Final Feasibility Study

LITTLE EGBERT MULTI-BENEFIT PROJECT

SOLANO COUNTY, CALIFORNIA

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List of Acronyms

AEP	Annual Exceedance Probability
AC	Acre
BiOp	Biological Opinion
BWFS	Basin Wide Feasibility Study
Caltrans	California Department of Transportation
CNRA	California Natural Resources Agency
CDFW	California Department of Fish and Wildlife
CEQA	California Environmental Quality Act
CFS	Cubic Feet Per Second
CNPS	California Native Plant Society
CVFED	Central Valley Floodplain Evaluation and Delineation Project
CVFPB	Central Valley Flood Protection Board
CVP	Central Valley Project
DCC	Delta Cross-Channel
DPC	Delta Protection Commission
DPS	Department of Public Safety
DSC	Delta Stewardship Council
DO	Dissolved Oxygen
DWR	California Department of Water Resources

List of Acronyms

DWSC	Deep Water Ship Channel
EC	Electrical Conductivity
EIR	Environmental Impact Report
EIS	Environmental Impact Statement
ESA	Endangered Species Act
ESU	Evolutionary Significant Unit
FMMP	Farmland Mapping and Monitoring Plan
FPS	Feet Per Second
FRMP	Flood Risk Management Plan
FRP	Fish Restoration Program
FS	Feasibility Study
FT	Feet or Foot
FWOP	Future Without a Project
GGS	Giant Garter Snake
GIS	Geographic Information System
HSI	Habitat Suitability Index
LEBLS	Lower Elkhorn Basin Levee Setback
LEJPA	Little Egbert Joint Powers Agency
LEMBP	Little Egbert Multi-Benefit Project
LET	Little Egbert Tract
LiDAR	Light Detection and Ranging
LMA	Local Maintaining Agency
LSND	Lower Sacramento North Delta
MHHW	Mean High High Water
MLLW	Mean Low Low Water
MTL	Mean Tide Level
MOU	Memorandum of Understanding
NAVD 88	The North American Vertical Datum of 1988
NDWA	North Delta Water Agency
NGVD 29	The National Geodetic Vertical Datum of 1929
NEPA	National Environmental Policy Act
NOAA	National Oceanographic and Atmospheric Administration
NPDES	National Pollution Discharge Elimination System
NMFS	National Marine Fisheries Service
NRCS	Natural Resources Conservation Service
O&M	Operations and Maintenance
OMRRR	Operation, Maintenance, Repair, Replacement, and Rehabilitation
OCAP	Long-Term Operational Criteria and Plan
OPC	California Ocean Protection Council
PG&E	Pacific Gas and Electric

List of Acronyms

RD	Reclamation District
RMA	Resource Management Associates
RTK	Real-Time Kinematic
SAFCA	Sacramento Area Flood Control Agency
SFEI	San Francisco Estuary Institute
SLR	Sea Level Rise
SPFC	State Plan of Flood Control
SR 84	State Route 84
SRFCP	Sacramento River Flood Control Project
SUTYOL	Sutter County and Yolo Bypass Model
T&E	Threatened and Endangered
USACE	US Army Corps of Engineers
USFWS	US Fish and Wildlife Service
USGS	US Geological Survey
VA	Voluntary Agreement
WES	Westervelt Ecological Services
WSE	Water Surface Elevation

1. Introduction

The Little Egbert Multi-Benefit Project Feasibility Study (LEMBP or Study) seeks to identify implementable project alternatives for the proposed Little Egbert Multi-Benefit Project (Project). The primary objectives of the proposed Project are to provide flood risk reduction to enhance public safety, preserve and enhance ecosystem benefits for the recovery of native species benefits and create new or enhanced recreational opportunities at the Little Egbert Tract (LET, Tract, Study Area, Site, or Property) in Solano County, California. Other goals of the Study are to produce technical analyses critical to forming a basis of understanding of hydraulic, geological, and ecological conditions, seek public input concerning the Project, test hydraulic and ecological effects of alternative features, and provide a framework to inform CEQA and NEPA analysis. All proposed Project alternative features including levee design, habitat design, and recreational elements are preliminary in nature and are intended to be used for future scoping and analysis. The Study was conducted by the Little Egbert Joint Powers Agency (LEJPA) in partnership with the California Department of Water Resources (DWR). LEJPA obtained a grant from the California Natural Resources Agency (CNRA) to fund the Study and DWR provided funding to support the recreation study and hydrodynamic modeling efforts. This Feasibility Study has been composed to help CNRA and DWR gain a better understanding of which Project Alternatives would be the most beneficial and feasible options.

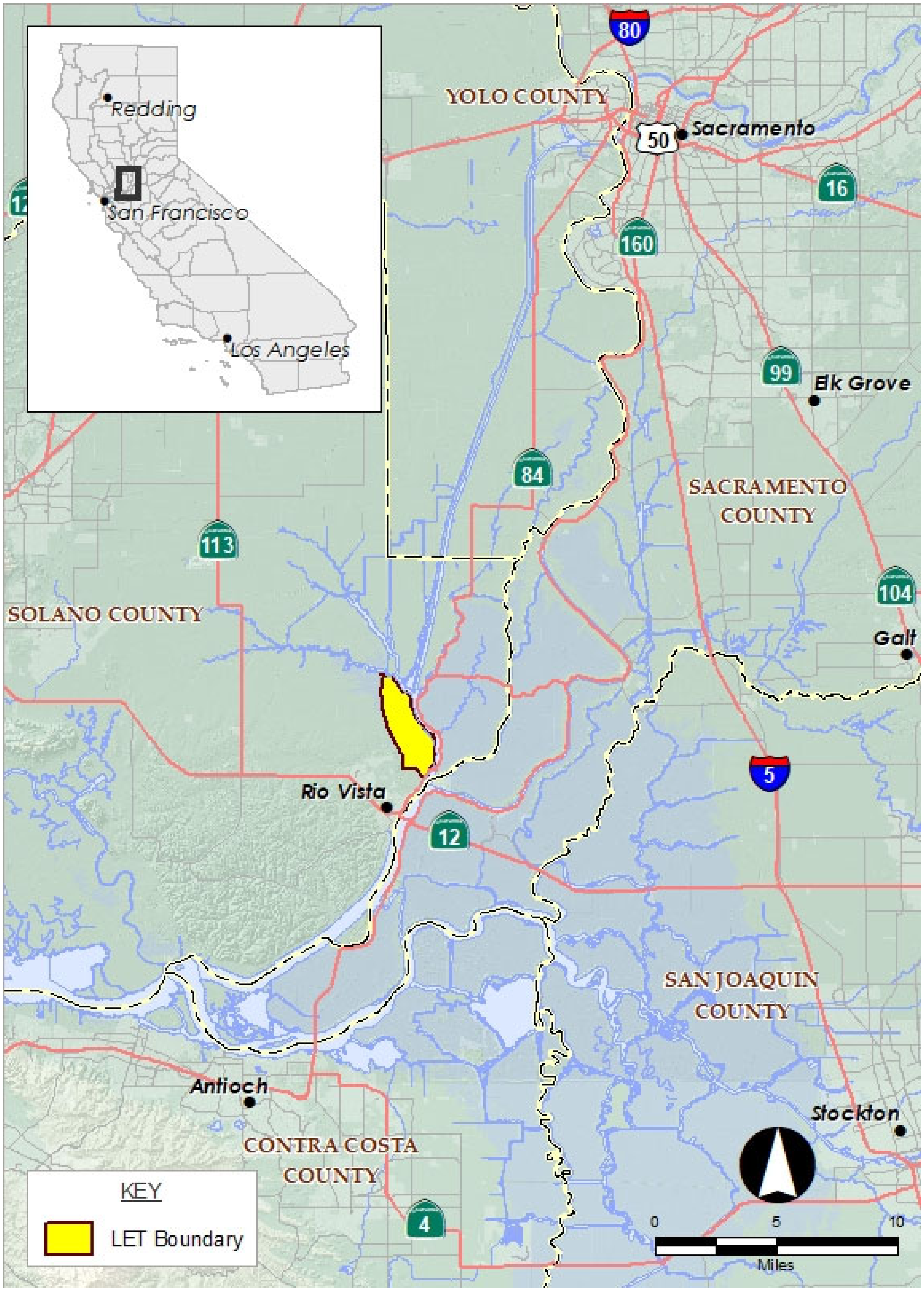
1.1. Project Setting

The Tract is located within the Sacramento-San Joaquin River Delta (Delta) and is part of the largest estuarine system on the West Coast (Figure 1). The Delta is home to around 500,000 (Water Education Foundation 2020) people from multiple historic farming communities and conveys water to around 4.5 million acres of farmland and two-thirds of California's population. The Delta ecosystem provides habitat for migratory birds of the Pacific Flyway, anadromous salmon, and many other threatened and endangered fish and wildlife species. As reported in the Delta Plan (2019, as amended), the region also includes some of the most fertile soil in the State The region is built upon thousands of years of peat soil accumulation from the freshwater marshes that covered the region since the end of the last ice age.

Of the approximately 3,127 Property-acres, approximately 2,600-acres are active farmland. The Tract is approximately one mile northeast of the City of Rio Vista and is bordered on the east by Cache Slough, on the northwest by Lindsey Slough, and the Sacramento River to the southeast. Rio Vista Municipal Airport (Airport) and Reclamation District (RD) 536 are located to the west of the Tract.

LET lies at the lower end of the Yolo Bypass at the confluence of some of the state's largest rivers and floodways. The study area includes sections of the Yolo Bypass, Sacramento River, Deep Water Ship Channel (DWSC), and several sloughs in the Delta.

Figure 1. Project Location Map



The Powell property, which is not part of the proposed Project, is adjacent and located to the south of the study area and is separated from the study area by the Watson Hollow Slough. This 350-acre property is privately owned and is being developed independently of the Project as a private mitigation bank (Bank) to re-establish tidal freshwater wetland and floodplain-associated vegetation within the interior of the property.

Several levees surround the Tract; the Tract is bound by levees on the west side and to the distant south including: the Mellin Levee, Mellin Levee Extension (Solano County Levee 44), RD 2084 restricted-height levee (Solano County Levee 28), and the RD 536 levee. The Mellin Levee and the RD 536 Levee are State Plan of Flood Control facilities. The restricted-height levee borders the east side of the Tract and is limited in elevation due to deed restrictions for flowage easements purchased by the State of California. When water levels are high enough, the restricted-height levee is designed to allow flows from the Yolo Bypass to enter and pass through the LET.

Relevant Delta Land Use and Resource Management Plans and Strategies:

- California Water Resiliency Portfolio
- Bay Delta Conservation Plan
- Rio Vista Airport Master Plan
- Delta Risk Management Strategy
- California Water Resilience Portfolio
- 2022 Central Valley Flood Protection Plan and Conservation Strategy
- Delta Plan
- Solano County – Cache Slough Complex Habitat Compensation Plan (in preparation)
- Lower Sacramento/Delta North Regional Flood Management Plan
- Solano County Multispecies Habitat Conservation Plan (HCP) (Draft 2012)
- Yolo Habitat Conservation Plan/Natural Community Conservation Plan (HCP/NCCP)

1.2. Project Background/History

This Study and alternative development takes into account the history of the three main goals: flood, habitat and recreation. All of which have dominated the landscape changes in the Central Valley for over 200 years. Below is a brief overview of these areas as context for the decision-making process regarding alternative selection.

If not described in the text, additional background information can be found in references listed here, in no particular order:

- U.S. Army Corps of Engineers (USACE). 1981
- The California Debris Commission: A History. Thompson, J., & Dutra, E. (1986)
- The Tule breakers. Madera, CA: Word Dancer Press
- Battling the Inland Sea (Kelley, R., 1998)

- California: A History (Starr, K., 1980)
- A Short Overview of California Indian History (Professor Edward D. Castillo, undated)
- A history of tillage in California's Central Valley (Michell, J.P, et al, 2016)
- Wetlands of the Central Valley: Status and Trends, 1939 to mid-1980s (Frayer, W.E., Peters, D.D. and Pywell, H.R., 1989)
- The Fall and Rise of the Wetlands of California's Great Central Valley (Garone, P., 2020)
- Local Water Governance in the Delta (Wilson C.M., A Report to the State Water Resources Control Board and the Delta Stewardship Council, 2014)
- State of California Sea-Level Rise Guidance (CA Natural Resources Agency and CA Ocean Protection Council, 2018)
- Ecological History (Bartolome, J. and Spiegal, S., 2014, updated version of a report originally published in Proceedings of the Man and the Biosphere Symposium
- Landscape Ecology: Study of Mediterranean Grazed Ecosystems, Nice, France. Oct. 7-8, 1989.
- Department of Agronomy and Range Science, University of California, Davis. Pages 2-15)
- Two Years Before the Mast (Dana, R.H., 1840)
- Cadillac Desert: The American West and Its Disappearing Water (Reisner, M. 1986)
- Sacramento District History (1929-2004) USACE, and from information on web pages, including:
- Yolo Foundation (https://www.yolobasin.org/storymap/),
- University of California (https://ucanr.edu/blogs/blogcore/postdetail.cfm?postnum=50373)
- Audubon Society (https://ca.audubon.org/news/case-wetlands-central-valley),
- U.S. Bureau of Reclamation (https://www.usbr.gov/mp/cvp/about-cvp.html),

1.2.1. Flood

The Yolo Bypass, situated in the southernmost portion of the Sacramento River system, diverts high flows from the Sacramento River over the Fremont Weir just downstream of Knights Landing and directs flows back into the Sacramento River just upstream of Rio Vista thus bypassing Sacramento and much of the North Delta.

Much of this system is over 100 years old and in need of modernization to sustain its design level of performance. The levees were originally set close to channels to increase water velocity and capacity to flush the hydraulic mining debris of the late 1800's. Since then, flood control dams constructed in the 20th century cut off much of the sediment supply and the increased water velocities erode the banks of the river channel. Many changes over the years are driving the need to modernize the flood system, including changes in river conditions, land uses, updated levee standards, and ongoing future changes to hydrology and sea levels due to climate.

Historically, LET was hydrologically connected to the broader Delta landscape, which was composed of vast assortments of emergent marsh, riparian, and open water habitats (Figure 2).

The Site was seasonally inundated, prior to the Sacramento River Flood Control Project (SRFCP) and adjacent levees being constructed. The RD 536 Levee was constructed by the U.S. Army Corps of Engineers (USACE) in 1924 and improved in 1942. The Watson Hollow Diversion Canal (Watson Hollow Slough) was constructed in 1943 to provide irrigation water to RD 536 and to facilitate drainage from the Montezuma Hills to the west to Cache Slough in the east. The Site is located at the downstream end of the Yolo Bypass, within the primary zone of the Sacramento-San Joaquin Delta. The Tract is currently protected by a restricted height levee that is limited in elevation by deed restrictions to 15.3 feet at the north end and 10.3 feet NAVD 88 at the south end.

1.2.2. Natural Landscape and Habitat

The Central Valley was historically abundant in natural resources, providing Native Americans and early explorers with food, fiber, and trade routes along waterways. However, the rapid influx of settlers following the Gold Rush significantly transformed the landscape. Through the 1850 Swamp Land Act, ownership of “swamp and overflowed” lands shifted from the federal to State government, encouraging the conversion of floodplains and marshes into agriculture. In addition, hydraulic “placer” mining in the surrounding gold mining regions caused erosion, sediment deposition in rivers and flooding of reclaimed lands. These factors led to construction of higher levees and further conversion of marshes and floodplains into agricultural areas during the late 1800’s and early 1900’s.

This transformation had a profound impact on the Central Valley’s ecosystem. More than 95 percent of its historic floodplains, riparian forests and marshes were lost (Figure 2), (San Francisco Estuary Institute-Aquatic Science Center, 2012). The loss of habitat has significantly contributed to the decline of numerous species, leading to the listing of some as threatened or endangered by federal and state agencies. As a result, new projects are required to conduct biological assessments of impacts, obtain permits from resource agencies, and provide offsets to mitigate adverse impacts on the listed species and their habitats.

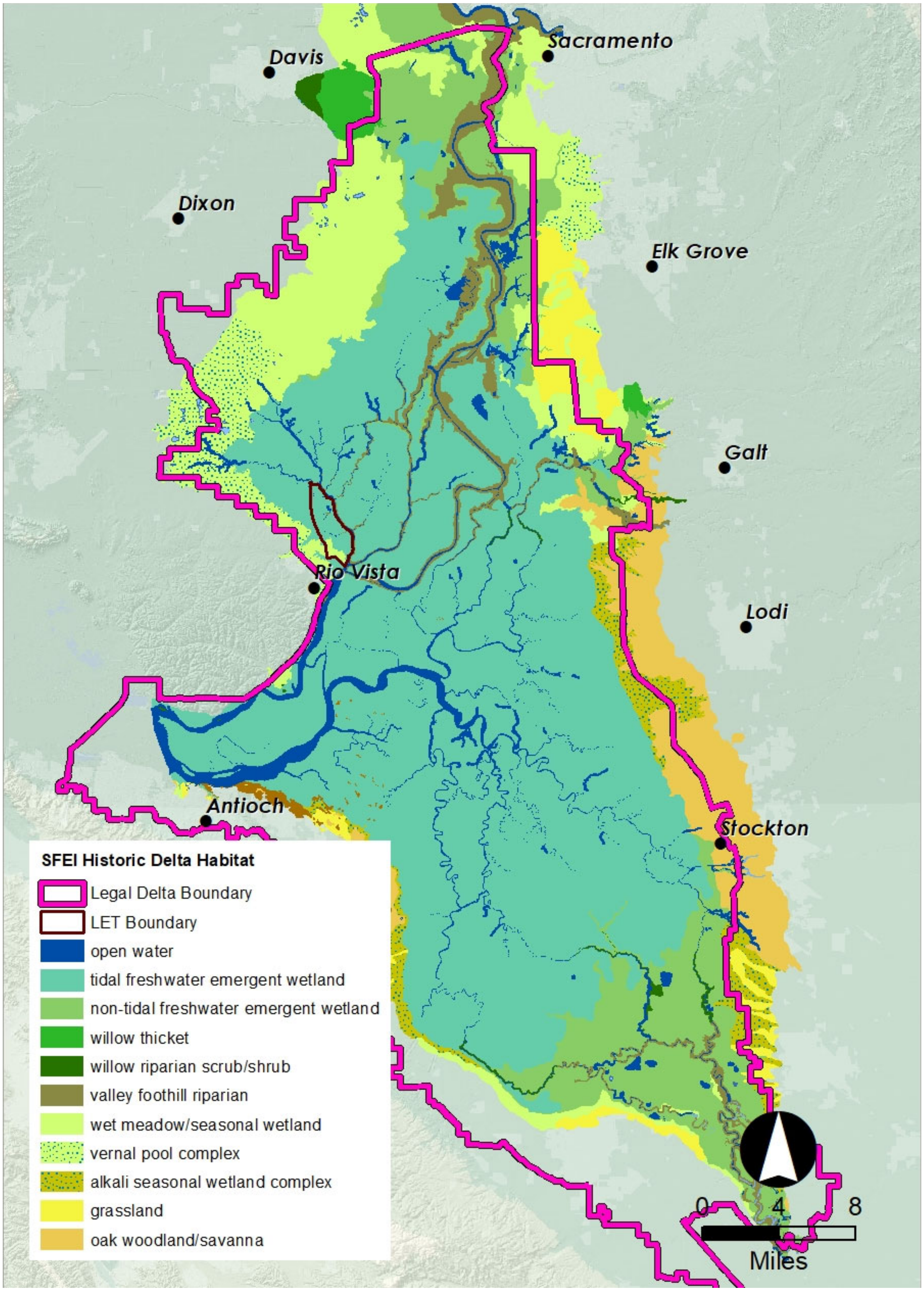
The Site lies at the interface of historic landscapes including the Yolo Basin, the Putah Creek alluvial fan, and expansive intertidal marshes (Whipple et al. 2012). The Plains Miwok would likely have had settlements within the Property and throughout the area. Historically, subtidal mud and sand bars, or “shoals,” were present at the Delta mouth. Intertidal flats were present at the mouth of Cache Slough. Further upstream, sediment deposition from Sacramento River flood flows created large levees with dense tall riparian forests. However, these levee flood flow sediment deposits diminished downstream and eventually disappeared near Rio Vista. The riparian vegetation along Cache Slough primarily consisted of willow and alder scrub (Whipple et al. 2012). In-channel islands that were occasionally associated with shoals also supported riparian scrub. For example, Wood Island near Rio Vista was a densely vegetated in-channel island that was removed when the Sacramento River was straightened and dredged (Whipple et al. 2012).

The Cache Slough Complex is currently recognized as one of the most promising areas for tidal freshwater habitat restoration due to its favorable elevation, intact drainage patterns, and connections with the Sacramento River (Moyle et al. 2016). The North Delta Habitat Arc, a corridor of fresh and brackish tidal aquatic habitat between the Yolo Basin and Suisun Marsh, provides essential habitat for native fishes such as Chinook salmon, delta smelt, and green sturgeon. The region also plays a significant ecological role as an aquatic-upland transition zone.

1.2.3. Agriculture

Agricultural production following the Gold Rush Period has had the most impact on the Central Valley with wholesale land conversion of verdant native grasslands, oak woodlands, cottonwood dominated floodplains and tule marshes (**Figure 2**). These dramatic changes were beyond the Native American's traditional agricultural practices, which were mainly subsistence farming with some trade, use of fire, and local irrigation as management tools.

Figure 2. Delta Historic Ecology



Agricultural changes started with cattle grazing introduced by the Spanish explorers and missionary settlements and moved quickly to large dryland farming and localized irrigation. With the 1850 federal Swamp Land Act and the subsequent 1867 state Green Act allowing formation of reclamation and levee districts, more 'waste lands' were converted to agricultural use. However, the Central Valley's Mediterranean climate is subject to intense wet (flooding) and dry (drought) periods, making consistent and sustainable farming a challenge.

With the establishment of the Reclamation Service by Congress in 1902 (renamed to the Bureau of Reclamation in 1923) and large federal funding, specifically for the Central Valley Project that constructed 22 dams over the next fifty years, irrigation of the Central Valley increased the yield and diversity of crops to the extent that the economic value today is over $17 billion dollars annually.

Maintaining a strong agricultural community that supplies over 25% of the nation's food source and supports local communities and their economy is an important consideration for the Project. The Site, however, is protected by a restricted-height levee that is intended to overtop during moderate to high flood events and has crop restrictions to prevent impeding flood flows. This limitation prevents high value crops, such as vineyard grapes and nut orchards, from being planted. Additionally, high groundwater table and soil conditions are not favorable for high value crops. With ongoing and predicted future climate-change and sea-level rise conditions, the restricted-height levee along Cache Slough has a higher risk of failure on a more frequent occurrence.

<u>Related Studies and Reports</u>

The Site has been studied for mainly flood control purposes for over two decades. Only recently have habitat needs been considered in State, regional, and local studies. The following studies, recovery plans, and conservation strategies are relevant to the LEMBP land use:

- SAFCA, Lower Sacramento Regional Project, Initial Report – October 2003
- RD 2084, Preliminary Analysis prepared by MBK Engineers – May 24, 2005
- SAFCA, Lower Sacramento Regional Project, Administrative Draft – January 2008
- USACE, Central Valley Integrated Flood Management Study, California, Draft Watershed Plan – November 2015
- DWR, CVFPP Basin-Wide Feasibility Study – November 2016
- DWR / SAFCA, Little Egbert Multi-Objective Project, Hydraulic Impact Analysis – May 2017
- Lower Sacrament River/Delta North Region Regional Flood Management Plan (RFMP) July 2014
- Central Valley Flood Protection Plan 2017 Update
- Cache Slough Comprehensive Regional Planning: Draft Baseline Characterization Report for the Advancement of Proposition 1 Eligible Projects Draft Final Phase 1 Report (July

2017) Lower Sacramento River/Delta North Regional Flood Management Plan (July 2014).

The previous SAFCA study listed related studies, plans and conservation strategies relevant to the LEMBP land use. Those related studies include:

- 2012 Central Valley Flood Protection Plan which recommends a State Systemwide Investment Approach in managing flood risk along the Sacramento River and San Joaquin River systems.
- DWR Basin-Wide Feasibility Study (BWFS) for the Sacramento River Basin to implement the CVFPP.
- MBK 2017 Hydraulic Impact Analysis of the Little Egbert Multi-Benefit Project Alternatives.
- Yolo Bypass Cache Slough Master Plan (draft under development).

In addition, conservation plans and recovery plans for listed species in the Sacramento – San Joaquin River and Delta system provide a greater understanding of species' lifecycle needs, which can be used in the LEMBP planning and design. These studies include:

- USFWS, Recovery Plan for the Sacramento-San Joaquin Delta Native Fishes – 1995
- CDFW, California Essential Habitat Connectivity Project: A Strategy for Conserving a Connected California – 2010
- National Ocean and Atmospheric Administration (NOAA), Recovery Plan for The Evolutionarily Significant Units of Sacramento River Winter-run Chinook Salmon and Central Valley Spring-run Chinook Salmon and the (DPS) of California Central Valley Steelhead – 2014
- CDFW, Five-year Status Review of the Swainson's Hawk Species (*Buteo swainsoni*) – 2016
- USFWS, Recovery Plan for the Giant Garter Snake (*Thamnophis gigas*) – 2017
- NOAA, Recovery Plan for the Southern Distinct Population Segment of North American Green Sturgeon – 2018
- USFWS, Endangered and Threatened Wildlife and Plants; Designation of Critical Habitat for the Western Distinct Population Segment of the Yellow-Billed Cuckoo – 2021 DWR, Sacramento River General Reevaluation Report (GRR)

In 2018, SAFCA completed a feasibility study (SAFCA or Concept Study) examining the potential changes for flood, habitat, and agriculture with a managed breach of the restricted-height levee. Fourteen action alternatives and one no-action alternative were evaluated. The 2018 study determined that under several alternatives flood conveyance was improved, including water stage reductions along upstream farm levees during moderate to high storm events, and aquatic habitat was expanded to benefit species. The 2018 Concept Study also suggested that the long-term agricultural use of the Site would likely be lost in the near future due to loss of economic viability to maintain the restricted-height levee. The 2018 study did not designate a preferred alternative as additional studies would be needed to refine the potential impacts and benefits.

The Project is also expected to contribute towards meeting goals outlined in the Voluntary Agreement MOU from March 29, 2022.

1.3. Project Description

This section describes the purpose and scope of the Project, Project leadership, agencies, project beneficiaries, and interested parties.

1.3.1. Purpose and Scope

The purpose of this Study is to evaluate a range of alternatives at the Little Egbert Tract to develop a multi-benefit project that creates regional flood risk reduction and increases floodplain habitat. This Study examines 15 additional alternatives to the SAFCA Study to address in more detail, and design features to refine for the Project. These areas include water quality, flood conveyance, levee improvements, habitat restoration, wind/wave erosion, and recreational opportunities.

The Study recognizes that the current land use of the Site is “at risk” for future restricted-height levee failures. This Study looks at alternatives to undertake a “managed-breached” condition in comparison to a “natural-breach” event. The completed document will be provided as a deliverable for the California Natural Resources Agency (CNRA) grant agreement.

1.3.2. Project Leadership

LEJPA was formed in October 2020. The agency’s two-member Board is comprised of one board member from Reclamation District (RD) 2084 and one board member from RD 536. The mission of LEJPA is to advance and implement a multi-benefit project on the Little Egbert Tract to benefit flood protection and increase floodplain habitat in Solano County, California. LEJPA served in the lead role and worked with DWR to get red-flag reviews through the development process of this Feasibility Study. LEJPA oversees scopes of work funded by the CNRA grant which is being executed by Westervelt Ecological Services (WES), HDR Engineering (HDR), MBK Engineers (MBK), Resource Management Associates (RMA), Environmental Science Associates (ESA), and Shannon & Wilson inc. DWR provided funding and oversees scopes of work for additional analyses deemed critical to complete the Study, and manages contracts Jacobs, CBEC Engineering, and Kearns and West.

1.3.3. Agencies, Project Beneficiaries, and Interested Parties

The following table summarizes Project agencies, beneficiaries and interested parties.

Table 1-1. Project Agencies, Beneficiaries, and Interested Parties

Jurisdiction	Agencies and Interested Parties
Federal	US Army Corps of Engineers
	Bureau of Reclamation
	NOAA Fisheries
	US Coast Guard
	US Fish and Wildlife Service Bay-Delta Office
	US Geological Service
	US Environmental Protection Agency
State	California Department of Water Resources
	California Natural Resources Agency
	California Department of Conservation
	California Department of Fish and Wildlife
	California Department of Boating and Waterways
	California Native American Heritage Commission
	California Department of Transportation
	California State Historic Preservation Office
Regional	Central Valley Flood Protection Board
	Delta Stewardship Council
	Delta Protection Commission
	Central Delta Water Agency
	North Delta Water Agency
	Sacramento Area Flood Control Agency
Local	Solano County
	Solano County Water Agency
	Solano County Airport Land Use Commission
	City of Rio Vista
	Port of West Sacramento
	City of Vallejo
Tribal	Chicken Ranch Rancheria of Me-Wuk Indians
	The Confederated Villages of Lisjan
	Cortina Rancheria – Kletsel Dehe Band of Wintun Indians
	Guidville Indian Rancheria
	North Valley Yokuts Tribe
	United Auburn Indian Community of the Auburn Rancheria
	Wilton Rancheria
	Yocha Dehe Wintun Nation
Reclamation Districts	Reclamation District 3 – Grand Island
	Reclamation District 501 - Ryer Island
	Reclamation District 536 – Egbert Tract
	Reclamation District 2060 – Hastings Tract
	Reclamation District 2067 – Brannan Islan

Table 1-1. Project Agencies, Beneficiaries, and Interested Parties	
Jurisdiction	**Agencies and Interested Parties**
Community Benefit Organizations	Reclamation District 2084 – Egbert Tract
	Reclamation District 2068 - Yolano
	Justice Outside
	Little Manilla Rising
	Restore the Delta
	Rise Stockton Coalition
	Third City Coalition
Non-Governmental Organizations	Yolo Basin Foundation
	Yolo Bypass Cache Slough Partnership
	Coalition for a Sustainable Delta
	The Nature Conservancy
	Trout Unlimited
	Golden State Salmon Association

1.4. Interested Parties Engagement

During the development of this Feasibility Study, LEJPA in partnership with DWR solicited feedback on Project Goals, Threshold and Ranking criteria. The Project Landowner, Financial Interests and Neighboring Landowners have been solicited to participate during the LEMBP outreach process. The following interested parties will be included in Project outreach:

Table 1-2. Project Outreach	
Landowner	Westervelt Ecological Services, LLC (WES), Page Baldwin Jr.
Financial Interests	WES, DWR, Solano County, CNRA, Solano County Water Agency, mineral rights holders, Caltrans, PG&E
Neighboring Landowners	Flannery Associates, LLC, State of California, Sacramento-San Joaquin Drainage District, City of Rio Vista

Additional interested agencies and non-profits that will be included in Project outreach are included in **Table 1-1** in Section 1.3.3.

LEJPA solicited feedback from the following groups: RD 501, RD 536, RD 2084, YBCS Projects Work Group, City of Rio Vista, Delta Protection Commission Staff, North Delta Water Agency, Delta Stewardship Council Staff, SCWA, CDFW, NMFS, USFWS, and general public through Board workshops.

2. Inventory and Forecast

2.1. Present Conditions

The study area for the Little Egbert Multi-Benefit Project is located within the lower reach of the Yolo Bypass immediately north of Rio Vista (see **Figure 1** above). The Tract is located downstream of the confluence of several watercourses including Lindsey Slough, Prospect Slough, Cache Slough, and the Sacramento River Deep Water Ship Channel (DWSC). Along with the inundated portion of Liberty Island, the confluence of these sloughs is commonly referred to as the Cache Slough Complex. Near the south end of the Tract, Cache Slough combines with the Sacramento River and Steamboat Slough. The location and configuration of the Property's location and levee places a hydraulic constraint on Cache Slough flows during high water events.

RD 2084 maintains a restricted-height levee (also known as Solano County Levee 28) along the west bank of Cache Slough. The top of the levee is limited in elevation by deed restrictions enacted when flowage easements were purchased by the State of California (**Figure 3**). The northern 3/4^{ths} of the 2084 levee is private and only provides access for farm activities and levee maintenance, while the southern 1/4th includes State Route 84, the Ryer Island Ferry and a private residence. On the western boundary of RD 2084 is a State Plan of Flood Control (SPFC) levee (RD 536 Levee) that serves as the west levee of the Yolo Bypass. The RD 536 levee protects the adjacent farmland when the restricted-height levee is overtopped or breached. (**Figure 4**).

Figure 3. Flood Flowage Easement Map

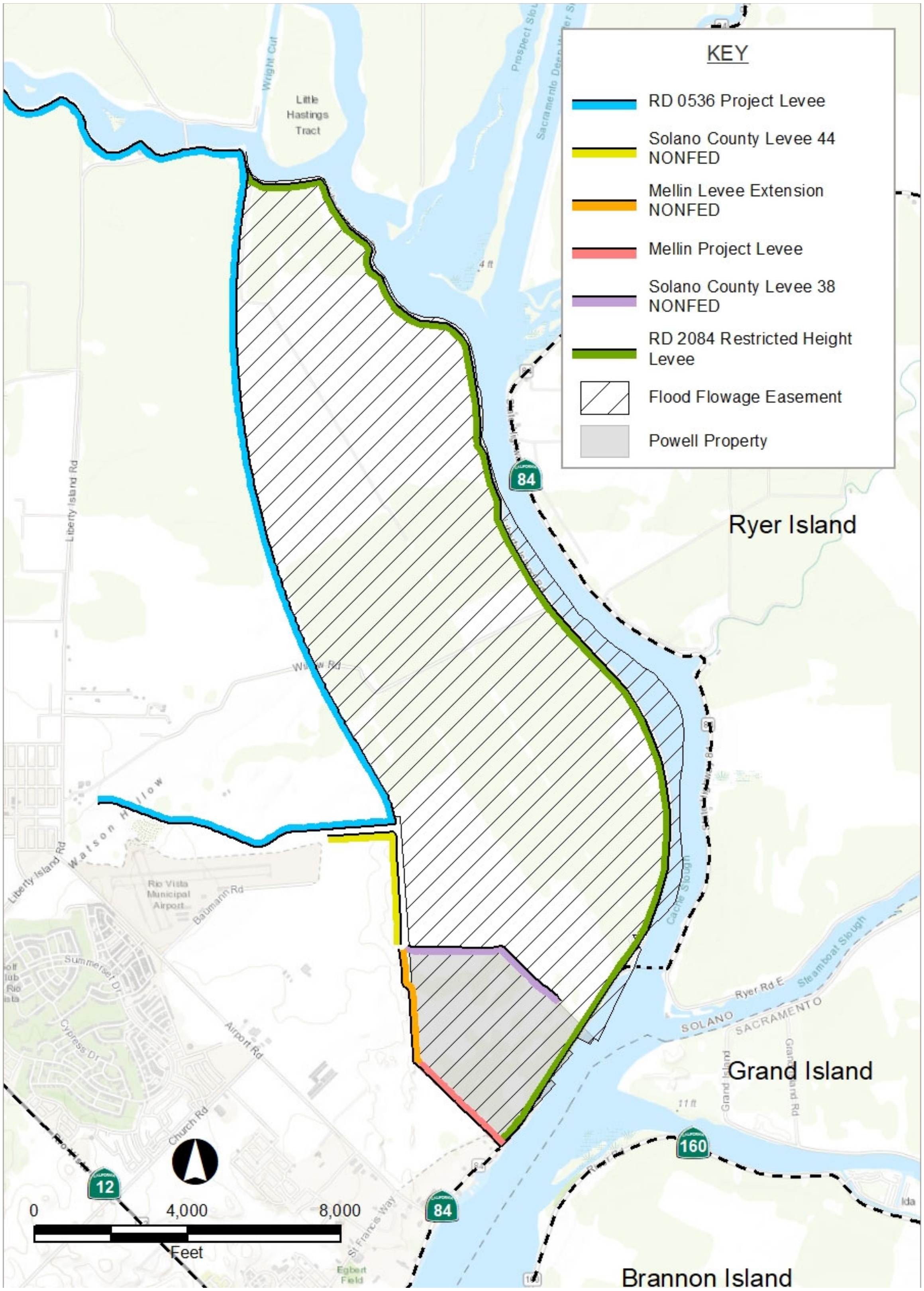
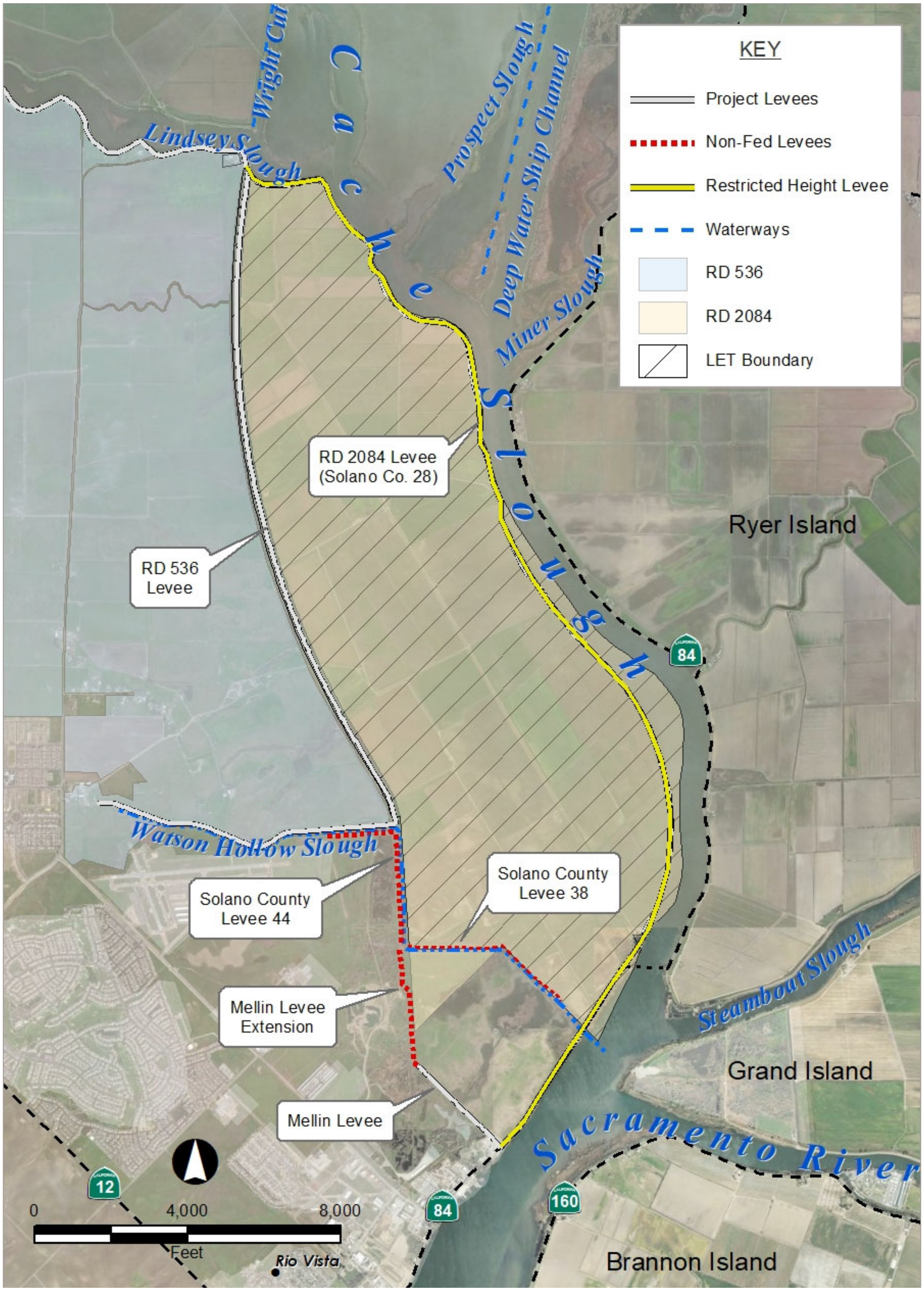


Figure 4. Tract Map



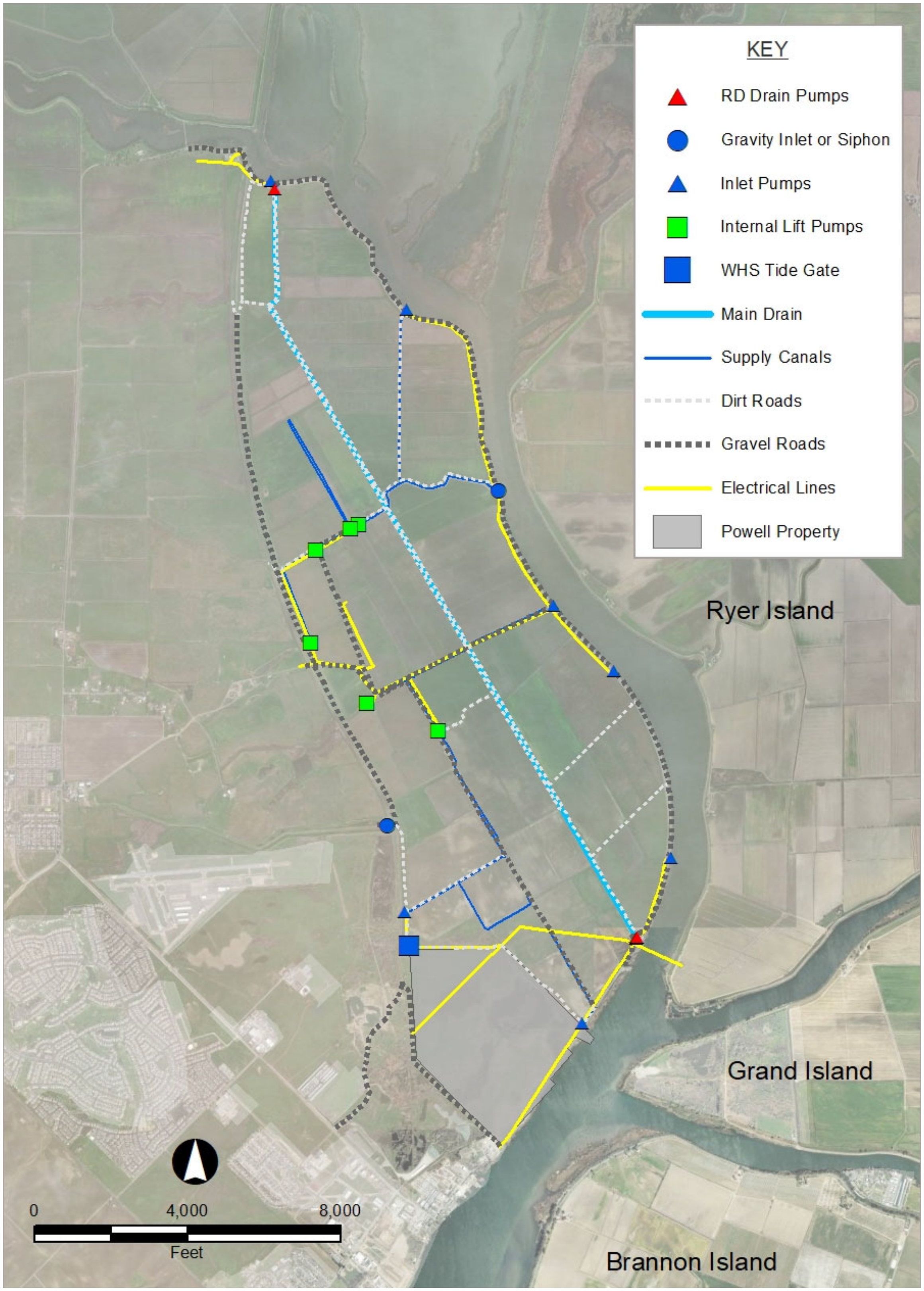
The property located immediately south of the Project is referred to as the Powell property (Powell) and is separated from the Tract by Watson Hollow Slough (WHS). The SPFC levee maintained by RD 536 (RD 536 Unit 2) does not extend to the south, but instead follows the north bank of Watson Hollow Slough west towards the Rio Vista Municipal Airport. To the south of the WHS, Solano County Levee 44 runs south and ends roughly at the boundary between LET and the Powell property. Solano County Levee 38 runs along the north side of Watson Hollow Slough at the south of the study area. The Project includes improvements to the Mellin Levee and Mellin Levee Extension, which connect the south end of Solano County Levee 44 to the Sacramento River at State Route 84.

Of the approximately 3,127 acres that make up the Tract, roughly 2,600 acres are in agricultural production with the remaining land dedicated to irrigation (canals and ditches) and access infrastructure (gravel roads). Per the flowage easement, no permanent building structures are permitted on the Property.

In addition, the flowage easement restricts the types of vegetation that can be grown on the site, specifically, “timber, brush or tules”. This means that high valued crops such as nut and fruit trees and grapes cannot be grown on the site. Thus, annual crops are grown, and are unlikely to yield enough income to fund extensive levee maintenance and repairs of the restricted height levee that are predicted to be required on a more frequent basis due to sea-level rise and climate changes.

Infrastructure essential to agricultural activities such as water control structures, pump facilities and power lines are present across the site (**Figure 5**). Multiple utility easements for power and gas transmission are recorded on site, but currently only the electrical easements providing power to on-site ag facilities, the residence, the ferry, and the transmission tower over Cache Slough are in use. LET lies under 2 active natural gas units (Lindsey Slough and Rio Vista) and 2 abandoned natural gas units (Liberty Island and Cache Slough) that have been in production since the 1940s. On site, there are 34 plugged and abandoned gas wells with the last active well abandoned in 2021. The Little Egbert Tract has never been and is currently not considered to be of any interest for non-petroleum minerals. The Real McCoy Ferry #2 (RMF), while not in the project area, is located at the Southeast end of the Little Egbert Tract. The RMF is classified as an extension to Highway 84 and provides access to the southern end of Ryer Island by crossing Cache Slough directly north of the confluence with Steamboat Slough. Located offsite to the west is the Rio Vista Municipal Airport, also known as Baumann Field.

Figure 5. LEMBP Agriculture Map



2.1.1. Major Waterways

The SRFCP is the core of the flood protection system along the Sacramento River and its tributaries. About 980 miles of levees, flood relief structures, weirs, and bypasses are included in the SRFCP and are designed to protect communities, cities, and agricultural lands of the Sacramento Valley and Sacramento-San Joaquin Delta. At the downstream end of the flood control system is the Yolo Bypass. It is a significant feature of the flood control system as it carries approximately 80 percent of the total Sacramento River watershed drainage area at the latitude of Sacramento.

The Yolo Bypass is approximately 41 miles north to south, and 3 miles wide, and covers approximately 59,000 acres of land in Yolo and Solano Country. At the upstream end of the Yolo Bypass is the Fremont Weir which diverts floodwaters from the Sacramento River, Feather River and Sutter Bypass into the Yolo Bypass. Flows from Knights Landing Ridge Cut, Cache Creek, Willow Slough Bypass, and Putah Creek also enter the Yolo Bypass downstream of the Fremont Weir. In addition, during high flows on the American and Sacramento Rivers, the gates on the Sacramento Bypass (just north of the confluence with the American River) are opened to divert water from the Sacramento River into the Yolo Bypass thereby reducing stages along the urban levees of metropolitan Sacramento and West Sacramento.

2.1.2. Cache Slough Complex

At the southern end of the Yolo Bypass is the Cache Slough Complex, which encompasses roughly 53,000 acres at the confluence of several rivers, sloughs, bypasses and watersheds. The Complex includes the following features from east to west: Steamboat Slough, Miner Slough, the Sacramento River Deep Water Ship Channel (DWSC), Prospect Slough, submerged portions of Liberty Island, Cache Slough and Lindsey Slough. Most of the Cache Slough Complex is within the Yolo Bypass. The planning area for this Project is a subset of the larger Cache Slough Complex, located at the southern end. The Cache Slough Complex acts as a water supply for urban and agricultural users in eastern Solano and southern Yolo counties. These dynamic waterways occur at the edge of the north Delta, receiving water flows from tides, rainwater runoff from significant portions of Solano and Yolo counties, and flood flows passing through the Yolo Bypass. The portion of Cache Slough immediately adjacent to the RD 2084 levee and Ryer Island is also part of the DWSC, which was widened (approximately 200 ft.) and dredged, approximately 30 feet below the riverbed (towards the RD 2084 levee), to accommodate international ship passage.

At the southern end of the study area at the location of the Ryer Island Ferry, the Cache Slough Complex creates a confluence with Steamboat Slough and the Sacramento River before flowing south past Rio Vista and entering Suisun Bay. Both Steamboat Slough and the Sacramento River at this location see high levels of navigation for shipping and recreation purposes. Flows at this confluence are fully tidal and experience approximately 4 feet of tidal range except during periods of significant outflow from upstream sloughs or Yolo Bypass drainage.

2.1.3. Other Waterways

Watson Hollow Slough (WHS) creates a physical boundary between LET and the Powell property on the southwest and southern edge of the Project site. WHS functions as a controlled water diversion for agricultural users as well as a drainage for approximately 17 square miles of land in the Montezuma Hills (**Figure 4**). WHS connects to the Sacramento River via four sub tidal culverts that run under State Route 84 approximately 0.4 miles south of the Ryer Island Ferry. The first mile of WHS functions as a tidal back water supplying riparian water diversions to LET and Powell lands. At mile 1.0, tidal flow to WHS is regulated via a tide gate to better facilitate agricultural water delivery to upstream users, specifically RD 536 and RD 2084.

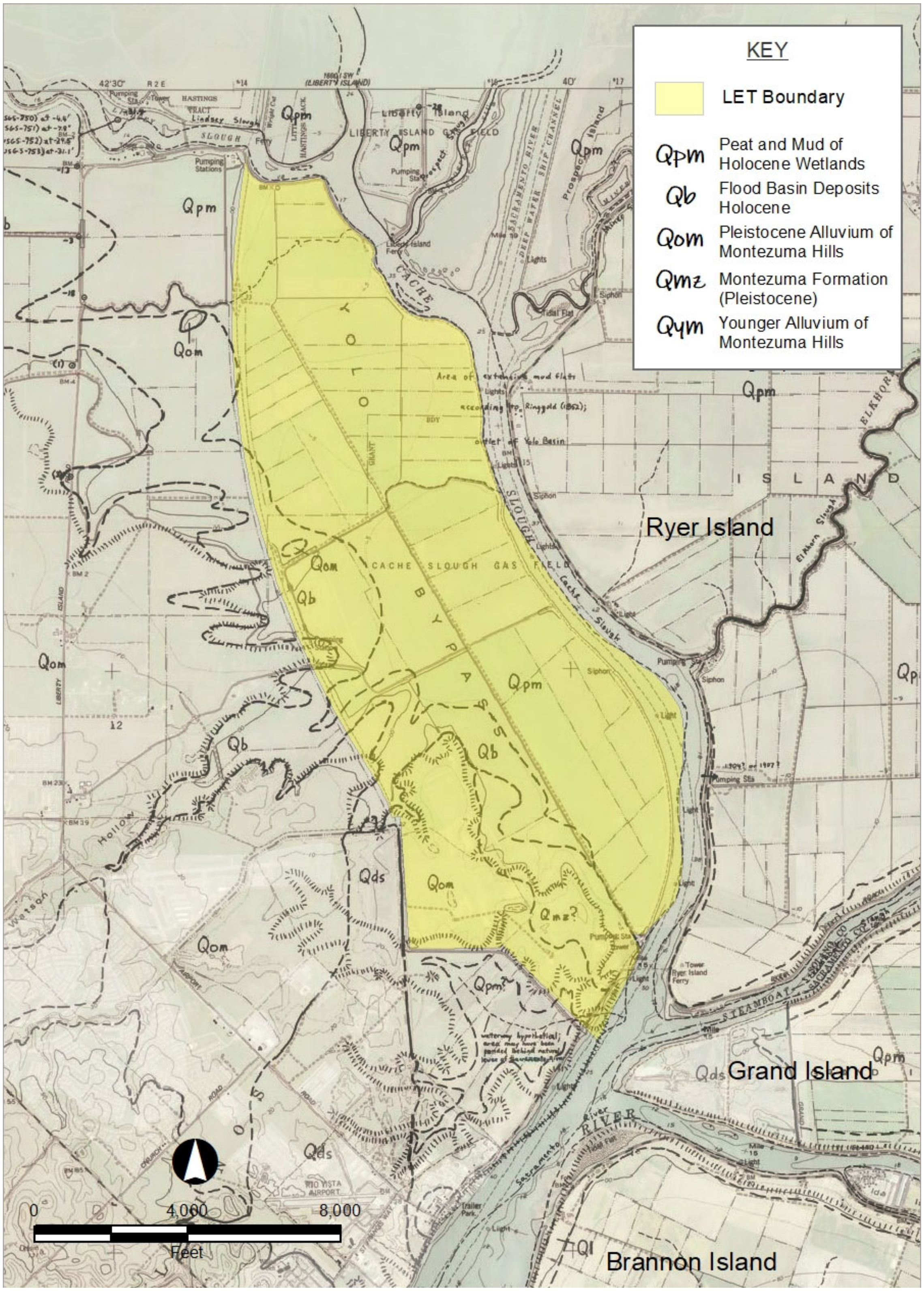
Located directly adjacent to LET and within Cache Slough, the Sacramento Deep Water Ship Channel (DWSC) is a shipping channel that serves the Port of West Sacramento. The US Army Corps of Engineers (USACE) is responsible for maintenance dredging of the DWSC. The DWSC transitions from the Cache Slough waterway into an engineered channel just north of LET within the Cache Slough Complex. The DWSC was initially authorized by the United States Congress as part of the Rivers and Harbors Act (RHA) of 1946 (Public Law 525, 79^{th} Congress, 2^{nd} Session) and was constructed between 1949 and 1963. The 43-mile long by 200 ft. wide DWSC has an authorized depth of 35 feet below MLLW and is dredged annually to maintain a minimum depth of 30 to 35 feet below MLLW (USACE, 2001). According to the Port of West Sacramento Manager, approximately 50,000 to 100,000 cubic yards of material is dredged from the DWSC annually. Several million cubic yards of previously dredged material is stockpiled at a location near the confluence of the DWSC with Cache Slough. During periods of high water, shipping along the DWSC is restricted due to the potential for ship wakes to negatively impact the RD 2084 restricted-height levee.

2.1.4. Topography, Geology, and Soils

Topographic assessment of the Tract is based upon both 2008 Light-Detecting and Ranging (LiDAR) data (developed by the DWR as part of the Central Valley Floodplain Evaluation and Delineation [CVFED] and Project), and Real Time Kinetic (RTK) GPS surveys conducted by licensed surveyors combined with photogrammetry data provided to the survey and design teams. Bathymetric surveys of Cache Slough were also conducted with RTK and side scanning sonar equipment. The Property ranges in elevation from -8 (NAVD 88) along the central drainage ditch to an average elevation of +22 (NAVD 88) along the RD 536 levee. Outside of levees, the highest terrain on the site ranges up to 10 feet and is located at the south, with lower areas located along the central and northern portions of the Tract.

The Property is located on the fringe of the north Delta at the foot of the Montezuma Hills. The United States Geologic Survey (USGS) has published maps depicting the geology of the Sacramento-San Joaquin Delta (Atwater 1982, Appendix 2). The Atwater map (**Figure 6**) depicts the landward margin of tidal wetlands and low river stages circa 1850, as well as the geologic formations of the site. The geology map indicates that areas mapped within the margins of tidal wetland are generally covered by peat and mud of tidal wetlands and waterways (Qpm) and flood basin deposits (Qb). The areas outside the margins of the tidal wetland are generally mapped as older alluvium of the Montezuma Hills and vicinity (Qom), and possibly the Montezuma Formation (Qmz).

Figure 6. Historic Geology Map



The U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) develops soil survey maps of the upper five feet of soil across the United States. The boundaries between soil units on the NRCS maps generally agree with the boundaries shown on the Atwater geologic map. The NRCS map shows that most of the site is blanketed by Egbert Clay, a high plasticity clay. The Egbert Clay is mapped in a similar area to the geologic unit mapped Qpm on the Atwater map. The southern and western portions of the site are blanketed by Diablo Ayar Clay, Pescadero Silty Clay, Valdez Silt Loam, Willows Clay and Clear Lake Clay in similar areas mapped as Qb, Qom, and Qmz on the Atwater map. These soil types along the southern and western portions of the site consist of a variety of silt and clay soil with varying plasticity. Some soils observed in the south end of LET meet USACE levee fill standards and could potentially be used for levee building material (**Appendix B**).

The soil conditions may generally be categorized into geologic units that include levee fill, marsh deposits, flood basin deposits, and older alluvium. The units are described in greater detail in Chapter 3 of **Appendix B** and are summarized below.

Fill for the RD 536 Levee consists of very stiff to hard, dry to moist, high-plasticity, clay. Fill for the Mellin Levee, Mellin Levee Extension, and Solano County Levee 44 mainly consists of sand with variable fines content, plasticity, and density. Fill for the RD 2084 Restricted Height Levee (Solano County Levee 28) consists primarily of high plasticity clay, silt, and organic soil that is dry to moist and soft to very stiff.

Marsh deposits were encountered near the ground surface over most of the parcel interior and beneath the levee fill in Solano County Levee 28 and long stretches of the RD 536 Levee, Mellin Levee, and Mellin Levee Extension. The marsh deposits typically consist of peat, organic clay, and organic silt. Marsh deposit soils were deposited in tidal waters and are typically relatively weak and compressible. The thickness of the marsh deposits generally increases from approximately 10 to 20 feet on the west side of the parcel to 35 to 40 feet near the east side.

Flood basin deposits are located near the interface between the marsh deposits and the older alluvium. The basin deposits typically consist of organic clay and organic silt with moderate to high plasticity. They are typically stiffer than the marsh deposits.

The older alluvium soils consist of sand, silt, and clay. Throughout most of the site, the older alluvium is buried below the marsh deposits and basin deposits and extended below the maximum depth explored. Near the southern end of LET, the older alluvium is present at the ground surface. Fine-grained alluvium (clay and silt) was consistently encountered at the top of the older alluvium deposit and in layers at greater depths. The fine-grained alluvium is generally stiff to very stiff. In between the layers of fine-grained alluvium, dense to very dense sand alluvium was encountered.

2.1.5. Climate and Hydrology

Table 2-1 below depicts tidal ranges within Cache Slough at LET and forms the basis of understanding for engineering and design of proposed levee fixes and ecological restoration. Tidal Datum elevations were provided from the DWR/USACE Prospect Island Ecosystem Restoration Project from the Prospect Island Environmental Assessment Initial Study. (USACE & DWR. 2001.)

Table 2-1. Tidal Elevation Ranges

Tidal Datums	Elevation (ft., NAVD 88)
Mean Higher High Water (MHHW)	6.5
Mean High Water (MHW)	5.9
Mean Tide Level (MTL)	4.4
Mean Low Water (MLW)	2.6
Mean Lower Low Water (MLLW)	2.1

As the Study Area is within the tidal prism of the Sacramento-San Joaquin River Delta, sea-level rise (SLR) will be an important factor in the Alternatives evaluation process. The California Department of Natural Resources' State of California Sea-level Rise Guidance (2018) provides a framework to evaluate risk tolerance for Projects. Based on the risk tolerance for the "likely range" (66% probability) in 2050, the Project planning team would use 1.1 feet SLR during the alternative evaluation. CVFPP estimates a projected sea-level rise of 3.7 ft. at the Golden Gate Bridge by the year 2072 (2022 CVFPP Update). Sea-level rise would not differentiate Alternatives from one another; however, it will need to be addressed during the environmental review to determine regional impacts.

2.1.6. Biological Resources

Natural communities and special-status wildlife, plants, and other sensitive biological resources were characterized for the Little Egbert Tract and adjoining Powell property in September 2019 to support geotechnical investigations at the site (ESA 2020) (**Appendix C, Exhibit A**).

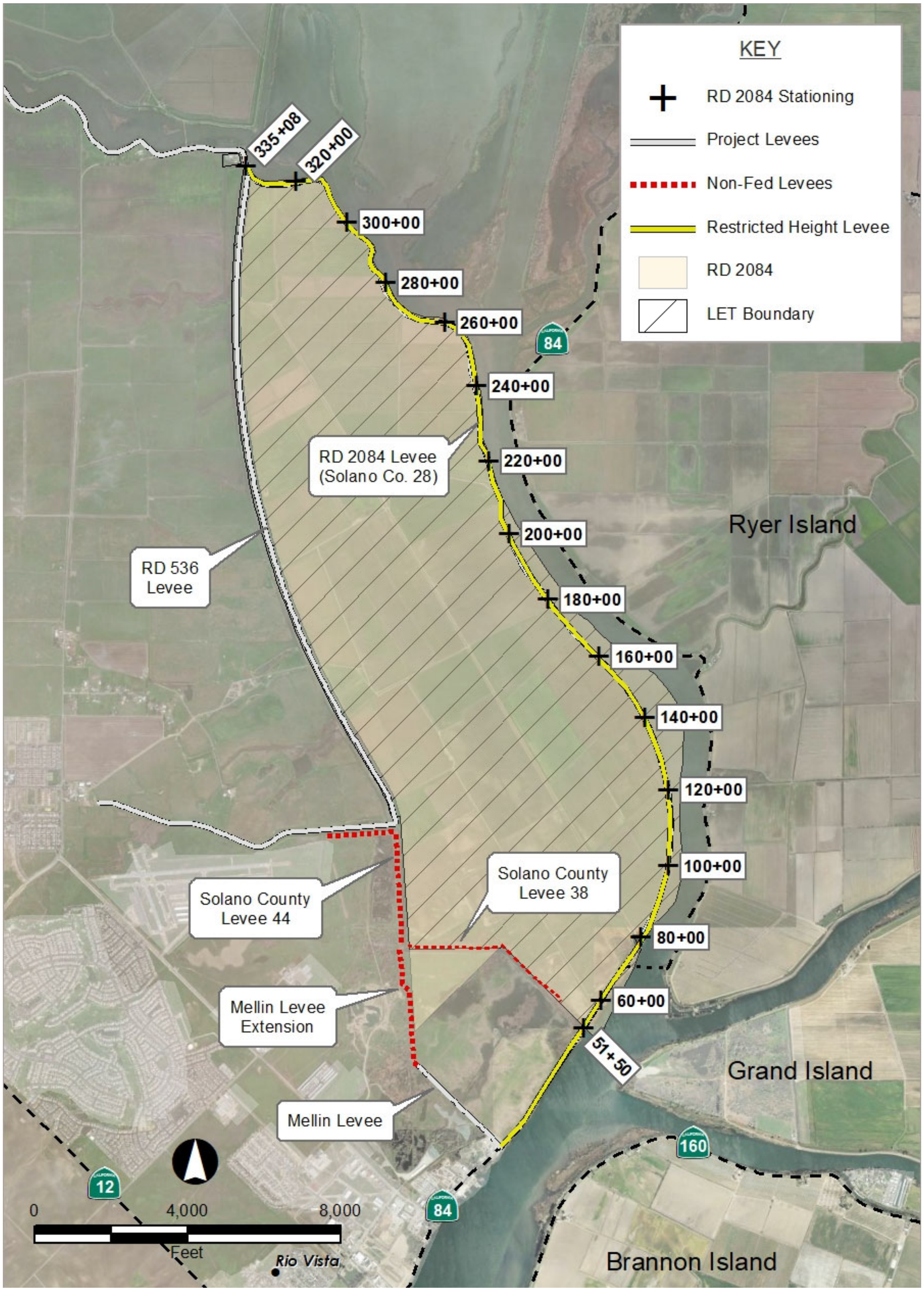
Upland communities within the Study Area consist of agricultural lands, grassland and ruderal vegetation.

LET is predominantly agricultural land cultivated in irrigated forage crops, such as alfalfa and silage corn, and dry-farmed winter wheat. The habitat value of agricultural lands varies by species, crop types and agricultural practices. Wintering waterfowl such as snow geese (*Anser caerulescens)* often forage in post-harvest fields. Raptors such as Swainson's hawk (*Buteo swainsoni*) forage over cropland for rodents and other small mammals. Potential nesting habitat for Swainson's hawk is limited since most of the trees are small.

The LET is located within the Pacific Flyway and supports a variety of resident and migratory bird species, as documented by surveys conducted for a wildlife hazard analysis (**Appendix C, Exhibit B**). During April-August 2020 the most abundant species in order of observed numbers were red-winged blackbird (*Agelaius phoeniceus*), cliff swallow *(Petrochelidon pyrrhonata*), great egret (*Ardea alba*), Swainson's hawk, Brewer's blackbird (*Euphagus cyanocephalus*), barn swallow (*Hirundo erythrogaster*), gulls, common raven (*Corvus corax*), house finch (*Haemorhous mexicanus*) and American crow (*Corvus brachyrhyncho*s). Other species observed in lower numbers included snowy egret (*Egretta thula*), American white pelican (*Pelecanus erythrorhyncho*s), Canada goose (*Branta canadensis*), and double-crested cormorant (*Phalacrocorax auritus*). Blackbirds (38% of observed birds) and swallows (25%) were the most common bird guilds observed during spring-summer. During fall and winter (September 2021-March 2022), the most abundance species were red-winged blackbird, snow goose (*Anser caerulescens*) and greater white fronted goose (*Anser albifrons*), Brewer's blackbird, tricolored blackbird (*Agelaius tricolor,* a flock foraging in October), savannah sparrow (*Passerculus sandwichensis*), house finch, American crow, European starling (*Sturnus vulgaris*) and dunlin (*Calidris alpina*). Blackbirds (50% of observed birds) and waterfowl (31%) were the most common bird guilds observed during fall-winter.

Riparian communities occupy a transitional zone between terrestrial and aquatic systems, typically above the mean higher high tide elevation. Mixed riparian scrub is a community of riparian trees and shrubs dominated by sandbar willow (*Salix exigua*) and arroyo willow (*S.lasiolepis),* the occasional Fremont's cottonwood (*Populus fremontii*), and a layer of Himalayan blackberry (*Rubus armeniacus*) and ruderal vegetation. Mixed riparian scrub at LET is limited to narrow bands of willow along the levee outboard along Cache Slough and the Sacramento River and the west side of State Route 84. Riparian vegetation is largely absent from RD 2084 (station 90+00 to 335+08) due to flowage easement restrictions, levee maintenance regimes, and the steepness of the levees themselves.

Figure 7. Stationing Map

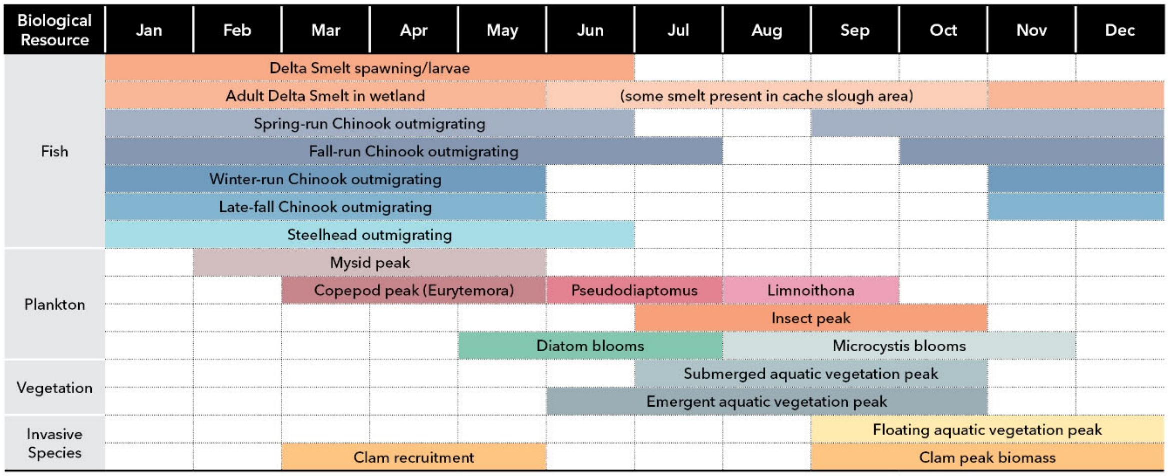


Aquatic features include freshwater emergent wetland with sparse to dense cover of tule (*Schoenoplectus acutus*) and some cattails (*Typha* sp.) along some canals and Watson Hollow Slough where it meets Cache Slough. Floating and submerged aquatic vegetation is present in some channels closer to the periphery, typically in shallower water. Common native species of emergent and aquatic plants include tule, cattail, nonnative water hyacinth (*Eichhornia crassipes*), nonnative water primrose (*Ludwigia* spp.), and duckweed (*Lemna* spp.). Non-native and invasive aquatic vegetation such as water hyacinth and water primrose can form dense mats that cover Watson Hollow Slough. Agricultural ditches and canals are found throughout the study area, although ditches within the interior of LET have little vegetation due to agricultural leveling and water management. These water bodies likely meet the definitions of waters of the U.S. and State and are potentially subject to regulation by the USACE under Section 404 of the Clean Water Act and by the Central Valley Regional Water Quality Control Board (CVRWQCB) under Section 401 of the Clean Water Act and Porter-Cologne Act. Beyond the LET outboard levee, Cache Slough and the lower Sacramento River provide open water and subtidal habitat, including shoals. This provides spawning, rearing and migratory habitat for native and non-native fish species.

Several species known to occur on or in the vicinity of the Study Area are protected pursuant to federal and/or State endangered species laws or have been designated as Species of Special Concern by CDFW. A comprehensive list of special-status species and their potential to occur is provided in Appendix C, Exhibit A. Special-status wildlife and plant species with moderate to high potential to occur in the Study Area include western pond turtle (Actinemys marmorata), giant garter snake (Thamnophis gigas), tricolored blackbird (Agelaius tricolor), Swainson's hawk, white-tailed kite (Elanus leucurus) and wooly rose-mallow (Hibiscus lasiocarpus var. occidentalis). As noted above, no elderberry shrubs (Sambucus sp.) were observed which rules out the presence of Valley elderberry longhorn beetle (Desmocerus californicus dimorphus).

Special status fish species with potential to occur in the surrounding tidal waters include delta smelt (*Hypomesus transpacificus*), longfin smelt (*Spirinchus thaleichthys*), Sacramento River winter-run Chinook salmon, Central Valley spring-, fall- and late-fall run Chinook salmon (*Oncorhynchus tshawytscha*), California Central Valley Distinct Population Segment (DPS) steelhead (*Oncorhynchus mykiss*) and Southern DPS green sturgeon (*Ascipenser medirostris*). **Table 2-2** shows the seasonal occurrence of listed fishes and other aquatic biota in the Delta. The LET is not within designated critical habitat for any listed plant or wildlife species, but Cache Slough is part of designated critical habitat for federally threatened delta smelt.

Table 2-2. Seasonal Occurrence of Listed Fishes



SOURCE:
Sherman, S., R. Hartman and D. Contreras, editors. 2017. Effects of Tidal Wetland Restoration on Fish: A suite of Conceptual Models. Interagency Ecological Program Technical Report 91. Department of Water Resources, Sacramento, California.

2.1.7. Land Use

The Tract sits at the southernmost tip of the Elmira-Maine Prairie agricultural region, one of nine broad geographic areas with unique characteristics identified in the Solano County General Plan (Solano County General Plan, 2008). The Elmira-Maine Prairie region covers the portion of the county north of Rio Vista, east of the Montezuma Hills, Jepson Prairie and east of Vacaville, south of Dixon and up to the Yolo Bypass along the Solano-Yolo County line or generally all areas within the Sac-San Joaquin delta. Primary agricultural uses and products grown in the Elmira-Maine Prairie region includes cattle and sheep rangeland, irrigated pasture, wheat, corn, and alfalfa.

The Property and neighboring lands under the Solano County General Plan are all zoned exclusively in agriculture (AG-20 through AG-160). Areas that fall under the City of Rio Vista's land use plans are zoned as Agricultural/Open Space, Heavy Commercial/Light Industrial/Public. General land use on nearby parcels includes irrigated pasture, rangeland, sand and gravel quarries, and light industrial lots adjoining State Route (SR) 84. The Ryer Island Ferry (aka Real McCoy Ferry II) is located on SR 84 at the southern end of the LET. In addition, nearby airports include the Rio Vista Municipal Airport (Airport) located approximately 0.4 miles west of the LET and Travis Air Force Base located approximately 12 miles west.

General Plan land use designation for the Project site is Agriculture. Most of the site has a Resource Conservation Overlay. The Zoning classification is A-80 (Agriculture 80-acre minimum parcel size). The California Department of Conservation classifies agricultural lands through the Farmland Mapping and Monitoring Program (FMMP). The LET is mapped as mostly Prime

Farmland, defined as "farmland that has the best combination of physical and chemical features able to sustain long term agricultural production. This land has the soil quality, growing season, and moisture supply needed to produce sustained high yields. Land must have been used for irrigated agricultural production at some time during the four years prior to the mapping date." This designation is due to the Property having a managed drainage and irrigation system.

Currently, a local farming company leases the property. Crops change from year to year but generally includes a rotation of alfalfa, winter wheat, safflower, canola, oats and silage corn in the remaining fields with roughly 2,600 acres under production. During the winter, sheep may graze alfalfa fields and vegetation on levees.

2.1.8. Recreation

No public recreation opportunities currently exist within the Project Site. Public recreation activities readily occur within the vicinity of the Project Site. These include fishing and boating in the navigable waters of surrounding rivers and sloughs, or walking and fishing along the water side of State Route 84. The remainder of the Tract is privately owned, actively farmed and does not allow public access to the interior of the Tract. Historically, Liberty Island Road ran along the top of the RD 2084 levee, but after the ferry shut down in the early 90s, all public rights of way were abandoned from the Hastings Island Bridge to the Ryer Island Ferry. Private roads connect to the north and west of the Tract, limiting land based public access to State Route 84 in the south.

2.2. Forecast – Future Without-Project Conditions

Under existing conditions, it is expected that the risk of restricted height levee failure will increase over time due to sea level rise, more frequent extreme storm events, and increased flows through the Yolo Bypass. Historically, the restricted height levee has overtopped and failed during the floods of 1964, 1986, and 1997. When the Tract floods, significant damage to the restricted height levee, RD 536 levee, SR84 and interior drainage infrastructure occurs. Following the January 1997 flood, the cost for RD2084 to repair the restricted height levee and dewater the island amounted to approximately $2.2 million *(State of California, Office of Emergency Services, Grantee's DSR Attachment, April 29, 1997)*. Repair and reclamation of the Tract today would likely be more expensive due to complexity of working in the water and the need to comply with federal, state, and local permit conditions. As mentioned under the Climate and Hydrology Section 2.1.5, the farming operations on the Tract will likely not generate enough revenue to fund adequate levee repairs when levee breaches become more frequent. Impacts of uncontrolled breaches at the Site to all levees, other neighboring lands, and regional water quality will be evaluated and determined in CEQA.

3. Concerns and Opportunities

3.1. General Overview

This study addresses concerns and opportunities in the immediate Project Study Area. The following section provides a summary of problems and opportunities that have been identified. A concern is an existing condition where efforts will be directed to resolve or improve the existing condition. The concerns described below include flood management infrastructure, flood risk, agricultural land use, habitat and long-term site management. An opportunity is an existing condition project implementation seeks to improve. The opportunities described below include a discussion of flood risk reduction, recreation, ecosystem benefits, and climate change adaptation benefits. Adaptability to current and future climate change conditions is critical to ensure long-term sustainability of the Project and the many benefits it can provide.

The persisting problems throughout the Sacramento River Delta, listed and described within this document, present opportunities to remediate and restore functions and benefits to the region that are at risk of loss.

3.2. Concerns

3.2.1 Flood Management Infrastructure Past Problems

The levee design for the Sacramento River Flood Control Project (SRFCP) were based on design discharge or channel capacity, water surface profiles and freeboard. The SRFCP was authorized by Congress in March 1917 and modified by various Flood Control and/or River and Harbor Acts in May 1928, August 1937, and August 1941. The SRFCP was completed between 1911 and 1961. In 1953, USACE turned over the SRFCP to the Reclamation Board who in turn gave assurances that they would operate and maintain the SRFCP in perpetuity.

The SRFCP design considered the floodplain elevations based on a specified design flow rate observed from the 1907 and 1909 floods. The design floodplain elevations had no specified recurrence interval or flood frequency and assumed concurrent flood events at the confluences of the river system. In 1928, the design flow rates had some minor revisions to the project design flows and floodplain, which were ultimately agreed upon by the Reclamation Board and the US Army Corps of Engineers in 1957 (commonly referred to as the ‘57 profile). The design flow rates and floodplain profiles are published in “Levee and Channel Profiles, Sacramento River Flood Control Project”, dated March 15, 1957. The SRFCP design flow rate for lower Yolo Bypass is shown in **Table 3-1.**

Table 3-1. SRFCP Design Flow Rate	
River/Reach	**1957 Design Discharge (cfs)**
Yolo Bypass – Fremont Weir to Knights Landing Ridge Cut	343,000
Yolo Bypass – Knights Landing Ridge Cut to Cache Creek	362,000
Yolo Bypass – Cache Creek to Sacramento Bypass	377,000
Yolo Bypass – Sacramento Bypass to Putah Creek	480,000
Yolo Bypass – Putah Creek to Miner Slough	490,000
Yolo Bypass – Miner Slough to Sacramento River	500,000

The design top of levee for the SRFCP was generally set at 3 feet of freeboard (over the floodplain) for main riverine channels and 5 to 6 feet of freeboard for the Sutter and Yolo Bypasses. Essentially, these levees were not engineered to meet current levee safety criteria and do not address our current flood management policies and standards for public protection such as levee certification for FEMAs National Flood Insurance Program and California's Urban Level of Protection criteria. Finally, since the SRFCP design flows and floodplains were adopted, there have been significant changes to the flood control system and climatology that have affected our understanding of extreme flood event flows in the Yolo Bypass. Current estimates (**Appendix A, Exhibit A**) of the 200-Year flood events in the Yolo Bypass downstream of the Sacramento Bypass is 557,000 cfs.

3.2.2 Flood Risk Problems

The future climate projections combined with the lack of the levees meeting the current engineering standards described in Section 3.2 are the flood risk drivers to the Project. The CVFPP 2022 concluded that temperature is projected to continue to increase in all locations in the Central Valley through the year 2072. This warming of temperatures will result in larger areas of the Sacramento and San Joaquin basins being above freezing temperatures when winter storms occur and a higher snow line. As a result, major storms will bring rainfall to larger areas of the basin instead of snow causing increased volumes of storm runoff. CVFPP 2022 Risk Analysis estimated regulated flows in the Yolo Bypass downstream of the Sacramento Bypass (Index Point SAC17a) to increase on the order of 2% to 22% by the year 2072 for the 200-Year flood event. This increase in flows in the Yolo Bypass O&M with a projected sea level rise of 3.7 feet by the year 2072 poses a significant flood risk to LET by increasing the probability that the restricted height levee fails or overtops.

3.2.3 Habitat Concerns

Habitat restoration near airports could potentially attract birds and elevate the risk of bird strikes on aircraft during takeoff or landing. The Project Area is located approximately 0.4 miles east of the Rio Vista Municipal Airport (Airport), and approximately 12 miles east of Travis Air Force Base. A Wildlife Hazard Analysis was conducted to evaluate existing and potential future conditions for wildlife hazards to aircraft as a result of the proposed Project (**Appendix C, Exhibit**

B). Surveys were conducted in all months and at key times of day to characterize seasonal and diurnal patterns of bird use. Many birds currently occur at the Project Area, especially overwintering waterfowl, which poses an existing level of wildlife hazard for the Airport. The Federal Aviation Administration database documented a single strike at the Airport in the preceding 12 years (a goose strike in 2011 that resulted in repairable damage and no human injury.)

The proposed LEMBP would substantially change the topography and inundation patterns of the site, transforming the land cover from agricultural fields cultivated in alfalfa and row crops to tidal open water with associated fringing wetlands and riparian benches. The open water habitat is expected to be similar to existing open water conditions in the adjacent Cache Slough and lower Liberty Island. New tidal emergent marsh along the western, eastern, and southern edges and riparian scrub vegetation on the habitat berms would also provide different habitat.

The proposed Project's change in land use is expected to change bird species composition, distribution, abundance, and activity (i.e., foraging, loafing, and/or movements). Of particular interest are those large species that pose the greatest risk of aircraft damage, in particular waterfowl, raptors, gulls, and large herons. Based on the current proposed design and general bird-habitat associations, several potential changes in wildlife hazard are expected with the constructed Project.

The risk from large waterfowl species (e.g., Canada goose, snow goose, and white-fronted goose) would be greatly reduced due to conversion of irrigated agriculture and pasture to open water. Large waterfowl, especially Canada goose, pose the greatest risk of damaging strikes. Under current conditions, Canada geese and snow geese were observed traversing, congregating, and loafing on irrigated pasture and agricultural lands in the Study Area. Geese do use open water, but flocks resting on the water are typically less densely concentrated (i.e., fewer birds) than feeding flocks that aggregate on agricultural fields. Bird species that prefer open water, such as diving ducks (e.g., bufflehead *(Bucephela albeola*)) and cormorants, would have more habitat, but these species do not aggregate in as high concentrations as birds foraging in fields (Appendix C, Exhibit B).

There would also be a reduction of risk from icterids (e.g., red-winged blackbird), swallows (abundant but minimally damaging) and terrestrial-foraging raptors (Swainson's hawks, turkey vulture) due to conversion of irrigated agriculture (foraging habitat) to mostly open water. Restoration of tall emergent wetland vegetation (in a smaller portion of the Project area) would increase potential nesting habitat for blackbirds.

There may be an increased risk from other bird species. Numbers of wading birds (e.g., herons, egrets) that use wetlands and shallow margins of open water (western edge of Study Area) and fish-eating raptors (osprey) that forage over open water may likely increase; however, their overall numbers would be lower than the waterfowl and raptor use under current conditions.

3.2.4 Long-term Management

Long term operation and maintenance of flood control facilities is vital to provide reasonable assurance that they are functioning as designed. Various USACE and DWR documents provide guidance for long term operation and maintenance of flood control facilities including requirements for routine and periodic inspections, requirements for monitoring during high water events, and requirements for repair of any identified damages. Additionally, existing Operation and Maintenance Manuals may already be in place that provide requirements for regular maintenance and operation of existing flood control facilities.

Consideration of operation and maintenance requirements is an important factor in the selection of a suite of improvement options. For example, a measure such as a cutoff wall does not require any maintenance to function as seepage barriers and, as such, would have lower overall long-term operation and maintenance requirements and costs. A measure such as a seepage berm, would require long term maintenance such as vegetation control, animal burrow control, and grading and would have higher long-term operation and maintenance requirements and costs. Specific operation and maintenance requirements would be developed based on the specific flood control features selected for implementation and in coordination with USACE, DWR, and local maintaining agencies. Options evaluated as part of this Feasibility Study considered long term operation and maintenance of levees as discussed under **Appendix D**.

3.3. Opportunities

Prior to construction of the LEMBP, long-term management of the habitat and levees will need to be addressed and responsible parties identified.

A long-term management program for the habitat will need to remain in perpetuity to preserve the new habitat and conservation values. This management entity may be the current local maintaining agency (LMA) or a new entity that would only manage the new habitat elements of the Project. The land's disposition to a future owner and land manager is not part of the feasibility study but is expected to be determined later before implementation of the Project. Long-term habitat management will include annual, accrued, and adaptive management activities.

While the current LMA's will likely continue to maintain their respective levees, identifying an entity to operate, maintain and provide assurances for new levees constructed as part of the Project will need to be carefully considered and determined prior to construction of new levee features. Future Annual maintenance may include coordination with the LMA's, access road maintenance/repairs, firebreak mowing, invasive species control, trash removal, water-born debris removal, trespass control, and maintenance of recreational features.

The successful implementation of the Project will help to mitigate the effects of habitat and ecosystem function loss experienced throughout the Delta. This opportunity will only last until an inevitable, unplanned flooding event occurs. A destructive, unforeseen flooding event could squander the opportunity to construct beneficial habitat and flood-fighting features simultaneously.

There is an opportunity to permanently remove portions of this restricted height levee, which would improve downstream conveyance for flood flows through the Yolo Bypass and improve floodplain connectivity. A description of the regional and site-specific opportunities associated with flood risk, and ecosystem function (along with the anticipated longer-term impacts of climate change and sea level rise) follows below.

3.3.1. Flood Risk Reduction Opportunities

The Property currently acts as a flow constriction point for low to moderate flood flows (i.e., 10-year flood) in the Yolo Bypass. As these flows occur more frequently, the water can create more frequent damage to levees over time. Improving flood conveyance through the Tract may reduce the stage elevation on upstream levees. Refer to **Appendix A, Exhibit A** for more information on hydraulic analysis of the Alternatives.

3.3.2. Ecosystem Opportunities

The LET is well-situated in Cache Slough Complex and is currently recognized as one of the most promising areas for tidal freshwater habitat restoration due to its favorable elevation, intact drainage patterns, and connections with the Sacramento River (Moyle et al. 2016). The North Delta Habitat Arc, a corridor of fresh and brackish tidal aquatic habitat between the Yolo Basin and Suisun Marsh, provides essential habitat for native fish such as Chinook salmon, delta smelt and green sturgeon. The region also plays a significant ecological role as an aquatic-upland transition zone.

Native fish populations in the Delta have dramatically declined since the early 2000s (Jassby, Cloern, & Cole, 2002). Contributing factors include historic loss of wetland habitat, altered hydrologic patterns, reduced food resources, non-native aquatic species including predators and competitors, climate change, and contaminants. Although the Cache Slough Complex offers some of the best remaining habitat for native fish such as delta smelt and juvenile Chinook salmon migrating down the Yolo Bypass and Sacramento River, native fish in this area still face challenges of physical habitat quality (such as reduced turbidity and wetland accretion due to reduced sediment loads) and biological factors (such as non-native aquatic vegetation and predatory fishes). Reduced access to seasonal floodplain habitats has also been hypothesized as a factor that could affect the rearing success of listed salmonids.

The Property is located in an important rearing and migration corridor for many fish species of concern in the Delta. Thus, restoring the Project Site to tidal inundation is expected to provide many direct and indirect ecosystem benefits. First, the Project is likely to provide enhanced spawning and/or rearing habitat for delta smelt, green sturgeon, Chinook salmon, steelhead, splittail, longfin smelt, and tule perch. All of these species are found in the area and are known to rear in shallow subtidal habitats of the Delta (Nobriga, Feyrer, Baxter 2005). Second, tidal inundation sites reduce stranding risk for Chinook salmon, green sturgeon, steelhead, and other migratory species that use the Yolo Bypass during large flood events (Sommer, T. R., Nobriga, M. L., Harrell et al., 2001) Finally, tidal inundation is more likely to provide enhanced food web subsidies (e.g., primary consumer productivity) to the Cache Slough region through detrital and pelagic primary producer pathways (Grimaldo, Stewart, Kimmerer, 2009).

Nearly 80 percent of the Swainson's hawk's known breeding population in California is located in the Central Valley and includes a year-round residential population in the larger Delta. Hawks have adapted to habitat loss by transitioning from foraging in open grassland to agricultural fields. Swainson's hawks were frequently observed at the Project Area during the wildlife hazard surveys in spring through fall, but not during the winter.

3.3.3. Climate Change and Sea-Level Rise Remediation Opportunities

The current flood management system was designed in the twentieth century when the system experienced much smaller flood events. The flood events today are larger and hydrologic variability is uncertain due to climate change, which may result in larger flood events over time (2022 CVFPP Update). These larger events will demand a greater flood storage capacity in the future.

The Project alternatives are designed with the intent to increase flood resiliency within the system in anticipation of these more frequent and larger flood events. In addition to increased flood capacity, the design of the alternatives includes increased upland, riparian, inundated floodplain habitat, and wetland habitat available to wildlife displaced by flood waters. These design elements are intended to more efficiently convey future flood events and to withstand sea-level rise and climate change, while simultaneously providing sustainable habitat benefits for native species.

Future sea-level-rise projections would affect flood water levels throughout the San Francisco Bay-Delta and the lower San Joaquin and Sacramento River watersheds. The 2017 CVFPP Updated modeling drew upon the mean-sea-level projection from the National Research Council (2012) adjusted to the year 2067. This projection included a sea-level-rise estimate at the Golden Gate Bridge of approximately 1.3 feet. For the 2022 CVFPP Update, updated guidance on sea level rise provided by the California Ocean Protection Council (OPC) (California Ocean Protection Council and California Natural Resources Agency 2018) was used. This OPC guidance predicts an approximately 3.7-foot sea level increase at the Golden Gate Bridge in the year 2072 using their medium-high risk aversion estimate. The medium-high risk aversion has a 1-in-200 chance of being exceeded. Although the likelihood is low that sea level rise will meet or exceed this value, it is recommended to be used for less adaptive, more vulnerable projects or populations that will experience medium-to-high adverse consequences because of underestimating sea level rise (2022 CVFPP Update).

4. Purpose and Goals

The Project purpose, goals, and constraints are discussed below. The Project purpose describes the reasons this project has been proposed. The goals are the result of these Project purposes. The constraints are limiting factors that may impact the overall Project deliverable.

4.1. Purpose

Project purpose and goals were collaboratively developed based on the objectives for implementing multi-benefit restoration projects within the Cache Slough Complex. The purpose of the endeavor is to develop a multi-benefit project that meets multiple Federal, State, and local policy goals in an open and transparent manner with ample opportunity for public input. The Project aims to enhance the land use of LET to provide a better resource for species and the communities within the Sacramento Delta region.

4.2. Goals

The goals for this Project include enhancing public safety, protecting, and enhancing natural ecosystem processes to increase habitat and support species, and protecting and enhancing opportunities for recreation. Each alternative was screened against the list of Project goals. Any alternative not meeting all goals was screened out. Specific goals, in no order of importance, include the following for the first screening step:

- Enhance Public Safety: Enhanced public safety, health, and quality of life for the State's citizens as outlined in State and local planning efforts (CVFPP, Lower Sac Delta North Regional Flood Management Plan, Solano County planning efforts). Reduce local and regional flood risk to agricultural and urbanizing areas while improving flood flow capacity by providing flood stage reductions and increased flood flow capacity within the Lower Yolo Bypass.
- Protect and Enhance Natural Ecosystem Processes to Increase Habitat and Support Species: Provide ecosystem and habitat restoration, as well as preserving and enhancing riparian and other native habitats to contribute to the recovery and sustainability of native species, where compatible with construction, operation, and maintenance of flood risk–reduction infrastructure, and consistent with adopted State and local plans. Create opportunities for environmental offsets and habitat restoration as outlined in local resource planning efforts (CVFPP Conservation Strategy, Delta Plan, Solano Multi species Habitat Conservation Plan, Cache Slough Complex HCP).
- Protect and Enhance Opportunities for Recreation: Provide improved or new public outdoor recreation, education, and open space opportunities, where compatible with construction, operation, and long-term operation and maintenance of flood risk-reduction infrastructure, and consistent with the State and local plans.

4.3. Project Considerations

Project Study considerations and constraints limiting the execution of the planning objectives were identified during the planning process. The Study did not identify any constraints that would prevent the planning objectives from being met. The following project constraints were identified and analyzed:

- Project levee protection for adjacent lands;
- Drainage for Watson Hollow Slough watershed;
- Irrigation for users of Watson Hollow Slough;
- Deep Water Ship Channel Navigation;
- Protection of species during construction (Aquatic and Terrestrial);
- Protection of cultural resources;
- Sea-level Rise/climate change;
- Wave fetch on Ryer Island, 501 levee, 536 levee and 2084 restricted height levee;
- SR 84 transportation corridor, including the Ryer Island Ferry (operations/access);
- Utilities
- Mineral rights access
- Water quality impacts
- Future flood conveyance
- Residential structures
- Adjacent land uses (e.g., Rio Vista Municipal Airport)
- Agricultural lands

4.4. Other Considerations

The following other considerations were analyzed in the Study:

- Public access/recreation
- Mitigation/habitat values
- Erosion (wind and wave fetch)
- Habitat condition change
- Balance of soils on site
- Opinion of Probable Costs of Implementation
- Long-term stewardship
- Safety

4.5. Ranking Criteria

All of the Alternatives were assessed to determine if they met the Project purpose and goals as part of the Threshold Criteria. If the Alternative made it through threshold criteria screening, it was ranked according to the ranking criteria developed by the team and informed by public input. The criteria are described in the following Sections.

4.5.1. Threshold Criteria

The criteria used for the threshold screening process are listed below. Threshold Criteria are pass/fail criteria; any alternatives not meeting all of the Threshold Criteria were screened out. The pass/fail Threshold Criteria are as follows:

- Ability to meet the Project Purpose and Goals.
- Levee Repair: Improve and/or repair existing levees and construct new levees impacted by the Project to current USACE standards.
- Improve resilience of the flood protection system, considering climate change and sea-level rise, as discussed in section 2.1.4.
- Avoidance of significant regional hydraulic effects. Preliminary hydrology and hydraulic modeling suggest changes to channel capacity and breach locations may require measures to mitigate significant regional hydraulic impacts. Alternatives that significantly increase regional water surface elevations are unacceptable.

4.5.2. Ranking Criteria

Ranking criteria were defined to judge and assess the relative ability of Alternatives to deliver certain benefits to meet the LEBMP's multiple goals (**Table 4-1**) qualitatively/professionally. Flood-benefit criteria are based on improving flood flow capacity of the bypass and avoiding downstream impacts. Agriculture criteria seek to avoid or minimize impacts to water supply, water quality, and agricultural operations. Ecological criteria are based on the Central Valley Flood Protection Plan (CVFPP) Conservation Strategy (Conservation Strategy) (DWR 2022).

These ranking criteria were used to determine which alternatives should be carried forward for further analysis. Each ranking criteria was scored qualitatively (high = 3, medium = 2, and low =1), with a high rank denoting that an alternative achieves the criteria to the greatest extent expected. To compare alternatives, values were assigned to each ranking criteria listed in **Table 4-1**. A Ranking Matrix was developed to organize and illustrate the ranking of each Alternative. The top Alternatives with higher total scores are the favored alternatives and would move on for more detailed analysis.

Table 4-1. Ranking Criteria for LEMBP Alternatives

Benefit	Ranking Criteria Number	Description
Flood	R1	Improves flood flow capacity within the Lower Yolo Bypass and reduces local and regional flood risk.
	R2	Avoids significant downstream flood stage impacts associated with increasing flows through the project footprint.
Municipal	R3	Avoids significant impacts to municipal water quality.

Table 4-1. Ranking Criteria for LEMBP Alternatives

Benefit	Ranking Criteria Number	Description
	R4	Avoids significant impacts to municipal water supply.
Agricultural	R5	Avoids significant impacts to agricultural water quality.
	R6	Avoids significant impacts to agricultural water supply.
	R7	Avoids significant impacts to *regional* agricultural operations (e.g., fragmentation, irrigation, drainage, and levee O&M).
	R8	Provide buffers to reduce the potential of restored lands to interfere with surrounding agricultural lands.
Ecological	R10	Increases and improves the quantity, quality, and connectivity of tidal wetland habitats (intertidal).
	R11	Improves the dynamic hydrologic and geomorphic processes tidal habitats (tidal hydrological regime).
	R12	Increases and improves the quantity, quality, and connectivity of tidal aquatic habitats (open water, subtidal flats) for native aquatic species.
	R13	Increases and improves the quantity, quality, and connectivity of floodplain habitats (riparian and upland), including upland transition zones to accommodate SLR.
	R14	Minimizes conditions that would support significant infestations of priority invasive species (aquatic vegetation).
Recreation	R15	Provides opportunities to incorporate new public outdoor recreation consistent with regional needs identified though interested party outreach.
	R16	Provide equitable and affordable access to public outdoor recreation for people of all income and ability levels.
Cost	R9	Cost effectiveness of an alternative to deliver the desired outcomes.

5. Formulation of Preliminary Alternatives

The following sections outline the process used to formulate, screen, and analyze each preliminary alternative. The discussion below includes management actions, the improvement of known levee deficiencies, flood fighting, habitat enhancement and the management of land transition from agriculture to habitat. Additional details on each section are described below.

5.1. Management Actions

Collaboratively identifying existing issues and future conditions were critical management actions during the alternative development process. Differentiating alternatives to be investigated further that meet the Project objectives was a primary concern of the team developing alternatives. The various management activities were categorized as being proactive as opposed to reactive, which would allow nature to reclaim the site. Screening of alternatives was also part of the management actions taken during alternative development. Future analysis of alternatives will be addressed in the CEQA process.

5.1.1. Fix-in-Place (of known problems on existing levees)

Consideration of repairs to known issues must be made. Surface protection of the water-side of all levees must also be recognized. The Project must also address through and under-seepage of the RD 536 levee. Additionally, the Project must meet current USACE and DWR standards for the RD 536 levee.

5.1.2. Flood Fighting

Each alternative was examined to determine the continuity of flood fighting capability during flood events for the RD 536 levee, along with the Mellin Levee. Erosion and interior protection within each Alternative were evaluated to determine what parts of the Project Study Area were vulnerable. Ensuring that Alternative designs maintain access to levee for LMAs is critical for containment of floodwaters.

5.1.3. Habitat Enhancement

Key factors were identified, and levels defined for each of the five ecological benefit criteria (**Table 5-1**) based on information about target species and life history requirements, ecosystem processes, habitat features and stressors. (**Appendix C, Exhibit A and Exhibit D)**. The evaluation considered opportunities to provide the following habitat features:

- Substantial amounts of high-quality aquatic habitat for target fish species
- Enhanced riparian and tidal marsh habitat along perimeter of LET
- Islands to create a “third habitat edge” within subtidal aquatic habitat
- Improved juxtaposition and spatial arrangement of aquatic features, such as along an elevation gradient

5.1.4. Manage Transition from Agriculture to Habitat

Managing the transition from agriculture to habitat will require many important considerations. Flood flows moving through the Tract will increase agricultural opportunities within the region for other properties. Increasing flood capacity and reducing pressure on upstream agricultural levees benefits all leveed lands within the region. The Project would also provide offsets to impacts of agricultural water supply diversions through the habitat conservation plan. Improving levee protection for adjacent agricultural lands is a significant benefit. Consideration of the tax revenue reduction for Solano County must also be addressed.

5.2. Preliminary Alternatives

In 2018, the SAFCA Study drafted and assessed 15 alternatives. Initial screening reduced the number of alternatives to 7 for final analysis. While some Project goals and objectives (flood and habitat improvement) were assessed in final arrays, the team was unable to make final recommendations due to the limited scope of the analysis. The LEMBP Feasibility Study was scoped to specifically address the subject matter gaps in the previous work to help DWR move into CEQA with preferred alternates. Additional alternatives were developed and evaluated in a 2-step ranking process under the current Study. The full array of 29 Project alternatives is described below, with figures provided in the List of Exhibits.

5.2.1. Alternative 1 – No Action Alternative

Alternative 1 is the "no action" alternative which does not include any alteration to the Project Study Area. This alternative would not modify or improve the existing levees, current infrastructure or alter the current land use.

During flood events, under Alternative 1, the restricted height levee will overtop and breach in various parts of the levee. The locations of these levee breaches are unpredictable. The flood events are anticipated to occur on a "1-in-25-year frequency" (SAFCA 2018) with breach failure points similar to the 1997 flood. The costs of repairing the levees and infrastructure to return the Site to current use is anticipated to be expensive, requiring pumping of ~24,000-acre feet of water and emergency repairs of levees via barge in Cache Slough. The repairs performed in state and federally jurisdictional waters may require an extensive permitting process and costly mitigation. The current landowner is unlikely to absorb the costs of repair because the revenue created from the current land use (agriculture) is insufficient to repair the levee and infrastructure, especially as breach frequencies are expected to increase over time due to climate change and sea level rise.

5.2.2. Alternative 2

This alternative was previously considered in the 2018 SAFCA Concept Study. Alternative 2 provides benefits for both flood risk reduction and habitat. In this alternative, the restricted height levee is degraded in the north and south end of the Project study area. A wind-wave habitat berm is constructed along the existing RD 536 levee. Habitat will be enhanced with a "subtidal tract interior that connects the two large levee degrades with two additional breaches to Cache Slough the restricted-height levee" (SAFCA 2018).

This alternative did not move forward because it failed to meet the purpose and goals of this project, outlined in Section 4 above.

5.2.3. Alternative 3

This alternative was previously considered in the 2018 SAFCA. This alternative provides habitat and flood risk reduction benefits. This alternative has similar features to Alternative 2 and includes the Powell property. In this alternative, a portion of State Route 84 and the Ryer Island Ferry western terminal would be relocated.

This Alternative did not move forward because it failed to meet the purpose and goals of this project, outlined in Section 4 above.

5.2.4. Alternative 4

Alternative 4 was considered in the 2018 SAFCA. This alternative "provides flood risk reduction benefits, creates permanent tidal marsh with associated subtidal habits and season floodplain habitats, and preserves a majority of the property in agriculture" (SAFCA FS 2018) in the southern portion of the interior. In this alternative, agriculture at the Study area will be subject to flooding when the restricted-height levee is flooded. The restricted-height levee flooded in 1986 and 1997 and experienced near misses in 2006, 2011 and 2017.

This alternative did not move forward because it failed to meet the purpose and goals of this Project, outlined in Section 4 above.

5.2.5. Alternative 5

Alternative 5 was previously considered in the 2018 SAFCA. Alternative 5 provides benefits for both agriculture and habitat. This alternative includes the construction of a new restricted height levee around the higher elevations, which would be restored with a tidal opening and channel to provide 600 acres of tidal marsh complex habitat. The remaining acreage would be agriculture with a restricted height 7,500'-wide inlet weir on the north end set at an elevation of MHHW+3'. The outlet weir is proposed to be a compound weir, 6,000'-wide set at an elevation of MHHW+3', and a 1,500'-wide section set at MTL+0.5'. An upgraded discharge pump was also included in this alternative.

This alternative did not move forward because it failed to meet the purpose and goals of this project, outlined in Section 4 above.

5.2.6. Alternative 6

This alternative was previously considered during the 2018 SAFCA. Alternative 6 provides benefits for both agriculture and habitat. This alternative contains the same design as Alternative 5 but has a different outlet weir configuration. A 3,000'-wide section of the downstream outlet weir will be set at MHHW+3, a 1,500'-wide section will be set at MTL+0.5', and a 2,500'-wide section will be set at an elevation of MHHW+3'.
This alternative did not move forward because it failed to meet the purpose and goals of this project, outlined in Section 4 above.

5.2.7. Alternative 7

Alternative 7 was previously considered during the 2018 SAFCA. This alternative provides benefits to habitat. The Powell property was utilized in this design alternative, with a tidal connection along the current SR 84, 4,500'-wide downstream outlet weir set at elevation 5'. A restricted height levee around the southern portion of the site is proposed with a wind-wave berm constructed on the northern side. The northern portion only includes a weir on the northern end consisting of a 7,500'-wide section set at elevation 9'.

This alternative did not move forward because it failed to meet the purpose and goals of this project, outlined in Section 4 above.

5.2.8. Alternative 8

Alternative 8 was previously considered during the 2018 SAFCA. This alternative provides benefits primarily to habitat and flood resilience, with a 600-acre portion of the southern end of the tract protected by a new restricted height weir to also allow agricultural use within that portion of the site. The central portion of the site contains a subtidal swale running from north to south with swales connecting the balance breaches along Cache Slough. This alternative includes a 7,500'-wide fully degraded upstream inlet weir, and a compound downstream outlet weir. The outlet weir includes a 3,000'-wide fully degraded section, and a 1,500'-wide section set at MTL+0.5'.

This alternative did not move forward because it failed to meet the purpose and goals of this project, outlined in Section 4 above.

5.2.9. Alternative 9

This alternative was previously considered during the 2018 SAFCA. This alternative provides benefits to agriculture, habitat, and flood resilience. In this alternative, 600 acres in the southernmost portion of the tract, along with the Powell property were protected for agricultural use with a restricted height levee. This alternative includes an inlet weir in the north end and outlet weir on the south end, with two balance breaches along Cache slough between the weirs. Dredge material will be reused along the 2084 levee to provide additional habitat. The upstream inlet weir is 7,500'-wide and fully degraded to the interior elevation. The downstream outlet weir is 3,000'-wide and fully degraded to the interior elevation.

This alternative did not move forward because it failed to meet the purpose and goals of this project, outlined in Section 4 above.

5.2.10. Alternative 10

Alternative 10 was previously considered during the 2018 SAFCA. This alternative provides 600-acres of tidal marsh and 600-acres of wild rice habitat, and flood resilience benefits. A new restricted height levee is proposed along the southern end of LET and running north, parallel to the RD 536 levee. This alternative contains an inlet weir on the north end and a compound outlet weir on the south end, with two balance breaches along the 2084 levee. Dredge material will be reused along the 2084 levee to provide additional habitat. The upstream inlet weir consists of a 7,500'-wide section fully degraded to the interior elevation. The downstream outlet weir consists of a 3,000'-wide section fully degraded to the interior elevation and a 1,500'-wide section set at MHHW+0.5'.

This alternative did not move forward because it failed to meet the purpose and goals of this project, outlined in Section 4 above.

5.2.11. Alternative 11

Alternative 11 was previously considered during the 2018 SAFCA. This alternative provides 600 acres of wild rice habitat and 1,000 acres of tidal marsh habitat, with the utilization of the Powell property and a large outlet weir across the entire southern end of the site. Dredge material will be reused along the 2084 levee to provide additional habitat. This alternative incorporates a large inlet weir in the north end and a large outlet weir in the south end, with two balance breaches along the 2084 levee. The upstream inlet weir is a 7,500'-wide section degraded to interior elevation. The downstream outlet is a compound weir with a 3,000'-wide section degraded to interior elevation and a 4,500'-wide section degraded to MHHW+0.5'.

This alternative did not move forward because it failed to meet the purpose and goals of this project, outlined in Section 4 above.

5.2.12. Alternative 12

This alternative was previously considered during the 2018 SAFCA. Alternative 12 includes flood risk reduction and habitat benefits, with the creation of 800 acres of tidal marsh. The Powell property was utilized in the design of this alternative and contains a new restricted height levee. The land to the west of the new restricted height levee is designed to provide habitat for giant garter snakes. The upstream inlet weir is a 7,500'-wide section degraded to interior elevation. The downstream outlet is a compound weir with a 1,500'-wide section degraded to interior elevation and a 4,500'-wide section degraded to MHHW+0.5'.

This alternative did not move forward because it failed to meet the purpose and goals of this project, outlined in Section 4 above.

5.2.13. Alternative 13

Alternative 13 was previously considered during the 2018 SAFCA. This alternative provides benefits to agriculture, flood resilience and habitat. Alternative 13 provides 600 acres of agriculture on LET and 400 acres of tidal marsh habitat on the Powell property. This design incorporates a subtidal channel and two balance breaches. The upstream inlet weir is a 7,500'-wide section degraded to interior elevation. The downstream outlet weir is a compound weir with a 3,000'-wide section fully degraded to interior elevation, a 1,500’-wide section degraded to MHHW+3’, and a 3,000'-wide section degraded to MHHW+0.5’.

This alternative did not move forward because it failed to meet the purpose and goals of this project, outlined in Section 4 above.

5.2.14. Alternative 14

This alternative was previously considered during the 2018 SAFCA. Alternative 14 provides flood risk reduction and habitat benefits. This alternative incorporates a seasonal floodplain with restored tidal marsh along the western edge of the site, a subtidal swale, and two balance breaches. The upstream inlet weir is a 7,500’-wide section degraded to interior elevation. The downstream outlet is a compound weir with a 1,500'-wide section fully degraded to interior elevation and a 1,500'-wide section degraded to MHHW.

This alternative did not move forward because it failed to meet the purpose and goals of this project, outlined in Section 4 above.

5.2.15. Alternative 15

This alternative was previously considered during the 2018 SAFCA. Alternative 15 provides flood risk reduction and habitat benefits. This alternative incorporates a seasonal floodplain with restored tidal marsh along the western edge of the site, a subtidal swale, and two balance breaches. This design is very similar to Alternative 14 but also incorporates the Powell property as a seasonal floodplain and tidal marsh. This alternative utilizes a 7,500’-wide upstream inlet weir fully degraded to interior elevation. The downstream outlet weir consists of a 2,000'-wide section degraded to MHHW and a 3,500'-wide section degraded to MHHW+0.5’.

This alternative did not move forward because it failed to meet the purpose and goals of this project, outlined in Section 4 above.

5.2.16. Alternative 16

Alternative 16 is the “no action” alternative used during the development of the more recently derived designs, which does not include any alteration to the Project Study Area. This alternative would not modify or improve the existing levees, current infrastructure or alter the current land use.

During flood events, under Alternative 16, the restricted height levee will overtop and breach in various parts of the levee. The locations of these levee breaches are unpredictable. The flood events are anticipated to occur on a “1-in-25-year frequency” (SAFCA LET FS 2018) with breach failure points similar to the 1997 flood.

5.2.17. Alternative 17.1

This Alternative was developed by the CNRA Feasibility Study technical team. This Alternative optimizes grading to create interior wave break habitat islands and wide habitat berms with the upstream inlet at EL -4.0 ft. NAVD88. The design includes adding a soil buffer to create wide habitat berms along the RD 536 Levee (approximately 445 ft.) and RD 2084 Levee (approximately 445 ft.), and excavation of a subtidal swale to approximately EL -10.0 ft. NAVD88 for habitat berm and island fill. It also includes a 20-ft.-wide channel to provide tidal water connection to a restored marsh, located north of Watson Hollow Slough with a water control structure under the RD 536 Levee, but is not intended to be a flood bypass feature. The downstream outlet is designed to be fully degraded with a 2,000 ft. outlet set at EL -10.0 ft. NAVD88, with two fully degraded balance breaches. This design is intended to decrease potential erosion related to wind and wave action but may require moving significant amounts of material and may increase downstream regional flood effects. This Alternative would require installation of a bridge or culverts to accommodate the tidal opening at the intersection of the feature with SR 84.

5.2.18. Alternative 18

This Alternative was developed by the CNRA Feasibility Study technical team. This Alternative focuses on the creation of habitat with narrow habitat berms. This design does not include a subtidal swale but does include land leveling and the upstream inlet sill is 2,500 ft. wide and set at +7.5 ft. NAVD88. The downstream outlet is set at EL -6.0 ft. NAVD88. The design includes adding a soil buffer to create habitat berms along the RD 536 Levee (approximately 180 ft.) and RD 2084 levee (approximately 180 ft.) and the incorporation of two fully degraded balance breaches along Cache Slough. It also includes a 20-ft.-wide channel to provide tidal water connection to a restored marsh, located north of Watson Hollow Slough, but is not intended to be a flood bypass feature.

This design is intended to improve regional water quality **(Appendix E)** but may allow more submerged aquatic vegetation growth due to limited flows through the interior.

5.2.19. Alternative 19.1

This Alternative was developed by the CNRA Feasibility Study technical team. This Alternative focuses on habitat within the Project Area. The design includes adding a soil buffer to create narrow habitat berms along the RD 536 Levee (approximately 295 ft.) and RD 2084 Levee (approximately 295 ft.), and excavation of a subtidal swale to approximately EL -10.0 ft. NAVD88 for habitat berm fill, and the incorporation of two fully degraded balance breaches along Cache Slough. It also includes a 20 ft.-wide channel to provide tidal water connection to a restored marsh, located north of Watson Hollow Slough, but is not intended to be a flood bypass feature. The upstream inlet is designed to be 2,500 ft.-wide set at EL +7.5 ft. NAVD88, and downstream outlet is 2,000 ft.-wide compound outlet set at EL -10.0 ft. NAVD88. This Alternative would require installation of a bridge or culverts to accommodate the tidal opening at the intersection of the feature with SR 84.

5.2.20. Alternative 20

This Alternative was developed by the CNRA Feasibility Study technical team. This Alternative focuses on maximizing net export of fish food while decreasing upstream flow of tidal water into Cache Slough and Lindsey Slough. The Alternative includes a controlled 2,000-ft., upstream inlet (compound breach) at +7.0 ft. NAVD88 with a 100 ft. full degrade section (-6.0 ft. NAVD88) and a 2,000-ft. compound downstream outlet at EL +7.0 ft. NAVD88 on the downstream outlet with a similar 100 ft. fully degraded section (-6.0 ft. NAVD88). The design includes adding a soil buffer to create narrow habitat berms along the RD 536 Levee (approximately 180 ft.) and Cache Slough levee (approximately 115 ft.), and excavation of a subtidal swale to approximately EL -10.0 ft. NAVD88 for habitat berm fill. It also includes a 20 ft.-wide channel to provide tidal water connection to a restored marsh, located north of Watson Hollow Slough, but is not intended to be a flood bypass feature. This Alternative would require installation of a bridge or culverts to accommodate the tidal opening at the intersection of the feature with SR 84.

5.2.21. Alternative 21

This Alternative was developed by the CNRA Feasibility Study technical team. This Alternative utilizes the same tidal pump breach configuration and habitat berms as Alternative 20 but includes a 'folded-horn' feature to increase tidal residence time. The folded-horn feature, set at EL +6.0 ft. NAVD88, is a double, linear sheet-pile 'maze' (residency barrier) with the intent to increase residency time in the center open water area of LET. The design focuses on maximizing net export of fish food while decreasing upstream flow of tidal water into Cache Slough and Lindsey Slough due to pumping. The design includes adding a soil buffer to create narrow habitat berms along the RD 536 (approximately 180 ft.) and Cache Slough levee (approximately 115 ft.), and excavation of a subtidal swale to approximately EL -10.0 ft. NAVD88 for habitat berm fill. The Alternative includes a controlled 2,000-ft., upstream inlet at +7.0 ft. NAVD88 with a compound breach containing a 100 ft. full degrade section (-6.0 ft. NAVD88) and a controlled 2,000-ft. outlet to EL + 5.0 ft. NAVD88 on the downstream outlet with a similar 100' ft. fully degraded section (-6.0 ft. NAVD88). It also includes a 20-ft.-wide channel to provide tidal water connection to a restored marsh, located north of Watson Hollow Slough, but is not intended to be a flood bypass feature. This Alternative would require installation of a bridge or culverts to accommodate the tidal opening at the intersection of the feature with SR 84.

5.2.22. Alternative 22

This Alternative was developed by the CNRA Feasibility Study technical team. This Alternative focuses on the creation of habitat with a subtidal channel and narrow habitat berms. This design includes a 2,500 ft. wide upstream inlet sill set at EL +7.5 ft. NAVD88. The downstream outlet is 2,000 ft. wide and is set at EL -6.0 NAVD88. The design includes adding a soil buffer to create narrow habitat berms along the RD 536 (approximately 180 ft.) and Cache Slough levee (approximately 115 ft.), and excavation of a subtidal swale to approximately EL -10.0 ft. NAVD88 for habitat berm fill, and the incorporation of two fully degraded balance breaches along Cache Slough. This design is intended to improve regional water quality **(Appendix E)** but may allow more aquatic weed growth due to limited flows through the interior.

5.2.23. Alternative 23

This Alternative was developed by the CNRA Feasibility Study technical team. This Alternative focuses on the creation of habitat with a subtidal channel and narrow habitat berms. This design includes an upstream inlet designed to be fully degraded and 2,500 ft. wide with a 2,000 ft. outlet set at EL -6.0 ft. NAVD88, and the incorporation of two fully degraded balance breaches along Cache Slough. This Alternative also includes a high flow bypass tidal opening to Cache Slough.

Through hydraulic modeling, this bypass feature was shown to create significant impacts to water surface elevations downstream. These higher water levels could potentially cause significant impacts to downstream levees. For this reason, this Alternative failed to meet the Threshold Criteria, outlined in Section 4, and subsequently was rejected. This Alternative would require installation of a bridge or culverts to accommodate the tidal opening at the intersection of the feature with SR 84.

5.2.24. Alternative 24.1

This Alternative was developed by the CNRA Feasibility Study technical team. This Alternative focuses on the creation of habitat with a subtidal channel, wave break habitat islands, and wide habitat berms. This design includes an upstream inlet sill 2,500 ft. wide and set at +7.5 ft. NAVD88. The downstream outlet is 2,000 ft. wide compound breach and is set at EL -4.0 NAVD88. The design includes adding a soil buffer to create wide habitat berms along the RD 536 Levee (approximately 445 ft.) and Cache Slough levee (approximately 215 ft.), excavation of a subtidal swale to approximately EL -10.0 ft. NAVD88 for habitat berm. This Alternative includes rehab with cutoff walls and seepage berms along the RD 536 Levee, and a water control structure within the RD 536 Levee.

5.2.25. Alternative 25

This Alternative was developed by the CNRA Feasibility Study technical team. This Alternative focuses on the creation of habitat with narrow habitat berms. This design does not include a subtidal swale but does include general site grading for drainage and the upstream inlet sill is 2,500 ft. wide and fully degraded, with the downstream outlet set at +7.5 ft. NAVD88. The outlet is 2,000 ft. wide and is set at EL -6.0 NAVD88. The design includes adding a soil buffer to create habitat berms along the RD 536 Levee (approximately 180 ft.) and Cache Slough levee (approximately 115 ft.) and the incorporation of two fully degraded balance breaches along Cache Slough. This design is intended to improve regional water quality **(Appendix E)** but may allow more submerged aquatic vegetation growth due to limited flows through the interior.

5.2.26. Alternative 26.1

This Alternative was developed by the CNRA Feasibility Study technical team. This Alternative focuses on the creation of habitat with a subtidal channel and narrow habitat berms. This design includes an upstream inlet sill 2,500 ft. wide and set at -4.0 NAVD88. The downstream outlet is 2,000 ft. wide and is set at EL -10.0 NAVD88. The design includes adding a soil buffer to create narrow habitat berms along the RD 536 Levee (approximately 295 ft.) and RD 2084 Levee (approximately 295 ft.), and excavation of subtidal swale to approximately EL -10.0 ft. NAVD88 for habitat berm fill, and the incorporation of two fully degraded balance breaches along Cache Slough. It also includes a 20-ft.-wide channel to provide tidal water connection to a restored marsh, located north of Watson Hollow Slough, but is not intended to be a flood bypass feature. This Alternative would require installation of a bridge or culverts to accommodate the tidal opening at the intersection of the feature with SR 84.

5.2.27. Alternative 27

This Alternative was developed by the CNRA Feasibility Study technical team. This Alternative focuses on the creation of habitat with a subtidal channel, wave break habitat islands, and wide habitat berms. This design includes an upstream inlet sill 2,500 ft. wide and set at +7.5 ft NAVD 88. This Alternative also includes a compound breach containing a 100 ft. full degrade section (-6.0 ft. NAVD88) and a controlled 2,000-ft. outlet to EL + 5.0 ft. NAVD88 on the downstream outlet with a similar 100’ ft. fully degraded section (-6.0 ft. NAVD88), and the incorporation of two fully degraded balance breaches along Cache Slough. It also includes a 20-ft.-wide channel to provide tidal water connection to a restored marsh, located north of Watson Hollow Slough, but is not intended to be a flood bypass feature. This Alternative would require installation of a bridge or culverts to accommodate the tidal opening at the intersection of the feature with SR 84.

5.2.28. Alternative 28

This Alternative was developed by the CNRA Feasibility Study technical team. This Alternative focuses on the creation of habitat with a subtidal channel, wave break habitat islands, and wide habitat berms. The Alternative includes a controlled 2,000-ft., upstream inlet at +7.0 ft. NAVD88 with a compound breach containing a 100 ft. full degrade section (-6.0 ft. NAVD88) and a controlled 2,000-ft. downstream outlet to EL + 5.0 ft. NAVD88 on the downstream outlet with a similar 100’ ft. fully degraded section (-6.0 ft. NAVD88). It also includes a 20-ft.-wide channel to provide tidal water connection to a restored marsh, located north of Watson Hollow Slough, but is not intended to be a flood bypass feature.

5.2.29. Alternative 29

This Alternative was developed by the CNRA Feasibility Study technical team. This Alternative focuses on the creation of habitat with a subtidal channel, and narrow habitat berms. This design includes an upstream inlet sill 2,500 ft. wide and set at +7.5 ft NAVD 88. This Alternative also includes a downstream outlet sill 2,500 ft. wide and set at +7.5 ft NAVD 88, and the incorporation of two fully degraded balance breaches along Cache Slough. It also includes a 20-ft.-wide channel to provide tidal water connection to a restored marsh, located north of Watson Hollow Slough, but is not intended to be a flood bypass feature. This Alternative would require installation of a bridge or culverts to accommodate the tidal opening at the intersection of the feature with SR 84.

5.3. Screening and Ranking of Preliminary Alternatives

The 29 proposed alternatives were screened against Project Threshold Criteria, then Ranking Criteria were used to determine which of the alternatives showed the highest potential functional value.

The first level of screening was a test against the Threshold Criteria. Any alternative that did not meet the Threshold Criteria was immediately rejected. All remaining alternatives were then tested against the Ranking Criteria. The four highest scoring alternatives were determined to be the final array of alternatives and moved on to additional analysis and a final ranking, as well as the no-action alternative.

Descriptions of the Project purpose and goals, Threshold Criteria, and Ranking Criteria can be found above in Section 4.5 of this Feasibility Study. The Threshold Criteria and Ranking Criteria results are shown below in sections 5.3.1 and 5.3.2.

5.3.1. Purpose, Goals, and Threshold Criteria Summary

Alternative 1, the “no-action” alternative, was retained throughout all levels of screening and ranking to be utilized as a baseline.

During the initial screening against the Threshold Criteria, Alternatives 2, 3, 14, and 15 were rejected because they fail to meet the first of the Project Purpose and Goals which aims to “enhance public safety, health, and quality of life for the state’s citizens.” Alternatives 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, and 29 were also rejected during this level of screening because these objectives fail to meet the goal that ensures the project protects and enhances natural ecosystem processes to increase habitat and supports species. Alternative 23 was rejected as it failed to avoid significant hydraulic effects, the final Threshold criterion.

Alternative 23 failed to avoid significant hydraulic effects.

5.3.2. Ranking Criteria Summary

The 11 alternatives that remained after screening against the threshold criteria were entered into a ranking table. The retained alternatives include numbers 17.1, 18, 19.1, 20, 21, 22, 24.1, 25, 26.1, 27, and 28. The ranking table lists the remaining alternatives along the X-axis and the ranking criteria along the Y-axis. A scale of one (low), two (medium), and three (high) was utilized to determine the proposed alternative’s ability to achieve each of the 16 ranking criteria (**Table 5-2**).

Table 5-1. Ranking Criteria

Rating	Description	17	18	19	20	21	22	24	25	26	27	28
	Remaining Alternatives:	**17**	**18**	**19**	**20**	**21**	**22**	**24**	**25**	**26**	**27**	**28**
Rating	**Description**	***Ranking Criteria (Low = 1, Medium = 2, High = 3)***										
R-1	Improves flood flow capacity within the Lower Yolo Bypass and reduces local and regional flood risk	2	1	1	1	1	1	1	2	2	1	1
R-2	Avoids significant downstream flood stage impacts associated with increasing flows through the project footprint	2	2	2	2	2	2	2	2	2	2	2
R-3	Avoids significant impacts to municipal water quality	2	2	2	2	2	2	2	2	2	2	2
R-4	Avoids significant impacts to municipal water supply	2	2	2	2	2	2	2	2	2	2	2
R-5	Avoids significant impacts to agricultural water quality	2	2	2	2	2	2	2	2	2	2	2
R-6	Avoid significant impacts to agricultural water supply	2	2	2	2	2	2	2	2	2	2	2
R-7	Avoid significant impacts to regional agricultural operations (e.g. fragmentation, irrigation, drainage, and levee O&M)	2	2	2	2	2	2	2	2	2	2	2
R-8	Provide buffers to reduce the potential of restored lands to interfere with surrounding agricultural lands	2	2	2	2	2	2	2	2	2	2	2
R-9	Comparative cost by alternative	2	2	2	2	1	2	2	3	1	1	1
R-10	Increases and Improves quantity, quality, and connectivity of tidal wetland habitats (intertidal)	3	3	3	3	3	2	3	1	3	3	3
R-11	Improve dynamic hydrologic and geomorphic processes (tidal hydrologic regime)	3	2	2	1	1	2	2	3	3	2	2
R-12	Increases and improves the quantity, diversity, and connectivity of tidal aquatic habitats (open water, subtidal flats) for native aquatic species	3	1	3	3	2	2	3	1	2	3	3
R-13	Increases and Improves quantity, quality, and connectivity of floodplain habitats (riparian and upland), including upland transition zones to accommodate sea-level rise	3	2	2	2	2	2	3	1	2	3	3
R-14	Minimize conditions that would support significant infestations of priority invasive species (aquatic vegetation)	2	2	2	1	1	3	2	2	3	1	1
R-15	Provides opportunities to incorporate new public outdoor recreation consistent with regional needs identified though interested party outreach	2	2	2	2	2	2	2	2	2	2	2
R-16	Provides equitable and affordable access to public outdoor recreation for people of all income and ability levels	2	2	2	2	2	2	2	2	2	2	2
	Average Scores of each Alternative	**2.3**	**1.9**	**2.1**	**1.9**	**1.8**	**2**	**2.1**	**1.9**	**2.1**	**2**	**2**
	RANK (1=HIGH)	1	4	2	4	5	3	2	4	2	3	3
	TOP TIER											

Table 5-2. Ranking Criteria Valuation

#	Ranking Criteria	High	Medium	Low
R-1	Improves flood flow capacity within the Lower Yolo Bypass and reduces local and regional flood risk	Decreases Baseflood EL> 2 feet	Decreases Baseflood EL > 1 to < 2 feet	Decreases Baseflood EL < 1 foot
R-2	Avoids significant downstream flood stage impacts associated with increasing flows through the project footprint	< +0.1 rise & localized increase	> + 0.1 to < +1.0 rise localized increase	> +1.0 EL rise & widespread increase
R-3	Avoids significant impacts to municipal water quality	< 1% increase in salinity	> 1% to < 10% increase in salinity	> 10 percent increase in salinity
R-4	Avoids significant impacts to municipal water supply	No change in water flow	Minimal change in water flow	Decreases water flow
R-5	Avoids significant impacts to agricultural water quality	< 1% increase in salinity	> 1% to < 10% increase in salinity	> 10 percent increase in salinity
R-6	Avoids significant impacts to agricultural water supply	No change in water flow	Minimal change in water flow	Decreases water flow
R-7	Avoids significant impacts to agricultural operations (e.g. fragmentation, irrigation, drainage, and levee O&M)	No impacts to agricultural operations	Minor impacts to agricultural operations	Major impacts to agricultural operations
R-8	Provides buffers to reduce the potential of restored lands to interfere with surrounding agricultural	Provides significant buffer	Provides some buffer	Provides no buffer
R-9	Cost effectiveness of an alternative to deliver the desired outcomes	Lowest 1/3 cost per acre	Middle 1/3 cost per acre	Highest 1/3 cost per acre
R-10	Increase and improve the quantity, quality, and connectivity of tidal wetland habitats (intertidal)	Extensive band of tidal emergent wetlands along shoreline (>200 feet of tidal habitat edge)	Narrow band of tidal emergent wetlands along shoreline (>50 to <200 feet of tidal habitat edge)	Smaller patch of tidal emergent wetlands with no interior channels (<50 feet of tidal habitat edge)
R-11	Increase and improve the quantity, diversity, and connectivity of tidal habitats (tidal hydrologic regime)	Open flow through with full tidal exchange	Muted tidal exchange	Impaired tidal exchange
R-12	Increase and improve the quantity, diversity, and connectivity of tidal aquatic habitats (open water, subtidal flats) for native aquatic species	Heterogeneous bathymetry (swales, flats, & islets)	Some bathymetric heterogeneity (swale)	Little or no bathymetric heterogeneity (no swale)
R-13	Increases and Improves quantity, quality, and connectivity of floodplain habitats (riparian and upland), including upland transition zones to accommodate sea-level rise	Wide habitat berms	Narrow habitat berms	No habitat berms
R-14	Minimize conditions that would support significant infestations of priority invasive species (aquatic vegetation)	> -15.0 subtidal elevations	> -8.0 to < -15.0 subtidal elevations	< -8.0- subtidal elevations
R-15	Provides opportunities to incorporate new public outdoor recreation consistent with regional needs identified though interested party outreach	Multiple opportunities	Minimum of one opportunity	No opportunities
R-16	Provides equitable and affordable access to public outdoor recreation for people of all income and ability levels	Provides open access to all	Provides moderate access to all	Provides limited access to all

5.4. Final Alternative Array

Four action alternatives were selected to go into more detailed analysis with the no-action alternative. These include Alternative 17, Alternative 19, Alternative 24, and Alternative 26 (see respective Figures 7-10.) While these four alternatives were found to best align with the ranking metrics, goals and objectives, there was a realization that they were all similar in a hydrodynamic sense. Both 17 and 26 included an identical set of full breach conditions while 19 and 24 both included identical weirs in the north and full breach conditions in the south. The team collectively decided the water quality and hydraulic studies would not appreciably differ between the 2 sets of conditions and elected to make the following changes:

- Alternative 17 – To remain as is.
- Alternative 19 – To remain as is.
- Alternative 24 – Include a 'water quality compound breach' at the outlet to test the hypothesis that reducing tidal exchange on the tract can reduce water quality impacts noticed in previous studies (RMA 2023). Balance breaches were also eliminated to further test the effects of limited tidal exchange with Cache Slough.
- Alternative 26 – Elimination of balance breaches to test overall effectiveness of these features under fully tidal conditions.

A summary of the features in each alternative are tabulated below in Table 5-3.

Table 5-3. Table Summary of Alternative Features

Alternative	North Breach	South Breach	Levee Repair	Tide Gate Structure	Balance Breaches	Habitat Berms	Sub-tidal Channel	Habitat Islands	South-Marsh Connection
17	Full Degrade to -4.0	Full Degrade to -10.0	Yes	Yes	Yes	Wide	Wide	Yes	Cache Slough via Bridge
19	to 7.5'	Full Degrade to -10.0	Yes	Yes	Yes	Narrow	Medium	Yes	LET Internal
24	to 7.5'	to 7.5' with notch	Yes	Yes	No	Wide	Wide	Yes	LET Internal
26	Full Degrade to -4.0	Full Degrade to -10.0	Yes	No	No	Narrow	Narrow	No	Cache Slough via Bridge

Table 5-4 indicates which companies modeled conditions for each alternative.

Table 5-4. Alternative Modeling

Alternative	Flood Hydraulic Analysis	Water Quality Analysis	Wind Wave Fetch Analysis	Particle Tracking Analysis
FWOP (not breached)	RMA	RMA		
FWOP (levee breached)	MBK, cbec		cbec	
FWOP (fully degraded levees)	MBK, cbec, RMA	RMA		
15				
16				
17	MBK, cbec		cbec	cbec
18				
19	MBK, cbec, RMA	RMA	cbec	cbec
20				
21				
22				
23				
24	MBK, cbec, RMA	RMA	cbec	cbec
25				
26	MBK, cbec, RMA	RMA	cbec	cbec
27				
28				
29				

Figure 8. Final Version of Alternative 17

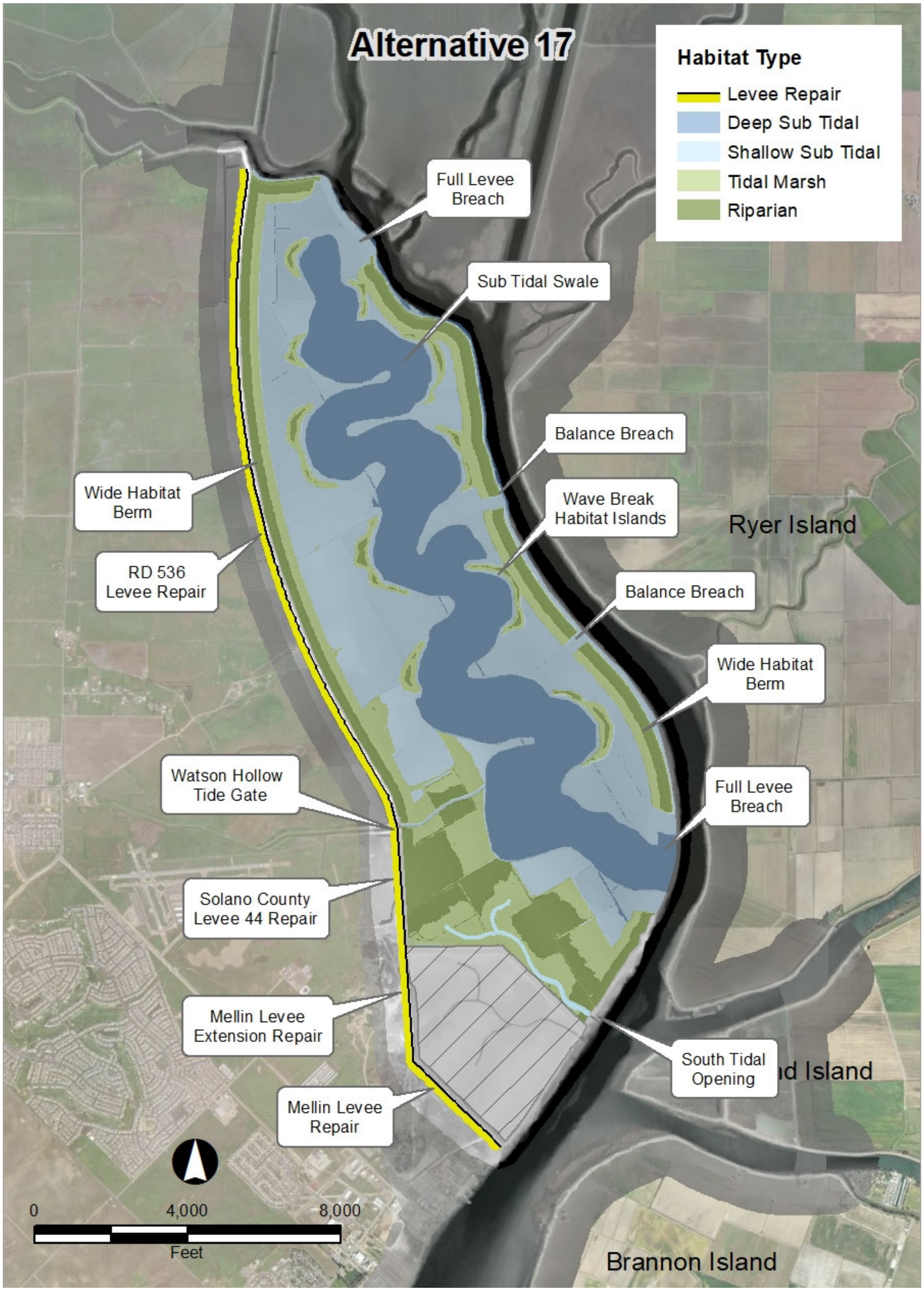


Figure 9. Final Version of Alternative 19

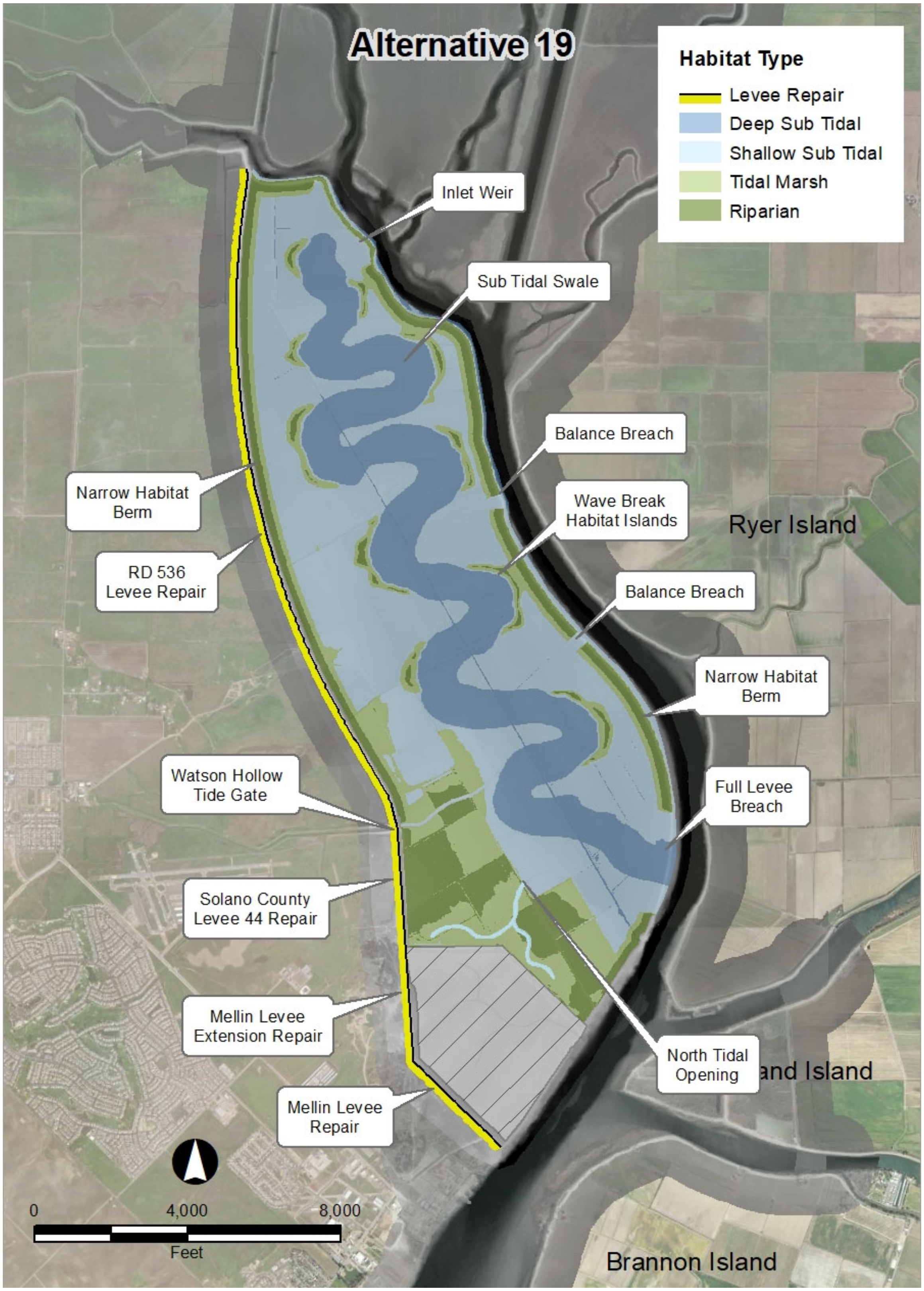


Figure 10. Final Version of Alternative 24

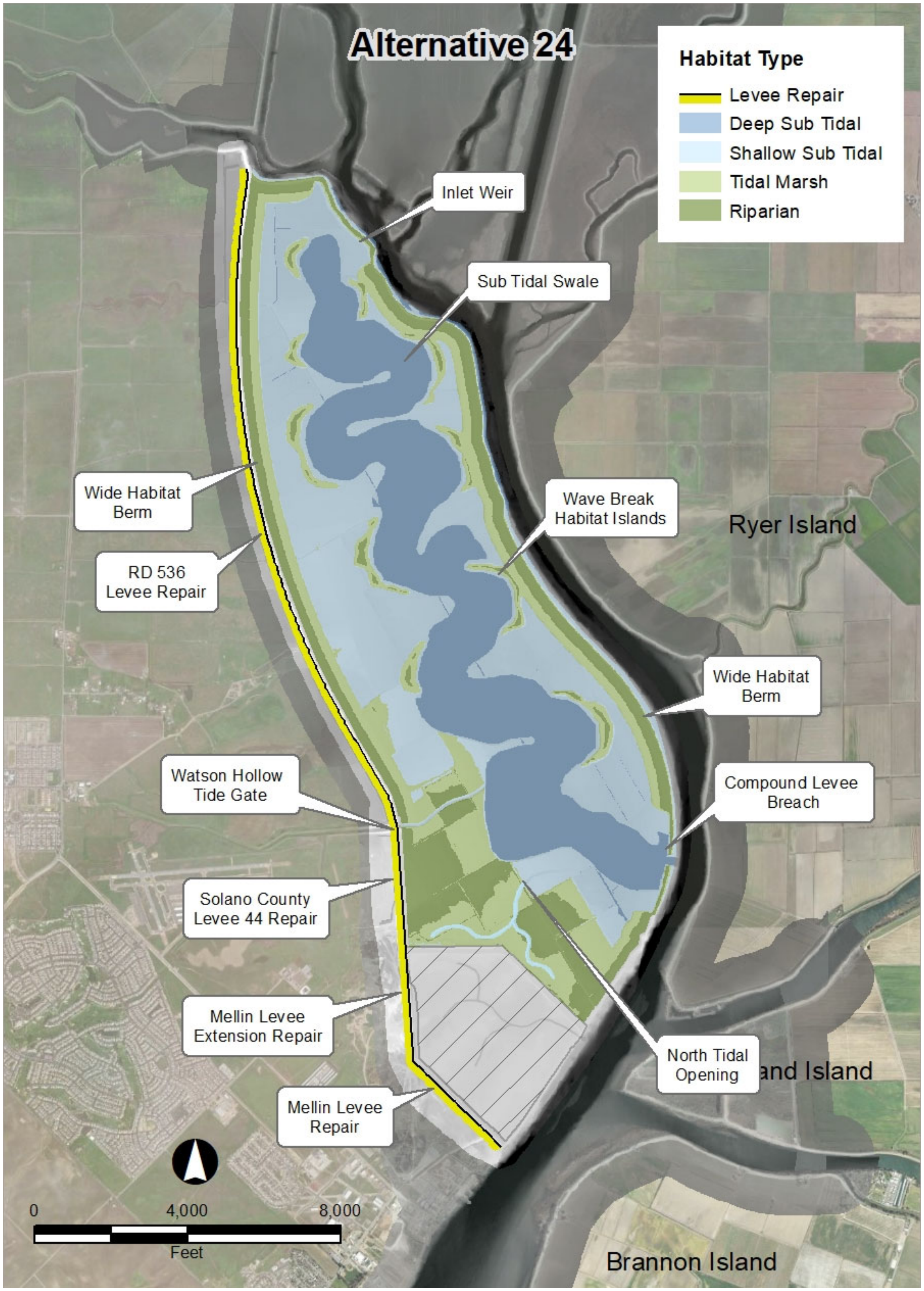
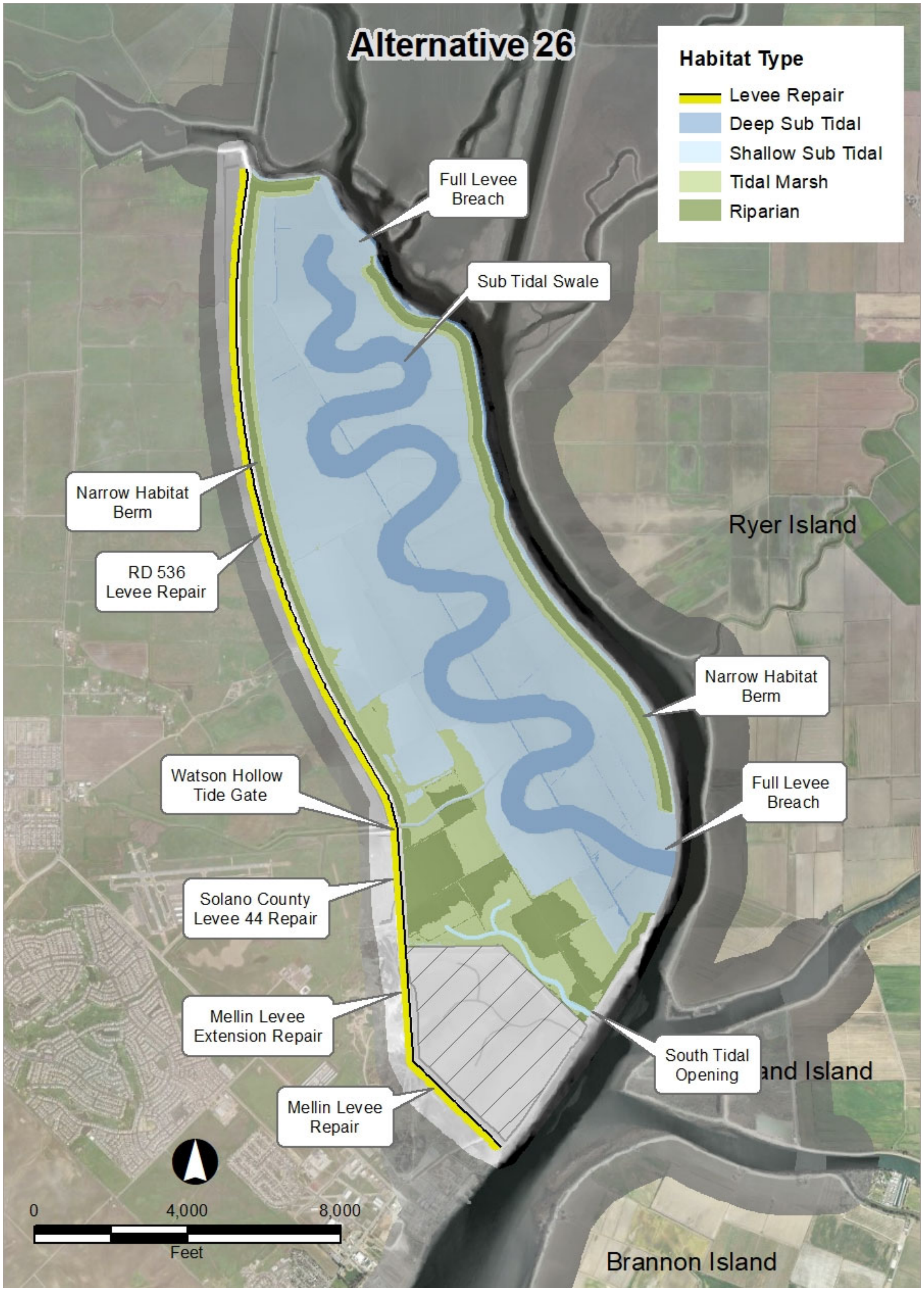


Figure 11. Final Version of Alternative 26



6. Evaluation and Comparison of Final Array of Alternatives

6.1. Hydrology and Hydraulics

This section examines regional hydrology and localized hydraulics for the final array of Alternatives. This includes flood hydraulics, hydrodynamic modeling, wave runup (fetch) analysis, and particle tracking.

6.1.1. Hydraulic Modeling

The study team conducted a comprehensive evaluation of the hydraulic performance of the final set of alternatives. The primary metric used to assess the performance was the change in maximum water surface elevations at both local and regional levels. To simulate different scenarios, a 1-dimensional (1D) and 2-dimensional (2D) hydraulic model of the lower Yolo Bypass was developed using the USACE Hydraulic Engineering Center River Analysis System (HEC-RAS) version 6.3.1. The model was configured to simulate the future without project condition (FWOP) and the four alternative options.

Data from the Central Valley Hydrology Study (CVHS), specifically the 10-Year and 200-Year flood events were used to simulate the FWOP and four alternatives. The event selection for these simulations was performed by the USACE as part of the Water Resources Development Act (WRDA) 2016.

For the 10-Year flood event, the results indicate that the greatest reduction in maximum water surface elevation (ranging from 0.6 to 1.4 feet) would occur just upstream of LET. These reductions gradually diminish to 0.4 to 0.6 feet approximately 6 miles upstream along the Yolo Bypass at Liberty Island. At the north end of RD 2068, the reductions become less substantial (0.1 feet).

When floodwaters exit LET and converge with Cache Slough, there is an increase in water surface elevation of 0.7 to 1.1 feet (specifically in Cache Slough upstream of Ryer Island Ferry). These localized effects diminish to zero at Cache Slough at Ryer Island Ferry and extending downstream to the Sacramento River at Rio Vista. Changes in water surface elevation for other points of interest in the region are tabulated for the 10-Year flood event in Table 6 of Appendix A, Exhibit A.

For the less-frequent 200-Year flood event, there are increases in water surface elevation upstream of LET ranging from 0.1 to 0.5 feet. These increases are a result of the reduction in flow area through the restricted height levee of LET under all alternatives. Additionally, there is an increase of approximately 0.5 feet in water surface elevation at Cache Slough upstream of the Ryer Island Ferry. However, the impacts on water surface elevation diminish to zero at Cache Slough at Ryer Island Ferry and extending downstream to the Sacramento River at Rio Vista. Changes in water surface elevation for other points of interest in the region are tabulated for the 200-Year flood event in Table 7 of Appendix A, Exhibit A.

The table below provides a summary of the results at select locations, showcasing the changes from existing conditions in water surface elevation (ft.) for the different alternatives and flood events.

Table 6-1. Flood Table

Location	Flood Event	Change in Maximum Water Surface Elevation (feet)			
		Alternative 17	Alternative 19	Alternative 24	Alternative 26
Yolo Bypass at Liberty Island	10-Year	-0.6	-0.4	-0.4	-0.6
	200-Year	0.1	0.1	0.2	0.0
Yolo Bypass near Upper Cache Slough	10-Year	-1.1	-0.7	-0.6	-1.1
	200-Year	0.1	0.2	0.3	0.1
Yolo Bypass upstream of Little Egbert Tract	10-Year	-1.4	-0.9	-0.8	-1.4
	200-Year	0.2	0.4	0.5	0.2
Miner Slough at Hwy 220	10-Year	-0.9	-0.6	-0.5	-0.9
	200-Year	0.1	0.3	0.4	0.1
Cache Slough above Ryer Island Ferry	10-Year	1.1	0.9	0.7	1.1
	200-Year	0.5	0.4	0.4	0.4
Sacramento River at Rio Vista	10-Year	-0.1	-0.1	0.0	-0.1
	200-Year	0.0	0.0	0.0	0.0

As indicated in the Table 6.1, notable reductions in water surface elevations occur in the lower Yolo Bypass for the 10-Year flood event. These reductions are attributed to the increased flow conveyance area of the Yolo Bypass through LET once the inlet berm begins to spill. The frequency (probability of occurrence) of floodwater conveyance can be enhanced by lowering the inlet berm elevation and increasing the effective flow area by widening and optimizing the weir as recommended in the H&H memo. Alternatives 17 and 26, with an inlet berm elevation below the mean low water, would increase the probability of the inlet berm overtopping from 8% to 100% (or all flood events). Alternatives 19 and 26 would increase the probability from 8% to 67%. A discussion of TOL vs. DWSE and how freeboard was checked can be found in Section 6.3.2 of this document.

While the elevation of the inlet berm (-4 ft. versus 7.5 ft.) impacts the frequency of flow conveyance, the total flow area of the inlet berm (length and height) affects water surface elevations upstream of LET. Alternatives 17 and 26, with an inlet berm flow area of 45,000 square feet, demonstrate the most significant reduction in water surface elevations for the 10-Year flood event and near neutrality for the 200-Year event, compared to Alternatives 19 and 24, which only have an inlet berm flow area of 17,000 square feet. The performance disparity between these alternatives is particularly pronounced in areas such as Lindsey Slough, Cache-Haas Slough, Miner Slough, DWSC, and the Yolo Bypass downstream of the Liberty Island gage.

The flood performance of Alternatives 19 and 24 could be enhanced by extending the inlet berm beyond its current length of 2,500 feet.
The full report on the flood hydraulic analysis is included as Appendix A, Exhibit A.

6.1.2. Hydrodynamic, Wave-runup, and Particle Tracking Analysis

To support this Study, cbec, with technical support from Jacobs, developed and applied 2-dimensional hydrodynamic, sediment transport, and wind-wave models to evaluate differences in the selected Alternatives. In addition, a separate 2-dimensional particle tracking model is being used to simulate mixing patterns within and around Little Egbert Tract (LET). Finally, a desktop analysis was performed to estimate levee runup due to wind and waves. Because modeling is still ongoing, the information provided in this section represents interim results focused on the hydrodynamic model calibration, particle tracking analyses to evaluate exposure/residence times, and desktop analysis to evaluate levee runup. A future final report will document additional ongoing analyses including spatially variable wind-wave modeling and sediment transport modeling results. This report will not be rewritten but a separate memo will be released upon completion.

This hydrodynamic modeling analysis informs several critical aspects of the LEMBP, including levee design, ecological functions, fish habitat and utilization, ecological restoration and landscape design, and water quality.

Alternative 17, Alternative 19, Alternative 24, and Alternative 26 and two Future Without Project (FWOP) conditions were evaluated. Digital Elevation Models (DEM) and roughness maps of the Alternatives and both FWOP conditions were provided by MBK Engineers. Common elements of the Alternatives include levee breaches at the north and south ends of LET, a meandering sub-tidal channel traversing the tract between the breaches, and habitat berms along the eastern and western levees. Other elements include balance breaches in the restricted height levee and habitat islands along the sub-tidal channel. Each Alternative is briefly described below and summarized in **Table 5-3**.

The Delft3D Flexible Mesh Suite 2D3D modeling package was chosen for this project because of its ability to couple unsteady-flow hydrodynamics and sediment transport with wind and waves (Deltares, 2023). The package was applied in 2D (depth-averaged) mode. Inputs to the hydrodynamic model include the topography and bathymetry of the channels and overbank areas (including levees), flow and stage boundary conditions at model boundaries, and wind data. Calibration was achieved by adjusting bed roughness values and comparisons with available stage and flow data within the model domain.

Detailed information on hydrodynamic (HD) model set-up, calibration results, and simulations conducted to support particle tracking, wind-wave analysis, and sediment transport is provided in a technical memorandum provided to DWR in June 2023. Upon completion of HD calibration, the FWOP and Alternative DEMs and roughness maps (provided by MBK) were incorporated into the model grids and simulations were completed for both FWOP and all four Alternatives for three selected hydrologic time periods encompassing a range of hydrologic conditions: 1) tidally-dominated period, 2) early season (first flush) runoff event on the Sacramento River, and 3) 2017 flood event, which includes substantial inflows from both the Yolo Bypass and Sacramento River. Results from the HD model provide velocity vector and depth information needed by the Particle Tracking model, as well as boundary conditions for Delft3D wave modeling.

6.1.2.1. Wave Runup Analysis and Results

When waves break against the levee, the momentum of the wave carries the broken wave up the levee face. One of the most common causes of levee erosion is wave runup (Oaks et al. 2012). Wave runup is defined as the elevation the wave uprush reaches above the still water surface elevation. For a given wave event, the actual runup elevation is highly variable through time.

The wave runup modeling analysis included detailed evaluations of wind speed and orientation, wave heights and periods, wave attenuation by vegetation, and wind and wave setup. cbec engaged HDR technical staff in discussions regarding considerations for wave runup estimation on the west levee (RD 536/Mellin levee) bounding LET. HDR staff stated that the west levee had been designed with a crest elevation based on the 1957 design water surface elevation (WSE) profile plus 7.0 ft. of freeboard. Two cross-section locations were identified for wind directions of 150° and 0° (clockwise from north) that generally yielded the maximum wind fetches for the west levee. At the cross-section locations, the 1957 WSE was determined to be 21.18 ft. NAVD88 (MBK, 2022). This WSE was used in further analyses to estimate wave runup as well as wind and wave setup to produce total water levels (TWL) for the two cross-section locations. Detailed descriptions of the assumptions, methods, and results are provided in the LEMBP Interim Report on Hydrodynamics, Wave Runup, and Particle Tracking

Results of the preliminary wind wave analysis for the west levee showed that wave runup is the largest contributor to TWL, followed by wave setup and finally wind setup. Additionally, wave attenuation by vegetation had a significant impact on wave runup, setup, and TWL values compared to the undeveloped vegetation condition. The attenuation methodology could be reverse engineered to determine an optimal riparian width and/or density if an ideal TWL value is known.

The maximum TWL of 5.36 ft. was realized for the maximum wind velocity of 33.8 ft/s, 150° wind direction, and for undeveloped vegetation. This TWL is 1.54 ft. below the design levee crest elevation. Fully mature vegetation reduces the TWL to 4.51 ft. for Alternatives with wide habitat berms (17 and 24) and to 4.66 feet for Alternatives with narrow habitat berms (19 and 26).

For future analysis with the Delft3D wave model, runup values are expected to be smaller given the simplifications made for the wind fetch, water depths, and bathymetry for the desktop analysis. Further, depending on the angle of incidence of the modeled wave trains, changes to the associated reduction factor will also decrease runup values. Delft3D modeling will account for wind and wave setup, wave refraction (changes in wave direction) and shoaling (wave height and wavelength changes) caused by changes in depth, wave dissipation due to wave breaking, white capping, bottom friction, and nonlinear wave-wave interactions. Thus, the TWL calculations from the desktop analysis are likely an upper limit.

6.1.2.2. Particle Tracking Analysis

Particle tracking simulations were conducted for the four Alternatives to understand exposure time within LET as well as exchange with adjacent areas. The HD model solutions were reformatted and imported into Program R, a computing language for statistical analysis, for use in a custom Particle Tracking Model (PTM). To differentiate the performance of each Alternative and understand their exposure times and circulation patterns (Section 6.1.2.1 and 6.1.2.2), neutrally buoyant particles were released on a 500-ft grid every 2-hours for two weeks in the Tract interior and tracked an additional two weeks (**Table 6-3)**. For this LEMBP Feasibility Study, only PTM simulations for the tidal hydrologic conditions are reported, as these are most relevant for understanding mixing processes within the tract during typical conditions.

Table 6-2. Particle Tracking Simulation Details

Hydrologic Condition	Simulation Window	Seeding Location	Particle Seeding Interval	# of Particles per Seeding Interval	Total # of Particles Released	Particle Life Duration
Tidal	4/15/2016 to 5/13/2016	LET interior - 500 ft grid	2 hr	455	76,440	2 weeks

6.1.2.2.1. Exposure Time

Food web productivity potential was assessed using the metric of exposure time. Exposure time aggregates the total amount of time a particle spends within the LET interior, allowing a particle to exit and re-enter LET multiple times. Exposure time was chosen over residence time, as residence time only tracks the length of time a particle takes to exit LET the first time. Because of the tides and reversing flows, particles can move in and out of LET several times during each tidal cycle.

Exposure time was computed for each particle seeded within the LET interior. The median exposure time was then calculated for each particle drop location. During the simulation, each particle drop location was seeded a total of 168 times. The resulting median exposure time grid was used to display a spatial map of exposure times throughout the LET interior. Previous work in the Delta has suggested that creating residence-time gradients is desirable for food web productivity, with one-to-three-day residence times being sufficient for diatom and phytoplankton production, but greater than 14-day residence time is necessary for zooplankton population growth and to benefit rearing of juvenile Chinook salmon and Sacramento splittail (SFEI-ASC, 2016).

For Alternative 17, over 15% of particles spent less than one day within LET. This is observed in the immediate vicinity of the southern degrade. Along the northern degrade, particles spent an average of 3 – 5 days within the tract. Particles tend to exit the tract on the flood tide, then get pulled back into the tract during the ebb tide. The balance breaches appear to play a limited role in exposure time. If a particle exits the tract via a balance breach it has a tendency to re-enter the tract via a balance breach or the southern degrade. Over 75% of the particles spend less than 7 days within the tract over the 14-day simulation, with a majority of those particles spending less than 3 days within the tract. In many cases the particles which stay within the tract for greater than 13 days tend to be areas of higher elevations and may experience prolonged dry periods.

Alternative 19 exhibits the most heterogeneous spatial distribution of exposure times. Degrading the northern levee to an elevation of 7.5 feet limits tidal exchange at the northern extent of LET and increases the number of particles which spend over 13 days within the tract from about 5% in Alternative 17 to closer to 30%. Zooplankton growth is thought to be enhanced with reduced circulation, and likely would prosper in the northern portion of LET. Conversely, diatom and phytoplankton production favors enhanced circulation, and Alternative 19 has nearly 30% of particles with exposure times less than 3 days in the southern extent of the tract (SFEI-ASC, 2016).

Alternative 24 features the least amount of levee degrades which results in the longest exposure times of the four Alternatives. Nearly 60% of all particles spend longer than 13 days within LET. The 7.5 feet elevation bench along the southern degrade also limits the number of particles which spend only a short duration within LET. About 5% of particles spend less than a day within the tract and only about 15-20% spend less than 3 days, which are the lowest values for these classes among the Alternatives.

Alternative 26 is similar to Alternative 17, as it features full degrades along the north and south levees; however, Alternative 26 does not include the balance breaches which spend less than one day within the tract. Alternative 26 has a greater degree of homogeneity along the eastern levee than Alternative 19, as the habitat berms create more flow complexity.

6.1.2.2.2. Export Analysis

An export analysis was used to identify the fate of particles after a defined time. Particles were tracked for fourteen days after a particle was seeded. Geographic regions were delineated to track particle locations. The percentage of total particles was then reported for each geographic region (**Table 6-4**).

Alternative 24 had the greatest number of particles still within LET (57%), while Alternatives 17 and 26 had the least number of particles within LET, with both at approximately 10%. For the particles leaving LET, the majority made it to the Sacramento River and traveled south of the Rio Vista bridge towards San Francisco Bay. Alternatives 17 and 26 again exhibited similar results with both simulations having nearly 86-88% of particles in the Sacramento River. Apart from Cache Slough, directly adjacent to LET, less than one percent of particles ended up in areas other than LET or the Sacramento River.

Overall, it appears that the northern degrade being a full or partial degrade and the size of the southern degrade controls the fate of particles the most. Alternative 24 has the highest particle retention rate within LET, and also features degrades to 7.5 feet on both the north and south levees with only a 250 ft. full degrade on the southern levee. Both Alternatives 17 and 26 have similar export and exposure times, suggesting that the balance breaches do not significantly impact the exposure times and fate of the particles. Particles are observed to move through the balance breaches but the interaction with Cache Slough is mostly confined to the dredged shipping channel along the east toe of the restricted height levee. Thus, exchanged particles tend to readily re-enter the tract interior as flow reverses on the tides.

Table 6-3. Export Analysis Results Table

Geographic Region	Alternative 17	Alternative 19	Alternative 24	Alternative 26
Cache Slough	2.74%	4.17%	2.25%	1.39%
DWSC	0.00%	0.00%	0.00%	0.00%
Lindsey Slough	0.08%	0.02%	0.00%	0.02%
Little Egbert Tract	9.90%	34.79%	57.15%	9.67%
Lookout Slough	0.05%	0.01%	0.01%	0.02%
Sacramento River	86.63%	60.57%	40.32%	88.23%
Three Mile Slough	0.30%	0.17%	0.10%	0.54%
Toe Drain and Prospect Slough	0.01%	0.09%	0.06%	0.00%
Upper Cache Slough	0.01%	0.01%	0.02%	0.01%
Yolo Bypass	0.29%	0.17%	0.10%	0.10%

6.2. Geotechnical

The geotechnical investigation for the Feasibility Study included field exploration, laboratory testing, and analysis for the features of the project including the levees, sills, bridges/culverts, water control structure for Watson Hollow and interior grading. The exploration and laboratory data are presented in the Geotechnical Data Report (GDR) from Shannon & Wilson dated June 19, 2023. The analysis and discussion of geotechnical aspects of the alternatives is presented in the report by Shannon & Wilson, dated June 16, 2023.

The basis of design for the project included designing the levees along the west side of the project to meet current design criteria for all alternatives. The analysis identified levee deficiencies including lack of freeboard, underseepage, and through seepage. The remedial measures are presented in the Geotechnical Investigation report (**Appendix B**) and the Evaluation of Levee Repair Options (**Appendix D**). The levee measures are discussed in Section 6.4.

The report identified borrow materials meeting the criteria for levee fill within the Little Egbert property. The borrow sites are in the southwest section of the project. Borrow material for the habitat berms and general grading is available throughout the property. The subsurface data is presented in the GDR.

6.3. Civil Engineering Elements

The following sections provide civil engineering related discussions for the levee repair options evaluated as a part of this feasibility study. The following three levee improvement options were evaluated:

- Levee Repair Option 1 – Cutoff wall construction with levee raise, geometry corrections, and full degrade/reconstruction of Mellin Levee and Mellin Levee Extension.
- Levee Repair Option 2 – Seepage berm construction with levee raise, geometry corrections, and full degrade/reconstruction of Mellin Levee and Mellin Levee Extension (maintain existing alignment).
- Levee Repair Option 2B – Seepage berm construction with levee raise, geometry corrections, and full degrade/reconstruction of Mellin Levee and Mellin Levee Extension (shift flood control features to fall within in existing rights-of-way).

Refer to **Appendix D** (Evaluation of Levee Repair Options) for additional information.

6.3.1. Survey and Mapping Conclusions

Survey and topographic information for this project was collected and prepared by Laugenour and Meikle. Right-of-way information was provided via preliminary ALTA/NSPS Land Title Surveys prepared by RFE Engineering.

The provided topographic and planimetric information was collected in 2021 and 2022 and is of adequate quality and extent for levee related feasibility studies, analysis, and design. Right-of-way surveys were prepared in 2019 and 2020 and are preliminary. As such, additional right-of-way related research, boundary surveys, acquisition of title reports and supporting documents, and preparation of right-of-way maps is needed in to order confirm right-of-way specific acquisition strategies and requirements.

A summary of the survey and mapping information used as basis for civil evaluations is included in Section 3 of **Appendix D**.

6.3.2. Top of Levee

Top of levee elevations are established to reduce the risk of overtopping by first determining the Design Water Surface Elevation (DWSE)then adding the required additional levee height in accordance with applicable criteria. Minimum levee cross sectional geometry is based on various guidance documents from USACE, DWR, and the CVFPB.

The RD-536 levee, Solano County Levee 44, Mellin Extension Levee, and Mellin Levee were evaluated against project specific criteria. Top of levee and geometry corrections were deemed necessary if the following conditions were not met:

- Levee crown widths are generally 20 feet or wider.
- Levee slopes are:
  - Two horizontal on one vertical (2H:1V) land side slope and 3H:1V waterside slope for Solano County Levee 44, Mellin Extension Levee, and Mellin Levee.
  - 2.5H:1V landside slope and 3H:1V waterside slope for the RD 536 levee consistent with the as-built plans.
- Existing geometry meets the requirements for freeboard:
  - 1957 DWSE plus seven feet for the RD-536 levee.
  - 0.5-percent ACE water surface plus 7 feet for Solano County Levee 44, Mellin Extension Levee, and Mellin Levee.
  - Theoretical levee prism placed at the DWSE plus required freeboard fits, in its entirety, within existing geometry.
  - Existing levee geometry meets the requirements for slope stability.

The provided topographic information was used to generate levee cross sections at 100-foot intervals. Cross sections were then compared to the criteria above and it was determined that top of levee and geometry corrections are required as follows:

- The RD 536 Levee generally meets side slope and crown width requirements but does not meet the requirement for freeboard.
- Solano County Levee 44, Mellin Levee Extension, and Mellin Levee do not meet any of the geometry requirements for side slopes, crown widths, nor freeboard.

Geometry corrections would be completed as part of addressing levee through and under-seepage issues.

6.3.3. Alignments

Existing flood control facility footprints (i.e., levee embankments, flood control features, and access roads) are generally located within existing rights (ex., right-of-way previously acquired in fee, or a flood control related easement, or possible prescriptive rights). Levee rehabilitation options that require shifting existing levee footprints, or constructing levees along new alignments, have the potential for significant environmental impacts, may require acquisition of new rights-of-way, increase overall project cost, and may impact implementation. As such, evaluations conducted for this Feasibility Study maintained existing levee alignments, to maximum extent possible, with the following exception:

- Levee smoothing to eliminate unnecessary angles and potential for erosion points (approximate 2,200 linear foot segment of levee between Solano County Levee 44 and Mellin Extension Levee). Incorporated into levee repair options 1 and 2.
- Levee repair option 2B that shifts all flood control improvements (levee and seepage berm) to fall within existing right-of-way and/or on the Little Egbert Tract (approximate 15,700 linear foot segment of the RD 536, Solano County Levee 44, and Mellin Extension Levee).

Additional detail and plan views showing levee alignments for all three levee repair options are included in **Appendix D**.

6.3.4. Penetrations and Encroachments

A preliminary review of encroachments, utilities, and penetrations was completed and is summarized in **Table 5-1** within **Appendix D**. Locations, types, and descriptions of penetrations and encroachments were determined based on a review of as-built documents, inspection reports, and a site reconnaissance. Generally, unpermitted encroachments and penetrations are assumed to be removed as part of construction. Permitted encroachments and penetrations are assumed to be improved to meet current levee design standards.

6.3.5. Borrow Sources

Levee raises, geometry corrections, and construction of seepage berms require material to be imported from on-site and/or off-site sources. Earthwork quantities were calculated, for the various levee repair options considered, using AutoDesk Civil 3D software, spreadsheets, and hand calculations.

The following assumptions were made for calculating quantities and levee borrow requirements:

- The top 6-inches of the levee crown contains aggregate base material and would be stripped and spoiled on-site.
- The top 6-inches of levee slopes contain organic material and would be stripped and spoiled on-site.
- Material excavated from the RD 536 levee is 100% reusable as levee embankment fill. Material excavated from Mellin, Mellin Levee Extension, and Solano County 44 levees is 0% reusable as levee embankment fill and would be hauled on-site (material may be reused for other site fills not related to levee embankments such as habitat restoration or enhancement).

- Zoned embankment construction (clay core and reuse of degrade material for the levee shells).
- All levee embankment fill would be obtained from on-site (adjacent Little Egbert Tract) excavations.
- Material not meeting requirements for levee embankments would be spoiled on-site.
- The geotechnical recommendations assume a 15 percent shrink factor between bank and compacted volumes. An additional five percent is included for other potential losses and for conservatism.
- Earthwork import from off-site sources is not needed.

A detailed breakdown of quantities, by levee repair option, is included in **Appendix D**. **Table 6-4** below provides a summary of levee borrow requirements by levee repair option.

Table 6-4. Summary of Borrow Requirements

Type	Levee Repair Options		
	Option 1 (CY)	Option 2 (CY)	Option 2B (CY)
Total Export From Little Egbert Tract	**990,000**	**1,233,000**	**1,279,000**
Total Import To Little Egbert Tract	**292,000**	**265,000**	**338,200**

Other materials, such as aggregate base, bentonite for cutoff wall placement, hydroseeding and rock for erosion protection are also required and would be imported from off-site sources.

6.4. Levee Remediation Actions

Various levee mitigation measures are available to address deficiencies in levees. Mitigation measures have unique benefits with no single measure addressing all deficiencies. Levee Repair Options selected to address levee deficiencies, therefore, rely on a combination of mitigation measures that are unique to this project and address project specific goals while adhering to project constraints. The following sections provide insights into several potential mitigation measures. An initial screening of additional measures along with more detailed evaluations and rankings of levee rehabilitation measures are included in **Appendix D**.

6.4.1. Cutoff Wall

Cutoff walls are vertical seepage barriers constructed, typically, through the center of a levee. The two common types of cutoff walls are soil-bentonite and soil-cement-bentonite. The soil-bentonite wall utilizes in situ soil mixed with bentonite slurry and the soil-cement-bentonite wall utilizes in situ soil mixed with cement slurry and bentonite slurry.

There are several methods for constructing cutoff walls including open trench excavation, deep soil mixing, cutter soil mixing, and trench remix-deep. The two common methods utilized locally are open trench excavation and deep soil mixing.

Open trench cutoff walls are constructed using an excavator with a long-stick boom capable of digging a trench to a maximum depth of approximately 75 to 85 feet. The cutoff wall trench is typically 36 inches in width. Bentonite slurry is placed in the trench to prevent caving during excavation. Excavated soil is then mixed with bentonite and water, to achieve the required cutoff wall permeability, and then pushed back into the excavated trench to form a seepage barrier.

Deep-soil-mixing walls are constructed using a crane-supported set of three mixing augers set side by side. These augers are drilled through the levee crown and foundation to the required depth (typically deeper than 85 feet). As the augers are inserted and withdrawn, cement slurry and bentonite slurry are injected through the tips and mixed with the native soil. An overlapping series of mixed columns is drilled to create a continuous seepage cutoff wall. Levee degrade for the deep-soil-mixing method is generally similar to that for the open trench method.

Cutoff wall construction requires levees to be degraded to prevent hydraulic fracturing, to provide an adequate working surface, and to ensure stability of the slurry trench and cutoff wall (open trench method). Levee degrade is generally by 1/3 to 1/2 of the levee height. Degrade material is generally side cast then reused for levee reconstruction it if meets, or can be blended to meet, requirements for levee fill.

Additional information and typical cutoff wall details are included in **Appendix D**.

6.4.2. Seepage Berms

Seepage berms are wide embankment fills constructed along the landside of the levee. They vary in width from a minimum of four times the levee height to, typically, a maximum of 300 feet. Seepage berm heights are typically a minimum of 5 feet at the levee landside toe and taper to 3 feet at the end of the berm. Seepage berms may be drained or undrained.

Drained seepage berms are constructed of earth fill over a layer of drain rock and filter sand, typically 1 to 2 feet thick in total. A layer of drain rock allows for the drainage of seepage. A layer of filter sand may be needed to prevent soil from migrating from the levee or foundation into the drain rock.
Additional information and typical seepage berm details are included in **Appendix D**.

6.4.3. Erosion Remediation – Rock Slope Revetment

Various measures are available to address the potential for erosion along levee slopes. Typical examples of erosion control measures implemented for levee projects include rock slope protection, concrete mat blankets, and seeding and vegetation. This project considered rock slope protection to address the potential for erosion. Depending on the type, erosion control measures would be placed after levee embankment construction has been completed.

Erosion protection is discussed in more detail in **Appendix F**.

6.5. Habitat Enhancement Actions

All alternatives would provide net gains in aquatic, tidal wetlands, and riparian habitat, in varying amounts and spatial arrangements. Dynamic hydrologic processes interacting with the physical landscape create structural features, which result in biological communities that support various species. The amount and spatial arrangement of physical features will influence overall ecological function at the site (SFEI-ASC 2016, SFEI 2020). Habitat design criteria and guidelines (**Appendix C, Exhibit D),** in combination with information about historic and existing site conditions, will be used to refine the preliminary alternatives to provide more detailed and ecologically sound designs for specific habitat elements and to benefit native species. This section summarizes guiding principles for desired habitat types: tidal aquatic, intertidal wetlands, riparian and upland transition.

6.5.1. Tidal Aquatic

Restoring tidal hydrologic processes is a key driver for creating tidal habitat. Food web production is an important component during the life cycle of many species of special concern such as Chinook salmon, green sturgeon, longfin smelt, Sacramento splittail, and delta smelt. Marsh topography that increases water residence time and traps detritus can foster increased productivity of juvenile salmon prey and concentration of terrestrial drift invertebrates (Simenstad et al. 2000). Allowing tidal waters to inundate the LET would increase aquatic food resources in this area of the Cache Slough Complex, with the greatest production likely from emergent marsh.

Water depth is a key factor in habitat suitability for fish. Depth preferences vary among species and lifestages, so providing bathymetric heterogeneity can maximize habitat opportunities for multiple species. For juvenile salmon water depths between 0.6 and 5 ft. are considered most suitable, with water depths 5 to 10 ft. the next highest suitability. Water depths greater than 20 ft. were considered unsuitable as salmon rearing habitat (SFEI 2020). Delta smelt are most frequently collected in water that is somewhat shallow (4-15 ft. deep) where turbidity is often elevated and tidal currents exist but are not excessive (Moyle et al. 1992). Green sturgeon utilize deeper habitats, 10 to 65 ft. deep, although juveniles may use shallower areas ~4-10 feet deep. Elevation (bathymetry) and hydrologic processes (tidal and fluvial) drive aquatic habitat structure and complexity, which in turn influences fish communities. Key parameters for fish habitat suitability include water depth and temperature, as well as wetland proximity and wetland edge (discussed under Tidal Wetlands) (SFEI 2020).

Grading designs for the LET should consider creating diverse topography that will maximize bathymetric heterogeneity and thus provide diverse habitat for multiple species. This can be achieved by excavating swales for deeper habitat, while grading areas and building berms to create in-channel islands (above MHHW) bordered by shoals and shallow habitat. One challenge will be balance cut and fill to meet needs of levees and terrestrial habitat features (habitat benches above MLLW). Alternatives 19 and 24 contain a subtidal swale with connected channel while Alternatives 17 and 26 have a separate channel with tidal opening. Subtidal swale channel connectivity is important for sturgeon and salmon.

Higher residence time is associated with higher productivity. However, areas that do not experience sufficient tidal flushing could be subject to stagnant conditions with poor water quality (low dissolved oxygen and cyanobacterial harmful algal blooms (CHABs). Shallow areas with minimal currents may be colonized by invasive aquatic vegetation (*Egeria densa*) that can both reduce turbidity needed by delta smelt and support non-native predatory fish. Shoals and in-channel island features should be placed to avoid creating backwater areas that could become stagnant or harbor dense aquatic vegetation.

6.5.2. Tidal Wetlands

The focus should be on increasing the area within intertidal elevations by site grading and/or addition of fill material. In general, marshes should be as large as possible, with more core and less edge, and distance between marsh patches should be minimized (SFEI-ASC 2016). Certain physical processes and habitat functions may not naturally occur in small patches, such as evolution of a full channel network (over 1,200 acres) (SFEI-ASC 2016). Tidal marshes should experience full tidal action to provide access for foraging aquatic organisms, enhance export of productivity, and promote marsh accretion via sediment deposition and accumulation of vegetative matter (SFEI-ASC 2016).

Establishment of wetland vegetation is affected by inundation regime, water velocity (including exposure to waves), salinity, substrate, and connectivity to existing patches of vegetation (Sherman et al, 2017). Vegetation in freshwater emergent tidal marshes of this area includes native species such as tules (*Schoenoplectus californicus* and *S. acutus* var. *occidentalis*) and cattails (*Typha*). In the high marsh several non-native species can invade wetlands, such as common reed (*Phragmites australis*) and perennial pepperweed (*Lepidium latifolium*) (Sherman et al., 2017). Studies of Liberty Island (Sloey et al., 2015) found that *S. californicus* typically occupies lower elevations (up to 0.2m below MLLW) and more exposed sites because it is more tolerant of flooding than *S. acutus*. Native vegetation can naturally colonize sites, but plantings can accelerate establishment and minimize risk of invasion. Transplants of adult tules and cattail can establish more successfully than rhizomes, especially in compacted soils that hinder underground growth (Sloey et al., 2015). Exposure to wind fetch and wave action can affect establishment and should be considered in placement and configuration of tidal marsh within the site.

6.5.3. Riparian and Uplands

A key design consideration is creating an elevation gradient from intertidal to riparian and higher uplands. The tidal-terrestrial transition zone supports a mosaic of habitat types, ranging on a gradient from riparian habitat along channels and bordering tidal marsh (elevations above MHHW) to upland habitat such as grasslands and oak woodland (SFEFI-ASC 2016). Riparian areas experience seasonal riverine flooding which can deposit fine sediment and promote vegetation recruitment. Restoring woody riparian habitat adjacent to marshes would recreate historic landscape patterns, improve habitat complexity and function and benefit a wide array of wildlife (SFEI-ASC 2016). Many terrestrial species benefit from access to upland habitat that is adjacent to wetlands.

Where possible, the total length, longitudinal continuity and width of the transition zone should be maximized as much as feasible (SFEI-ASC 2016). The area within 250 m of the tidal wetland is important as a buffer zone (CRAM guidance) and habitat for terrestrial species. In addition, a broad transition zone will also accommodate sea level rise by providing space for habitat migration or transgression to higher elevations. The amount of intertidal wetland and riparian habitat will be determined by the size (width) and elevation of habitat benches constructed along the levee toe.

Riparian habitat in this region of the North Delta was historically riparian scrub. Sandy dredge spoils provide suitable recruitment conditions for sandbar and arroyo willow. Plantings can also be installed to jumpstart vegetation using a desired mix of tree, shrub, and herbaceous species (Appendix C, Exhibit D)

6.6. Alternative Remediation Actions

The Study does not go into rigorous detail with design features, some technical studies and in the development of the opinion of probable (construction) costs (OPC). Without such details, there may be tangible design features or off-site impacts that need to be examined and considered for inclusion in each action Alternative's assessment. These secondary design and implementation OPC elements should be included as environmental considerations for the Project in order for the action Alternatives to be evaluated in whole. The Study team identified some potential remediation actions that should be addressed in some manner during the future environmental review and design development process. In no particular order these may include:

- Surrounding levee protection from flow velocity changes (Ryer Island)
- Groundwater seepage / retention from static water level changes
- Electrical utility grid changes that service the local communities
- Agricultural water quality and delivery adjustment to meet existing standards
- Transportation infrastructure (including Real McCoy Ferry #2 and SR 84) protection from flow velocity and quantity changes
- Existing residence utilities relocation / maintaining same level of service
- Construction implementation work windows to protect listed threatened and endangered (T&E) species and the local community
- Interim and long-term funding assurances for operations and maintenance adaptive management
- Recapping of existing decommissioned gas wells if in the Project's cut and fill locations

- Protection of the habitat conditions' integrity from potential chronic human disturbances

6.7. Alternative Costs

The development of the Action Alternatives' OPC focused on the major design elements for each Alternative. These included, but were not limited to, needed improvements to existing Project Levees to meet the current standards set by the USACE and DWR/CVFPB, habitat transition zone widths (i.e., wide berm verses standard narrow berm) that dual as wave fetch / run-up protection along levees, and protection from both flood and tidal flows entering / exiting the re-established floodplain / aquatic habitats. Following the Standard Classification for Cost Estimate Classification System (ASTM E2516-11), a 30-percent contingency has been included with all Alternatives. **Table 6-6** provides a list of the respective Alternative designs and OPC for each of the Alternatives.

Levee repair options considered comparative costs for levee improvements (and associated facilities and impacts) as well as assumed right-of-way acquisition costs. Generally, Levee Repair Option 1 has the highest cost and Levee Repair Option 2 has the lowest. Additional detail and information regarding cost methodology, factors considered in development of unit costs, and line-item descriptions used for developing levee repair option comparative costs are included in **Appendix D**.

The No Action Alternative OPC assumes there would be need for emergency repairs for adjacent levees and landscapes, and which would likely require mitigation offsets for repair impacts to listed species. The No Action Alternative OPC focused on only implementing flood protection on the immediately adjacent RD 536 Levee and did not address regional impacts from a nature-driven breach and no emergency repairs to the RD 2084 restricted height levee. The No Action OPC also does not include any active restoration of the habitat transitions zones (i.e., riparian floodplain, tidal marsh, subtidal swale, etc.). The Study team noted that once nature reclaims the Property, any mitigation and/or conservation values that can be used as offsets for other public / private project impacts, would likely be either reduced or completely lost. Detailed cost estimates can be found in **Appendix D**.

Table 6-5. Alternative Costs

Alternative	Estimated Cost
17	$397,800,000
19	$374,400,000
24	$396,500,000
26	$348,400,000

Table 6-5. Alternative Costs	
No Action	$65,600,000

**Alternatives OPC includes 30% contingency*

6.8. Environmental Constraints Analysis

Typical environmental constraints are those that affect the design and implementation of the project. Identification of these constraints are intended to guide the design process in order to eliminate or reduce (below a significant threshold) environmental impacts to humans as well as the natural environment. In no particular order, the environmental constraints identified by the team from the Project implementation are:

- Construction air quality that may require tier 4 equipment and higher levels of dust control
- Limited, reduced or adjusted months for construction so to not have impacts to listed species
- Placement of environmental commitments ahead of the managed breach
- Interim and long-term management process and funding mechanism
- Native plants established to a point where the vegetation can withstand or be resilient to the new flows

6.9. Recreation

The Feasibility Study process included a specific focus on how recreation features could be added to the project. This effort included an extensive outreach campaign to solicit public input on recreation needs and potential uses in the area and the development of specific recommendations based on public outreach and studying the recreation opportunities provided by each of the four design options. This section summarizes the outreach effort and the recreation opportunities identified.

From November 2022 through May 2023, a total of 59 individuals were engaged through interviews, informational calls, focus group meetings, and/or pop-up events. These individuals represented local government, state agencies, recreation groups, community benefit organizations, and general public. Key themes of feedback received across engagement activities conducted during this time period are as follows:

- Prioritize the identification and implementation of flood-specific components of the project ahead of implementing recreational opportunities.
- Ensure cost-effectiveness of recreational opportunities as well as their compatibility with existing or planned land uses within the project area.
- Future recreation opportunities should be prioritized based on how accessible they are to as wide of an audience as possible. This would include public boat launches, camping

sites, running and potable water, picnic tables, and amenities to support fishing (for example, fish cleaning stations).

Based on public input, and by studying the four project options developed in this Feasibility Study, opportunities for new recreation uses were identified. All four project options offer some level of enhanced recreation within Little Egbert Tract, primarily because of the levee breaches. The levee breaches would allow boating access into the interior of Little Egbert Tract, especially for shallow-water craft equipped with mud motors. This increased access is expected to benefit anglers seeking shallow-water areas off the main channel. This Feasibility Study seeks to provide new recreation facilities, if possible, that further enhance public access for recreation uses as part of the multi-benefit project. The potential facility options are discussed in this section, with concept designs presented in Chapter 8, Multi-Benefit Concepts.

The southern portion of the multi-benefit project provides an opportunity for public access onto Little Egbert Tract via an existing farm road off SR 84. Under all options, this area of the project would be restored as upland and riparian habitat, providing some opportunity for vehicle access to recreation features and for parking safely away from the state highway. This area could be developed for less intensive recreation uses, such as nature appreciation. Trails through the upland and riparian areas, including interpretive signage, would provide access to restored habitat and education about the benefits of habitat restoration. Proximity to the subtidal areas offers additional opportunities for nature appreciation under a range of tidal conditions, especially if boardwalks are provided. The addition of launch sites for personal watercraft provides an even greater opportunity for recreation access. Paddling within the subtidal swale provides for additional nature appreciation, such as birdwatching. In addition, public outreach revealed the increased popularity of fishing from personal watercraft, which would be provided by access to the subtidal swale from new trails and boardwalks.

Constraints to the development of recreation features in the southern portion of the multi-benefit project include compatibility with habitat restoration goals and ensuring no conflicts with the nearby Rio Vista Airport. Habitat restoration may include mandates that some areas are left entirely for nature, with no human encroachment. Compatibility between low-impact recreation uses and the project's habitat goals still needs to be evaluated. Regarding the airport, the southern portion of Little Egbert Tract is within various airport safety zones, which limit land uses including prohibiting group recreation facilities. The Solano County Airport Land Use Commission is expected to review the project, including any potential recreation features, for compatibility with these safety zones.

The northern portion of the project is near the site of a former ferry crossing (Liberty Island Ferry) with a history of recreation access. However, at this time, there is no public access and boat launching is limited to those with permission to access the area. Property ownership is private, with access rights to the existing RD 536 corporation yard located just west of Little Egbert Tract. If access rights can be resolved, then additional recreation opportunities can be provided in this area. Public opinion has been very favorable to restored access for boat launching in this area, and the proximity to Lindsey Slough provides an excellent opportunity for a larger facility offering access to motorized watercraft, car and trailer parking, and potential amenities including fishing access and picnic areas. Although the feedback has indicated these new facilities should be provided at the old ferry site, just west of Little Egbert Tract, this Feasibility Study considered locating the facility on Little Egbert Tract itself. Under all potential options, there is room for a boat launch between the west end of Little Egbert Tract and the nearest levee breach. However, further study is needed to confirm the levee breach location given hydrodynamic conditions near the mouth of Lindsey Slough.

An additional recreation opportunity may be available if low-impact facilities are developed at the south end of the project and a boat launch is provided near the old ferry site. With active recreation sites at both the north and south ends of the project and with levee restoration, including wide habitat berms, along the entire west side of the project, there is an opportunity for a longer recreation trail connecting the two areas. Although the Feasibility Study team is aware of the strong preference to keep recreation features off levees, the habitat berms provide an ability to develop a trail feature with fewer conflicts with levee maintenance objectives. This linear recreation feature appears to work only with developed recreation features at the end points and with the ability to ensure that emergency access can be provided along the levee itself.

For all potential recreation features that could be developed as part of the multi-benefit project, operations and maintenance must be addressed. At this time, the entity responsible for ensuring routine maintenance (e.g., trash pickup) and conducting safety patrols has yet to be identified. No recreation features should be developed until these ongoing obligations are resolved, including ensuring reliable funding.

It may be necessary to conduct future considerations and analysis of the following:

- Potential traffic changes in the area
- Pavement design
- Trail design
- Boardwalk elevation
- Material considerations for inundated features
- Utility needs
- Routine maintenance
- Security measures

6.10. Water Quality

The RMA Bay-Delta model was applied to evaluate salinity impacts of the Little Egbert Multi-Benefit Project (LEMBP or Project) relative to a Base (No Action) condition. The No Action condition represents the current state of Little Egbert Tract (no tidal action and not included in the grid). Three restoration alternatives (Alternative 19, Alternative 24, and Alternative 26) were considered, as well as a Future Without Project (FWOP) scenario with fully degraded levees along Cache Slough and Lindsey Slough. All grids include newly constructed tidal marsh restoration sites as well as those in late planning stages under the California Eco Restore Program. Little Egbert Tract and all other restoration sites are represented in sufficient detail to achieve the modeling goal of assessing regional salinity impacts.

The RMA Bay-Delta model is a widely accepted tool that has been shown to be effective at predicting salinity distribution throughout the Delta. The model has been applied to flow and salinity impacts analysis for numerous tidal marsh restoration projects throughout the Bay-Delta.

The evaluation periods were January 1 to December 31, 2018, and January 1 to December 31, 2020. These periods cover a below normal hydrology (2018) and a dry year hydrology (2020). These periods were selected to reflect some of the historical salinity variation, including yearly and seasonal fluctuations in the dynamic Bay-Delta system.

The RMA Bay-Delta model is a 2-D depth averaged / 1-D cross-sectionally averaged model extending from the Golden Gate to the Sacramento River above the confluence with the American River, and to the San Joaquin River near Vernalis. The 2-D elements are employed to represent areas of open water and large channels (e.g., Suisun Bay, Cache Slough Complex, Cache Slough, the lower Sacramento River and restoration areas) while the 1-D elements are used to represent the channelized portions of the Delta.

The hydrodynamic model predicts depth and velocity throughout the model domain. These results are used to drive salt transport in the water quality model. In the model, Electrical Conductivity (EC) is used as a surrogate for salinity similar to other Delta models such as DWR DSM2.

The model has been calibrated for the years 2018 and 2020 during a parallel modeling effort that has focused on improving model boundary conditions in the Cache Slough Complex (RMA, 2023).

Electrical conductivity (µmhos/cm or µSiemens/cm), or EC, was modeled as a surrogate for salinity. EC is used as a stand-in for the more precise term of Specific Conductance (SC) for the electrical conductance corrected to 25° C. The RMA Bay-Delta model is limited to computing a depth-averaged EC. The salinity model analysis was performed for 2018 and 2020.

Salinity impacts were evaluated for select D-1641 compliance locations and Contra Costa Water District intake locations.

Table 6-6. Salinity Impacts

D-1641 Station ID	Location	Beneficial Use
D22	Sacramento at Emmaton	Agriculture
D15	San Joaquin at Jersey Point	Agriculture, Fish and Wildlife
D29	San Joaquin at Prisoners Point	Fish and Wildlife
C5	Contra Costa Canal at Pumping Plant 1	Municipal and Industrial
C9	West Canal at mouth of Clifton Court Forebay	Municipal and Industrial
DMC1	Delta-Mendota Canal at Tracy Pumping Plant	Municipal and Industrial
SLBAR3	Barker Slough NBA Intake	Municipal and Industrial
C19	City of Vallejo Intake Cache Slough	Municipal and Industrial
C2	Sacramento at Collinsville	Fish and Wildlife
D12	San Joaquin at Antioch	Municipal and Industrial
CCWD Intake at Mallard Slough		
CCWD Intake at Old River		
CCWD Intake at Victoria Canal		

The modeling results showed that Little Egbert Multi-Benefit Project alternatives produced both decreases and increases in computed EC both seasonally and spatially. The largest salinity increases occurred in the Sacramento River at Emmaton during the summer of 2020. The largest salinity decreases occurred in Barker Slough during the spring of 2020. South Delta export/water intake locations see salinity increases peaking at 2% – 4% during the fall months.

The alternatives generally increased EC by 1 to 4% from the Base condition for central and south Delta locations in the summer and fall, with larger increases occurring in 2020 versus 2018. At Emmaton, salinity increase of 3% to 11% occurred throughout much of the simulation periods. In Barker Slough, salinity decreased by as much as -6%.

The most favorable salinity results (smallest increases over Base) occur for Alternative 24. The least favorable salinity results (largest increases over Base) occur for Alternative 26 and FWOP, which produce very similar salinity results. The notable exception is at the Barker Slough NBA intake, where the FWOP alternative produces the largest salinity reductions and Alternative 24 produces the smallest reductions.

Salinity impacts appear to be greatest when Little Egbert Tract is fully breached at both ends (Alternative 26) or with fully degraded levees (FWOP). With a higher northern inlet weir that overtops only during high flows (Alternatives 19 and 24), the impacts are reduced. The compound southern breach in Alternative 24 further restricts flow and reduces impacts, however peak flood tide velocities at this breach are estimated to reach up to 6 ft/s.

The second goal of the salinity model evaluation was to determine the potential for Little Egbert Multi-Benefit Project alternatives to result in non-compliance with the D-1641 water quality objectives. Seasonal EC standards apply to Agriculture, Fish and Wildlife compliance stations at the Sacramento River at Emmaton (D22), Sacramento River at Collinsville (C2), and the San Joaquin River at Jersey Point (D15) and Prisoners Point (D29). Little Egbert Multi-Benefit Project alternatives EC values over the compliance periods (Apr 1 – Aug 15 for D22 and D15, Oct 1 – May 31 for C2, Apr 1 – May 31 for D29) were predicted to be well under the compliance limits, with the exception of Jersey Point, where Alternatives 19 and 26 and the FWOP scenario were predicted to exceed the standards on the last day of the compliance period in 2018.

Evaluation of changes to X2 indicates that the Little Egbert Tract alternatives would generally increase monthly averaged X2 by 0.2 km or less.

6.10.1. Restricted Height Levee

Breaches in the restricted height levee increase tidal prism into the Delta, which increases salinity in the central and south Delta and Suisun Marsh. The increase in the Delta tidal prism is greatest with full breaching at both the north and south ends of Little Egbert Tract (e.g. Alternative 26). With only the southern breach, a full breach at the south end (e.g. Alternative 19) has a greater tidal prism impact than the narrow breach (e.g. Alternative 24). Balance breaches may slightly increase impacts, however separate simulations would need to be performed with and without these breaches to quantify the impact.

7. Recommendations and Implementation

7.1. Additional Design Analyses

Development of designs for flood control projects is a multi-phased process requiring additional steps and coordination with various agencies prior to issuing design packages for construction. The following next steps and additional design analyses are recommended:

- Selection of a levee improvement option for further design development.
- Development of final geotechnical recommendations.
- Coordination with agencies, property owners, utility owners, and interested parties.
- Development of detailed borrow assessments.
- Development of plans, specifications, and cost estimates.
- Development of environmental documentation.
- Obtaining the applicable Federal and State permits required for construction of levee rehabilitation measures.
- Further development of ROW related information such as boundary and parcel surveys.

- Development of ROW acquisition strategies and costs.

7.1.1. Hydraulics

During the environmental review and design phases of the project, if an alternative with an inlet berm elevation of 7.5 feet is being considered, it would be beneficial to investigate the possibility of increasing the length of the inlet berm beyond 2500 feet. By extending the inlet berm length, the flow conveyance area can be further increased, which may result in additional reductions in water surface elevations upstream of LET and along the Deep-Water Ship Channel and Miner Slough for flood events greater than the 10-Year flood.

Also, moving the inlet berm to the west could potentially facilitate the flow of water into the LET and align it with historic breach locations on the restricted height levee. This adjustment could help improve the conveyance of floodwaters and reduce water surface elevations along the levees of RD 536 and RD 2060 on Lindsey Slough. By strategically placing the inlet berm in alignment with the areas prone to breaches, it can reduce the work needed to armor the restricted height-levee in areas not prone to breach and enhance the overall hydraulic performance of the flood control system in the Yolo Bypass. However, it is important to note that any modifications or reconfigurations should be carefully evaluated, considering engineering feasibility, environmental impacts, and stakeholder considerations.

This investigation would involve conducting detailed hydraulic modeling and analysis to assess the potential benefits of a longer inlet berm length and moving the berm to the west. The goal would be to optimize the design of the inlet berm to achieve the maximum reduction in water surface elevations while considering other project constraints and environmental impacts and interested party considerations.

7.1.2. Geotechnical

The geotechnical report supports the feasibility level study and the various alternatives. Additional analysis will be required to support the design of the project and for development of the plans and specifications.

7.1.3. Environmental Documentation and Permitting

DWR will serve as the CEQA lead agency to approve and potentially carry out the Proposed Project. The Project is expected to require preparation of an Environmental Impact Report (EIR). The USACE will determine if the Proposed Project will be required to prepare a project-specific National Environmental Policy Act (NEPA) document. Numerous state and federal agency permits or approvals will be required. CEQA commenced during the Summer of 2023. Additional information can be found in the Permitting Strategy Plan (**Appendix C, Exhibit C)**. The agencies in the following Table may have authority over portions of the Proposed Project.

Table 7-1. Anticipated Environmental and Regulatory Requirements

Federal Agency	Permit or Approval
U.S. Army Corps of Engineers	Section 404/10 Permit: NWP 27 (Restoration) or Individual Permit
	Section 408 Permit
	NEPA (via USACE)
USFWS	Section 7 FESA Consultation (via USACE) Informal or Formal with Biological Opinion (BiOp)
NMFS	Section 7 FESA and MSA Consultation (via USACE) Informal or Formal with BiOp
SHPO	Section 106 NHPA Consultation (via USACE)
USCG	Section 9 RHA Permit (via) USACE
FEMA	CLOMR (conditional letter of map revision) LOMR (letter of map revision)
EPA	Oversight for certain federal permits
State Agency	**Permit or Approval**
DWR	CEQA
Regional Water Quality Control Board (Regional Water Board	Section 401 Water Quality Certification/Waste Discharge Requirements
	NPDES (Section 402 CWA) and SWPPP
CDFW	Section 1600 LSAA CESA Compliance: Section 2080.1- Consistency Determination (CD) (w/ federal BiOps) Or Section 2081 – Incidental Take Permit (ITP)
MBTA	Migratory Bird Treaty Act
DSC	Delta Plan – Certification of Consistency
SHPO	Section 106 NHPA Compliance
	PRC 5024
CalGEM	Well Permits
CVFPB	Encroachment permit
California Department of Transportation (Caltrans)	Encroachment Permit/Permit Engineering Evaluation Report (PEER) Process

7.1.4. Recreation Concepts

Based on the discussion in Section 6.10, four design concepts were developed for possible inclusion into the multi-benefit project. Each concept was optimized for specific restoration options, primarily in terms of land and water surface elevations, but can be easily adapted to fit the other options as well. These concepts are a first step in a fully integrated project description encompassing all parts of the LEMBP. Although the concepts shown are based on Feasibility Study levels of design, additional design challenges are expected to include the following:

- Verifying the appropriate elevations of recreation features, such as boardwalks and parking lots, relative to expected future water surface elevations (high tide and low tide).
- Designing recreation features to withstand periodic inundation, including such factors as flood frequency, duration, depth, and flow.
- Gaining access to the recreation sites, including any required expansion of easements through private property.
- Adapting the recreation feature concepts to refinements in the Feasibility Study options. This is especially important if the optimal locations for levee breaches need to change as a result of more detailed hydrodynamic modeling. Cultural Resources in the areas will also need to be considered.

Although these and other challenges remain, the four recreation feature concepts presented here show that multi-benefit objectives can be realized. Little Egbert Tract can be redeveloped for flood system enhancement and ecosystem uplift while also including new public recreation opportunities.

7.1.4.1. Design Concept 1A. Pedestrian Trails and Small Craft Boat Launch

Shown on **Figure 11**, this concept covers features in the tidal riparian upland area in the southern portion of the Tract, based on elevations in CNRA Alternative 17. Parking lots are accessible by car from SR 84, and vehicular access uses the existing unpaved road feature (elevation +8 to +10 feet). This “spine” allows access deeper into the area with three potential parking areas.

Features include unpaved nature trails with trailhead educational signage about restoration components. Loop trails are in upland elevations above the typical tidal high-water level. Boardwalks are provided over regularly saturated areas along the basin edges to provide an up-close experience of the tidal habitat. This concept plan depicts approximately 3 miles of trails and a 1,500-foot segment of boardwalk.

At the terminus of the spine road, access to water recreation uses one of the parking areas with a layout that accommodates vehicles with small trailers used for transport of kayaks or canoes. Portable restrooms may be provided. The tidal basin is reached via an accessible ramp path and boardwalk that slopes down from the parking area. Multiple launch points are located at high tide/low tide elevations along the boardwalk and pier.

Figure 12. Recreation Concept Design Drawing 1A

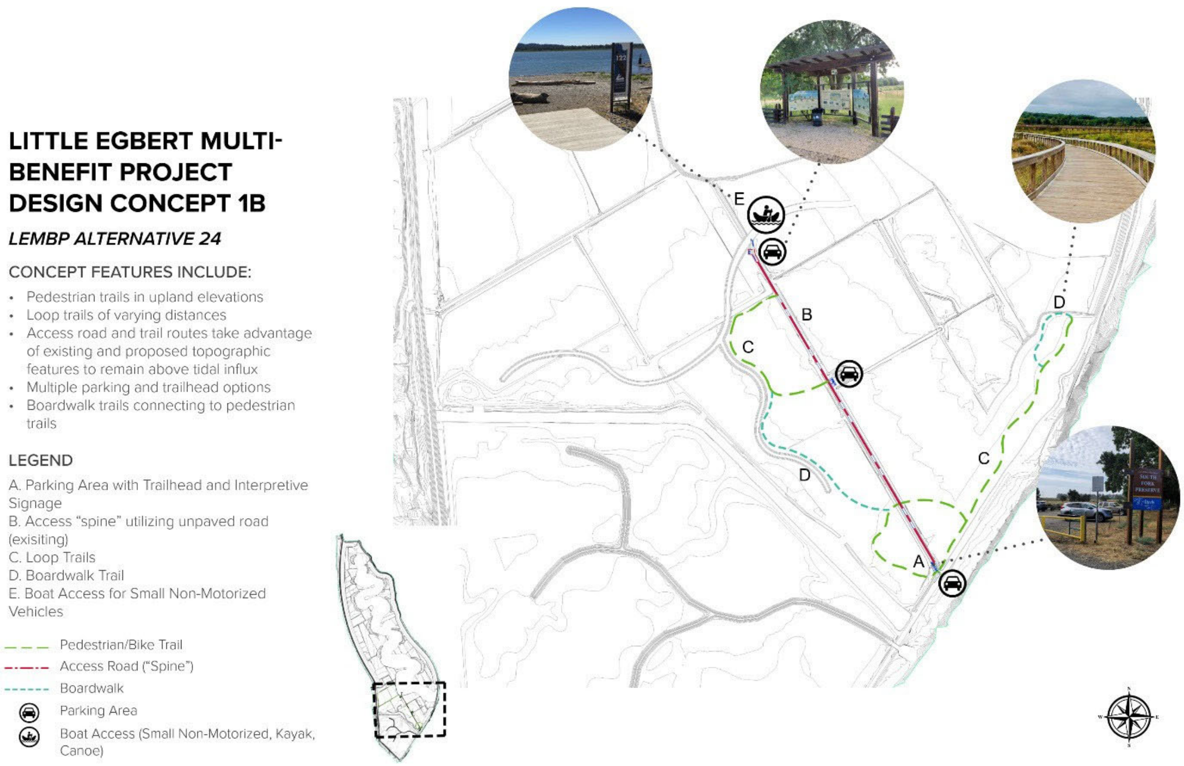
7.1.4.2. Design Concept 1B. Pedestrian Trails and Small Craft Boat Launch

This concept, shown on **Figure 12**, covers features in the tidal riparian upland area in the southern portion of the tract, based on elevations in CNRA Alternative 24. Similar to Design Concept 1A, parking lots are accessible by car from SR 84, and vehicular access uses the existing unpaved spine road to access additional parking areas.

This concept provides the same recreational opportunities described in Design Concept 1A, but with a reduced total trail length of 1.3 miles and slightly longer boardwalk segments. Topographic elevations in Alternative 24 limit the extents of upland trail areas that are not regularly inundated by tidal flux.

The spine road terminates at a deep tidal swale, and access to water recreation uses the parking area near the end of the road.

Figure 13. Recreation Concept Design Drawing 1B



7.1.4.3. Design Concept 1B. Motorized Boat Launch

This concept, shown on **Figure 13**, consists of a motorized boat launch on the northern bank of the tract, west of the levee breach. Parking lots are accessible by car from Liberty Island Road.

The motorized boat launch requires permission to extend the public roadway access along Liberty Island Road, which is currently private. The access road would follow the existing road to a flat upland area along the Cache Slough shoreline.

Features include a motorized boat launch ramp, parking for vehicles and trailers, a shade pavilion, picnic tables, an accessible shore fishing dock and kayak launch, and restrooms. The restrooms will not have running water unless it becomes available from a feasible source.

The northern extent of the pedestrian trail detailed in Design Concept 3 would terminate at the parking lot for the boat launch.

Figure 14. Recreation Concept Design Drawing 2

7.1.4.4. Design Concept 3. Pedestrian Trail Along Habitat Berm

Shown on **Figure 14**, this concept expands the pedestrian trails depicted in Design Concepts 1A and 1B to extend north along the habitat berm following the western levee of the tract. Parking is accessible by car from SR 84 to the south and Liberty Island Road to the north.

A pedestrian bridge extends the trail system at the access road terminus of Feature 1B; alternately, the westernmost segment of loop trail depicted in Feature 1A continues north to Liberty Island Road. The trail can either use the proposed levee maintenance road at the toe of the levee slope or run along the highest bench of the habitat berm.

Design Concept 3 (**Figure 14)** includes all the recreational amenities of Design Concepts 1A and 1B, with the provision of an extended trail running the entire western length of the Little Egbert tidal habitat restoration area. Boardwalks and/or pedestrian bridges will be needed where the trail crosses swales or sloughs.

Figure 15. Recreation Concept Design Drawing 3

7.2. Other Considerations

The following subjects were considered during analysis of this Project.

7.2.1. Climate Change Sea-Level Rise

The habitat design considered habitat evolution in response to climate change and sea level rise. Habitat benches would provide an elevation gradient from intertidal to uplands to allow habitat migration to higher elevations. The placement and gradient of habitat benches will be refined with consideration of sea level rise scenarios for the region and will be an integral part of the future CEQA Scoping Design Process. The west levee had been designed with a crest elevation based on the 1957 design water surface elevation (WSE) profile plus 7.0 ft. of freeboard. The 7.0 ft. of freeboard is a combination of 6.0 ft. to bring the levee to Federal standards, and 1.0 ft. for uncertainty. The uncertainties could include factors like climate change and sea level rise. Further analysis of levees, breaches, tide gate, and other features may be necessary regarding the latest sea-level rise predictions.

7.2.2. Agricultural Sustainability

Agricultural Sustainability and regional economic impacts will be evaluated in more detail in a later phase of the project. Higher O&M costs during winter 2022-2023 storms will prompt a quantitative analysis of climate change variability and SLR effects on agricultural sustainability in future considerations.

7.2.3. Water Quality

It may be necessary to simulate additional alternatives to determine the water quality impacts of specific design features. For example, if a scenario with balance breaches is selected, simulation of an identical configuration, but without the balance breaches, would be needed to determine the impact of the balance breaches.

For the final selected Action Alternative, analysis of bromide and chloride impacts should be performed. D-1641 water quality objectives at water intakes are based on chloride. Bromide, although not a D-1641 water quality objective, is a concern at water intakes. Both bromide and chloride can be estimated from modeled EC and Martinez source fraction results and will generally follow the same trends as EC. Thus, it is expected that, for example, the alternative with the largest EC impacts would also have the largest bromide and chloride impacts.

Organic carbon may be of interest to the Project. Modeling a Little Egbert tracer could be used to illustrate the potential for export of organic carbon to exist as a food web benefit or detriment to water exports.

7.2.4. Penetrations and Encroachments

A preliminary review of encroachments, utilities, and penetrations was completed and is summarized in **Table 5-1** within **Appendix D**. Refer to Section 6.3.4 of this report.

7.2.5. Drainage System Improvements

Watson Hollow Slough (WHS) is located between the RD 536 and Solano County 44 levees. WHS serves as water conveyance for agricultural use during the irrigation season and runoff drainage during the wet season. WHS joins with Cache Slough at the most southeastern corner of the LET through four (4) existing 60-inch culverts. An existing tide gate with two (2) 36” culverts are used by the local landowners for irrigation. The existing tide gate is located approximately 3,200 linear feet downstream of the gap between the RD 536 and Solano County 44 levees. Additionally, an existing 18-inch pipe is in the RD 536 levee and provides irrigation water to the canals located along the landside of the levee.

Alternatives 17.1, 19.1, and 24.1 of this Project propose to close the gap between these two levees and construct a new Water Control Structure (WCS) in the Watson Hollow Slough gap. The new WCS will provide a continuous line of flood protection and be sized such that it can pass a 100-year flood from WHS without significant impacts to the upstream floodplain. The new WCS will be gated to prevent Yolo Bypass water from backing up into WHS (west of the levee). The existing tide gate in WHS would no longer be needed and subsequently removed.

The reconfiguration of WHS was initially evaluated during the study phase that began in 2021 and an interior drainage analysis of WHS was prepared (MBK, 2022) and several hydrologic events from flood to tidal level events were selected to identify potential design constraints and design flows for the reconfiguration of the slough. The study team utilized the design hydrology from the initial study and provided a design analysis to improve the drainage system that utilizes WHS. As part of a future design phase the WCS will be evaluated further considering efficiency and constructability. Evaluations would consider the primary means for flow conveyance, which are anticipated to be either a series of pipe or box culverts. Dewatering requirements would also be considered; however, specific analysis for a dewatering system including sizing of pumps and dewatering durations would be completed by a construction contractor during the construction phase.

Construction of a new Water Control Structure (WCS) would include the following:

- Installation of sheet piles or bladders in the vicinity of the gap and dewatering of area within the gap.
- Excavation of the bottom of Watson Hollow and removal of approximately 5 feet of unsuitable material.
- Construction/placement of a new WCS with gates.
- Levee earthwork construction to tie the RD 536 and Solano County 44 levees (match crown elevations). The new levee embankment would match the geometry of the RD 536 levee.
- Seepage mitigation (cutoff wall or seepage berm) would be required through the gap.
- Removal of sheet piles and dewatering equipment.
- Levee crown and side slope surfacing.

The proposed configuration of WHS is to provide positive drainage only during rainfall-runoff events from WHS. The positive drainage only configuration was selected to prevent fish from migrating into Watson Hollow Slough once LET is tidally connected to Cache Slough. This configuration can be achieved by installing a check or flap gate on the downstream end or on the LET side of the water control structure. During high flows on the Yolo Bypass, flood waters would not be able to enter WHS while irrigation water will be provided to RD 536 by a proposed lift station. Irrigation pumps will be provided intake screens designed to protect fish from being entrained into a diversion and to prevent them from being impinged on the screen surface.

Based on preliminary information provided by MBK either eight 48-inch diameter culverts or two 5-foot-high by 15-foot-wide box culverts are needed to convey drainage runoff. Preliminary material quantities and costs have been developed for both culvert options and are summarized in **Appendix D**. Pipe culverts with flap gates are preferred over a box culvert with flap gates due mostly to the cost of operating and maintaining a box gate. The weight of 5 foot high by 15-foot wide box culverts will require electrical power and redundant power systems to assure functionality of the gates. Electrical power requirements will also require additional easements to accommodate routing of power lines to the power source and an O&M entity will need to be identified and prescribed operations of the gates, all of which will incur costs in perpetuity.

8. Recommended Next Steps

DWR will be the lead agency for LEMBP CEQA efforts.

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