concepts

Benefits:
The concepts result in minimal negative impacts to agriculture by maintaining the start of planting season. The evaluation also shows minimum negative impacts to recreational waterfowl hunting on public and private wetlands rice fields during and after the waterfowl hunting season.
Upstream of Nelson Slough, the benefits result from redirecting more water to the high side of Sutter Bypass at the Highway 20 Bridge and using gravity to sustain inundation and flow through rice fields. Below Nelson Slough, benefits result from multiple river connections providing greater duration of inundation in the Lower Sutter Bypass.

The individual concepts were formulated and evaluated separately to understand the benefits and impacts afforded by each and then packaged and revised to create a combination of the optimal benefits according to the landowners involved. The suite of concepts, as supported by the landowners within the Sutter Bypass, work in combination to provide a significant increase in suitable habitat conditions for juvenile salmon rearing, waterfowl, and shorebirds. Benefits accrue on the farmed ground downstream of the Sutter National Wildlife Refuge.

Benden Farms Suite of Concepts
Benefits: The team has evaluated each concept in the suite of Benden Farms individually. As part of Phase II, the landowner may proceed with cumulative evaluation of benefits.

The suite of concepts results in increased juvenile salmon rearing benefits due to increase in-river habitat and increased potential to increase juvenile rearing habitat on winter inundated fields.

Water Management Conveyance

- Canal and Road Improvements

Benefits could include road access during a range of potential flows from Moulton Weir with a potential operable gate and the resulting inundation. Potential solutions include large diameter culverts through earthen embankments to support roads. The solutions support the following criteria: 1) access during a range of potential flows from Moulton Weir with an operable gate, 2) access across the three primary channels bifurcating the property, and 3) work with the existing three water channels across the property.

Land Management

- **Fish food Production on Fields**

Benefits include enhancing the extent and duration of shallow inundation of off-channel lands under a range of inflows from Moulton Weir with or without an operable gate. The shallow inundation could benefit salmon through juvenile salmon rearing habitat and/or fish food production and export. The inundation could also provide increased habitat for birds.

- **Juvenile Salmon Rearing on Fields**

The benefits include increased juvenile salmon rearing habitat on fields.

In-River Function

- **Juvenile Salmon Rearing on Fields**

Benefits could include increased available juvenile salmon rearing habitat and restored riparian areas in the Sacramento River corridor inside the levee. The concept could generate 50-plus acres of frequently inundated juvenile salmon rearing habitat, with or without accommodation for a new Moulton Weir Operable Gate. Roughly 100-plus acres along the Sacramento River inside the levee would provide significant aquatic and terrestrial benefits at higher inundation levels.

The pastureland is high ground and significant earthwork would be required to remove roughly 500,000-plus cubic yards. The riparian restoration would need to be designed to respect flood control designs for Moulton Weir.

The landowner and the technical team will undertake further refinement and evaluation of these initial concepts. This landowner property can serve as a model for individual property exploration of concepts followed by examining multiple units together on a subregional level.

Studies Findings

The Floodplains Reimagined Program undertook development of a few studies to support evaluation of benefits. These studies are summarized below under the Concept Types of Land Management and In-River Function concepts:

Land Management

- Fish Food Inventory Decision Support Tool.
- Flow Measurements at Butte Creek Sanborn Slough Bifurcation Structure.

In-River Function

- Juvenile Salmon Rearing Habitat Enhancement Opportunities within the Sacramento River Corridor.

A description of each of the above studies' purpose and outcomes follows.

Land Management Studies

Fish Food Inventory

Purpose: This activity's purpose was to evaluate benefits and opportunities to grow and deliver fish food to juvenile salmon in the Sacramento River. To achieve this analysis, the team developed a GIS-based Decision Support Tool for the Sacramento Valley. The Technical Team used the tool to identify priority rice fields for fish food production benefits based on their distance to salmon-bearing waterways.

The tool can be used to: 1) identify and rank rice fields best suited to fish-food production programs and 2) adjust that ranking based on waterfowl and shorebird interests or concerns, 3) rank and select bidders in existing fish-food production incentive programs.

Outcomes: The results show that thousands of acres of rice fields are close enough to produce and deliver fish food to the juvenile salmon rearing in the neighboring streams. Fish biologists indicated that increases in food resources could potentially be available up to 20 miles downstream from drained rice fields.

The following acres of rice-fields are within 20 miles of canals to streams bearing juvenile salmon:

1. 250,000 acres of rice-fields located within 20 miles of canals
2. 90,000 acres of rice-fields are within less than 5 miles of canals

This tool has allowed the project to evaluate preliminary concepts in relation to the practices that provide the multi-species benefits including winter-flooding of rice fields, rice-straw decomposition, and wildlife food production especially in dry water-years.

Results demonstrate that both fish and birds could benefit from winter production of fish food given certain operational and timing conditions. First, both fish and birds benefit when rice fields retain the flexibility to re-flood fields after draining and exporting the fish food. Second, fish and birds both benefit from fish food production in February and March. During this time, shorebird and waterfowl populations would likely benefit from any fields flooded for a fish-food production program. However, during December and January- when waterfowl in Sacramento are at their peak - the negative tradeoffs between fish-food production and wintering waterfowl habitat are the highest as waterfowl populations in the Sacramento Valley are at their peak.

This analysis identified nearly 450,000 acres of rice fields in the Sacramento Valley. There may be an opportunity to apply this ranking to prioritize rice fields for food production and export to other salmon-bearing streams. In addition, the tool could be expanded to include other land types that could produce fish food such as wetlands and other types of agriculture fields suited to holding water.

Flow Measurements: Butte Creek, Sanborn Slough Bifurcation Structure

Purpose: The study informs flow gauging on Butte Creek and hydrologic modeling. This reduces uncertainty to evaluate potential multi-benefit solutions. Butte Creek landowners generally agree that there is a need for improved streamflow and diversion measurement in Butte Creek. Without measurement it is difficult to evaluate potential benefits of changed inundation patterns and their effects on fish. This study begins to inform streamflow measurement.

There is a particular need to measure the instream flow in Butte Creek and the diversion into Sanborn Slough that delivers water to the downstream hunting clubs. Technical assistance measured the instream flow magnitudes in Butte Creek and the diversion flows into Sanborn Slough at the Sanborn Slough Bifurcation Structure where the flows are diverted.

This structure is located at the top of the Butte Sink about one-quarter mile downstream from Colusa Highway. The structure is operated by the Wild Goose Club and RD 1004 to divert water for different purposes during different times of the year. It is important for diverting flow down

Sanborn Slough for the duck hunting clubs to inundate their managed wetlands before hunting season.

Outcomes: The study confirmed that the diversion of flow from Butte Creek at the Bifurcation Structure is consistent with the agreement for flow management between RD1004 and Wild Goose. During conditions when the overflow weir was not spilling, 70% of Butte Creek's instream flow was diverted into Sanborn Slough. The study also found that during weir spills at higher flows, a higher percentage of Butte Creek instream flow went down Butte Creek and a lower percentage of flow was able to be diverted into Sanborn Slough. However, when weir spill ceased, the diversion into Sanborn Slough returned to 70%. The study informed ways in which flow gauges could be installed at this site for long-term water management. The study outcomes represent a snapshot of flow measurements and not long-term data, which is still needed. The Technical Team measured flows on Butte Creek and Sanborn Slough during late 2022 and early 2023 to assess the flow splits during flood up and hunting seasons.

In addition, the flow measurements also informed detailed calibration of Sanborn Slough Bifurcation Structure's parameters in the Floodplains Reimagined basin-scale hydraulic model, to ensure the model was reproducing the measured data.

In-River Function Studies

Juvenile Salmon Rearing Habitat Enhancement Opportunities within the Sacramento River Corridor

Purpose: This study's purpose was to identify and characterize seasonal pools that may serve as rearing habitat for juvenile salmonids in the Sacramento River corridor between Hamilton City and Colusa. These pools vary in shape and size and may take the form of oxbow lakes, local depressional points, and agricultural fields. These areas become inundated during high flow events for the Sacramento River. As flood waters recede, these areas disconnect from the mainstem river. These pools may provide rearing habitat for juvenile salmonids. These pools are protected from mainstem channel flows that do not exceed the threshold for inundating these side pools. During the disconnected period, juvenile salmon have the chance to grow. Then, in another high-water event, the pools would be inundated and reconnect with the main channel, providing juvenile salmon a pathway downstream. However, if another flood event does not inundate these areas, these pools can remain disconnected, stranding juvenile salmon and sometimes drying out completely, killing the salmon unless rescued.

Outcomes: The study's results demonstrate that isolated rearing pools are a common occurrence across the Sacramento River floodplain and further analysis is required to determine specific habitat benefits or risks of individual pools.

The analysis determined that in the study area there are over 350 potential pools that could be inundated by high flows in the Sacramento River. The high flows range from 10,000–80,000 cfs. Most of these pools are likely to be inundated 2-12 times annually based on analysis of historic hydrology. This outcome represents both an opportunity for juvenile salmonid floodplain rearing habitat and the potential for fish stranding risk where pools may have insufficient outlet to the main channel as flood flows recede.

Divergence of Viewpoint: There is divergence of viewpoint around the significance of benefit and risk of attempting to improve this in-river rearing habitat. Some estimate significant population level benefits to improving the naturally dynamic benefits of in-river rearing habitat. However, others only see nominal benefits and increased risk of stranding and mortality for salmon. This is an area of scientific uncertainty for future exploration.

Scientific Uncertainties Findings

To advance the evaluation and development of multi-benefit solutions it is critical to reduce uncertainty where possible. Reducing uncertainty can make decision-makers more confident in the estimated outcomes. Different types of uncertainties include scientific, data, and model uncertainties.

The Program Team convened an Ad-Hoc Group of fish biologists and species managers to identify scientific uncertainties. The group focused on significant reduceable scientific uncertainties and data needs that can clarify potential outcomes for decision-makers. Importantly, the representatives hold diverging viewpoints on the potential benefits of proposed multi-benefit concepts. However, they were able to converge around the key scientific uncertainties and data needs. This convergence around scientific uncertainties can be a powerful guide for science activities for future phases of the Floodplains Reimagined Program and its partners.

Reduceable scientific uncertainties for juvenile salmon habitat benefits and habitat suitability include:

Juvenile Salmon Habitat Benefits

- Evaluate in-river lateral fish distribution and behavior, and relative rates of entrainment of juvenile salmon at flood basin weir locations. Consideration of differing channel geometries, river reaches, and adjacent habitat types
- Evaluate juvenile salmon movements and residence times in flood basins
- Evaluate relative rearing survival rates of fry, parr, and pre-smolt life stages in flood basins, including conveyances and outlet, and the river channel
- Reconcile caged fish growth study rates with free-swimming growth and survival
- Determine if larger size translates to higher survival in Delta and/or ocean

Juvenile Salmon Habitat Suitability

- Use and/or preferences for depth and cover type within floodplain environments
- Connectivity and conveyance features and how they affect access, movement, and survival
- Evaluate managed field operations — fish access/egress passage

Approach

The approach to reducing scientific uncertainties is as follows:

- Work together to develop a shared understanding of the science of floodplains
- Address and investigate scientific uncertainties at the root of divergence of viewpoints and inform comparisons and evaluation of tradeoffs between multi-benefit concepts
- Support development of science around concepts parties are willing to explore

Model Uncertainties

Model uncertainties that affect the measured outcomes include structural and parameter uncertainty. There are several structural uncertainties that could increase our confidence in the evaluation of potential scenarios. For a fuller explanation of modeling uncertainties, see the Modeling Technical Memorandum in the Appendix.

Key Takeaways

This section will summarize key outcomes and takeaways for the Program's approach, development of multi-benefit concepts on landscape level, and for concept types.

Overview

- Landowner needs and concerns are paramount to developing a voluntary program
- Promising opportunities for multiple benefits
- Can meet multiple criteria, at different times and places, but not all at once
- Concepts require juvenile salmon presence, access, and habitat
- 2-inch depth margin of overlap for optimal habitat for juvenile salmon rearing habitat and bird habitat
- Some subregions are better suited to provide fish food rather than juvenile salmon rearing habitat

Baseline

- Primary Factors Influencing Inundation Patterns, Habitat Conditions, and Land Use Impacts
    - Proximity to primary waterways within the subregions
    - Water management on winter flooded rice and seasonal wetlands
    - Connection between each field or management unit to the primary waterways
- Butte Basin
    - Performs highly for juvenile salmon and bird habitat suitability
    - Positive and negative effects on agriculture and recreational waterfowl hunting
- Colusa Basin
    - Performs well for bird suitability habitat and low for juvenile salmon rearing
    - Variable positive and negative effects on agriculture and recreation.

- Sutter Bypass Basin
    - Variable bird suitability. There are diverging viewpoints about existing juvenile salmon habitat suitability in the Sutter Bypass

Feasibility

Hydrologic Feasibility

- All Phase I Preliminary Concepts are hydrologically feasible

Landowner Willingness

Landowners provided the following input:

- Support improving salmon recovery while respecting existing land uses
- Support for managed releases rather than uncontrolled flooding
- Request for holistic landscape solutions that protect non-participating neighbors
- Interest in considering increased frequency and duration of inundation rather than increased depth of inundation
- Interest in solutions that avoid potential decreases to 1) land value, 2) recreational hunting opportunities, 3) access, 4) safety, and 5) longevity of infrastructure including roads, buildings, and water conveyance.

Phase I Preliminary Concepts Benefits

Individual Concepts

- Show potential opportunities to increase juvenile salmon habitat. There still needs to be presence and flow for the juvenile salmon to benefit from the habitat.
- Show potential opportunities for fish food production.
- Show potential decreases for compatibility with bird habitat and waterfowl hunting and managed wetlands but neutral for agriculture.

Suite of Concepts

- Show potential opportunities to increase juvenile salmon habitat. There still needs to be presence and flow for the juvenile salmon to benefit from the habitat.
- Future analysis for fish food production and bird habitat suitability.
- Show potential compatibility with waterfowl hunting, managed wetlands, and agriculture.

Studies

- Fish Food Inventory —The assessment shows thousands of acres of rice fields are close enough to produce and deliver fish food to the juvenile salmon rearing in the neighboring streams.
- Butte Creek Flow Measurement — The study confirmed that the diversion of flow from Butte Creek at the Bifurcation Structure is consistent with water management agreements.

- Juvenile Rearing Enhancement Opportunities in Sacramento River Corridor— The results of this study demonstrate that isolated rearing pools are a common occurrence across the Sacramento River floodplain.

Scientific Uncertainties

Key takeaways for scientific uncertainties include the following areas. These areas are described more fully as recommendations for next steps for reducing scientific uncertainties in

- Salmon — juvenile Chinook salmon rearing in the following areas:
  - Growth, Survival and Movement Behavior
  - Floodplain Habitat Suitability
  - Benefits Subsequent to Floodplain Rearing
- Salmon and Birds — tradeoffs between adult and juvenile salmon.
- Food Resources —overlaps between bird habitat suitability and food resources.

Conclusion

The outcomes of this Phase I will inform the Program's future efforts as outlined in the Future Outlook section.

SECTION FOUR

Phase 1 Report

4

Section 4: Future Outlook

The Floodplains Reimagined team is grateful for the extensive participation from a diverse and extensive group of program partners. Phase 1 resulted in the following conclusions that will inform continued Program development and implementation:

- The principle of landowner willingness is foundational to a successful and sustainable program that leads to a healthy watershed.
- Providing landowners and managers with access to expertise to explore understanding of potential ramifications and/or benefits of changed management on or around the floodplains is key to support the voluntary and sustainable goals of the Program.
- Floodplains improvements and functionality appear to be critical to the recovery of native fisheries. There needs to be a continued dedication to understanding biological benefits and reducing data gaps.
- Engagement, Communication, and Outreach will remain Program priorities for an implementable credible Program with reduced future conflict.
- Landscape scale restoration requires extensive investment that will require substantial participation by Federal and State entities.

Future Approach

In this section, the report identifies lessons learned and their influence on the Floodplains Reimagined future approach. The key elements for the program's overall future approach include principles, technical assistance, science to reduce uncertainty, and coordination. In terms of option development, the future approach will include evaluation criteria development, multi-faceted option development, and evaluation.

Overall Approach

Principles

The Floodplains Reimagined future approach will retain its key principles and adapt to new needs arising from external changes. The Floodplains Reimagined governing principle remains "landowner willingness". This principle relies on the other principles that projects be voluntary and respect land uses. This approach has allowed the Program to meet landowners and agencies where they are and build a shared understanding of concerns and interests. This Program is committed to provide a platform that will allow stakeholders to engage in their own solution-making in the face of future pressures that may affect existing operations. Floodplains Reimagined prioritizes investment in engagement to minimize future conflict. In service of these principles, the Program will employ the strategies of restraint, patience, mutual learning and building trust.

Phase 2 Priorities

Landowner Support through Technical Assistance

Floodplains Reimagined developed a local technical assistance approach to support landowner and water user understanding and foster engagement. The technical assistance program provides local water users the opportunity to explore questions, concerns, and develop understanding of their potential participation in a landscape scale restoration program. More directly, this allows water users (landowners and managers) to understand potential impacts to their existing operations/land uses and use that information to gauge future engagement, planning, and action.

The Program supported three types of assistance that provided distinctly valuable results as follows: 1) subregional landowner groups achieved consensus on subregional multi-benefit options to offer the agencies, 2) individual landowners championed innovative analysis of their property and management that could inspire other landowners, 3) non-governmental groups produced landscape level analyses and inventories that will inform the development of options and evaluation of benefits across the landscape.

Based on the successful results from technical assistance, the Program will continue to empower local development of multi-benefit options and analysis of the landscape. In the short-term, the Program will focus on replicating the model of subregional landowner groups across the Sutter Bypass, Butte, and Colusa subregions. Landowner groups will evaluate options that benefit fish and are acceptable for their livelihoods and preservation of the values they place on the landscape. In the long-term, the Program will invest in both individual landowners who want to explore innovative approaches to share with other landowners and non-governmental organizations to study and analyze the key uncertainties identified in Phase I.

Advancing Floodplain Science through Reducing Scientific Uncertainty

As described in Section 3, it is necessary to reduce scientific uncertainties around Chinook salmon needs and potential benefits. There is a divergence of viewpoints and lack of data among scientists, water managers and agencies around the understanding of benefits of some floodplain activities for salmon. The Program Team will build on the work around understanding the scientific uncertainties regarding floodplain fish science. The goal is to reduce data gaps and increase the ability to evaluate potential restoration approaches in context of available resources. This will allow for a more robust decision-making framework for floodplain landowners and water managers while supporting native fish population recovery.

Coordination

In Phase I, the Floodplains Reimagined Program coordinated between efforts in the region at the level of setting priorities and objectives, developing evaluation criteria, compilation of efforts and links on the website. For our future approach, the Program Team will: 1) share information from related efforts, 2) engage stakeholders and interested parties, and 3) coordinate with related efforts to streamline and create value for multiple efforts. In particular, the Program will coordinate with other broader level planning efforts including Science Work Group for the Agreements for Healthy Rivers and Landscapes, the Central Valley Flood Board's Conservation Strategy efforts, and the Central Valley Program Improvement Act Science Integration Team.

Concept Development Process

The Floodplains Reimagined team learned key lessons about developing options to improve the floodplain function for salmon. The lessons are 1) collaborate with Program partners, specifically landowners and managers to develop concepts and options, 2) include multi-faceted and subregional options, and 3) expand evaluation criteria to include future stakeholder considerations (e.g. climate change/greenhouse gases).

Respect Existing Land Use: Landowners and Managers are Vital to a Voluntary Program

In Phase II, Floodplains Reimagined proposes to convene three subregional technical assistance groups. The three new groups will represent the Floodplains Reimagined region of focus including Butte Sink, Butte Slough, and Colusa Drain. This approach is based on the model used by Sutter Bypass Butte Slough Water Users Association during identification of multi-benefit options for the mid-Sutter Bypass.

The Program Team supported the formation of these three groups in 2023. The groups are currently starting to develop their technical approach with the Program Team. All three will be applying for technical assistance funding from Floodplains Reimagined by Q3 of 2024.

While the Program Team will focus on convening these subregional Technical Assistance Groups, they will also be open to proposals for the planning of individual studies, assessments, and projects with landowners that meet Program objectives. Stakeholder engagement has increased significantly through Phase 1; a myriad of individuals has stepped forward already to request assistance.

The purpose of subregional groups is to provide a framework for landowners to explore options that could meet multiple interests, assessed with the Evaluation Criteria. The desired outcome is for each group to develop 2-3 multi-benefit options for proposal to the Advisory Committee. The Advisory Committee will discuss evaluation of benefits and areas of alignment or divergence.

Multi-faceted and Subregional Options

In Phase I, landowners resisted single-faceted preliminary concepts presented as building blocks for option development. For example, Butte landowners resisted preliminary concepts of increased inundation with operable gates on weirs without the inclusion of mitigation measures such as elevated roads and infrastructure improvement. Landowners viewed these preliminary concepts as too risky as presented despite messaging that the concepts were not meant to be implemented in isolation of mitigation measures. Landowners expressed concern that single-focused concepts could gain traction and be taken out of context.

Landowners emphasized that any multi-benefit options need to address impacts in an integrated manner. Concern was expressed that one landowner's actions could have significant impacts on neighbors. This shared concern underscores the need to ensure that one landowner's voluntary action does not generate negative impacts for non-participating landowners.

The Program recommitted to its governing principle of landowner willingness when, in the spring of 2023, landowners in the Butte subregion expressed that some floodplain reconnection concepts, for example operable gates at flood control weirs were non-viable in their opinion. These concepts were found so objectionable that landowners requested the Program refrain from including them in the set of potential considerations. While landowners resisted those modeled options, the Program built credibility by respecting and reflecting landowner preferences. This approach has prioritized trust and relationships above the scheduled production of deliverables on a set timeline. This resulted in a significant increase in landowner and manager engagement and precipitated multiple technical assistance requests. The Program will be more robust and sustainable, as a result.

For the future approach, the Program Team will work with landowners to explore and develop multi-beneficial concepts with mitigation (e.g. improved agricultural infrastructure) recommendations. Importantly, subregional landowner groups have the ability to develop options in privacy, allowing development of multi-faceted options with mitigations prior to discussions with state and federal agency representatives. This sequence will help reduce the landowner sense of risk in developing preliminary concepts in conjunction with state and federal agencies whose authorities pose an unstated risk of potential regulation even in a voluntary forum.

Evaluation Criteria

In Phase I, the Program developed a set of evaluation criteria for assessing options. It is important to note that while the criteria enjoy support, participants identified areas of divergence and scientific uncertainties that will need to be reduced to inform updates to criteria. The Program built off other floodplain function programs and made significant contributions to advancing a set of well-supported criteria with identified gaps. The investment in this region can be leveraged by other floodplain function programs by adopting and adapting the evaluation criteria to their projects and regions.

For the Floodplain Reimagined future approach, the Program will build new criteria to fill the identified gaps, update criteria with new science, and make the criteria available to other regions for application.

New and updated evaluation criteria will include:

- [Update] to Juvenile Salmon Habitat Suitability Criteria
- [NEW] Food Web Production and Export Evaluation Criteria
- [NEW] Fate of Food Web and Benefits for Salmon

In the future, the Program will also update the assumptions in evaluation criteria based on science proposed in the section on Scientific Uncertainties and Data Needs:

- Juvenile Salmon Habitat Suitability Evaluation Criteria

  - Update assumptions for measuring benefits to salmon and the scale of the benefits.

- Water Quality Criteria for Fish Food Production and Juvenile Salmon Rearing

Future Work on Preliminary Concept Exploration

The initial results of Phase I will guide future work to develop and iterate on preliminary concepts. This section outlines general areas of future work, and the relationship between that work and each of the concept types: 1) River Connections, 2) Water Management Conveyance, 3) Land Management, and 4) In-River Function.

Future work focuses on the development of concepts that can be combined to provide benefits to fish, birds, and wildlife, while meeting healthy watershed and fish recovery goals.

River Connections

- Package river connections concepts with water management and land management concepts to provide multi-benefits.
- Explore river connection concepts that use operable gates and managed releases rather than uncontrolled flow over inoperable notches.
- Develop river connection concepts that increase duration and frequency of inundation of off-channel lands rather than concepts that increase the magnitude of overflow and inundation.
- Explore conceptual evaluations of:
  - Cumulative effects of river connections combined with other types of concepts that could produce cumulative benefits for salmon, birds, and landowners.
  - Operable gated weirs on Butte Creek in the area of M&T Ranch or 3Bs to benefit juvenile salmon habitat suitability.
  - New river connections at the outside of river bends indicated higher densities of juvenile salmon to increase access to juvenile salmon habitat on inundated lands outside the river channel.
  - Operable gates at Moulton and Colusa weirs with updated input from studies to reduce scientific uncertainty.
  - Areas of opportunity to allow for shallow inundation when natural larger floods occur, acknowledging that the current bathtub design increases depth rather than extending the inundated area and potential infrequent wetting of margin areas and their habitat suitability for floodplain wildlife.

Water Management Conveyance

- Colusa Subregion– Explore increased frequency of inundation at the optimal levels could support increased fish food production and export.
- Explore conceptual evaluations of:
  - Combinations of weir modifications with water conveyance to increase fish food production and bypass non-participating landowners
  - Upgrades to flood control infrastructure for multiple benefits
  - Upgrades to improve volitional passage and avoid stranding for juvenile and adult salmon

- Modifications to extend the region of inundation beyond the reach of Moulton and Colusa weirs' current overflow areas
- River and diversion structures that could increase movement of juvenile salmon from the Sacramento River into Butte Creek upstream of Butte Sink

Land Management

- Butte Subregion– Explore the benefits to Butte spring-run or Sacramento winter-run Chinook from increased fish food production in the Butte Basin.
- Sutter Subregion– Explore whether potential increase in fish food production and delivery to the Sacramento River will result in estimated benefit to Sacramento River juvenile salmon rearing.
- Colusa Subregion– Explore concepts to increase frequency of inundation in the Colusa Basin to produce fish food and deliver it to the juvenile winter-run Chinook in the Sacramento River.
- Explore conceptual evaluations of:
  - Late winter and spring managed wetland management practices for benefits to juvenile and adult salmon and other native fish
  - Sites Reservoir water supply for winter inundation of fields to benefit juvenile salmon rearing, fish food production, and bird habitat
  - Fish passage improvements in managed wetlands
  - Locations and distribution of instream juvenile fish-rearing and refuge habitats along the Sacramento River and its tributaries and their spatial relation to water returns from rice fields
  - Existing natural food availability in the Sacramento River and its tributaries to identify high benefit locations for fish food delivery from rice fields

- Evaluations related to waterfowl bioenergetics:
  - Inundated areas that have been exposed to high amounts of waterfowl foraging pressure and depleted waterfowl food resources which could be a small loss to wintertime inundation (e.g., areas that were flooded early when the total flood footprint was small, areas that had concentrated waterfowl use prior to flood)
  - Delayed winter inundation in some managed wetlands, ideally areas at low risk of natural inundation, until later in January to offset limited food resources
  - Voluntary deep inundation after mid-February, when most waterfowl have left the Sacramento Valley, food demand is low, and seed resources are mostly depleted

- Evaluation related to waterfowl hunting and managed wetlands:
  - Improving drainage capacity within managed wetlands could reduce the time wetlands spend in a non-huntable condition. However, this is counter to the efforts to provide fish the benefits of floodplains (increased residence time in wetlands)
  - Assessment of properties that could be optimized to manage and protect against damage from more frequent inundation

In-River Function

- Explore and prioritize opportunities to improve existing juvenile salmon rearing habitat within the Sacramento River corridor inside the levees.
- Explore evaluations of:
    - Improvement of quality and quantity of juvenile salmon rearing habitat within Butte Creek and Butte Slough
    - Butte Creek berm setbacks on agricultural fields and managed wetlands to optimize juvenile salmon rearing habitat and decrease risk of juvenile salmon stranding in an area where juvenile fish numbers are known to be high
    - Habitat corridor with the Butte Sink Mitigation Bank and RD70

Scientific Uncertainties and Data Needs

The following are key scientific uncertainties that if reduced could significantly inform the measurement of benefits and predictability of outcomes of various concepts. The next two sections will outline 1) Scientific uncertainties related to program priorities and 2) scientific uncertainties related to juvenile Chinook salmon.

Scientific Uncertainties for Salmon, Birds, Wetlands, and Tradeoffs

- Floodplain Wildlife - Salmon
    - Scientific Uncertainties related to juvenile Chinook salmon life stage as outlined in more detail in the section below
    - Quantification of risk tradeoffs between benefits to adult salmon with juvenile salmon
    - Quantification of the benefit of fish food production and delivery to the Sacramento River and incorporation into the evaluation of salmon benefits
    - Quantification of benefits of delivering fish food to main river channels
- Floodplain Wildlife – Birds
    - Quantification of availability of invertebrate densities within managed wetlands and rice fields, and how their abundance changes over time
    - Quantification and assessment of overlap of diets of water bird and juvenile salmon and benefits of fish food production on agricultural fields

Scientific Uncertainties Related to Juvenile Chinook Salmon in the Region

Collaboration across fishery scientists with expertise and vast experience in Northern California fisheries was one of the biggest successes of Phase 1. Scientists broke down silos to honestly discuss the knowns and the unknowns regarding floodplain and fish science as it relates to a goal of population recovery. (Appendix). The Program is committed to continuing this work of identifying data gaps and developing and implementing approaches to narrow these gaps for the purpose of improved science and better decision making.

River-floodplain ecosystems are large, temporally dynamic, and spatially heterogeneous, which can make it challenging to collect data in these systems. However, restoration and management of highly managed systems like the BBSB for the benefit of juvenile salmon require additional data both to reduce uncertainty in decision making and validate hypothesized ecological benefits. The development of models and analyses described above attempts to parameterize those hypothesized relationships with data that are available. The modeling and analyses

combined with discussions of other scientists participating in Floodplains Reimagined have revealed key areas of uncertainty that should be addressed. Some of these apply specifically to relationships within the Floodplains Reimagined footprint and others are related to fundamental uncertainties that link floodplain dynamics with the entire life cycle of Chinook salmon and the native fish assemblage.

Juvenile Salmon Access to the Butte Basin/Sutter Bypass

Key data needs:

1. Quantitative relationships between discrete hydrologic events and fish movement and arrival at junctions
2. Quantitative relationship between fish movement in junction and hydrologic/hydraulic metrics
3. Channel and weir junction characteristics that influence lateral distribution and behavior of migrating fish at junction locations and their potential for entrainment in the bypass

Growth, Survival, and Movement Behavior

Key data needs:

1. Growth of freely moving and migrating juvenile salmon during the hydrologic conditions of interest in both the main channel and floodplain
2. Habitat-specific estimates of survival for rearing juvenile salmon in habitats, and under hydrologic conditions of interest
3. Survival during egress through bypass outlets (e.g., Sacramento Slough)
4. Survival during egress/migration under extended rearing scenarios
5. Spatial distribution of rearing juvenile salmon in the BBSB
6. Patterns and factors associated with movements onto, within, and off the floodplain and back into the main river channel

Floodplain Habitat Suitability

Key data needs:

1. Use and/or preferences for depth and cover type of juvenile rearing salmon within floodplain environments, including managed floodplains of the Central Valley.
2. More detailed understanding and representation of connectivity and conveyance features, including managed field operations, and how they affect ingress, egress, movement, and survival within the floodplain and between the floodplain and main river channel
3. Greater understanding of detrimental impacts and/or trade-offs relative to other life stages (e.g., potential for adult passage via within-floodplain infrastructure).
4. Field-based validation comparing observed juvenile fish use and predicted habitat within Central Valley floodplains.

Benefits Subsequent to Floodplain Rearing

Key data needs:

1. Studies that specifically test hypothesized benefits of size during migration through the Delta
2. Studies that specifically test hypothesized benefits of size during early ocean residence
3. Test relationships between growth rate and migration timing
4. Identification and quantification of other mechanisms of hypothesized benefits
5. Validation of isotopic techniques and better resolution of isotopic sources within potential rearing habitat in the river, floodplain, and estuary.

Funding and Investments

Funding

Landscape scale restoration needs to be supported by reliable and extensive investment to achieve success. The Program partners are working together to identify and secure long-term reliable funding to establish and implement restoration and operation across this ½ million-acre footprint. Potential funding sources under could include but not limited to Federal funding via US Army Corps of Engineers, US Bureau of Reclamation, and Natural Resources Conservation Service.; State funding via the Agreements for Healthy Rivers and Landscapes or the proposed climate change resiliency bond.

The Program team will continue to pursue landscape scale investment as part of the implementation plan for Floodplains Reimagined.

Investments

In the near-term, the Program will invest in developing subregional multi-benefit options with subregional landowner groups, reducing scientific uncertainty, developing further evaluation criteria, and building consensus and a shared understanding of the science and benefits of various options.

Floodplains Reimagined plans to invest long-term in support of floodplain function for the region, reducing uncertainty around benefit for Chinook salmon, and supporting landowners to explore acceptable floodplain function options. In the long-term, the Program will continue to coordinate with related efforts. Coordination could produce synergy or provide a model from Floodplains Reimagined to other floodplain efforts in the Central Valley. The Program Team will also gather science and outcomes from other watershed efforts in the Colusa, Sutter, and Butte regions as well as on the Sacramento River, Yolo Bypass, Cache-Slough, and Feather River. The Program will support both organizational partners and landowners to better understand the relationship between these efforts and Floodplains Reimagined, and streamline requests, best practices, data gathering, and shared understanding of results.

References

(CVJV) Central Valley Joint Venture. 2020. Central Valley Joint Venture 2020 implementation plan: Sacramento, California: U.S. Fish and Wildlife Service.

(DWR and USBR) California Department of Water Resources and Reclamation District 1500. (2012). Yolo Bypass Salmonid Habitat Restoration and Fish Passage Implementation Plan, Long-Term Operation of the Central Valley Project and State Water Project Biological Opinion. Reasonable and Prudent Alternative Actions I.6.1 and I.7.

(DWR) California Department of Water Resources. 2022. Central Valley Flood Protection Plan, State Plan of Flood Control Descriptive Document.

(NCWA) Northern California Water Association. 2006. Sacramento Valley Integrated Regional Water Management Plan, Northern California Water Association.

(NCWA) Northern California Water Association. 2020. Feather River Regional Agricultural Water Management Plan, Northern California Water Association.

(RD 1500 and DWR) Reclamation District 1500 and California Department of Water Resources. 2023. Sutter and Tisdale Bypasses Flood & Multi-Benefit Management Plan. Prepared by KSN, cbec, and Douglas Environmental.

(SWC) State Water Contractors. 2019. Development of baseline data for fish growth and lower trophic production on the Sutter Bypass – 2018 pilot study. Prepared by: Cordoleani, Flora & Holmes, Eric & Jeffres, Carson, Agreement Number 63624-447552.

(USBR and DWR) U.S. Bureau of Reclamation and California Department of Water Resources. 2019. Yolo Bypass Salmonid Habitat Restoration and Fish Passage Project.

[CDFW] California Department of Fish and Wildlife. 2021. State and Federally Listed Endangered and Threatened Animals of California. State of California Natural Resources Agency, Department of Fish and Wildlife, Biogeographic Data Branch. Available from: https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=109405&inline.

[CVJV] Central Valley Joint Venture. 2020. Central Valley Joint Venture 2020 Implementation Plan. Sacramento, CA: U.S. Fish and Wildlife Service. Available from: https://www.centralvalleyjointventure.org/science/2020-implementation-plan.

[USCPP] U.S. Shorebird Conservation Plan Partnership. 2015. Shorebirds of Conservation Concern in the United States of America — 2015. Washington, D.C.: U.S. Fish and Wildlife Service. Available from: http://www.shorebirdplan.org/science/ assessment-conservation-status-shorebirds/

Amoros, C., Bornette, G., 2002. Connectivity and biocomplexity in waterbodies of riverine floodplains. Freshwater Biology 47, 761–776. https://doi.org/10.1046/j.1365-2427.2002.00905.x

Andrews, C.S., Miranda, L.E., Goetz, D.B. and Kröger, R., 2014. Spatial patterns of lacustrine fish assemblages in a catchment of the Mississippi Alluvial Valley. Aquatic Conservation: Marine and Freshwater Ecosystems, 24(5), pp.634-644.

Arthington, A.H., Balcombe, S.R., 2011. Extreme flow variability and the 'boom and bust' ecology of fish in arid-zone floodplain rivers: a case history with implications for environmental flows, conservation and management. Ecohydrology 4, 708–720. https://doi.org/10.1002/eco.221

Atwater, B.F. 1980. Attempts to correlate late quaternary climatic records between San Francisco Bay, the Sacramento-San Joaquin Delta, and the Mokelumne River, California. PhD dissertation. University of Delaware.

Bayley, P.B., 1991. The flood pulse advantage and the restoration of river-floodplain systems. Regulated Rivers: Research & Management 6, 75–86. https://doi.org/10.1002/rrr.3450060203

Beechie, T., Imaki, H., Greene, J., Wade, A., Wu, H., Pess, G., Roni, P., Kimball, J., Stanford, J., Kiffney, P. and Mantua, N., 2013. Restoring salmon habitat for a changing climate. River research and applications, 29(8), pp.939-960.

Brouder, S. M. and Hill. 1995. Conjunctive use of farmland adds value: Winter flooding of rice lands provides waterfowl habitat. California Agriculture: 49, 58-64. J. E.

Bryan K. 1923. Geology and ground-water resources of Sacramento Valley, California. Government Printing Office, Washington, DC.

Bunn, S.E., Arthington, A.H., 2002. Basic principles and ecological consequences of altered flow regimes for aquatic biodiversity. Environmental Management 30, 492–507. https://doi.org/10.1007/s00267-002-2737-0

Butte Subbasin. 2022. Butte Subbasin, Sustainable Groundwater Management Act (SGMA) Groundwater Sustainability Plan (GSP). Prepared by Davids Engineering, Inc; Woodard & Curran, Inc.; GEI Consultants, Inc.

Colusa and Glenn Groundwater Authority. 2021. Colusa Subbasin, Groundwater Sustainability Plan (GSP).

Cordoleani, Flora & Holmes, Eric & Bell Tilcock, Miranda & Johnson, Rachel & Jeffres, Carson. (2021). Evaluating the role(s) of the Butte sink and Sutter Bypass for Butte Creek spring-run Chinook Salmon and other Central Valley juvenile salmonid populations -2020 study year. [Preprint]. DOI: 10.13140/RG.2.2.10226.22722.

Cordoleani, Flora & Holmes, Eric & Bell Tilcock, Miranda & Johnson, Rachel & Jeffres, Carson. (2022). Evaluating the role(s) of the Butte sink and Sutter Bypass for Butte Creek spring-run Chinook Salmon and other Central Valley juvenile salmonid populations -2020 study year. [Preprint]. DOI: 10.13140/RG.2.2.23704.11521.

Davidson, T.A., Mackay, A.W., Wolski, P., Mazebedi, R., Murray-Hudson, M., Todd, M., 2012. Seasonal and spatial hydrological variability drives aquatic biodiversity in a flood-pulsed, sub-tropical wetland. Freshwater Biology 57, 1253–1265. https://doi.org/10.1111/j.1365-2427.2012.02795.x

DiGaudio R.T., Dybala K.E., Seavy N.E., Gardali T. 2017. Population and habitat objectives for avian conservation in California's Central Valley grassland–oak savannah ecosystems. San Francisco Estuary and Watershed Science. 15(1):6. doi:10.15447/sfews.2017v15iss1art6.

Ducks Unlimited. 2017. Assessing Waterfowl Benefits from Water Used to Grow Rice in CA. Prepared for California Rice Commission.

Dudgeon, D., Arthington, A.H., Gessner, M.O., Kawabata, Z.-I., Knowler, D.J., Lévêque, C., Naiman, R.J., Prieur-Richard, A.-H., Soto, D., Stiassny, M.L.J., Sullivan, C.A., 2006. Freshwater biodiversity: Importance, threats, status and conservation challenges. Biological Reviews 81, 163–182. https://doi.org/10.1017/S1464793105006950

DWR. 2022. State Plan for Flood Control Descriptive Document. Central Valley Flood Protection Board. Available from: https://cvfpb.ca.gov/wp-content/uploads/2022/11/2022-SPFC-DescriptiveDoc_Final.pdf

Dybala K.E. 2016. bioenergmod: Bioenergetics Modeling. R package 0.1.0. Available from: https://github.com/kdybala/bioenergmod.

Dybala K.E., Clipperton N., Gardali T., Golet G.H., Kelsey R., Lorenzato S., Melcer Jr. R., Seavy N.E., Silveira J.G., Yarris G.S. 2017. Population and habitat objectives for avian conservation in California's Central Valley riparian ecosystems. San Francisco Estuary and Watershed Science. 15(1):5. doi:10.15447/sfews.2017v15iss1art5.

Dybala K.E., Reiter M.E., Hickey C.M., Shuford W.D., Strum K.M., Yarris G.S. 2017. A bioenergetics approach to setting conservation objectives for non-breeding shorebirds in California's Central Valley. San Francisco Estuary and Watershed Science. 15(1):2. doi:10.15447/sfews.2017v15iss1art2.

Euliss, N.H., and Harris, S.W. 1987. Feeding ecology of Northern Pintails and Green-winged Teal wintering in California. Journal of Wildlife Management 51: 724–732

Fleming K.K., Brasher M.G., Humburg D.D., Petrie M.J., Soulliere G.J. 2017. Derivation of regional, non-breeding duck population abundance objectives to inform conservation planning. North American Waterfowl Management Plan Science Support Team Technical Report 2017-01.

Frayer W.E., Peters DD, Pywell H.R. 1989. Wetlands of the California Central Valley: status and trends: 1939 to mid-1980's. Portland, OR: U.S. Fish and Wildlife Service. Available from: http://www.fwspubs.org/doi/suppl/10.3996/012014-JFWM-003/suppl_file/012014-jfwm-003.s10.pdf.

Fredrickson L.H., Reid F.A. 1988. Waterfowl Use of Wetland Complexes. Waterfowl Management Handbook. 1. Available from: https://digitalcommons.unl.edu/icwdmwfm/1.

Fredrickson, L.H., and Taylor, T.S. 1982. Management of Seasonally Flooded Impoundments for Wildlife. United States Department of the Interior, Fish and Wildlife Service Resource Publication 148. Washington, District of Columbia. 29 p.

Gallardo, B., Gascón, S., González-Sanchís, M., Cabezas, A., Comín, F.A., 2009. Modelling the response of floodplain aquatic assemblages across the lateral hydrological connectivity gradient. Marine and Freshwater Research 60, 924–935. https://doi.org/10.1071/MF08277

Garone PF. 2006. The fall and rise of the wetlands of California's Great Central Valley: A historical and ecological study of an endangered resource of the Pacific Flyway. University of California, Davis. Available from: https://www.proquest.com/openview/54fc8f66f5ef3424dc1d84b937ab7d5f/1?pq-origsite=gscholar&cbl=18750&diss=y.

Gilbert GK. 1917. Hydraulic-mining debris in the Sierra Nevada. U.S. Geological Survey. Washington, DC: U.S. Government Printing Office.

Gilmer D.S., Euliss N.H., Jarvis, RL. 1982 Feeding ecology of waterfowl wintering on evaporation ponds in California. The Cooper Ornithological Society.

Golet G.H., Dybala K.E., Reiter M.E., Sesser K.A., Reynolds M., Kelsey R. 2022. Shorebird food energy shortfalls and the effectiveness of habitat incentive programs in record wet, dry, and warm years. Ecological Monographs. doi:10.1002/ecm.1541.

Grosholz, E., Gallo, E., 2006. The influence of flood cycle and fish predation on invertebrate production on a restored California floodplain. Hydrobiologia 568, 91–109. https://doi.org/10.1007/s10750-006-0029-z

Heitmeyer M.E., Connelly D.P., Pederson R.L. 1989. The central, imperial, and Coachella Valleys of California. In: Smith L.M, Pederson R.L., Kaminski R.M., editors. Habitat management for migrating and wintering waterfowl in North America. Lubbock: Texas Tech University Press; p. 475–505.

Heitmeyer, M. E. 1989. Agriculture/wildlife enhancement in California: The Central Valley Habitat Joint Venture. Transactions of the North American Wildlife and Natural Resources Conference 54:391-402.

Howitt R., MacEwan D., Garnache C., Medellin-Azuara J., Marchand P., Brown D. 2013. Agricultural and Economic Impacts of Yolo Bypass Fish Habitat Proposals, Yolo County.

Junk, W.J., Bayley, P.B., Sparks, R.E., 1989. The flood pulse concept in river-floodplain systems. Canadian Special Publication of Fisheries and Aquatic Sciences 106, 110–127.

Matthews, L. J., Petrie, M., and Eadie, J. M. 2022. Impacts of Changing Postharvest Agricultural Practices on Abundance of Waste Grain in California's Central Valley. Journal of Fish and Wildlife Management, 13(2), 32–333. https://doi.org/10.3996/JFWM-21-061

Naylor, L.W. 2002. Evaluating moist-soil seed production and management in Central Valley Wetlands to determine habitat needs for waterfowl. M.Sc. thesis, University of California, Davis, California, USA

Opperman, J.J., Galloway, G.E., Fargione, J., Mount, J.F., Richter, B.D., Secchi, S., 2009. Sustainable floodplains through large-scale reconnection to rivers. Science 326, 1487–1488. https://doi.org/10.1126/science.1178256

Opperman, J.J., Moyle, P.B., Larsen, E.W., Florsheim, J.L., Manfree, A.D., 2017. Floodplains: Processes and Management for Ecosystem Services. University of California Press.

Petrie, M. J., Fleskes, J. P., Wolder, M. A., Isola, C. R., Yarris, G. S., & Skalos, D. A. (2016). Potential effects of drought on carrying capacity for wintering waterfowl in the central valley of California. Journal of Fish and Wildlife Management, 7(2), 408–422. https://doi.org/10.3996/082015-JFWM-082

Poff, N.L., Allan, J.D., Bain, M.B., Karr, J.R., Prestegaard, K.L., Richter, B.D., Sparks, R.E., Stromberg, J.C., 1997. The natural flow regime. BioScience 47, 769–784. https://doi.org/10.2307/1313099

Poff, N.L., Olden, J.D., Merritt, D.M., Pepin, D.M., 2007. Homogenization of regional river dynamics by dams and global biodiversity implications. Proceedings of the National Academy of Sciences 104, 5732–5737. https://doi.org/10.1073/pnas.0609812104

Reid F.A., Fehringer D, Spell R, Petrik K, Petrie M. 2018. Wetlands of California's Central Valley (USA). In: Finlayson CM, Milton GR, Prentice RC, Davidson NC, editors. The Wetland Book: II: Distribution, Description, and Conservation. Dordrecht: Springer Netherlands. p. 697–703. doi:10.1007/978-94-007-4001-3_119.

River Partners. 2021. Lower Sutter Bypass Anadromous Fish Habitat Management Planning Project, available at https://lowersutterbypassfish.org/

River Partners. 2022. Economic Analysis of Agricultural Production in the Lower Sutter Bypass for Alternative Inundation Scenarios, Pacific Agroecology and Economics, LLC.

Shuford W.D., Dybala KE. 2017. Conservation objectives for wintering and breeding waterbirds in California's Central Valley. San Francisco Estuary and Watershed Science. 15(1):4. doi:10.15447/sfews.2017v15iss1art4.

Shuford W.D., Gardali T. 2008. California Bird Species of Special Concern: A ranked assessment of species, subspecies, and distinct populations of birds of immediate conservation concern in California. Western Field Ornithologists, Camarillo, California, and California Department of Fish and Game, Sacramento, California. Available from: https://wildlife.ca.gov/Conservation/SSC/Birds.

Shuford W.D., Page GW, Kjelmyr JE. 1998. Patterns and dynamics of shorebird use of California's Central Valley. Condor. 100:227–244. doi:10.2307/1370264.

Simões, N.R., Dias, J.D., Leal, C.M., de Souza Magalhães Braghin, L., Lansac-Tôha, F.A., Bonecker, C.C., 2013. Floods control the influence of environmental gradients on the diversity of zooplankton communities in a neotropical floodplain. Aquatic Sciences 75, 607–617. https://doi.org/10.1007/s00027-013-0304-9

Smith L.M., Euliss N., Browne B., Wilcox D.A. 2008. Linking ecosystem processes with wetland management goals: Charting a course for a sustainable future. Wetlands (Wilmington, N.C.)

Strum K.M., Dybala KE, Iglecia MN, Shuford WD. 2017. Population and habitat objectives for breeding shorebirds in California's Central Valley. San Francisco Estuary and Watershed Science. 15(1):3. doi:10.15447/sfews.2017v15iss1art3.

Tockner, K., Malard, F., Ward, J.V., 2000. An extension of the flood pulse concept. Hydrological Processes 14, 2861–2883. https://doi.org/10.1002/1099-1085(200011/12)14:16/17<2861::AID-HYP124>3.0.CO;2-F

Tockner, K., Pusch, M., Borchardt, D., Lorang, M.S., 2010. Multiple stressors in coupled river–floodplain ecosystems. Freshwater Biology 55, 135–151. https://doi.org/10.1111/j.1365-2427.2009.02371.x

Tockner, K., Schiemer, F., Baumgartner, C., Kum, G., Weigand, E., Zweimüller, I. and Ward, J.V., 1999. The Danube restoration project: species diversity patterns across connectivity gradients in the floodplain system. River Research and Applications, 15(1-3), pp.245-258.

Tockner, K., Stanford, J.A., 2002. Riverine flood plains: Present state and future trends. Environmental Conservation 29, 308–330. https://doi.org/10.1017/S037689290200022X

Visit Yuba Sutter. 2022. Sutter National Wildlife Refuge. Available from: https://visityubasutter.com/activity/sutter-national-wildlife-refuge

Ward, J.V., 1989. The four-dimensional nature of lotic ecosystems. Journal of the North American Benthological Society 8, 2–8. https://doi.org/10.2307/1467397

Ward, J.V., Tockner, K., Schiemer, F., 1999. Biodiversity of floodplain river ecosystems: ecotones and connectivity. Regulated Rivers: Research & Management 15, 125–139. https://doi.org/10.1002/(SICI)1099-1646(199901/06)15:1/3<125::AID-RRR523>3.0.CO;2-E

Whipple, A. A., Viers, J. H., & Dahlke, H. E. 2017. Flood regime typology for floodplain ecosystem management as applied to the unregulated Cosumnes River of California, United States. Ecohydrology, 10(5), e1817. DOI: 10.1002/eco.1817

Whipple, A.A., Grantham, T., Desanker, G., Hunt, L., Merrill, A. 2019. Chinook Salmon Habitat Quantification Tool: User Guide (Version 1.0) (No. 953), Prepared for American Rivers. Funded by the Natural Resources Conservation Service Conservation Innovation Grant (#69-3A75-17-40), Water Foundation and Environmental Defense Fund. San Francisco Estuary Institute, Richmond, CA.

Whipple, A.A., Grossinger, R.M., Rankin, D., Stanford, B., Askevold, R.A. 2012. Sacramento-San Joaquin Delta Historical Ecology Investigation: Exploring Pattern and Process. Prepared for the California Department of Fish and Game and Ecosystem Restoration Program. A Report of SFEI-ASC's Historical Ecology Program, SFEI-ASC Publication #672, San Francisco Estuary Institute-Aquatic Science Center, Richmond, CA.

Yoshiyama, R.M., Fisher, F.W. and Moyle, P.B., 1998. Historical abundance and decline of chinook salmon in the Central Valley region of California. North American Journal of Fisheries Management, 18(3), pp.487-521.