SHERMAN ISLAND BELLY WETLAND RESTORATION ADAPTIVE MANAGEMENT PLAN

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1. Project Purpose

The Sherman Island Belly Wetland Restoration Project (Project) will restore approximately 1,000 acres of permanent palustrine emergent wetlands and associated upland habitat within a 1,936-acre Project boundary through a combination of reestablishment and rehabilitation. The intent of the Project is to stop or reverse subsidence, provide native habitat for a diversity of wildlife, and sequester atmospheric carbon. By maintaining permanent and adequate water levels, the growth and subsequent decomposition of emergent vegetation is expected to grow peat which will raise surface elevations on the property. The Project is expected to provide year- round wetland and upland habitat for waterfowl and other wildlife. The Project will provide climate benefits by sequestering atmospheric carbon dioxide (CO^2) that will help provide a net reduction in greenhouse gases (GHGs). Pending the availability of funding, the Project Site will provide an opportunity for researchers to use on-site monitoring and data from applied research sites on Sherman and Twitchell Islands to quantify climate benefits. GHG reductions quantified for the site's permanent water management regime have the potential to be extrapolated to other similar sites throughout the Delta.

1.2 Project Goals and Objectives

The Project will create approximately 1,000 acres of permanently flooded wetlands on Sherman Island. The Project will be located on property owned by the Department of Water Resources. This project builds upon the methods and outcomes of several other projects, including the Twitchell Island East End Project (~740 acres) and the Sherman Island Whale's Mouth Project (~600 acres). As such, the uncertainty of the project is low.

The goals of the project are:

1. Control and reverse subsidence by using permanent flooding techniques;
2. Create wetland and riparian habitat and monitor biological enhancement;
3. Provide carbon sequestration benefits and evaluate the net GHG benefits by restoring permanently flooded emergent wetlands on highly organic soils;
4. Demonstrate the applicability of tested management practices to Delta and Suisun Marsh.

Based upon the extensive previous experience gained by similar projects in the Delta there is a high degree of certainty the goals and objectives will be achieved. The Project will provide subsidence reversal benefits and develop knowledge that can be used by operators of private wetlands, including "duck clubs," which manage lands for waterfowl-based recreation. By maintaining permanent water, the growth and subsequent decomposition of emergent vegetation is expected to control and reverse subsidence. The Project is expected to provide year-round wetland habitat for waterfowl and other wildlife. To achieve final restoration goals, these wetlands will be managed through a system of water supply structures (including siphons, ditches, and swales), berms to provide proper water management depths and site access, and water control structures. Proper water management is critical for establishing and maintaining healthy habitat conditions in all managed wetlands. Managing water for the appropriate time of application, duration of inundation, and depth are the three key factors to support the desired vegetation and wildlife communities in a managed marsh. The restored permanent wetlands will require regular and attentive water deliveries, draw downs, and overall management to achieve the project's goals.

Throughout the year, water levels will be managed to encourage the establishment and maintenance of annual, perennial, emergent, and submerged aquatic vegetation. Subsequently, these vegetation communities will provide habitat for a variety of wetland dependent wildlife. Water management provides the means to vary water levels within and between units to distribute nutrients, decrease stagnant conditions, provide quality habitat, and minimize vector production.

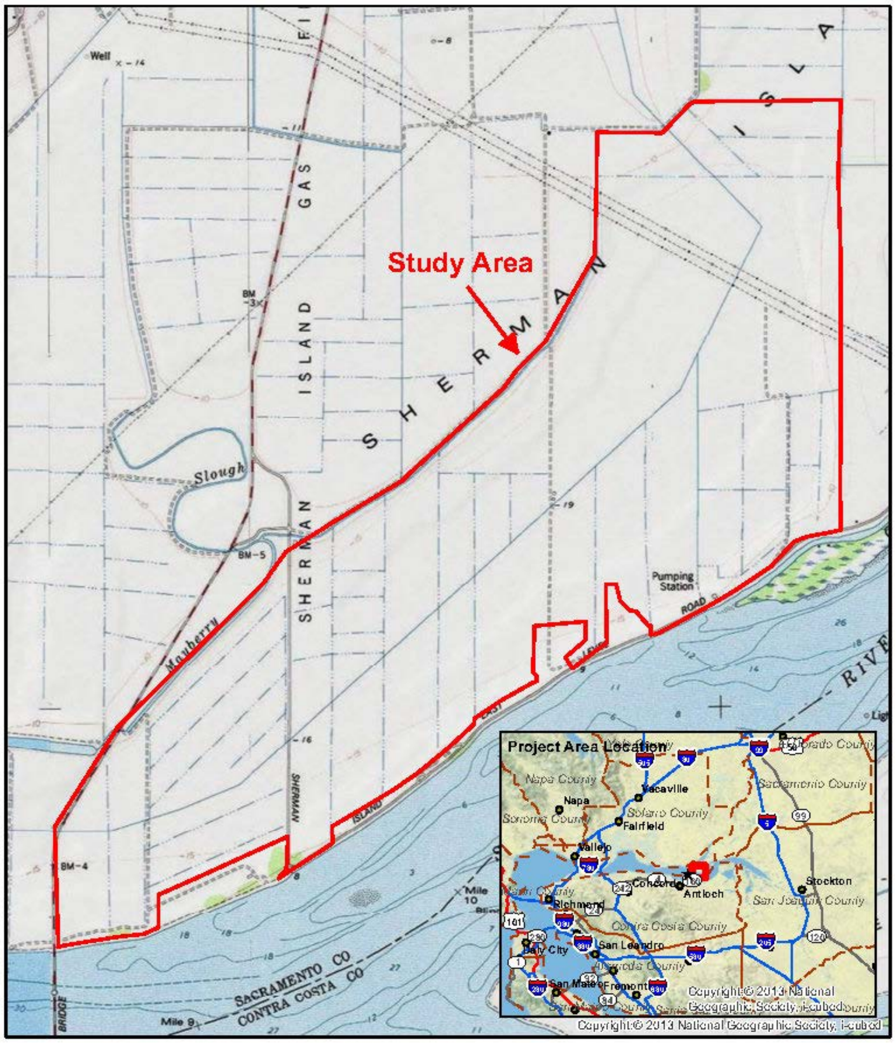

FIGURE 1-1 PROJECT SITE AND VICINITY MAP

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1.3 Project Description

Regional Setting

Sherman Island is located in Sacramento County just to the north of the city of Antioch, California. The island is in the western portion of the Sacramento-San Joaquin Delta (Delta) and is located near the confluence of the Sacramento and San Joaquin rivers (See Figure 1-1).

Pre-Project Conditions

Historically, the study area was a marsh that was diked off from the Sacramento River and drained between 1850 and 1860 to facilitate agriculture. As a result of more than 150 years of farming practices, irrigation, and exposure of soils to air, the study area has subsided as much as 10-20 ft. A high water table currently makes the project site unsustainable as a long-term agricultural area.

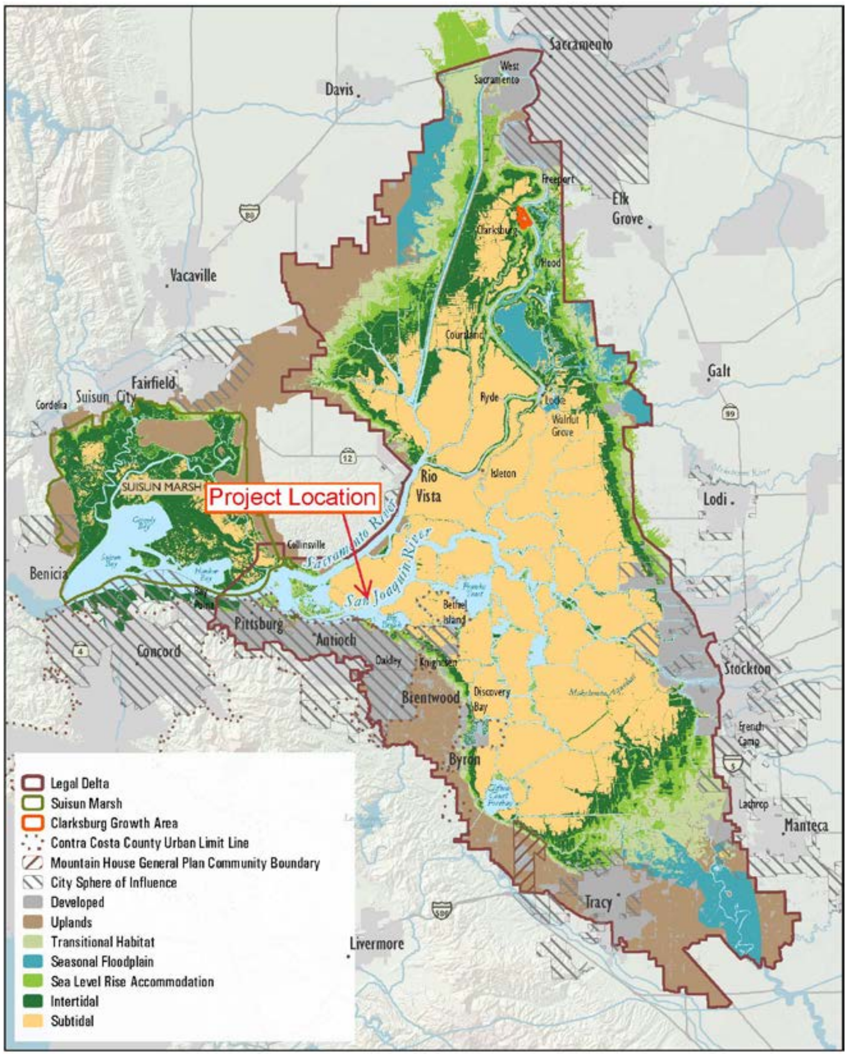

FIGURE 1-2: LOCATION OF THE SHERMAN ISLAND RESTORATION PROJECT (BASE MAP IS FIGURE 4-6 OF THE DELTA PLAN (ELEVATION HABITAT MAP)).

Before the Delta was diked, drained, and farmed, it was subject to significant seasonal fluctuations in freshwater inflows, which worked in concert with large tidal ranges. Natural levees were formed by sediments deposited during spring floods and stabilized by vegetation. Dominant vegetation within the natural levees included tules - marsh plants that live in fresh and brackish water. Decomposing tules and reed vegetation formed the peat soils over thousands of years.

Once the soil was diked and then dried, the peat soils decompose, which leads to compaction and subsidence. Subsidence has reduced the distance from the soil surface to the water table. The resulting high water table makes the Site unsustainable for crop production, although much of the site is currently used for pasture.

The project site is located on Sherman Island which is completely surrounded by a levee system. The site has subsided between 10 feet and 30 feet below the adjacent elevations of the San Joaquin River. The site is comprised of a complex network of berms, water delivery and drainage ditches, and water control structures. Pre-project wetlands on the site are a product of water brought onto the island as part of the flood irrigated management practices, seepage through the perimeter berm, and precipitation. Water is delivered onto the property via siphons in the southern section of the study area and water control structure in the northern section of the study area. It is then conveyed to the agricultural fields by a series of water delivery canals and manipulated with water control structures.

Additional pre-project site conditions are documented in the Wetland Delineation Report (October 2018) and the Special Status Plant Survey Report.

Detailed Project Description

The Project focuses on the restoration of palustrine emergent wetlands, complemented with upland and grassland plantings to add diversity of structure and habitat to the site. Restoration of wetlands will be accomplished by upgrading existing water management infrastructure and installing new infrastructure such as water control structures and water conveyance channels. In addition, the Project may create habitat loafing islands. When the Project is completed, water will be maintained on the Project Site year-round, effectively creating a permanent wetland. Restoring permanent wetlands on Delta islands has been shown to halt and reverse subsidence. This Project will combine the wildlife benefits of wetland restoration with the importance of reversing Delta island subsidence. Upland vegetation may be planted at higher elevation areas adjacent to the wetlands. Pending permit approval, site preparation will begin in May 2020. Construction activities in 2020, will be completed by October 15. Work will commence again in May 2021 and will be completed by October 15. If work is not completed in 2020, it will commence again in May 2022. All work will be performed on-site. Additional project information can be found in the CEQA Initial Study/Mitigated Negative Declaration (SCN 2019029126) project description and subsequent sections and appendices.

<u>Planned Construction</u>
During construction of the Project, perimeter ditches, perimeter berms, interior berms, interior water conveyance swales, habitat islands, and water control structures will be installed or improved or constructed. It is anticipated that the Project will excavate approximately 1,200,000 cubic yards from various locations within the Project site and relocate that material in different areas to build the necessary project features. No material will be exported, and a cut/fill balance will be achieved. Details of planned improvements to water management infrastructure and construction of additional infrastructure required to manage the Project as emergent wetlands are described below.

New perimeter and interior berms up to 6-feet high and 16-feet wide will be constructed and utilized to separate management units to allow for water levels to be maintained at the optimal management elevation. The existing elevation of the Project site ranges from approximately 14 feet above sea level to 20 feet below sea level. The berms will have at least 3 ft of freeboard and a 12-ft or 16-ft top width. The 16-ft wide berms will be utilized as haul roads, providing access to the site for future maintenance purposes. Berm height above existing ground will vary depending on existing topography. Materials to create the perimeter berm will be obtained onsite from the creation of swales and other open water areas. Development of perimeter and interior berms will allow water levels to be increased to restore and maintain permanently flooded emergent wetlands onsite. The top of the improved perimeter berm elevations will vary; however, the typical height will be approximately 9-14 ft below sea level.

Approximately 35 water control structures will be installed. The interior of the site will be divided into 12 managed wetland units, separated by approximately 75,000 lineal feet of proposed berms, and crossed with conveyance swales, in order to facilitate appropriate water and vegetation management capabilities. Water levels in each unit will be managed independently to restore the desired emergent wetland conditions throughout the site. When the Project is completed, water is proposed to be maintained in the project area year-round, effectively creating a permanent wetland.

Water will be conveyed within the wetland units and through the managed system via gravity flow from the higher elevation units to the lower elevation units. The water level in the wetland units can be lowered, or removed to provide better circulation, through an outlet water control structure that drains to the Sherman Island drainage canal pump station south of the project boundary. The ultimate outcome of the Project will be approximately 990 acres of freshwater emergent wetlands. Each wetland unit will be a mosaic of open water, swales and emergent vegetation comprised predominantly of species such as California bulrush (*Schoenoplectus californicus*) and narrow leaved cattails (*Typha angustifolia*).

Interior water conveyance swales will be excavated in the wetland management units to provide water delivery and circulation to desired areas of the Project. The conveyance swales will provide numerous wetland and wildlife benefits to the project area. Material excavated to construct the swales will provide material for the interior and perimeter berms. Construction of conveyance swales will convert existing wetland and upland areas into permanent open water that will facilitate water conveyance.

The swales will be managed to encourage the growth of submerged aquatic and floating wetland vegetation and discourage the growth of invasive species. Open water areas will provide waterfowl with areas to land, loaf, and feed. It is anticipated that the presence of permanent open water will increase the amount of waterfowl breeding and brood rearing in the Project site.

Conveyance swales will have an approximately 30-ft wide bottom with gradual 5:1 side slopes. Most of the existing agricultural drainage ditches on Sherman Island have rectangular configurations. These existing drainage ditches will be regraded to provide a more gradual side slope. A gradual swale side slope will allow for easy wildlife movement across the ditches and swales while reducing swale erosion by encouraging vegetation growth along the swale's edges. Depth of swale excavation will vary depending on existing topography, however swales are generally designed to a depth of 2.5 feet below existing ground surface. In addition to the swales, larger open water areas will also be created through excavation. These larger open water areas will be connected to the conveyance swales and are similarly designed to a typical depth of 2.5 feet below existing ground surface. The large open water areas will serve as waterfowl brood rearing areas in the spring and loafing/storm-shelter locations in the winter. Material borrowed from these areas will be incorporated into the interior and perimeter berms or used to construct habitat islands.

As part of creating varying topography and diverse emergent wetland vegetation communities within the project area, habitat islands will be established in multiple locations. Habitat islands will vary in size and shape. The subtle change in micro-topography as a result of the habitat islands will create habitat diversity and greater hydro-geomorphic interspersion.

The water source to the 10 wetland units east of Sherman Island Crossing Road will be delivered by four existing gravity siphons along the San Joaquin River Levee and five newly installed water control structures from the Overland Water Delivery Canal. At this time, it is anticipated that siphons 13, 15, 19, and 20 will be utilized as the primary source of water to the southern edge of these units. Each of these siphons are constructed of 12-inch diameter pipe that is reportedly capable of providing approximately 2,500 gallons per minute. All of these siphons currently have operational fish screens to ensure fish are not entrained within the newly constructed wetland.

It is anticipated that newly installed water control structures 25, 26, 35, 43, and 44 will be utilized as the primary source of water to the northern edge of these units. The water control structures will each include a 10-inch polyvinyl chloride (PVC) pipe that will draw water from the Overland Water Delivery Canal and convey it via gravity flow to the newly constructed wetland units. The Canal is fed by 3 existing siphons on the Sacramento River Northwest of the project site adjacent to Decker Island. All siphons feeding this Canal have operating fish screens, as well.

Water to the 2 wetland units west of Sherman Island Crossing Road will be delivered by one existing gravity siphon along the San Joaquin River Levee. At this time, it is anticipated that siphon 21 will be utilized as the primary source of water to the southern edge of these units. Siphon 21 is constructed of a 12-inch diameter pipe that is reportedly capable of providing approximately 2,500 gallons per minute. This siphon also has an operating fish screen.

Water will be conveyed within the wetland system via gravity flow from the higher elevation units to the lower elevation units until it finally makes its way back to the District's pump station along the southern boundary of the Project.

Improvements to the outlet of the functional siphons may include replacing outlet valves and installing additional appurtenances as needed to improve the control of the water supply to the Project. All siphon improvements will take place on the interior (land) side of the San Joaquin River levee. All siphons utilized are equipped with water meters as well as previously stated fish screens. Water delivered to the site will circulate through the system to maintain appropriate water quality conditions and prevent stagnation and maintain appropriate salinity levels.

Several existing agricultural drainage ditches occur within the interior and exterior of the Project. These ditches connect to the master drainage system of the southeastern portion of Sherman Island. The drainage ditches within the proposed project boundaries will be incorporated into the internal water conveyance system (swale system). A ditch along the exterior perimeter of the restoration area, north of the existing Main Drain, will be constructed to provide drainage from the surrounding landscape and will include proper drainage for the District's toe ditches. This ditch will have a 4-foot bottom and 2:1 side slopes. A ditch along the exterior of the restoration area, south of the existing Main Drain, will be constructed as a realignment of the Main Drain. This ditch will have a 12 -foot bottom and 2:1 side slopes. The existing Main Drain running through the proposed wetland units to the east of Sherman Island Crossing Road will be incorporated into the proposed swale system. Ten earthen ditch plugs will be placed within the Main Drain to improve water flow through the swale system.

An area along the southern edge of the Project site will likely be utilized as a borrow area during construction. High points within this borrow area will be graded and excavated material will be used to complete construction of the berms and habitat islands, if necessary. This area will be outside of the exterior berm of the wetland units. Following project completion, the borrow area is currently proposed to be used as open pasture or for agricultural crop production.

Construction Schedule and Methods

Construction activities will be performed during the dry season between May 1st and October 15th in 2019 depending on permit acquisitions and if necessary between May 1st and October 15th, during subsequent years. Earth moving activities will be performed by a licensed contractor and will likely use agricultural scrapers to transport soils during the excavation of swales and open water areas to construct the Project's interior and perimeter berms as well as habitat islands. Excavators will likely be used to create ditches and install piping.

Delta islands have extensive peat soils that retain groundwater. A field investigation during the height of the irrigation season revealed an elevated water table and saturated soils throughout the Project. This was largely due to extensive flood irrigation activities in the pasture fields and high water in the perimeter ditches. Construction will likely require the water table be lowered as much as possible. Initial site preparation includes the dewatering of ditches in order to dry soils for construction, where feasible. This will be accomplished by verifying that the interior agricultural ditches are clean and flowing freely to the District's drainage canal. The District's discharge pump located near the site may also need to be adjusted to keep the water level in the main drainage ditch lower than normal.

Proposed work within the Overland Water Delivery Canal includes the installation of five water control structures within the channel and the removal of eight. Conditions and/or biological resources may require the work areas are dried out and as such, coffer dams may need to be constructed within the canal adjacent to the work areas to isolate these areas from flowing or standing water.

Up to twenty-six temporary coffer dams may be constructed, one upstream and one downstream of each of the thirteen proposed water control structure installation and removal locations within the Overland Water Delivery Canal. Each temporary coffer dam will temporarily fill approximately 0.04 acres of ditch. Each will be approximately 50 feet wide and require approximately 200 cubic yards of material. Both upstream and downstream coffer dams will be removed after construction of the water control structures is completed. The material used to construct the coffer dams will be sourced from onsite and ultimately used to construct Project features after removal.

Initial site preparation for the Project will include the removal of vegetation, including invasive weeds. This site preparation will take place in areas where swales and ponds will be excavated and used as a source for borrow material necessary to construct the berms. Additionally, the areas that will be the foundation for berm construction will be stripped of vegetation, minimizing the plant material within the berm that would compromise the permeability of the berms.

The Project will be completely enclosed by a perimeter berm that will prevent any discharge of storm runoff. Best management practices (BMPs) for erosion control and hazardous materials handling will be implemented during construction. Any spills of hazardous materials will be cleaned up immediately and reported to the responsible resource agencies within 24 hours. Any such spills, and the success of the cleanup efforts, shall also be reported in post-construction compliance reports. Measures will be taken to minimize windborne transport of fine particles to adjacent areas. A storm water permit issued by the State Water Resources Control Board will be obtained prior to project construction.

Natural Resources and Management

Management of the Site will have three goals: to maintain permanently flooded emergent wetlands to reverse subsidence, maximize GHG sequestration, and provide permanent wetland and upland habitat for a diverse range of wildlife. The Habitat and Water Management Plan is included as Appendix F of the Initial Study and Mitigated Negative Declaration (Appendix A of this document).

Existing Habitat Conditions

Existing habitat conditions on the site are included in the Wetland Delineation Report (Wetland Delineation for the Sherman Island Wetland Restoration Project: Phase II Sacramento County, California, October 30, 2018) and the Botanical Assessment and Protocol-level Rare Plant Survey (WRA 2018).

Desired Habitat Conditions

The desired habitat conditions include a restored wetland with permanently flooded emergent vegetation dominated by round stem bulrush and cattails with a diverse mosaic of associated upland habitat types. Berms will attain a cover of grasses with shrubs and trees which may be planted on the berm slopes, which will be maintained for site access. Habitat restoration areas will be planted in a diverse complex of shrubs, trees, and grassland, which will provide valuable ecological complexity. Habitat areas will be designed to maximize habitat value while minimizing the maintenance required to manage for invasive weeds.

Consultation with the Sacramento Yolo Mosquito and Vector Control District (SYMVCD) has been initiated and preliminary design review has taken place. Additional consultations with SYMVCD, and incorporation of design recommendations, will ensure water flow and water level criteria for mosquito control will be realized. This collaboration will allow the SYMVCD to implement a wide variety of effective mosquito control options, if they become necessary. Mosquito control best management practices (BMPs) as identified in the Central Valley Joint Venture "Technical Guide to Best Management Practices for Mosquito Control in Managed Wetlands" (Kwansy et al. 2004), have been incorporated into the engineering design as well as the Habitat and Water Management Plan (Appendix A).

Water Use

As discussed above, water to the site will be provided by siphons along the San Joaquin River, as well as the Sacramento River via the Sherman Island Overland Water Delivery Canal. All siphons utilized for this project are equipped with flow meters as well as fish screens maintained by DWR. Water will be conveyed within the wetland system via gravity flow from the higher elevation units to the lower elevation units until it finally makes its way back to the District's drainage canal and pump station located south of the Project Site.

A Habitat and Water Management Plan (Appendix A) was prepared that includes a complete water budget for the Site. As water levels will remain fairly constant throughout the year, the Site is expected to divert less water from the San Joaquin and Sacramento Rivers on an annual basis than the existing irrigated agricultural uses during the summer months. It is anticipated that water will be used during the winter to slowly fill the wetlands until an initial average operating level of approximately 1 – 2 feet is achieved. This initial water level will be maintained during the first full year to prevent bank erosion due to wave wash from occurring prior to emergent vegetation establishment. Water will then slowly be added over the following late winter and early spring, again from District drainage, to increase the average operating level to approximately 2.5 feet in the deepest areas and 0.5 feet in the shallowest, which will be the optimal average operating water level. Maintenance of water levels throughout the year will require only minimal water withdraws from the San Joaquin River to balance evapotranspiration.

1.4 Restoration Potential

Figure 1-3 demonstrates how the proposed Project Site would likely look after construction is completed and temporary impacts have been recovered. The overall Project will be an improvement of water supply, conveyance, and water management capabilities. Approximately 867.957 acres of existing degraded wetlands occurring in highly disturbed pasture lands will be enhanced through activities mentioned in the Detailed Project Description. The Project will also provide a functional lift by diversifying habitats (varied topography of swales and potholes), allow the site to be more efficiently managed, and will be more productive migratory bird habitat. In addition, approximately 100.757 acres of additional wetland habitat will be created by the implementation of this project.

Additional benefits of the Project include stopping and/or reversing subsidence and potentially sequestering atmospheric carbon. By maintaining permanent and adequate water levels, the growth and decomposition of emergent vegetation is expected to grow peat which will raise the surface elevation.

According to the Delta Plan Policy ER P2, the location of the restoration site is appropriate for the type of restoration proposed. The proposed project is a semi-permanent wetland, which is appropriate for subsided delta islands as they have been shown to stop and, in some cases, reverse subsidence.

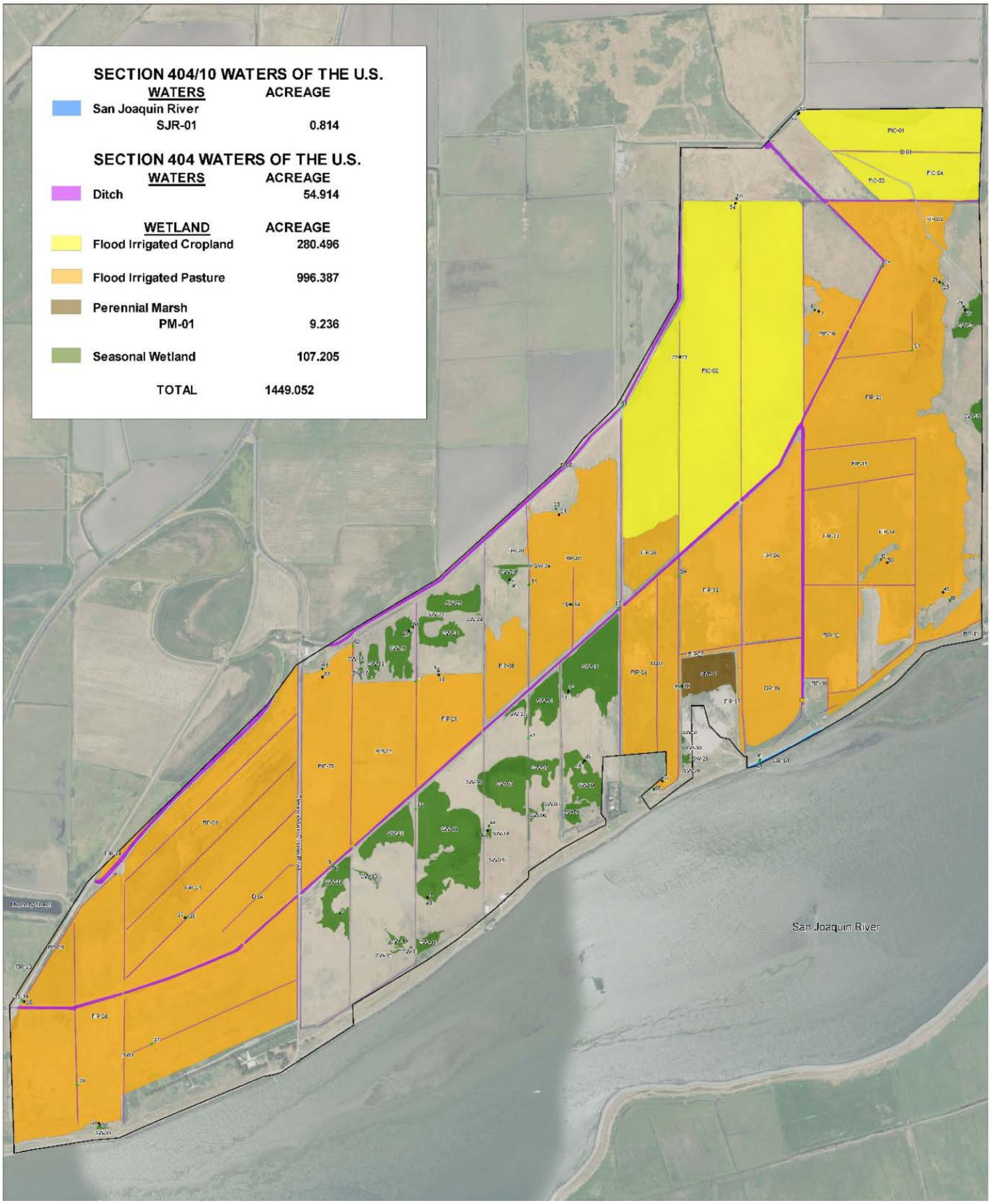

FIGURE 1-3 MAP OF EXISTING WATERS AND WETLANDS WITHIN THE PROJECT SITE

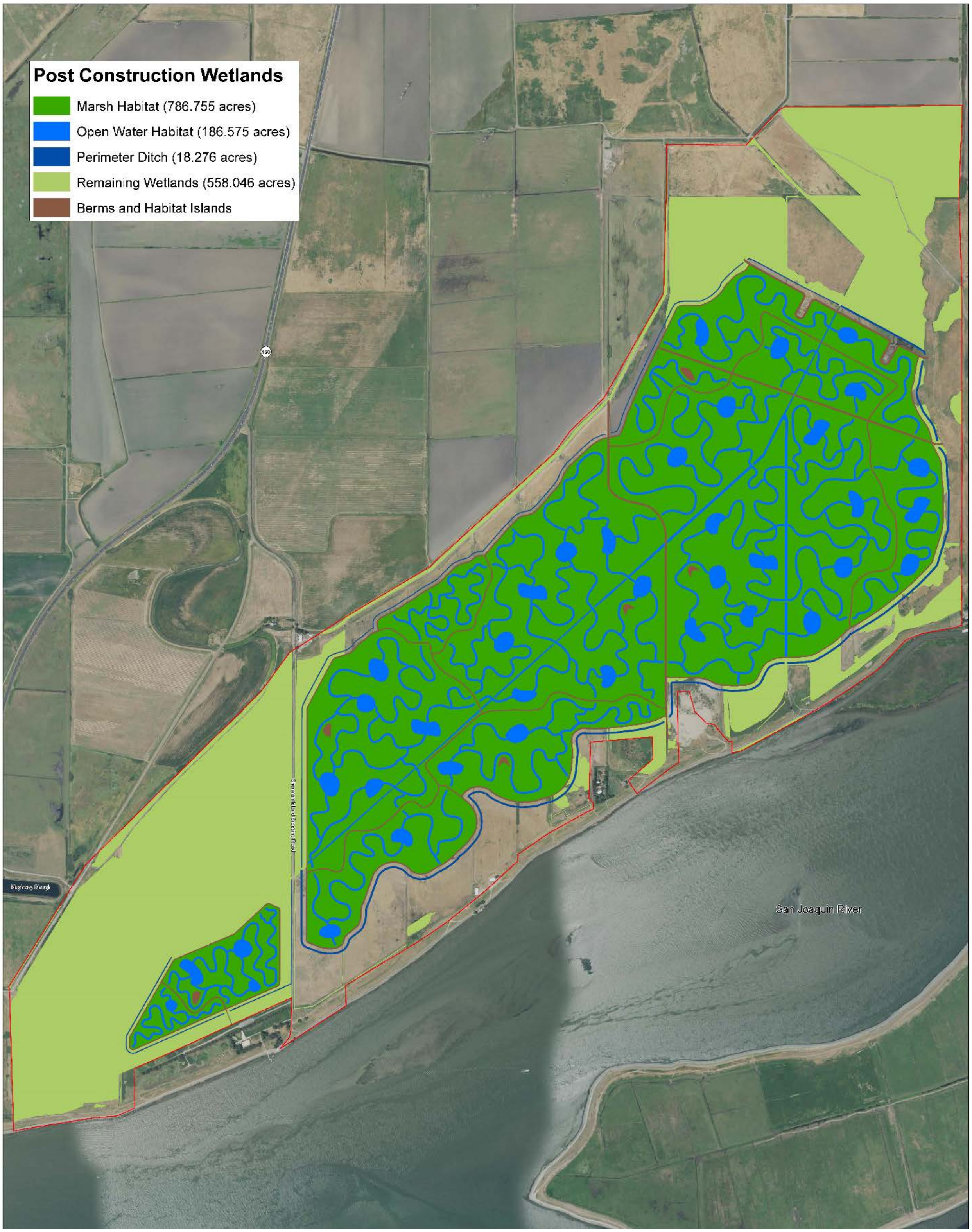

FIGURE 1-4: SHERMAN ISLAND HABITAT RESTORATION PROJECT FEATURES AND POST-RESTORATION HABITAT.

2. Adaptive Management

2.1 Purpose

Adaptive management is a structured approach to environmental management and decision-making in the face of uncertainty. It involves taking risks, assuming that plans may not always turn out as intended, having a backup plan, and continuing to evaluate progress toward goals. It provides a pathway for undertaking actions when knowledge about a system is incomplete and then modifying the approach as knowledge is gained and uncertainty is reduced. Adaptive management makes learning more efficient and improves management practices.

Adaptive management fosters flexibility in management actions through an explicit process. It entails having clearly stated goals, identifying alternative management practices or objectives, framing hypotheses about ecological causes and effects, systematically monitoring outcomes, learning from the outcomes, sharing information with key players and decision-makers, and being flexible enough to adjust management practices and decisions (see Delta Independent Science Board 2016). Conceptual models often are used in adaptive management programs to integrate available knowledge and to provide synthesis and a means of developing and exploring promising management actions before they are attempted as field experiments or pilot projects.

Adaptive management may reduce uncertainty when management actions are thought of as experiments. By using a structured design that includes appropriate controls (or references), monitoring, and replication, observed outcomes can be disentangled from a welter of potentially confounding factors (Zedler 2005). As a result, one can have a good idea of why a management action did or did not work as expected.

The Delta Reform Act requires that adaptive management be used in science-based management of the Delta and its resources. A state or local agency that proposes to undertake a covered action, prior to initiating the implementation of that covered action, is required to submit a written certification to the Delta Stewardship Council, with detailed findings demonstrating that the covered action is consistent with the Delta Plan (Water Code Section 85225).

2.2 Use of Best Available Science

Through project planning and implementation, DWR commits to utilizing the best available science to design, manage, and monitor the site. Adaptive management of the Project will be based on the utilization of input from monitoring data in conjunction with adaptive review of whether restoration goals and objectives are being achieved.

A number of Local and State governmental institutions (e.g. Delta Conservancy, California Department of Fish and Wildlife, California Climate Action Registry, California Air Resources Board) are interested in reducing, capturing or offsetting carbon and nitrogen emissions to meet the guidelines legislated by AB 32 to reduce the State's 1990 carbon emissions by 80% by 2050. One potential, is to restore or create wetlands, with the intent of sequestering carbon, reducing N_2O emissions, and building up the soils [*Crooks et al.*, 2009; *R L Miller et al*2008; *Simenstad et al.*, 2000; Hemes et al. 2019; *Deverel et al. 2014; 2017; Knox et al. 2015* .

At present, there is limited scientific information available to guide such restoration decisions and assess the impact of these actions is sparse. Improving knowledge of soil accretion rates, optimal design criteria for reconstructed wetlands and environmental trade-offs of land conversion is critical for successful environmental management. Once the wetlands are established, research is needed to answer the following questions:

- Under current agricultural practices, what are the net greenhouse gas (N_2O, CH_4, CO_2, water vapor) emissions from drained Delta peatlands, both rich and poor in organic matter content?
- How will restoration of native tule/cattail wetlands alter carbon sequestration, N_2O emissions, and CH_4 production in the Delta peatlands compared to current baseline conditions?
- How do fluxes of N_2O, CH_4, CO_2 and water vapor vary and co-vary seasonally, annually and inter-annually over peatland pastures, crops and wetlands?
- What are the effects of weather, water table, salinity and vegetation function on net greenhouse gas fluxes, over short and long time scales?
- How do greenhouse gas fluxes of newly created wetlands change with time as soil carbon pools build and the density of vegetation increases?
- Can we accurately upscale CO_2, N_2O, and CH_4 fluxes to the region and produce greenhouse accounting protocols using proxies that will be of value to State Agencies for assessing carbon offsets and planning additional wetland restoration projects?

To address these questions, we have installed and continue to operate a small regional network of automated and static surface flux chambers and eddy covariance towers to measure a suite of greenhouse gas fluxes across a representative spectrum of land-use classes in the Delta. The combination of automated surface flux chambers and the eddy covariance method is suitable for this task as it is able to measure greenhouse gas fluxes directly and on a quasi-continuous basis [*Baldocchi*, 2003; *Baldocchi et al.*, 2012]. Moreover, recent developments in commercially-available, affordable, and stable tunable diode laser spectrometers and open-path sensors allow investigators to establish sites off the power grid make flux measurements at locations that are scientifically interesting, as power-hungry pumps are not needed [*Matteo Detto et al.*, 2011].

DWR in coordination with the University of California at Berkeley has been measuring the dominant greenhouse gas (N_2O, CH_4, CO_2 and H_2O) fluxes across a suite of sites in the delta that represent current agricultural practices, restored wetlands and rice production, which is an alternative to wetlands for over a decade. As a result, we have established a network of 9 continuous greenhouse gas measurements sites across the Delta and include a wide variety of organic content soils (< 20%) and soils with high organic content (> 40%) in the Central Delta [*Steven J. Deverel and Leighton*, 2010].

In addition to our flux measurements, we have conducted modeling activities to encompass the prediction of CO_2, CH_4 and N_2O from wetlands, pasture and agricultural land across low and high organic content soil. Modeling is critical for up-scaling measurements to the region and for providing future wetland restoration projects an affordable and reliable means of quantifying carbon offset credits. Modeling will also be essential for the GHG accounting framework described in the Delta Conservancy/The Nature Conservancy proposal for this solicitation as shown in the following figure.

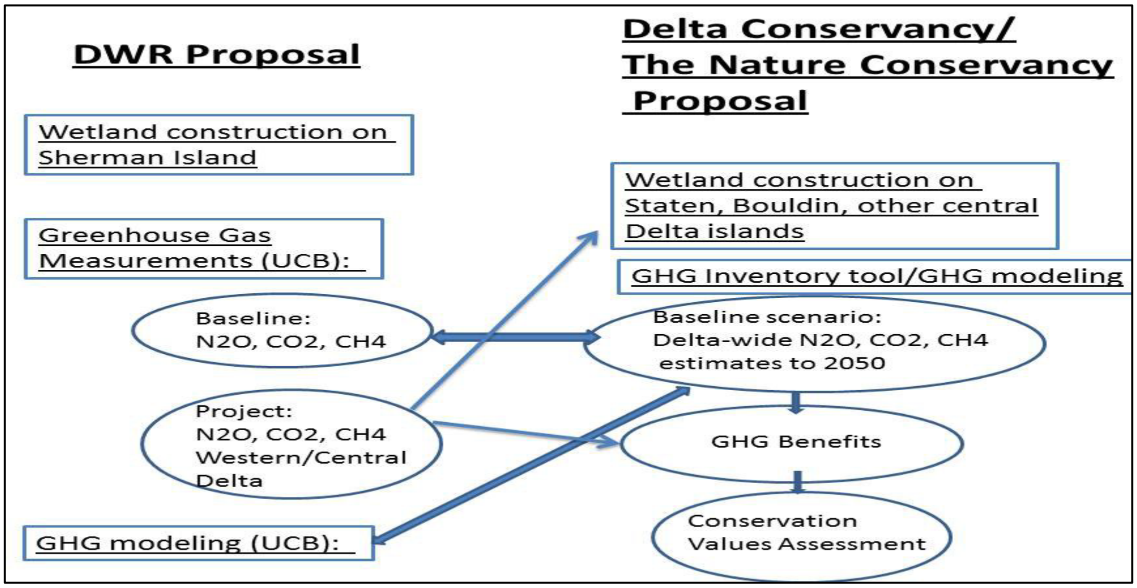

FIGURE 2-1 RELATION BETWEEN DWR AND DELTA CONSERVANCY/THE NATURE CONSERVANCY PROPOSALS.

These Projects have allowed DWR to partner with others to develop GHG Emissions Reduction and Carbon Sequestration Protocols to place Delta landowners in a position to be able to capitalize on the emerging carbon market if they elect to change from growing crops to growing carbon.

The Project Site is currently managed as a flood irrigated pasture, which includes a regular and extensive disturbance regime associated with field prepping and grazing. This site has an extensive amount of pepperweed (*Lepidium sp.*) and Himalayan Blackberry (*Rubus armeniacus*). As a result of more than 130 years of farming practices and subsequent oxidation of the peat soils, land elevations are more than 20 ft below the water levels in both the Sacramento and San Joaquin Rivers. Phase 2 (Whale's Belly) is currently managed as flood irrigated agricultural fields, where farmers grow corn, alfalfa, and hay. Similar to the phase 1 (Whale's Mouth) site, there is significant amounts of invasive plant species; however, ground elevations in this area are as much as 23 feet below the water levels of adjacent rivers.

3. Monitoring

Based upon outcomes of several other projects, including the Sherman Mayberry Project (~300 acres), Twitchell Island East End Project (~740 acres) and the Sherman Island Whale's Mouth Project (~600 acres), we have a high level of certainty that the monitoring goals, measures, triggers, and actions are applicable and relevant.

The Sacramento-San Joaquin Delta ecosystem is extremely dynamic on multiple temporal and spatial scales. In the absence of rigorous monitoring, fluctuations in natural populations of native and non-native flora and fauna, as well as variations in the physical environment related to climate and anthropogenic influences, are likely to complicate the assessment of wetland restoration actions. This document outlines the Project approach to ascribing changes in habitat at the restoration site. Monitoring is an integral component of adaptive management as well. The plan incorporates elements of the Framework (IEP TWM PWT 2017a) and comprises three major components:

- Compliance monitoring – compliance with construction-related permitting requirements.
- Routine effectiveness monitoring – evaluating hypotheses related to the premise that wetland restoration will provide benefit in accordance with project objectives.

3.1 Compliance Monitoring

Regulatory permits obtained for constructing the Project have associated conservation and mitigation measures that require specific monitoring actions to satisfy compliance. These monitoring elements focus on permitting requirements and mitigation measures under Section 404 of the Federal Clean Water Act, Section 10 of the Rivers and Harbors Act, Section 401 of the Federal Clean Water Act, Section 7 of the Federal Endangered Species Act, Section 1602 of the California Fish and game Code, and Section 2081(b) of the California Fish and Game Code. Environmental permit applications have been submitted to permitting agencies and are expected to be completed by late 2019. The CEQA Mitigation Monitoring Reporting Plan is provided as Appendix B.

As a restoration project the project does not have any additional required monitoring post construction completion.

3.2 Effectiveness Monitoring

Effectiveness monitoring will track progress towards objectives by measuring indicators of ecological status and function ("metrics") and comparing the measurements to expected or hypothesized outcomes. Sampling techniques ("methods") will include terrestrial surveys of vegetation, hydrologic and water quality and GHG monitoring via instrumentation. Measurements of physical and biological components will be used to evaluate the evolution of habitat on the site including marsh morphology, vegetation response (including non-native invasive plants), habitat component contributions to the food web, and identification of occupied fish habitat.

The effects of restoration on local and regional biological resources will be evaluated relative to pre-construction conditions ("baseline"), concurrent monitoring of an existing wetland (Whale's Mouth).

Objective 1: Restore and Enhance Wetlands by constructing approximately 1000 acres of new wetlands on Sherman Island

Wetlands are defined by a three-parameter approach and focus on soils, hydrology, and vegetation. Due to the historic nature of the project site being comprised of tidal marsh, soils within the project site are pre-dominantly hydric. Water on the site post project will be managed by siphons and water control structures. Thereby leaving vegetation as a relatively uncontrolled variable to be the most accurate indicator of hydric or wetland conditions. Vegetation such as round stem bulrush (*Shenoplectus californicus*) and broad-leaved cattail (*Typha latifolia*), typically referred to as Tules, are the prevalent species targeted. As such, tules are a great indicator species as to whether the project will achieve the restoration and enhancement acreage objectives. These wetlands will be constructed by building berms throughout the site, so that water can be introduced at a depth between 6 and 36 inches in the areas that are designated for tule growth. A system of swales and lakes will be dug throughout the site that will enable water to flow freely from one cell to another. The material that is obtained form making the swales and lakes will be used to build the berms (as described in the project overview). Some tule seed will be broadcast adjacent to berms, however most of the tule and cattail growth will stem from natural recruitment. Based upon outcomes of several other projects, including the Sherman Mayberry Project (~300 acres), Twitchell Island East End Project (~740 acres) and the Sherman Island Whale's Mouth Project (~600 acres), we have a high level of certainty that Objective 1 will be achieved.

Objective 2: Sequester GHG, approximately 6-10,000 metric tons CO_2-eq per year (CO_2 and CH_4 flux).

Baseline GHG (CO_2 and CH_4) has been collected over the last 15 years within the Delta. GHG emissions (CO_2 and CH_4) at this irrigated pasture site ranges between 5.7 to 6.6 metric tons CO_2-eq per acre per year. Additionally, analysis of mature wetland systems on Twitchell Island shows GHG (CO2 and CH4) sequestration rates to be between 1.0 and 5.2 metric tons CO2-eq per acre per year. Based upon this data, it is expected that these wetlands (once mature) will have a net GHG sequestration rate of approximately 6-10 metric tons CO2-eq per acre per year.

N_2O data is currently being collected at this site but has not yet been thoroughly analyzed. However, N_2O data was collected in 2007-08, on a nearby similar site, which showed emissions of 302 ± 168 g CO2-eq m^{-2} y^{-1}. These values are up to an order of magnitude higher than managed peatlands in other regions (Jungkunst and Fiedler 2007; Langeveld and others 1997; Regina and others 2004; Schils and others 2006) and dominated the global warming potential for this site (Teh et al. 2011). While this data does not solely support Delta-wide N_2O emissions estimates for this baseline type, it does suggest that N_2O is quite possibly an extremely large contributor to GHG in the Delta. Furthermore, because wetlands are not a major contributor of N2O, the potential GHG sequestration of this project is likely greater than 10,000 metric tons CO2-eq per year. Based upon outcomes of several other projects, including the Sherman Mayberry Project (~300 acres), Twitchell Island East End Project (~740 acres) and the Sherman Island Whale's Mouth Project (~600 acres), we have a high level of certainty that Objective 2 will be achieved.

Objective 3: Reverse land subsidence on Sherman Island

Research conducted by DWR, USGS, and UCB has shown growing wetland crops that are flooded year-round (especially during the summer and early fall months) reverses subsidence. Tule wetlands not only stop the peat soils from subsiding but also reverse subsidence by accreting root mass which eventually yields soil production.

Since 1997, DWR has constructed and studied several large-scale wetlands in the West Delta by monitoring the effects of growing tules, including land surface elevation changes and recently carbon sequestration. The data show that surface elevation changes due to accretion ranges from 1.3–2.2 inches each year and sequesters greenhouse gases. In comparison, the areas used for agricultural purposes lose up to 1 inch of soil per year, mainly from the oxidation of peat soils. This oxidation results in the emission of greenhouse gases. The land surface net gain for growing tules on peat soils can result in up to 3 inches per year. Based upon outcomes of several other projects, including the Sherman Mayberry Project (~300 acres), Twitchell Island East End Project (~740 acres) and the Sherman Island Whale's Mouth Project (~600 acres), we have a high level of certainty that Objective 3 will be achieved.

Additional Project Benefits

Secondary Objective 1: Increase diversity and relative cover of native plant species and minimize the establishment and growth of non-native, invasive plant species

The proposed construction sites for both phases of this project are currently managed as irrigated pasture but have significant infestation of pepper weed and Himalayan Blackberry. By permanently flooding significant acreages of land we will eliminate the aforementioned invasive species by growing native tule/cattails.

Additionally, both phases consist of restoring native plants on the upland berms, islands, and surrounding areas. Selected upland species including grasses, shrubs, and trees will be planted at the appropriate elevations to ensure survival. The "Whale's Mouth" plan sheets include a proposed planting plan and species palette, which will be typical for all restoration projects.

Secondary Objective 2: Restore and enhance nesting, roosting, foraging, and cover habitats for native wildlife species

DWR biologists have shown that restoration of wetlands and uplands have a positive impact on the bird communities. Bird surveys on wetlands show a 2 to 3 fold increase in diversity and richness from baseline conditions (corn and pasture) at sites where restoration has occurred (DWR, unpublished data 2014). Riparian Habitat Joint Venture Focal Species (RHJV 2004) such as Common Yellowthroat (*Geothlypis trichas*) and Song Sparrow (*Melospiza melodia*) are significantly more abundant on a per acres basis at sites where restoration has occurred, compared to sites still in row crops or pasture (DWR, unpublished data 2014). Additionally, special status species such as Yellow-breasted Chat (*Icteria virens*) and Willow Flycatcher (*Empidonax traillii*), while absent at sites in active agriculture or pasture, have been detected at restored sites. The following Charts show data analysis graphically. Statistical data analysis is available upon request.

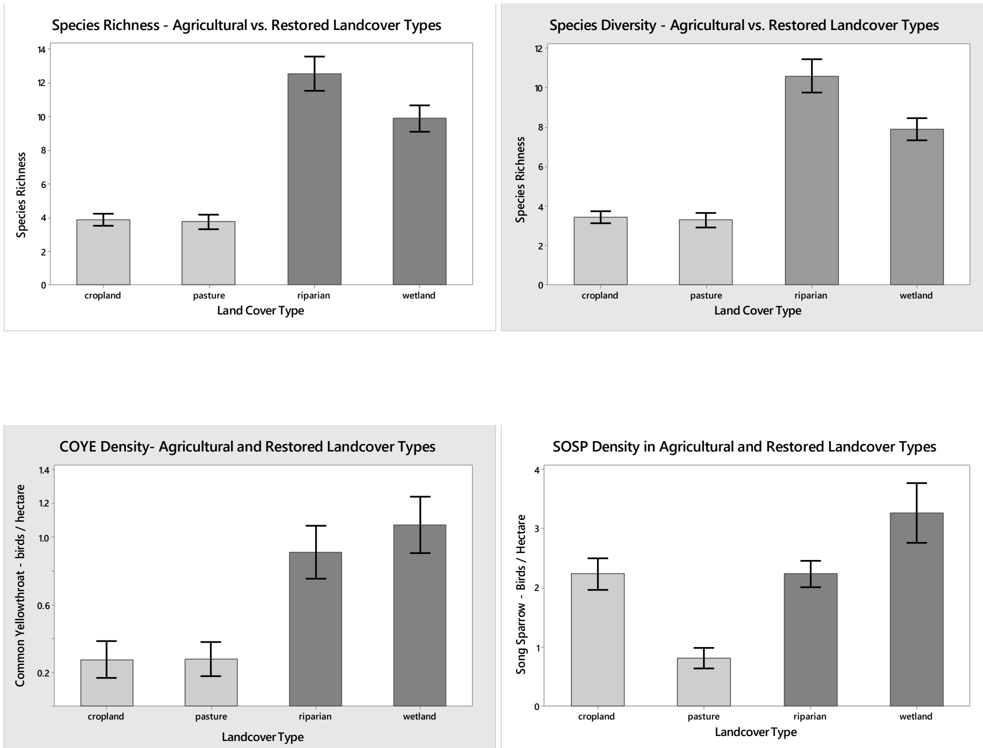

FIGURE 3-1 EFFECTS OF LAND COVER TYPES ON BIRD OBSERVATION ON SITE

The above data is in addition to informal observational data by DWR biologists showing increased populations throughout the year of several hawk, shorebird, owl, and waterfowl species. Additionally, DWR biologists have seen waterfowl nesting and associated increase of duck and geese populations at the wetland sites versus agricultural sites. Lastly, this project will provide increase habitat for protected species including Giant Garter Snake, Western Pond Turtle, Swainson's Hawk, and other migratory birds. DWR biologist will continue to monitor this site and provide comparative analysis for before and after project implementation.

TABLE 3-1 SHERMAN ISLAND WETLAND RESTORATION METRICS AND MONITORING

Objective	Measurement Method	Target	Adaptive Management Practice
1) Tule Coverage	Aerial photography will be used to determine the % vegetative cover within the wetland cells.	- 10% coverage by year 2 - 30% coverage by year 3 - 50% coverage by year 4 - 75% coverage by year 5	Based upon measurements, water levels within the will be manipulated to achieve optimal vegetative growth.
2) GreenhouseGas sequestration	Eddy Covariance measurements for CO_2 and CH4.	- Net GHG sequestration by end of year 3	Based upon measurements, consultation with researchers will be conducted and a strategy to achieve goals will be implemented.
3) Subsidence Reversal	Survey elevations will be taken at specific points within the project area and annual elevation measurements will be obtained to determine accretion rates.	- Elevation gains on average of 1" per year over a 10-year period	Based upon data, consider water level and Tule coverage options to maximize accretion rates.
Additional Project Benefits			
4) Invasive Plant Species	Quarterly inspection of entire site by qualified personnel.	- Limit invasive plant species within project site.	Work with PCA to determine appropriate herbicide treatment for invasive based upon field inspections. Evaluate health and coverage of intended ground covers and replant if needed.
5) Avian Response	Periodic bird surveys to determine both abundance and species diversity within the project area.	- Increase in avian population and species varieties over baseline performance.	Work with biologists to determine habitat response and changes needed to encourage improvements in both abundance and diversity.

4. Data Quality, Management, and Dissemination

Standard operating procedures (SOPs) documented in the Framework for all field sampling, laboratory processing, and data entry activities will be used. When possible, the SOPs used will be comparable to those of long-term regional monitoring programs to maximize data comparability. Metadata will be documented at all stages of data collection and processing and stored in standard formats along with the data. All data manually entered into the database will be cross-checked for transcription errors. Spurious data points will be identified using raw data scatter and box-and-whisker plots, and outliers identified by this method will be dealt with on a case-by-case basis, with full records of any changes. Project monitoring annual reports will include summaries of all monitoring data, along with any analyses completed to-date. Data, their summaries, and/or reports may also be shared with other researchers and the public via the CDFW FTP site, and one or more wetland inventories or hubs (e.g. BIOS, EcoAtlas, and Estuarine Portal). Data will be shared as soon as reasonably possible after collection.

5. Restoration Objectives: Intervention Thresholds and Responses

While it is not anticipated that major modification to the site will be needed, an objective of this plan is to guide monitoring to identify any thresholds that may compromise the Project objectives, and to propose potential management responses or further focused monitoring efforts. Table 3-1 summarizes the Project objectives, the expected outcomes related to those objectives, the metrics by which progress towards meeting the objectives is measured, as well as thresholds for undertaking a management response if goals are not being met or problems occur which require intervention.

6. Responsible Parties

DWR is the party responsible for ensuring execution of the restoration, management, and certain monitoring of the site. Generally, DWR is responsible for ensuring management and monitoring activities are completed, maintaining records, reporting, and coordinating and approving any research activities proposed on the site. DWR will plan, permit if necessary, and execute any potential management actions deemed necessary in consultation with the technical advisory committee.

Various groups within DWR, as well as qualified consultants, are responsible for specialized monitoring as described in this plan. The monitoring biologists shall be familiar with wetland biology and have knowledge relative to monitoring protocols, management techniques, endangered species needs, and general ecology.

7. References

American Public Health Association (APHA). 2017. Standard methods for the examination of water and wastewater, 23 edition. American Public Health Association, American Water Works Association, and Water Environment Federation.

Baxter, R., R. Breuer, L. Brown, L. Conrad, F. Feyrer, S. Fong, K. Gehrts, L. Grimaldo, B. Herbold, P. Hrodey, A. Mueller-Solger, T. Sommer, and K. Souza. 2010. Pelagic organism decline work plan and synthesis of results through August 2010. Interagency Ecological Program for the San Francisco Estuary, Sacramento, CA.

Brown, T. 2009. Phytoplankton Meta Data. IEP Bay-Delta Monitoring and Analysis Section, Department of Water Resources, Sacramento, CA.

Campisano, R., K. Hall, J. Griggs, S. Willison, S. Reimer, H. Mash, M. Magnuson, L. Boczek, and E. Rhodes. 2017. Selected Analytical Methods for Environmental Remediation and Recovery (SAM) 2017. U.S. Environmental Protection Agency,, Washington, DC.

CDFW. 2009. California Endangered Species Act Incidental Take Permit No. 2081-001-03 on Department of Water Resources California State Water Project Delta Facilities and Operations. California Department of Fish and Game (Now Fish and Wildlife), Sacramento, CA.

CDFW. 2017. Bay Delta Region Studies and Surveys. www.dfg.ca.gov/delta/data

CDWR, and CDFW. 2012. Fish Restoration Program Agreement Implementation Strategy: Habitat Restoration and Other Actions for Listed Delta Fish. Department of Water Resources and Department of Fish and Game in coordination with the US Fish and Wildlife Service and the National Marine Fisheries Service, Sacramento, CA.

Contreras, D., R. Hartman, S. Sherman, A. Furler, and A. Low. 2016. Pilot study phase I: Results from 2015 gear methodology trials in the North Delta. California Department of Fish and Wildlife, Fish Restoration Program, Stockton, CA. Available online. http://www.water.ca.gov/environmentalservices/docs/frpa/frp_monitoring_pilot_phase_I_final_report.pdf

Contreras, D., R. Hartman, S. Sherman, and A. Low. 2017. Pilot study phase II: Results from 2016 gear evaluation in the North Delta. California Department of Fish and Wildlife, Fish Restoration Program, Stockton, CA. Available online. https://water.ca.gov/LegacyFiles/environmentalservices/docs/frpa/pilot_phase_II_report_FINAL_3MAY2017.pdf

Contreras, D., R. Hartman, S. Sherman, and A. Low. 2018. Sampling fish and invertebrate resources in tidal wetlands of the Sacramento-San Joaquin Delta. California Department of Fish and Wildlife, Fish Restoration Program, Stockton, CA.

Delta Independent Science Board. 2016. Improving Adaptive Management in the Sacramento-San Joaquin Delta. Delta Stewardship Council, Sacramento, CA. http://deltacouncil.ca.gov/docs/delta-stewardship-council-february-25-2016-meeting-agenda-item-12-attachment-1-improving.

Deverel SJ, Lucero CE, Bachand S. 2015. Evolution of Arability and Land Use, Sacramento–San Joaquin Delta, California. San Franc Estuary Watershed Sci [Internet]. [cited 2016 Nov 22];13(2). Available from: http://escholarship.org/uc/item/5nv2698k https://doi.org/10.15447/sfews.2015v13iss2art4

Deverel, Steven J.; Ingrum, Timothy; Lucero, Christina; & Drexler, Judith Z.(2014). Impounded Marshes on Subsided Islands: Simulated Vertical Accretion, Processes, and Effects, Sacramento-San Joaquin Delta, CA USA. San Francisco Estuary and Watershed Science, 12(2). jmie_sfews_12893. Available from: http://escholarship.org/uc/item/0qm0w92cibid 5

Deverel SJ, Bachand S, Brandenberg SJ, Jones CE, Stewart JP, Zimmaro P. 2016b. Factors and Processes Affecting Delta Levee System Vulnerability. San Franc Estuary and Watershed Sci [Internet];14(4). Available from: http://escholarship.org/uc/item/36t9s0mp https://doi.org/10.15447/sfews.2016v14iss4art3

Deverel SJ, Oikawa P, Dore S, Mack S, Silva, L. 2017. Restoration of California deltaic and coastal wetlands, Version 1.0. April 201. American Carbon Registry. Available from: http://americancarbonregistry. org/carbon-accounting/standards-methodologies/ restoration-of-california-deltaic-and-coastal-wetlands

Drexler JZ. 2011. Peat formation processes through the millennia in marshes of the Sacramento–San Joaquin Delta, CA, USA. Estuaries Coasts 34:900–911.

DWR and DFG. 2010. Agreement between the Department of Water Resources and the Department of Fish and Game regarding implementation of a Fish Restoration Program in satisfaction of federal biological opinions for the State Water Project Delta Operations. California Department of Water Resources and California Department of Fish and Game, Sacramento, CA. https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=40849&inline.

DWR, C. 2013. Methylmercury Import and Export Studies on Tidal Wetlands In the Sacramento-San Joaquin Delta and Yolo Bypass. California Department of Water Resources Sacramento.

Feyrer, F., B. Herbold, S. A. Matern, and P. B. Moyle. 2003. Dietary shifts in a stressed fish assemblage: Consequences of a bivalve invasion in the San Francisco Estuary. Environmental Biology of Fishes 67(3):277-288.

Fischenich, C. 2001. Stability Thresholds for Stream Restoration Materials. Ecosystem Management and Restoration Branch Program Technical Notes Collection (ERDC TNEMRRP-SR-29), U.S. Army Engineer Research and Development Center, Vicksburg, MS.

Gewant, D., and S. M. Bollens. 2012. Fish assemblages of interior tidal marsh channels in relation to environmental variables in the upper San Francisco Estuary. Environmental Biology of Fishes 94:483-499

.

Gould, A. L., and W. J. Kimmerer. 2010. Development, growth, and reproduction of the cyclopoid copepod *Limnoithona tetraspina* in the upper San Francisco Estuary. Marine Ecology Progress Series 412:163-177.

Grimaldo, L. F., A. R. Stewart, and W. Kimmerer. 2009. Dietary segregation of pelagic and littoral fish assemblages in a highly modified tidal freshwater estuary. Marine and Coastal Fisheries: Dynamics, Management and Ecosystem Science 1:200-217.

Grimaldo, L., F. Feyrer, J. Burns, and D. Maniscalco. 2017. Sampling uncharted waters: Examining rearing habitat of larval Longfin Smelt (*Spirinchus thaleichthys*) in the Upper San Francisco Estuary. Estuaries and Coasts 40:1771-1784.

Hasenbein, M., L. M. Komoroske, R. Connon, J. Geist, and N. A. Fangue. 2013. Turbidity and Salinity Affect Feeding Performance and Physiological Stress in the Endangered Delta Smelt. Integrative and Comparative Biology 53(4):620-634.

Hemes et al. 2019, Assessing the carbon and climate benefit of restoring degraded agricultural peat soils to managed wetlands, Agricultural and Forest Meteorology, 268, 202-214

Hennessy, A. 2009. Zooplankton Meta Data. IEP Bay-Delta Monitoring and Analysis Section, Department of Water Resources, Sacramento, CA.

Herbold, B., D. M. Baltz, L. Brown, R. Grossinger, W. Kimmerer, P. Lehman, C. S. Simenstad, C. Wilcox, and M. Nobriga. 2014. The role of tidal marsh restoration in fish management in the San Francisco Estuary. San Francisco Estuary and Watershed Science 12(1). http://www.escholarship.org/uc/item/1147j4nz.

Hickson, D., and T. Keeler-Wolf. 2007. Vegetation and land use classification and map of the Sacramento-San Joaquin River Delta. Vegetation Classification and Mapping Program , California Department of Fish and Game, Bay-Delta Region.

Howe, E. R., C. A. Simenstad, J. D. Toft, J. R. Cordell, and S. M. Bollens. 2014. Macroinvertebrate prey availability and fish diet selectivity in relation to environmental variables in natural and restoring North San Francisco Bay tidal marsh channels. San Francisco Estuary and Watershed Science 12(1). http://www.escholarship.org/uc/item/0p01q99s.

IEP Tidal Wetland Monitoring Project Work Team (PWT). 2017a. Tidal wetland monitoring framework for the upper San Francisco Estuary: Monitoring plan guidance. https://www.water.ca.gov/-/media/DWR-Website/Web-Pages/Programs/Environmental-Services/Interagency-Ecological-Program/Files/Tidal-Wetland-Monitoring-Framework-for-the-Upper-San-Francisco-Estuary.pdf?la=en&hash=5668D6D21C50D0A666919680FB5EE825FC9C57BE.

IEP Tidal Wetland Monitoring Project Work Team (PWT). 2017b. Tidal wetland monitoring framework for the upper San Francisco Estuary: Standard Operating Procedures.

https://www.water.ca.gov/-/media/DWR-Website/Web-Pages/Programs/Environmental-Services/Interagency-Ecological-Program/Files/Standard-Operating-Procedures.pdf?la=en&hash=0692951CEC5D0C897C53120475421A79C7ED648D.

Knox SH, Sturtevant C, Matthes JH, Koteen L, Verfaillie J, Baldocchi DD. 2015. Agricultural peatland restoration: effects of land-use change on greenhouse gas (CO2 and CH4) fluxes in the. Sacramento–San Joaquin Delta. Glob Change Biol 21(2):750-765. https://doi.org/10.1111/gcb.12745

Lehman, P., K. Marr, G. Boyer, S. Acuna, and S. Teh. 2013. Long-term trends and causal factors associated with *Microcystis* abundance and toxicity in San Francisco Estuary and implications for climate change impacts. Hydrobilogia 718:141-158.

Lehman, P. W., S. Mayr, L. Mecum, and C. Enright. 2010. The freshwater tidal wetland Liberty Island, CA was both a source and sink of inorganic and organic material to the San Francisco Estuary. Aquatic Ecology 44(2):359-372. http://dx.doi.org/10.1007/s10452-009-9295-y.

Lowe, S. 2002. Data Collection Protocol Tidal Marsh Benthic Community, Wetlands Regional Monitoring Program Plan 2002. S. F. E. Institute, editor, Richmond, CA.

Lucas, L. V., and J. K. Thompson. 2012. Changing restoration rules: Exotic bivalves interact with residence time and depth to control phytoplankton productivity. Ecosphere 3(12):art117. http://dx.doi.org/10.1890/ES12-00251.1.

Maier, G. O., and C. A. Simenstad. 2009. The role of marsh-derived macrodetritus to the food webs of juvenile Chinook salmon in a large altered estuary. Estuaries and Coasts 32(5):984-998.

Miller RL, Fram MS, Wheeler G, Fujii R. 2008. Subsidence reversal in a re-established wetland in the Sacramento– San Joaquin Delta, California, USA. San Franc Estuary Watershed Sci [Internet]. [cited 2013 June 20];6(3). Available from: http://escholarship.org/uc/ item/5j76502x https://doi.org/10.15447/sfews.2008v6iss3art

Moyle, P. B., J. R. Lund, W. A. Bennett, and W. E. Fleenor. 2010. Habitat variability and complexity in the Upper San Francisco Estuary. San Francisco Estuary and Watershed Science 8(3). http://www.escholarship.org/uc/item/0kf0d32x.

Mueller-Solger, A. B., C. J. Hall, A. D. Jassby, and C. R. Goldman. 2006. Food resources for zooplankton in the Sacramento-San Joaquin Delta.

National Marine Fisheries Service. 2009. Biological Opinion and Conference Opinion on the long-term operations of the Central Valley Project and the State Water Project. National Marine Fisheries Service, Long Beach, CA.

National Marine Fisheries Service. 2014. Recovery plan for the evolutionarily significant units of Sacramento River Winter-run CHinook Salmon and Central Valley Spring-run Chinook Salmon and the distinct population segment of California Central Valley Steelhead. California Central Valley Area Office. July 2014.

Reynolds, C.S. 1997. Vegetation Processes in the Pelagic. A Model for Ecosystem Theory. Ecology Institute, D-21385 Oldendorf/Luhe, ISSN 0932-2205.

RMA. 2015. Initial Modeling of Local and Regional Impacts of the Proposed Winter Island Tidal Marsh Restoration. Technical Memorandum. Resource Management Associates, Davis, CA.

Robinson, A., S. Safran, J. Beagle, R. Grossinger, and L. Grenier. 2014. A Delta Transformed: Ecological Functions, Spatial Metrics, and Landscape Change in the Sacramento-San Joaquin Delta. San Francisco Estuary Institute-Aquatic Science Center, 729, Richmond, CA.

Roegner, G. C., H. L. Diefenderfer, A. B. Borde, R. M. Thom, E. M. Dawley, A. H. Whiting, S. A. Zimmerman, and G. E. Johnson. 2008. Protocols for monitoring habitat restoration projects in the lower Columbia River and estuary.

[SFEI–ASC] San Francisco Estuary Institute–Aquatic Science Center. 2014. A Delta Transformed: Ecological

Functions, Spatial Metrics, and Landscape Change in the Sacramento-San Joaquin Delta. [Internet]. [accessed 2015 December 16]. A Report of SFEI-ASC's Resilient Landscapes Program. Publication #729. Richmond (CA): San Francisco Estuary Institute-Aquatic Science Center. Available from: http://www.sfei.org/sites/default/files/ DeltaTransformed_SFEI_110414.pdf

Sherman, S., R. Hartman, and D. Contreras, editors. 2017. Effects of Tidal Wetland Restoration on Fish: A Suite of Conceptual Models. Department of Water Resources, Sacramento, CA.

Simenstad, C., J. Toft, H. Higgins, J. Cordell, M. Orr, P. Williams, L. Grimaldo, Z. Hymanson, and D. Reed. 2000. Sacramento/San Joaquin Delta Breached Levee Wetland Study (BREACH) Preliminary Report, Seattle, WA.

Slater, S. B., and R. D. Baxter. 2014. Diet, prey selection and body condition of age-0 Delta Smelt, *Hypomesus transpacificus*, in the upper San Francisco Estuary. San Francisco Estuary and Watershed Science 14(4).

Sommer, T. R., W. C. Harrell, A. M. Solger, B. Tom, and W. Kimmerer. 2004. Effects of flow variation on channel and floodplain biota and habitats of the Sacramento River, California, USA. Aquatic Conservation 14(3):247-261.

Sommer, T. R., M. L. Nobriga, W. C. Harrell, W. Batham, and W. J. Kimmerer. 2001. Floodplain rearing of juvenile chinook salmon: Evidence of enhanced growth and survival. Canadian Journal of Fisheries and Aquatic Sciences 58(2):325-333.

United States Fish and Wildlife Service. 2008. Formal Endangered Species Act Consultation on the Proposed Coordinated Operations of the Central Valley Project (CVP) and State Water Project (SWP). United States Fish and Wildlife Service, Sacramento, California.

Utermöhl, H. 1958. Methods of collecting plankton for various purposes are discussed. SIL Communications, 1953-1996 9(1):1-38. https://doi.org/10.1080/05384680.1958.11904091.

Wells, E. 2015. IEP Environmental Monitoring Program Benthos Metadata. C. D. o. W. Resources, editor. Division of Environmental Services, Bay-Delta Monitoring and Analysis Section, West Sacramento, CA. http://www.water.ca.gov/bdma/meta/benthic.cfm.

Whitley, S. N., and S. M. Bollens. 2014. Fish assemblages across a vegetation gradient in a restoring tidal freshwater wetland: diets and potential for resource competition. Environmental Biology of Fishes 97(6):659-674. http://search.proquest.com/docview/1518010595?accountid=147320.

Zedler, J. B. 2005. Ecological restoration: guidance from theory. San Francisco Estuary and Watershed Science 3(2):31.

Appendix A – Habitat and Water Management Plan

HABITAT AND WATER MANAGEMENT PLAN
Sherman Island Belly Wetland Habitat Restoration Project

Prepared By:
California Department of Water Resources

and

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December 2018

INTRODUCTION

The **Sherman Island's Belly Wetland Habitat Restoration Project (Project)** will create approximately 1000 acres of permanently flooded wetlands on Sherman Island. The Project will be located on property owned by the Department of Water Resources (DWR; Figure 1). The goals of the project are:

- ☐ Control and reverse subsidence by using permanent flooding techniques;
- ☐ Create wetland and riparian habitat and monitor biological enhancement;
- ☐ Provide carbon sequestration benefits and evaluate the net greenhouse gas (GHG) benefits by restoring permanently flooded emergent wetlands on highly organic soils;
- ☐ Demonstrate the applicability of tested management practices to Delta and Suisun Marsh.

The Project will provide subsidence reversal benefits and develop knowledge that can be used by operators of private wetlands, including "duck clubs," which manage lands for waterfowl-based recreation. By maintaining permanent water, the growth and subsequent decomposition of emergent vegetation is expected to control and reverse subsidence. The project is expected to provide year-round wetland habitat for waterfowl and other wildlife.

To achieve final restoration goals, these wetlands will be managed through a system of water supply structures (including siphons, ditches, and swales), berms to provide proper water management depths and site access, and water outflow control structures. Proper water management is critical for establishing and maintaining healthy habitat conditions in all managed wetlands. Managing water for the appropriate time of application, duration of inundation, and depth are the three key factors to support the desired vegetation and wildlife communities in a managed marsh. The restored permanent wetlands will require regular and attentive water deliveries, draw downs, and overall management to achieve the project's goals.

Throughout the year, water levels will be managed to encourage the establishment and maintenance of annual, perennial, emergent, and submerged aquatic vegetation. Subsequently, these vegetation communities will provide habitat for a variety of wetland dependent wildlife. Water management provides the means to vary water levels within and between units to distribute nutrients, decrease stagnant conditions, provide quality habitat, and minimize vector production.

PROJECT SUMMARY

The Project Site is located on Sherman Island, in southwest Sacramento County, CA and is shown on the Antioch North, CA USGS topographic quadrangle. This un-sectionalized portion of Sherman Island would be considered to be generally located within Sections 4, 5, 8, and 9, Township 2N Range 2E. This land is owned by the Department of Water Resources (DWR).

Sherman Island is approximately 10,000-acre Island in the western Delta approximately 70 mi southwest of the City of Sacramento. Historically, the project area was a marsh that was diked off from the Sacramento River and drained between 1850 and 1873 to facilitate agriculture. As a result of more than 130 years of farming practices, irrigation, and exposure of soils to air, the project area has subsided as much as 20 ft. A high water table currently makes the Project Site unsustainable as a long-term agricultural area.

Before the Delta was diked, drained, and farmed, it was subject to significant seasonal fluctuations in freshwater inflows, which worked in concert with large tidal ranges. Natural levees were formed by sediments deposited during spring floods and stabilized by vegetation. Dominant vegetation within the natural levees included tules - marsh plants that live in fresh and brackish water. Decomposing tules and reed vegetation formed the peat soils over thousands of years. In waterlogged conditions, decaying tules decompose slowly to release carbon dioxide and methane, which is trapped in the soils by water. Once the soil was diked and then dried, the peat soils decompose, which leads to subsidence.

Subsidence has reduced the distance from the soil surface to the water table. The resulting high water table makes the Site unsustainable for crop production, although much of the Site is currently used for corn production and pasture.

Recent environmental concerns in the Delta have prompted DWR to re-evaluate how properties in the region are managed. DWR is particularly interested in incorporating land-use practices that reduce or reverse subsidence. Research has shown that wetlands that are permanently flooded halt and can reverse subsidence, as well as sequester GHG. Therefore, DWR is interested in restoring the entire project site back to the palustrine emergent wetland type that existed in the early part of last century. In addition, subsidence reversal and GHG in the project area will be monitored and evaluated with the hope of undertaking similar projects elsewhere in the Delta. Management of the restored wetlands will be undertaken by DWR and/or a wetland manager.

The project will restore palustrine emergent wetlands and enhance existing emergent wetlands on site by upgrading existing and installing new water management infrastructure including berms, seasonally flooded islands, water control structures, and water conveyance channels on site.
When the project is completed, water will be maintained in the project area year-round. Restoring permanent wetlands on Delta islands has been shown to halt and reverse subsidence. This project will combine the wildlife benefits of wetland restoration with the importance of reversing Delta island subsidence. Construction activities and earthwork associated with the project will be performed between the months of May and October. Planting will commence during the fall months and continue through spring. Work will be completed within the Site.

Proper water management is critical for maintaining healthy habitat conditions in all managed wetlands. This permanent wetland will require regular and attentive water deliveries, draw downs, and overall management to achieve the project goals. Water depths, duration of inundation, and timing of flooding are the three key features of water management and all contribute to support the desired vegetation and wildlife communities.

WATERFOWL REQUIREMENTS

The Project will be managed to provide a variety environmental functions and values. One of those is wildlife habitat, particularly for breeding and wintering waterfowl. This project differs from other traditional Central Valley waterfowl areas in that it has been designed to maintain permanent vegetation and open water areas throughout. While permanent emergent wetlands are less productive for wintering waterfowl than seasonal wetlands, permanent emergent wetlands provide greater benefit for breeding waterfowl.

Breeding Season

California's breeding duck population is dominated by mallards, although wood ducks, gadwall, and cinnamon teal ducks are also common nesters in the Central Valley. These dabbling ducks need three primary habitat types for successful breeding: pair water, upland nesting areas, and brood water. When properly managed, the site will have an appropriate mixture of permanent wetland vegetation and open water with adjacent upland nesting habitats to encourage waterfowl reproduction.

Pair water refers to habitats used by breeding ducks while establishing territories and accumulating fat and protein reserves prior to nesting. These areas are typically used as brood ponds later in the season. Pair water typically consists of shallow ponds adjacent to upland nesting areas that have abundant invertebrate populations.

Waterfowl nesting occurs between early March and mid-June in upland vegetation adjacent to permanent water. Desirable nesting cover for most waterfowl consists of robust vegetation of approximately 12 inches or more in height within several hundred feet of permanent water. Although hens rely primarily on body reserves for energy during nesting, they do take "nest breaks" to feed.

Upon successfully hatching a clutch, hens lead their hatchlings to nearby brood water. Here, hens rely on invertebrates as their primary food source for rebuilding body mass depleted from egg laying, while ducklings rely on invertebrates for the next several months during their period of rapid growth prior to fledging. Wetlands with adequate cover and abundant invertebrate food supplies are necessary for optimal hatchling survival. Relatively tall wetland plants such as cattails (*Typha* sp.), tules (*Schoenoplectus acutus* or *californicus*), and other robust emergent vegetation provide cover for many species of wildlife, particularly young ducklings, which need to be able to escape predators.

Wintering Season

Upwards of 4 to 5 million waterfowl winter in the Central Valley. While the areas of the Sacramento Valley near the Sutter Buttes and the Grasslands region of the San Joaquin Valley traditionally support the majority of these birds, wetland habitats in the Delta region are also important. The most productive habitat for wintering waterfowl in the Central Valley is managed seasonally flooded marsh, or moist soil wetlands. These managed habitats support abundant high-calorie seed sources.

Wintering waterfowl have two main habitat requirements: areas with high-calorie foods and resting areas. The Delta region was historically permanently flooded marsh with dense emergent vegetation. This vegetation was dominated by hard-stem bulrush, or tules. While tules do not produce as many energy rich seeds as seasonal wetland plants, they nevertheless provide quality food sources and sheltered resting areas that are protected from storms and predators. Other quality plant food sources in permanent wetlands are submerged aquatic vegetation including widgeon grass and sago pondweed. These plants grow in deeper water than emergent vegetation and have extremely rich seeds, tubers, and associated invertebrate food resources.

Dense tule stands can also provide sheltered rest areas that are protected from storms and predators. Ponds, sloughs, and channels lined with tules are good foraging areas and also make excellent resting areas.

These food sources supply the energy needed to replenish waterfowl body fat reserves following fall migration and to build additional fat reserves to fuel the upcoming spring migration. Wintering waterfowl need to conserve energy as much as possible. Waterfowl that are frequently disturbed lose energy quickly from the demands of taking flight.

WATER MANAGEMENT INFRASTRUCTURE AND MAINTENANCE

Infrastructure

The Project site is divided into four separate wetland management units (Figure 3). Each unit is separated from the other units and the adjacent properties by a berm. This allows for flexibility for maintaining, raising, or drawing down water within and between each unit.

Approximately 1,200,000 cubic yards of material will be redistributed within the site, which is necessary to sculpt the swales and to create berms for this wetland habitat area. Approximately 35 water control structures will be installed. The interior of the site will be divided up into as many as 12 managed wetland units separated by approximately 75,000 lineal feet of proposed interior berms, and crossed with excavated conveyance swales, in order to facilitate appropriate water and vegetation management capabilities. Water levels in each unit will be managed independently to restore the desired emergent wetland conditions throughout the site. When the Project is completed, water is proposed to be maintained on the Project Site year-round, effectively creating a permanent wetland.

Water will be conveyed within the wetland system via gravity flow from the higher elevation units to the lower elevation units until it finally makes its way back to the District's drainage canal, to the east of the project boundary. The ultimate outcome of the restoration project will be approximately 1000 acres of freshwater emergent wetlands. Each wetland unit will be a mosaic of open water channels and emergent vegetation comprised predominantly of species such as California bulrush (*Schoenoplectus californicus*) and narrow leaved cattails (*Typha angustifolia*). Other native plant restoration components will include installation of native trees and shrubs compatible with their respective hydrologic regime as well as a substantial amount of upland transitional area, all of which will provide great diversity and increased habitat opportunity for wildlife.

Interior water conveyance channels will be excavated in the wetland management units to provide water delivery and circulation to all areas of the Site. The conveyance channels will provide numerous wetland and wildlife benefits to the project area. Material excavated to construct the channels will provide material for the buttress berm and the interior and perimeter berms. Construction of conveyance channels will convert existing wetland and upland areas into permanent open water that will facilitate water conveyance.

The channels will be managed to encourage the growth of submerged aquatic and floating wetland vegetation and discourage the growth of invasive species. Open water areas will provide waterfowl with areas to land, loaf, and feed. It is anticipated that the presence of permanent open water will increase the amount of waterfowl breeding and brood rearing in the project area. Conveyance channels will have an approximately 30-ft wide bottom with 5:1 side slopes.

Most of the existing agricultural drainage ditches on Sherman Island have rectangular configurations. These existing drainage ditches will be regraded to provide a more gradual side slope. A gradual swale side slope will allow for easy wildlife movement across the ditches and swales while reducing swale erosion by encouraging vegetation growth along the swale's edges. Depth of swale excavation will vary depending on existing topography, however swales are generally designed to a depth of 2.5 feet below existing ground surface.

In addition to the channels, larger open water areas will also be created through excavation. These larger open water areas will be connected to the conveyance channels and have the same bottom elevations. They will serve as waterfowl brood rearing areas in the spring and loafing/storm-shelter locations in the winter. Material borrowed from these areas will be incorporated into the interior and perimeter berms or used to construct loafing islands.

The water source to the 10 wetland units east of Sherman Island Crossing Road will be delivered by four existing gravity siphons along the San Joaquin River Levee and five newly installed water control structures from the Overland Water Delivery Canal. At this time, it is anticipated that siphons 13, 15, 19 and 20 will be utilized as the primary source of water to the southern edge of these units. Each of these siphons are constructed of 12-inch diameter pipe that is reportedly capable of providing approximately 2,500 gallons per minute. All of these siphons currently have operational fish screens to ensure fish are not entrained within the newly constructed wetland.

It is anticipated that newly installed water control structures 25, 26, 35, 43, and 44 will be utilized as the primary source of water to the northern edge of these units. The water control structures will each include a 12-inch polyvinyl chloride (PVC) pipe that will draw water from the Overland Water Delivery Canal and convey it via gravity flow to the newly constructed wetland units. The Canal is fed by 3 existing siphons on the Sacramento River Northwest of the project site adjacent to Decker Island. All siphons feeding this Canal have operating fish screens, as well.

Water to the 2 wetland units west of Sherman Island Crossing Road will be delivered by one existing gravity siphon along the San Joaquin River Levee. At this time, it is anticipated that siphon 21 will be utilized as the primary source of water to the southern edge of these units. Siphon 21 is constructed of a 12-inch diameter pipe that is reportedly capable of providing approximately 2,500 gallons per minute. This siphon also has an operating fish screen.

Water will be conveyed within the wetland system via gravity flow from the higher elevation units to the lower elevation units until it finally makes its way back to the District's pump station along the southern boundary of the Project.

Improvements to the outlet of the functional siphon may include replacing outlet valves, installing flow meters, and installing additional appurtenances as needed to improve the control of the water supply to the Site. All siphon improvements will take place on the interior (land) side of the San Joaquin River levee. Water delivered to the Site will circulate through the system to maintain appropriate water quality conditions and prevent stagnation.

Several existing agricultural drainage ditches occur within the interior and exterior of the Site. These ditches connect to the master drainage system of the southeastern portion of Sherman Island. The drainage ditches within the proposed project boundaries will be incorporated into the internal water conveyance system (swale system). A ditch along the exterior perimeter of the restoration area will be constructed to provide drainage from the surrounding landscape, and will include proper drainage for the District's toe ditches.

Maintenance

The project's water management infrastructure is designed for durability although some annual and regular maintenance will be required. The siphons will be inspected frequently (several times a week during irrigation months) to maintain efficient operation. Flash board riser water control structures will require periodic inspections to maintain proper and efficient water management.

Both interior and exterior berms must be inspected for evidence of erosion around water control structures and outlet pipes. Additional inspection of berms and levees is required to identify any holes. Animal burrows and other holes should be repaired and filled immediately to prevent berm failure. Drainage and supply ditches will be maintained and cleaned as needed to allow for efficient water flow.

WATER MANAGEMENT GUIDELINES

Proper water management in any managed wetland is essential for providing quality wetland conditions that support the desired functions and values. Water depths, timing, and duration of inundation, dictate the vegetation community present in any wetland. In a managed wetland, a pre-determined hydrologic regime can be implemented to produce a particular vegetation community and provide the conditions necessary to support the desired wildlife community.

Desired Wetland Condition

Proper vegetation composition and distribution is necessary for controlling subsidence, sequestering GHG, and minimizing vector production. For this project, the optimal vegetation community will be composed of a mixture of cattails and bulrush as these plants are adapted to withstand persistent flooded conditions. Vegetation density should be maximized to control and reverse subsidence. Conversely, open areas are desirable for waterfowl habitat and vector control. To balance these objectives, the established wetland vegetation community should have up to 70% vegetative cover to provide sufficient open water pathways throughout the entire site. Each wetland management unit will have a varying ratio of vegetation to open water depending on ground elevations and maximum water surface elevations.

A permanently flooded wetland structure achieves multiple objectives. Subsidence control and reversal is achieved through persistent flooded conditions and robust emergent vegetation.
Wildlife habitat is improved by providing a diverse mixture of open water and vegetation. Mosquito and

vector control is facilitated with multiple open water areas, which provides access for treatment. Waterfowl hunting is facilitated by providing foraging areas, hunter access throughout the marsh, and providing waterfowl resting areas.

Water Depths, Duration, and Timing

The project will be managed to achieve a relatively constant water level that will provide the desired vegetation/ open water distribution. However, during the project's first year, water will be managed substantially different than subsequent years to encourage the rapid establishment of desirable wetland vegetation. Water depths for the first growing season will be managed to provide optimal germination conditions for cattails and tules on approximately 40% of the area of each wetland management unit. The first several months of the growing season will be critical for monitoring and evaluating the germination extent and rate. Water levels must be managed at first to encourage and then limit germination in order to achieve the desired vegetation to open water ratio.

Precise and careful management of unit water surface elevations is essential to prevent establishment of robust vegetation across the entire unit. When germination reaches the desired coverage, water levels will be raised to prevent additional germination while not drowning the new growth. During this time, germination will be evaluated weekly and water levels adjusted accordingly. If the desired vegetation coverage is not achieved during the first year, this procedure will be followed each successive year until the desired vegetation community is achieved.

Following the establishment of the desired vegetation community, water levels will be managed consistently on an annual basis to maintain wetland vegetation consistent with the project's goals.

Sherman Island Drainage System

Reclamation District 341 is responsible for the operation and maintenance of the drainage system within Sherman Island. This infrastructure consists of a network of drainage ditches and discharge pumps. The Project is part of the southeastern drainage sub-system for the Island. This ditch network collects surface and groundwater from the western half of Sherman Island then channels it to the pumping station on the southwestern side of the island and ultimate discharge into the Sacramento River. The ditches surrounding the project will drain into the existing main ditch on the eastern edge of the site and drain back into the District's main drainage canal. This ditch connects directly to the pump station (Figure 2).

VEGETATION MANAGEMENT

Regular maintenance of the desired wetland vegetation will be necessary following its successful establishment. The project's goal for a permanent wetland condition supporting quality wildlife habitat can only be achieved in the long-term through proper maintenance and management of both wetland and upland vegetation. Ideally, the project should require only minimal management of wetland vegetation and limited annual management of upland vegetation. The desired wetland vegetation community consists of approximately 70% vegetative cover from cattails and tules along with seasonal wetland vegetation located on the islands and submerged aquatic vegetation in the deeper water. The desired upland vegetation is perennial and annual grasses and forbs on the perimeter and interior berms and uplands.

Flooding for Emergent Vegetation

Wetland vegetation management through control of water depths is the most effective tool for controlling vegetation growth in permanent wetlands. This tool not only provides the conditions for optimal spread of desirable vegetation, but can also limit its spread to create the desired mixture of emergent vegetation to open water. In general, water depths of less than 12 inches during the growing season will promote seed germination and have little control of rhizomatous vegetation. Water depths in this range are optimal to encourage the growth of emergent vegetation. Water depths between 12 and 36 inches will prevent germination but allow for the spread of vegetation by rhizomes. Once the desirable vegetation community is established, water depths during the summer season should be maintained in this range to limit continued spread of emergent vegetation. Water depths of greater than 36 inches will prevent seed germination as well as the spread of emergent vegetation via rhizomes. Persistent water depths of greater than 36-inches during the growing season will eventually eliminate emergent vegetation from these deep flooded areas. Water depths in the conveyance channels should be maintained in this range to maintain water conveyance capabilities.

Draw Downs

Wetland drawdowns are an important management tool for permanent wetlands. Drawdowns reinvigorate wetland nutrient cycles and stimulate vegetation growth. A wetland under draw down conditions mimics a drought cycle. Drawdowns will depend on site conditions and may not be necessary for a period of up to 7 years following establishment of desired vegetation community. Within this time frame, the wetland units should be drawn down on a rotational basis where not more than one unit is drawn down at any one time. This will allow for adequate habitat to remain available on most of the site.

Beginning the fourth year following the establishment of the desired vegetation community, each wetland unit should be drawn down and completely dried on a rotating schedule for several months of the growing season (May through September). This management technique would occur every 5-7 years to reinvigorate the marsh, to control problematic vegetation by mowing or herbicide application, as a best management practice to limit mosquito production, and/or to repair berms and water control structures as needed.

Habitat Islands and Riparian Vegetation

Habitat islands are an important component of the Project. Islands have a diverse array of species, habitat structure and eco-tones. As such, careful consideration of flooding depths and duration must be evaluated for each unit during fluctuation of water levels. Generally, Tules respond faster to water fluctuations than trees or shrubs. Due to the rhizome root system, if Tules are flooded out by depths greater than 2.5-3 feet, populations can recover quickly by reducing the flooding depth and promoting new germination. However, with woody species the flooding tolerances are less. Generally, wetland tree and shrub species as well as riparian species prefer saturated to slightly inundated condition. Surface water conditions resulting in significant flooding of trees and shrubs for durations longer than a several days in the summer and a few weeks during the winter months may kill woody species permanently. This may be necessary for long term increases in water depths for subsidence reversal purposes. However, increases in water depths for non-native invasive species control and or promotion of other native wetland plant communities should be limited to the tolerable constraints of the woody species during normal practices. A good indicator of the limits of tolerable conditions can be noted by observing signs of stress from the trees and shrubs located in the deepest flooded areas of each unit. Signs of stress can include yellowing or browning of leaves, twig dieback or buds failing to open.

It is anticipated that over the course of many years, through accretion that the upland portions of habitat islands will eventually be transformed into wetland habitat. This planned natural progression will likely continue to provide habitat diversity as it will become a deciduous forested and deciduous scrub-shrub wetland habitat amongst a larger area of emergent wetland.

Irrigation of Islands

During hot summer months when irrigation water is readily available, increasing surface water elevations to irrigate habitat islands may be beneficial for tree, shrub and herbaceous species survival as well as non-native species control. After vegetation establishment, surface water elevations should be increased by 0.5 to 1 foot for about 1 week during summer months. The irrigations will also help control upland invasive species like Himalayan blackberry (*Rubus armeniacus*), perennial pepperweed (*Lepidium* sp.), and cocklebur (*Xanthium strumarium*).

Supplemental Planting

Mortality of planted woody species, generally between 20-50 percent, is common for restoration projects. It is very extremely important to replant areas that are prone to erosion in order to establish a diverse vegetative component throughout the project area. Supplementing transitional areas such as berms and islands with additional plantings can be achieved during normal maintenance of berms. Typically, willow tree and shrub branches will need to be trimmed along the access portions of the berms. This maintenance should be conducted during the late fall and winter months when possible. During these months branches can be cut into “Stakes” which can then be planted in areas where additional plantings are desired.

Mowing and Herbicides

Mechanical and chemical removal of problematic vegetation is an important component for habitat management. Wetland vegetation will need to be controlled if plant coverage expands beyond 80% or if the swales and potholes become overgrown with emergent vegetation. Aerial photos can be used to evaluate the percentage of vegetation coverage. Any unit with a vegetation problem will need to be drawn down and dried to allow mower access.

Upland vegetation on the tops of berm should be mowed annually to provide vehicular access to water control structures for regular maintenance, and access by larger equipment for special maintenance needs. Upland vegetation should not be mowed during the avian nesting season between March 1 and June 30.

Annual control of weedy vegetation will be required on annual basis to promote the desired wetland and upland vegetation communities and avoid and control exotic/invasive species. These exotic/invasive species include Himalayan blackberry (*Rubus armeniacus*), common reed (*Phragmites australis*), perennial pepperweed (*Lepidium* sp.), cocklebur (*Xanthium strumarium*), and other species as identified in the field. Each of these species has the capability to overtake both wetland and upland communities. Deeper water levels within the wetland area will help to control the spread of these species. These species can be problematic if not controlled vigorously along the edges of the wetland areas. In areas in which mowing is not practical, chemical control using an herbicide labeled for application in wet environments is recommended. Glyphosate formulated herbicides are effective for controlling annual weeds as well as common reed if applied correctly. Perennial pepperweed can be controlled with imazapyr or chlorsulfuron formulated herbicides. Himalayan blackberry can be controlled using triclopyr in dry areas. All herbicide applications must follow application rates and procedures identified on the packaging label, and will be applied by a certified/licensed applicator.

PEST MANAGEMENT

Pest management is often a necessary management activity for manipulated wetlands in the Central Valley and Sacramento-San Joaquin Delta regions. Mammalian and invertebrate pests can be problematic for the successful operation of the project and achieving the projects goals and must be controlled when warranted.

Mammals

Wetlands and riverine habitats in the Central Valley are preferred habitats for muskrats and beavers. These rodents can damage wetland management infrastructure by burrowing into berms, levees, and around water control structures. If left unchecked, these excavations can ultimately compromise the structural integrity of the water management infrastructure.

To minimize the potential damage these rodents can have on water management infrastructure, several of the berms have been designed with 3:1 side slopes. Gradual slopes limit burrowing activity compared with steep slopes such as a 1:1. In berms constructed at 3:1 slopes, annual inspection is necessary to fill any burrows.

Beavers are instinctively drawn to the sound of flowing water. When the source of the sound is located, beavers will attempt to build a dam and halt the flow of water. Water control structures will be cleared of any debris that may prevent adequate water flow.

Mosquitoes

Wetlands in the Central Valley and Sacramento-San Joaquin Delta are well known for their capabilities to produce mosquitoes. Because of its flooded pasture land uses, Sherman Island in particular produces some of the highest numbers of mosquito larvae in the western Delta. The island is within the Sacramento-Yolo Mosquito and Vector Control District (SYMVCD). The SYMVCD regularly inspects and controls mosquito larvae on the island using larvacide control methodologies. In an effort to minimize mosquito production from this project, the SYMVCD has been an active participant in the planning process.

With the current threat of West Nile and the potential spread of the H5N1 avian influenza, using water and habitat Best Management Practices (BMPs) to limit the growth and spread of mosquitoes is important. The BMPs included in Attachment B have been incorporated and utilized during the development and long-term management of the project to minimize the growth of mosquito populations.

Figure 1. Sherman Island Belly Wetland Restoration Project Site & Vicinity Map

Base maps: Jersey Island, CA USGS 7.5 minute topographic quadrangles

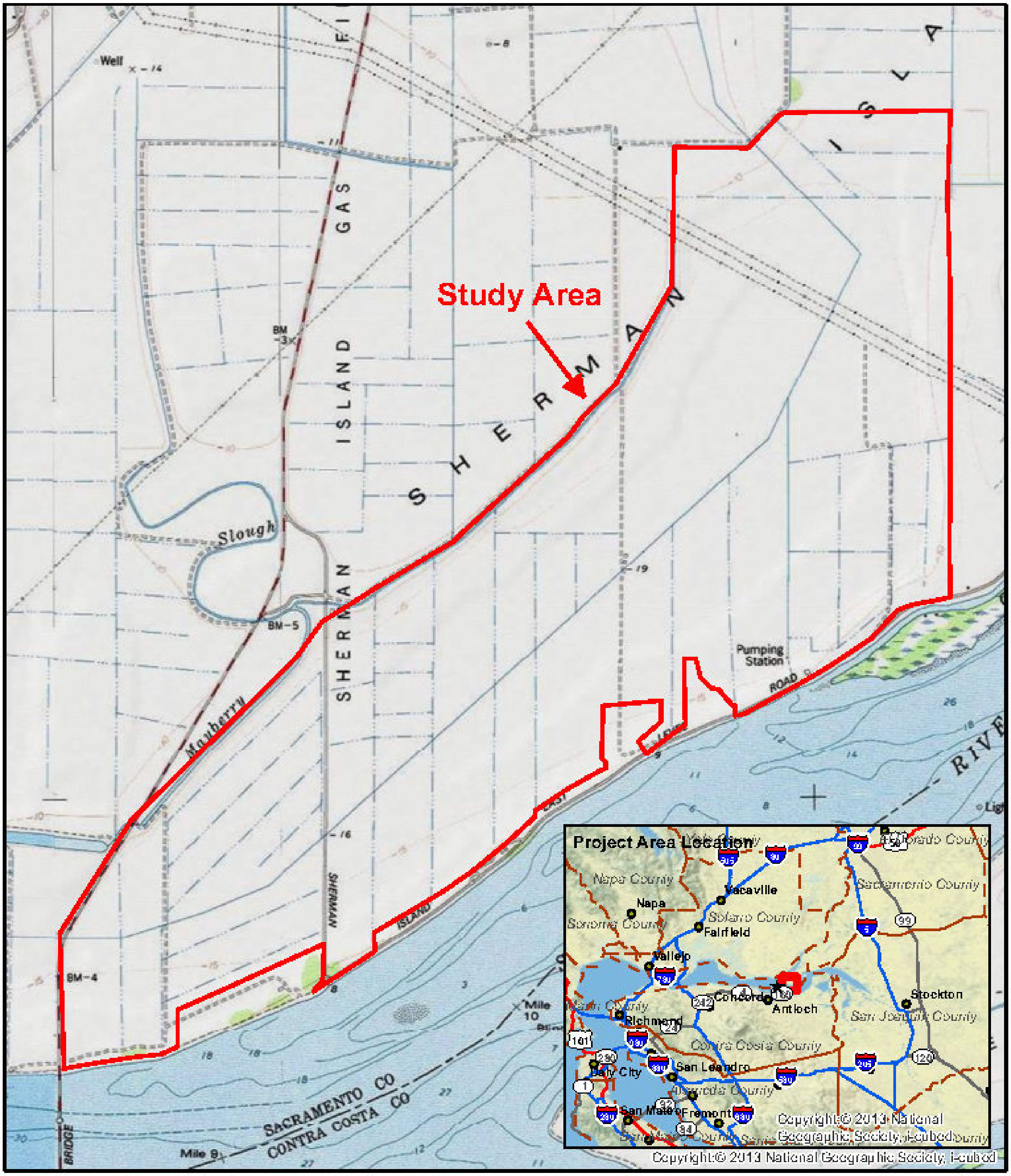


Figure 1. Sherman Island Wetland Restoration Project: Phase II Site & Vicinity Map

Base maps: Jersey Island, CA USGS 7.5 minute topographic quadrangle
Sections 1, 2, 3 & 10 of T2N, R2E; Sections 25, 26, 35 & 36 of T3N, R2E, Sacramento County, CA

N

0 1,000 2,000 Feet

DUCKS UNLIMITED

Figure 2. Infrastructure Map

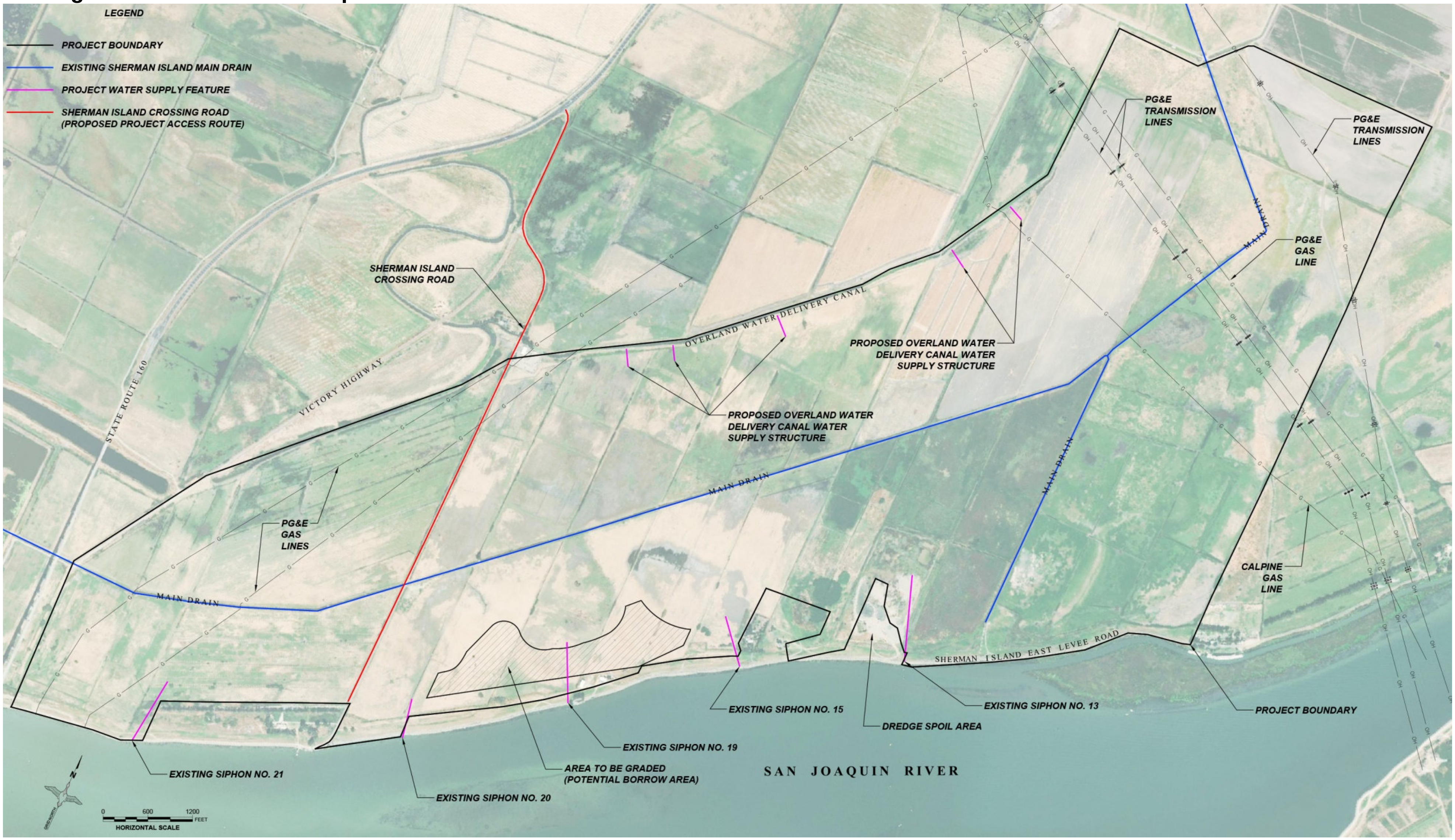
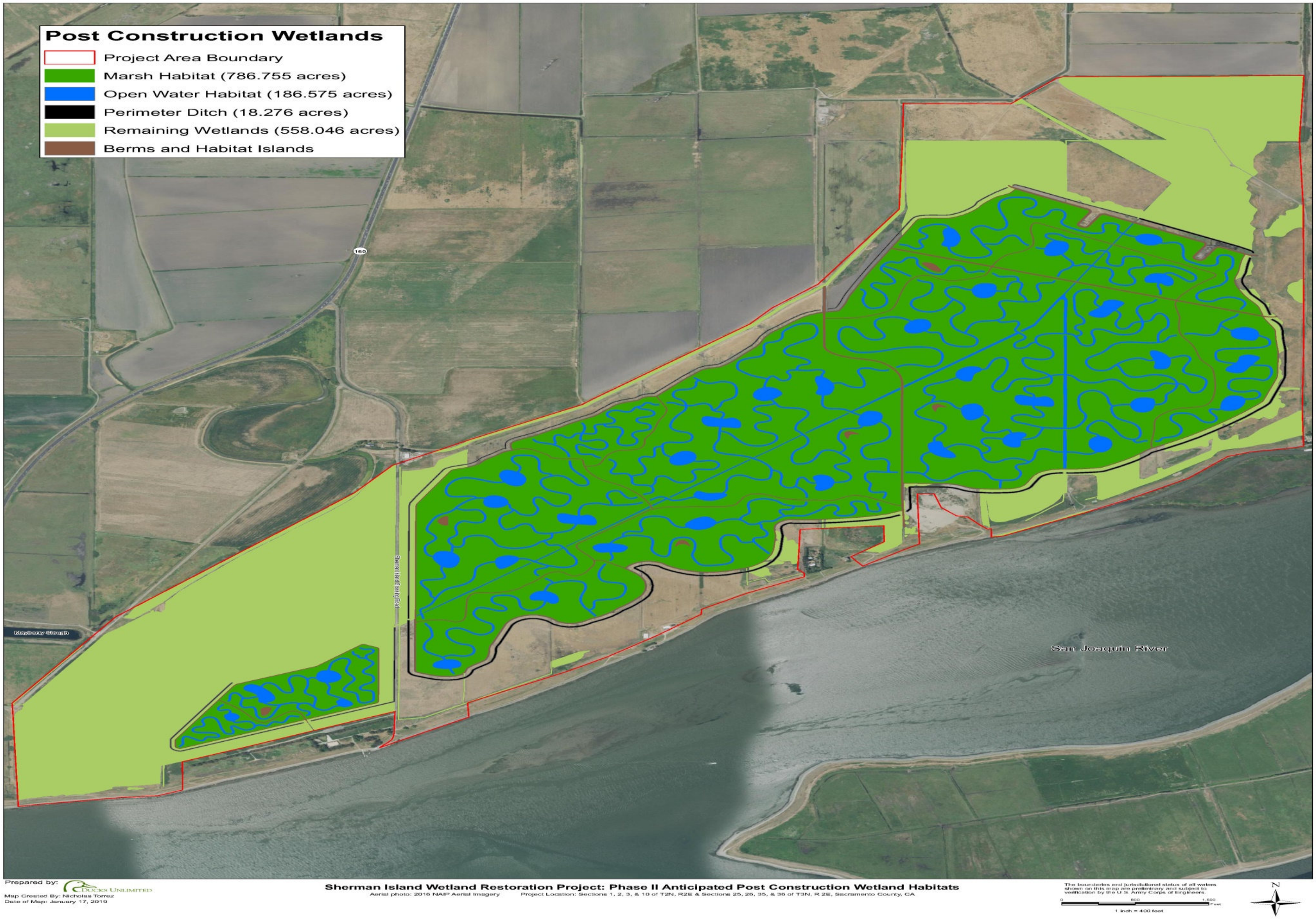


Figure 3. Restoration Plan Map



WATER BUDGET

Background
Currently, the site proposed for this wetland restoration project is being utilized as irrigated pasture for grazing cattle and cropland. The pasture is irrigated so that standing water occurs on some of the ground so the cattle can use the standing water for drinking. In contrast, this project will convert these pastures to permanently flooded wetlands to stop and reverse the effects of subsidence. Additionally, we anticipate constructing the project over three years and have approximated the acreage developed during the first year to be 100 acres, second year to be 400 acres, and the final 500 acres being constructed during the third year. We anticipate flooding up each phase during the months of January through May subsequent to construction completion of that phase. We have estimated the water requirements for the planned wetland as shown in the following table.

Water Demand for Proposed Future Wetland
Total Demand and Components of the Water Budget
Under steady state conditions, the water budget for the proposed wetland can be represented as: Total water demand = evapotranspiration - precipitation. During flood up the water budget for the proposed wetland can be represented as: Total water demand = evapotranspiration + flood depth - precipitation.

The total project site is approximately 1000 acres, and assuming a high groundwater table resulting in low subsurface flow a desired average increase in water depth will be 1.5 feet. Tables 1, 2, and 3, show the components of the water budget with initial flooding and establishment of wetland vegetation per phase, as well as ET balance for the previously constructed phase. Table 4 shows water requirements after construction and flood up has occurred (steady state).

Table 1. Water Demand by Month for Years 1-3 and all subsequent years

Month	Year 1	Year 2	Year 3	Subsequent Years
	Acre -feet			
January	1.27	5.09	6.36	0
February	6.13	24.52	30.65	0
March	21.15	84.59	105.74	0
April	45.97	183.87	229.83	0
May	65.67	262.68	328.35	0
June	55.27	271.34	490.02	427.3
July	60.26	301.29	602.56	602.56
August	52.69	263.45	526.91	526.91
September	38.15	190.74	381.47	381.47
October	17.54	87.72	0	0
November	0	0	0	0
December	0	0	0	0

Evapotranspiration

We estimated wetland evapotranspiration (ET) using meteorological data obtained from UC Berkeley sites on both Sherman and Twitchell Islands. The data set includes data for both agricultural crops, as well previously constructed wetlands.

Monthly ET in ft	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**Sept**	**Oct**	**Nov**	**Dec**
Wetlands (Average)	**0.06**	**0.10**	**0.19**	**0.30**	**0.46**	**0.57**	**0.61**	**0.53**	**0.40**	**0.25**	**0.10**	**0.07**
West Pond	0.07	0.07	0.10	0.18	0.31	0.50	0.61	0.54	0.42	0.27	0.11	0.07
East End	0.06	0.09	0.21	0.34	0.48	0.59	0.61	0.53	0.39	0.22	0.09	0.06
Mayberry	0.06	0.11	0.20	0.35	0.53	0.61	0.65	0.55	0.44	0.27	0.11	0.07
Sherman (Whale's Mouth)	0.07	0.13	0.26	0.35	0.53	0.57	0.56	0.49	0.37	0.26	0.09	0.08
Agricultural Sites:	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Sherman Pasture	0.04	0.08	0.16	0.26	0.31	0.32	0.30	0.26	0.21	0.14	0.06	0.05
Twitchell Alfalfa	0.06	0.12	0.23	0.33	0.41	0.41	0.39	0.32	0.24	0.19	0.10	0.07
Twitchell Corn	0.08	0.13	0.19	0.31	0.35	0.19	0.39	0.40	0.23	0.10	0.07	0.09
Bouldin Corn	0.04	0.17	0.19	0.25	0.20	0.20	0.51	0.43	0.20	0.04	0.05	0.05
Average rainfall (in)	3.62	3.46	2.76	1.14	0.67	0.20	0.04	0.04	0.28	0.94	2.09	3.27
Average Rainfall in ft	0.30	0.29	0.23	0.10	0.06	0.02	0.00	0.00	0.02	0.08	0.17	0.27

CENTRAL VALLEY JOINT VENTURE TECHNICAL GUIDE TO BEST MANAGEMENT PRACTICES FOR MOSQUITO CONTROL IN MANAGED WETLANDS

Dean C. Kwasny[1], Mike Wolder[2], and Craig R. Isola[2]

BEST MANAGEMENT PRACTICES

The BMPs in this document are habitat-based strategies that can be implemented when needed for mosquito control in managed wetlands. These strategies represent a range of practices that wetland managers can incorporate into existing habitat management plans or in the design of new wetland restoration or enhancement projects. Ideally, BMPs can be used to decrease the production of mosquitoes and reduce the need for chemical treatment without significantly disrupting the ecological character, habitat function, or wildlife use in managed wetlands. It should be recognized that BMPs function as a first line of defense in deterring mosquito production and can be used in combination with other Integrated Pest Management (IPM) tools such as, biological controls, larvicides (Appendix A), and adulticides (Appendix B) when necessary.

In many cases, BMPs overlap with commonly used habitat management practices to conserve water and manage wetland vegetation for wildlife (Batzer and Resh 1992a, Batzer and Resh 1992b, Resh and Schlossberg 1996). Not all BMPs will be appropriate for a given wetland location or set of circumstances. Therefore, habitat managers are encouraged to work closely with both their local MVCD and agency biologists to select BMPs based on their potential effectiveness for regional or site specific conditions, and habitat management strategies. The implementation of BMPs will likely be limited by cost and personnel constraints, potential impacts on wetland habitat, and wildlife response to these measures.

In the following section, BMPs have been classified into five categories. These categories are not listed in order of importance and may be used in combination.

- Water Management Practices
- Vegetation Management Practices
- Wetland Infrastructure Maintenance
- Wetland Restoration and Enhancement Features
- Biological Controls

Following each category is a table summarizing the BMPs that outlines strategies, mosquito control objectives, advantages, and disadvantages (Tables 1 through 6).

Water Management Practices

Water management is one of the wetland manager's greatest tools for reducing mosquito populations (Table 1). However, it requires that water is readily available, of sufficient quantity and quality, and that the conveyance infrastructure is adequate to permit rapid flooding or drainage. In some instances, circumstances outside the control of wetland managers may limit the ability to implement water management BMPs. Such circumstances may include when agriculture drain water or delivered water is available for flooding, limited water quantity or poor water quality, and undersized water delivery or drainage infrastructure. In managed wetlands where these limitations are not an issue, the following water management practices should be considered.

<u>Timing of Flooding</u>: The timing of wetland flooding can greatly influence mosquito production (Fanara and Mulla 1974; Batzer and Resh 1992a). Delayed flooding may reduce mosquito production by shifting flooding schedules later in the year, when temperatures are cooler and mosquito production is less of a problem. Delayed flooding should be considered for wetlands with historic mosquito problems and those in close proximity to urban areas. However, delayed flooding means that less wetland habitat is available for wildlife during times of the year such as August and

September, when wetlands are particularly limited. Delayed flooding may also have limited applicability for some properties that are required to take water on a “when available” schedule and have little control over the timing of flooding. Delayed flooding may be especially difficult for State and Federal areas that are obligated to provide “early” habitat to reduce crop depredation by waterfowl.

Given the limited feasibility of delayed flooding on some properties, phased flooding of wetlands may be useful to allow habitat managers to provide some level of early flooded habitat while delaying flooding on a portion of a property. Phased flooding involves flooding habitat throughout the fall and winter in proportion to wildlife need and takes into consideration other wetland habitat that may be available in surrounding areas.

For wetlands that are flooded early (August - early September) or in close proximity to urban areas, the use of vegetation and water management BMPs should be a high priority (Tables 1 and 2). *BMPs: Delayed or phased fall flooding, Early fall flood-up planning (see Table 1 for additional explanation)*

Speed of Wetland Flooding: As a general rule, the faster water can be applied during fall flooding and spring/summer irrigation, the fewer generations of mosquitoes will be hatched. Slow feather-edge flooding, although beneficial to foraging waterbirds, can produce multiple, staggered hatches of floodwater mosquitoes and, if treatment is necessary, often requires MVCDs to visit wetlands over a number of days for control activities (Garcia and Des Rochers 1983). Such an intensive treatment effort is expensive and results in additional disturbance to wildlife.

BMPs: Rapid fall flooding, Rapid irrigation (see Table 1 for additional explanation)

Water Control: Once wetlands have been flooded, it is important for wetland managers to maintain consistent pond elevations so that water surface elevation fluctuations do not occur, except during planned drawdowns or periods of low mosquito production (i.e. winter months). Fluctuating water levels tend to expose wetland edges to drying and provide suitable habitat for floodwater mosquitoes to lay eggs (Garcia and Des Rochers 1983). When water levels are subsequently raised, a new cohort of mosquitoes may be hatched. Water levels should be maintained by checking water levels frequently and adding water to offset any losses. A constant maintenance flow of water will also help maintain steady water levels, improve water quality, and reduce stagnation.

If possible, wetlands can be flooded to deeper water depths during the fall and allowed to recede during the cooler winter months to provide shallow water depths for foraging waterbirds. Deeper water depths (24 inches) at initial flooding have been shown to significantly reduce mosquito densities at Grizzly Island Wildlife Area (Batzer and Resh 1992a, b).

When flooding wetlands, water sources containing mosquito predators should be used to help colonize wetlands with predacious insects or mosquitofish that are passively transported by water from upstream locations (Collins and Resh 1989). Predator populations can be maintained in permanent waterways used to flood seasonal wetlands. In the Suisun Marsh, where water is readily available for flooding, seasonal wetlands are often initially flooded, and if mosquitoes become abundant, water levels are drawn down to concentrate mosquito larvae in ditches for biological control, larvicide treatment, or to drown larvae through turbulent water movement (Chappell pers. comm). Following this action, wetlands are immediately re-flooded.

BMPs: Maintain stable water levels, Circulate water, Use deep initial flooding, Subsurface irrigate, Utilize water sources with mosquito predators for flooding, Flood and drain wetland (see Table 1 for additional explanation)

<u>Frequency and Duration of Irrigation</u>: Spring and summer irrigation is a common wetland management practice used to increase seed production and biomass of moist-soil plants (Naylor 2002), and reduce competition from undesirable plants in seasonal wetlands. The need to irrigate seasonal wetlands should be assessed closely by wetland managers. During years with above average spring precipitation, irrigations may not be necessary to maximize moist-soil plant production. When possible, managers should shorten the duration of irrigation to 4 to 10 days to reduce the likelihood of hatching floodwater mosquitoes and eliminate the possibility of creating habitat for standing water mosquitoes. However, shorter irrigations may not always be feasible, especially when growing more water intensive plants such as watergrass and smartweed, or when conducting flooding to control undesirable plant species. In the case of weed control, plants should be monitored and water held only long enough to eliminate weeds. The necessary timing can be determined when weeds have turned black or have disintegrated. Finally, following wetland irrigations, water should be drawn down into waterways containing mosquito predators that can consume any mosquito larvae which may have hatched.

BMPs: Reduce number of irrigations, Use rapid irrigation, Draw down and irrigate in early spring, Irrigate prior to field completely drying, Drain irrigation water into ditches or other water sources with mosquito predators, Use subsurface irrigation (see Table 1 for additional explanation)

Table 1. Water Management Practices to reduce mosquito production in managed wetlands.

Best Management Practice	Strategies	Mosquito Control Objective	Advantages	Disadvantages
Delayed or phased fall flooding	Delay flooding of some wetland units until later in the fall. Delay flooding units with greatest historical mosquito production and/or those closest to urban areas.	To delay initiation of floodwater mosquito production in seasonal wetlands by reducing the amount of mosquito habitat available during optimal breeding conditions (warm summer/early fall weather). Reduce the time available for standing water mosquito production in seasonal wetlands.	Depending on flood date, can reduce the need or amount of additional treatment. Delayed flooding can provide "new" food resources for wildlife later in the season when wetlands are finally flooded.	Reduces the amount of habitat for early fall migrants and other wetland-dependent species, and may increase potential for waterfowl depredation on agricultural crops (especially rice). Flooding is often dictated by water availability or contractual dates for delivery. Delayed flooding may still produce mosquitoes in warm years. Private hunting clubs can't lease blinds that aren't flooded.
Early fall flood-up planning	Apply BMPs to wetlands identified for early flooding. To the extent possible, areas targeted for early fall flooding should not be near urban centers and should not have a history of heavy mosquito production.	To reduce the early season production of mosquitoes or to reduce their encroachment on urban areas.	Allows for the provision of early flooded habitat while minimizing mosquito production and conflicts with urban areas.	Some additional effort required to monitor and identify suitable areas. Requires the extensive use of BMPs so mosquitoes are not produced.
Rapid fall flooding	Flood wetland unit as fast as possible. Coordinate flooding with neighbors or water district to maximize flood-up rate.	To minimize number of mosquito cohorts hatching on a given area.	Reduces the need for multiple treatments needed by synchronizing larval development and adult emergence. In turn, reduces wildlife disturbance by MVCDs.	Requires coordination & ability to flood quickly. Reduces slow, feather-edge flooding that is heavily utilized by waterbirds.
Rapid irrigation	4-10 day irrigation (from time water enters the pond to complete draw-down).	Shorten irrigation period to reduce time available for mosquitoes (especially *Culex tarsalis* and *Anopheles freeborni*) to complete lifecycle.	Provides some level of wetland irrigation while reducing the time available for mosquitoes to complete lifecycle.	Requires ability to rapidly flood & drain wetland. If flooding is used for weed control, rapid irrigation may not be feasible.

Maintain stable water level (summer and early fall flooding)	Provide constant flow of water into pond to reduce water fluctuation due to evaporation, transpiration, outflow, and seepage.	To reduce conditions for additional floodwater mosquito production in summer and fall.	Provides a stable wetland environment for breeding wildlife during spring and summer. Discourages undesired excessive vegetative growth which could also become additional mosquito breeding substrate.	Requires regular monitoring and adjustments to water control structures. May be difficult if water availability is intermittent or unreliable. Reduces mudflat habitat that is attractive to shorebirds and waterfowl.
Water circulation	Provide a constant flow of water equal to discharge at drain structure.	To keep water fresh and moving to deter stagnant conditions for mosquito production; reduces water level fluctuation and potential production of floodwater mosquitoes.	Discourages warm water conditions associated with avian botulism outbreaks.	Requires landowner to purchase additional "maintenance" water. May be difficult if water availability is intermittent or unreliable.
Deep initial flooding (18-24")	Flood wetland as deep as possible at initial flood-up.	To reduce shallow water habitat for mosquito breeding. May provide more open water by over-topping vegetation, thereby facilitating mosquito predation or wind action that drowns larvae.	Potentially slows mosquito development by eliminating warm, shallow water habitat.	Requires additional water and infrastructure adequate to flood deeply. Reduces shallow water foraging habitat for shorebirds and waterfowl.
Utilize water sources with mosquito predators for flooding wetlands	Flood wetlands with water sources containing mosquito fish or other invertebrate predators. Water from permanent ponds can be used to passively introduce mosquito predators.	To inoculate newly flooded wetlands with mosquito predators.	May establish mosquito predators faster than natural colonization.	Requires source of water with already established mosquito predators. Not applicable to wetlands flooded with well water.
Drain irrigation water into ditches or other water bodies with abundant mosquito predators	Drain irrigation water into locations with mosquito predators as opposed to adjacent seasonal wetland or dry fields.	To reduce the amount of larvae through natural predation and minimize the number of adults that emerge.	Already a common wetland management practice.	Must have ditch or water body with established predator population available to accept drain water.

Flood & drain wetland	Flood wetland and hatch larvae in pond. Drain wetland to borrow or other ditch where larvae can be easily treated, drowned in moving water, or consumed by predators. Immediately reflood wetland.	Hatches mosquito larvae and moves them to a smaller area for treatment before they can emerge as adults.	Can eliminate or reduce the need for additional mosquito control efforts.	Additional cost to purchase water to re-flood wetland. Timing is critical. Requires monitoring and is labor intensive.
Reduce number of irrigations	Evaluate necessity of irrigation, especially multiple irrigations, based on spring habitat conditions and plant growth. Eliminate irrigations when feasible.	To eliminate unneeded additional irrigations which could provide potential habitat for mosquitoes.	Reduces potential need for additional mosquito control. Saves water and manpower costs. Discourages excessive growth of undesirable vegetation (i.e. joint and bermuda grass)	May reduce seed production or plant biomass with less irrigation.
Early spring draw-down and irrigation	Draw-down wetland in late March or early April. Irrigate in late April or early May when weather is cooler and mosquitoes are less of a problem.	To reduce need for irrigation in June, July, and August, when potential for mosquito production would be higher.	Wetland irrigation can be accomplished without creating potential mosquito problems. May allow moist-soil plants to take advantage of natural rainfall during the spring.	Reduces shallow wetland habitat for migratory shorebirds and waterfowl in April and May, during a major migration period. Newly germinated wetland plants may be impacted by cold weather conditions. May stimulate germination and growth of undesirable wetland plants.
Don't let field completely dry and crack between spring draw-down and irrigation	Irrigate wetland before soil completely dries.	To eliminate necessary drying period for floodwater mosquito to lay eggs.	May reduce mosquitoes produced from irrigation	Requires close monitoring of soil moisture to correctly time irrigation.
Subsurface irrigation	Maintain high ground water levels by keeping boat channels or deep swales permanently flooded.	To reduce amount of irrigation water during mosquito breeding season.	Reduce need for surface irrigation while maintaining soil moisture to promote moist-soil plant production.	Requires deep swales or boat channels to be effective. Requires additional pipes in channels for equipment access. May not produce intended irrigation result if water table is naturally low. Requires that water be maintained longer than normal in swales. May promote unwanted vegetation growth in swales or promote irrigation of non-target plants in wetland.

Wetland Infrastructure Maintenance

Wetland infrastructure is the foundation for habitat management. A properly functioning water delivery and drainage system, well maintained levees, correctly operating water control structures, and efficient pumps are key to avoiding the unnecessary production of mosquitoes through simple neglect (Table 3). Time and money invested in these proactive maintenance activities will reduce mosquito production and help landowners avoid additional costs of controlling mosquitoes and unwanted vegetation when fall flooding or irrigating wetlands.

Levee and Water Control Structure Inspection and Repair: Levees and water control structures should be inspected on an annual basis to identify problem areas that may inadvertently leak water and produce mosquitoes. This includes identifying weak spots or rodent damage in levees that may seep water during flooding. Water control structures should be water-tight and properly sealed to prevent seepage.

Ditch and Swale Cleaning: Vegetation in water delivery ditches and swales can be problematic by creating habitat for mosquitoes or by simply impeding the flow of water that facilitates rapid flooding or drainage. Typical maintenance activities of water delivery and drainage ditches include the use of herbicides or periodic dredging to remove problem vegetation that inhibits water flow. Ditches and swales should be cut to grade to prevent the unintentional trapping of water. Likewise, silt that accumulates in front of outlet structures should be removed so it does not trap water in drainage swales.

Pump Tests and Repair: If wetland managers use pumps for flooding, periodic pump testing should be conducted to verify pumps are operating at optimum efficiency. This will make sure that pumps are providing maximum output, and will facilitate rapid flooding.

Table 3. Wetland infrastructure maintenance activities used to reduce mosquito production in managed wetlands.

Best Management Practice	Strategies	Mosquito Control Objective	Advantages	Disadvantages
Levee Inspection & Repair	Walk or drive levees, flag problem spots, repair as needed. Consider design elements to improve integrity of levee (see levee design in Table 4).	To reduce mosquito habitat/production caused by seepage into adjacent fields or dry ponds.	Allows for early identification of problem spots. Helps conserve water and reduces growth of unwanted vegetation.	Requires annual monitoring and funding for repairs.
Water Control Structure Inspection, Repair, & Cleaning	Inspect structures and repair or replace as needed. Remove silt and vegetation build-up in front of structures. Adequately close, board or mud-up controls.	To reduce mosquito habitat/production caused by seepage into adjacent ponds or drainage ditches. Remove silt blockages that may trap water and impede drainage.	Enhances water management capabilities and limits unwanted vegetation or standing water.	Requires annual monitoring and funding for cleaning or repair.
Ditch Cleaning	Periodically remove silt or vegetation from ditches to maintain efficient water delivery and drainage.	To allow for rapid flooding/drainage & reduce vegetation substrate for breeding mosquitoes.	Enhances water management capabilities and limits unwanted vegetation or standing water.	Requires funding for ditch cleaning. Excessive vegetation removal on ditch banks can result in negative impacts to nesting birds and other wildlife.
Pump Tests & Repair	Test pump efficiency and make any necessary repairs to maximize output.	Could identify output problems and if corrected, allow managers to flood more rapidly.	May promote faster irrigation and flood-up if output can be improved.	Requires pump test. May be costly to repair or replace pump/well.

Wetland Restoration and Enhancement Features

All well planned wetland restoration and enhancement projects begin with an initial survey and design phase. It is during this phase that landowners and restoration biologists have the opportunity to discuss design features with MVCDs and incorporate BMPs to reduce mosquito production. Time spent at the design stage can save thousands of dollars in annual operation and maintenance costs and prevents problems resulting from poor water management and unintended mosquito production.

Wetland design typically focuses on aspects of water control that promote vegetation beneficial to wildlife, conserve water, and allow for periodic vegetation control. In turn, water control is also an important mosquito BMP (Sacramento-Yolo Mosquito and Vector Control District 2008, Contra Costa Mosquito and Vector Control District 2001).

Wetland design features to reduce mosquito production: Wetland design features that reduce mosquito production include independent flooding and drainage capabilities of wetland units, size considerations in the design of wetland units to facilitate rapid flooding, and the incorporation of design features that promote habitats for mosquito predators and allow those predators access to mosquitoes. Water delivery ditches, water control structures, and levees should be designed and built to specifications that prevent wind and water erosion, provide equipment access for maintenance activities, and reduce damage caused by burrowing animals (Table 4). These design features will facilitate other mosquito BMPs such as water and vegetation management practices, infrastructure maintenance, and natural mosquito predation.

BMPs: Independent water management, Adequately sized water control structures, Swale construction, Wetland size consideration, Ditch design, Levee design & compaction, Deep channels or basins constructed in seasonal wetlands, Permanent water reservoir that floods into seasonal wetlands.

Appendix B - Mitigation Monitoring Report Plan

Proposed Mitigation	Impact	Summary of Measures
IV. BIOLOGICAL RESOURCES		
MM 3.a	Air Quality Plan	To mitigate for any significant impacts, a strict no-idle of heavy equipment policy will be enforced. In addition, to avoid the spreading of substantial dust (PM10) as a result of scraping or grading activities, water trucks will be utilized to keep the soil moist and heavy. Additionally, if wind is forecasted to be greater than 30 miles per hour on a given day, construction work will be postponed in order to avoid the creation of substantial dust (PM10).

MM 4.a(2)	Giant garter snake	Within the Project Site, aquatic ditch habitat for GGS will be lowered as much as possible and then maintained as low as possible for at least fifteen consecutive days prior to the initiation of construction activities Complete dewatering is likely not possible due to the high water table and continuous levee under seepage on the Project Site. At most 24-hours prior to the commencement of construction activities, the Site shall be surveyed for giant garter snakes by a USFWS-approved biologist. The biologist will provide the USFWS with a written report that adequately documents the monitoring efforts within 24-hours of commencement of construction activities. The Project Site shall be re-inspected by the monitoring biologist whenever a lapse in construction activity of two weeks or greater has occurred. ☐ A Worker Environmental Awareness Training Program for construction personnel shall be conducted by a USFWS-approved biologist for all construction workers, including contractors, prior to the commencement of construction activities. • Conducting grading, clearing, grubbing, or other similar construction-related disturbance of suitable upland habitat within 200 feet of suitable aquatic and/or wetland habitat will be conducted during the GGS active period of May 1 to October 1, when GGS are able to avoid or evade construction activities. If it appears that construction activity may go beyond October 1, the project proponents shall contact the USFWS as soon as possible, but not later than September 15 of the year in question, to determine if additional measures are necessary to minimize take. Construction activities within 200 feet from the banks of snake aquatic habitat will be avoided during the snake's inactive season. ☐ Clearing activities will be confined to the minimum necessary to facilitate construction activities. ☐ Project-related vehicles will observe a twenty mile-per-hour speed limit within construction areas, except on existing paved roads where they will adhere to the posted speed limits. ☐ If a snake is encountered during construction activities, all activities will cease and the USFWS will be notified immediately to determine the appropriate procedures related to the collection and relocation of the snake. A report will be submitted to the USFWS and will include the date(s), location(s), habitat description, and any corrective measures taken to protect the snake, within one (1) business day. The applicant is required to report any take of listed species to the USFWS immediately by telephone at 916- 930-5603 and by electronic mail or written letter addressed to the Assistant Field Supervisor, ESA/Regulatory Division of the BDFWO, within one (1) working day of the incident. • Contract and bid specifications will require contractor to implement best management practices (BMPs) to prevent wildlife entanglements in fencing, and impacts to water quality in undrained ditches. These shall include all food-related trash items (e.g., wrappers, cans, bottles, and food scraps) will be disposed of in closed containers and removed at the end of each workday.

MM 4.a(3).	Swainson's hawk, Western burrowing owl, Tricolored blackbird, White-tailed kite, , Loggerhead shrike, Modesto song sparrow, and Migratory Birds & Birds of Prey	• If construction is scheduled to begin between February 1 and August 31 then a qualified biologist shall conduct a preconstruction survey for active nests at the construction site and within 0.25 mile of the construction site from publicly accessible areas within 30 days prior to construction. If no active nest of a bird of prey or MBTA bird is found, then no further mitigation measures are necessary. • If an active nest of a bird of prey or MBTA bird is found, then the biologist shall flag a minimum 250 foot (1320 ft. (0.25 mile) for Swainson's hawk) Environmentally Sensitive Area (ESA) around the nest if the nest is of a bird of prey, and a minimum 100-foot ESA around the nest tree if the nest is of an MBTA bird other than a bird of prey. • No construction activity shall be allowed in the buffer until the biologist determines that the nest is no longer active, or unless monitoring determines that a smaller buffer will protect the active nest. • The buffer may be reduced if the biologist monitors the construction activities and determines that no disturbance to the active nest is occurring. The size of suitable buffers depends on the species of bird, the location of the nest relative to the project, project activities during the time the nest is active, and other project specific conditions. Before any work is authorized within a buffer, DFW shall be consulted. If construction is allowed within the buffer, a biologist will be present to monitor nests and will have the authority to halt construction activities within the buffer if the nesting birds show signs of agitation or potential abandonment. Active nests with transportation routes that are within the buffer zone should be monitored for signs of distress, with routes being altered, or implementing other measures to minimize disturbances.
MM 4.c.	Jurisdictional wetland impacts	• Project proponent shall obtain a Section 404 CWA Nationwide Permit and a Section 401 CWA Water Quality Certification for impacts to Corps jurisdictional features. The project proponent shall fulfill the requirements of the permits.
MM 9.f	Water Quality Impacts - Mosquitos	Project proponent shall incorporate Best Management Practices (BMPs) to limit the growth and spread of mosquitoes is important. The BMPs included in Appendix F will be incorporated and utilized during the development and long-term management of the project to minimize the growth of mosquito populations.