# Third Draft
# Habitat Restoration Conservation Measures

***Note to Steering Committee:*** *This handout presents the third draft of habitat restoration conservation measures. A summary list of proposed habitat restoration conservation measures is presented in Table 1. This draft includes revisions proposed by SAIC—no comments were received from the Steering Committee to the second draft habitat restoration conservation measures presented to the Steering Committee on October 17, 2008. All new text added to this draft from the second draft is displayed in underlined red text; text in black is the same as delivered in the second draft. These draft conservation measures will be discussed at the October 31, 2008 Steering Committee meeting.*

**Table 1. List of Proposed Habitat Restoration Conservation Measures**

| Category | Draft Conservation Measure |
|---|---|
| **Habitat Restoration Conservation Measures** | |
| **Floodplain Habitat Restoration** | FLOO1.1: Modify the Fremont Weir and the Yolo Bypass to provide for a higher frequency and duration of inundation. |
| | FLOO2.1: Create and operate a new flood bypass in the Yolo Bypass/Cache Slough Complex ROA to restore seasonally inundated floodplain habitat. |
| | FLOO2.2: Restore floodplain habitat along __ miles of the San Joaquin River from Vernalis to Mossdale. |
| | FLOO2.3: Restore floodplain habitat along __ miles of the San Joaquin River from Mossdale to French Camp Slough. |
| | FLOO2.4: Restore between __ and __ acres of inundated floodplain habitat in the South Delta Restoration Opportunity Area. |
| **Freshwater Intertidal Marsh Habitat Restoration** | FIMA1.1: Restore a mosaic of __ to __ acres of freshwater intertidal marsh, shallow subtidal aquatic, and transitional grassland habitat within the Yolo Bypass/Cache Slough Complex Restoration Opportunity Area. |
| | FIMA1.2: Restore a mosaic of __ to __ acres of freshwater intertidal marsh, shallow subtidal aquatic, and transitional habitat within the Cosumnes/Mokelumne ROA. |
| | FIMA1.3: Restore a mosaic of __ to __ acres of intertidal marsh and shallow subtidal aquatic habitat within the West Delta Restoration Opportunity Area. |
| | FIMA1.4: Restore a mosaic of __ to __ acres of intertidal marsh, shallow subtidal aquatic, and transitional grassland habitat within the South Delta Restoration Opportunity Area. |
| | FIMA1.5: Restore a mosaic of __ to __ acres of intertidal marsh, shallow subtidal aquatic, and transitional grassland habitat within the East Delta Restoration Opportunity Area. |
| **Brackish Intertidal Marsh Habitat Restoration** | BIMA1.1: Restore a mosaic of __ to __ acres of brackish intertidal marsh, shallow subtidal aquatic, and transitional grassland habitat within the Suisun Marsh Restoration Opportunity Area. |
| **Channel Margin Habitat Restoration** | CHMA1.1: Support development and implementation of levee construction and maintenance designs that incorporate aquatic, intertidal marsh, and riparian habitat features. |
| | CHMA1.2: Provide for the establishment of native riparian woody vegetation and emergent vegetation on BDCP constructed levees. |
| | CHMA1.3: Enhance channel margin habitats along __ to __ miles of Steamboat and Sutter Sloughs to improve habitat conditions for covered fish species. |

| Category | Draft Conservation Measure |
| --- | --- |
| **Riparian Habitat Restoration** | RIPA1.1: Restore between __ and __ acres of riparian forest and scrub communities as a component of restored floodplain, freshwater intertidal marsh, and channel margin habitats. |

*The extent of habitat restoration is not identified in this draft of the conservation measures. The Habitat Restoration Technical Team has developed criteria for identifying the extent of physical habitat ( floodplain, intertidal marsh, channel margin, and riparian) that feasibly could be restored in each of the Restoration Opportunity Areas (ROAs) and for prioritizing each of the restoration opportunities associated with each ROA (Figure 1). It is anticipated that results of this process will be presented for discussion at the November 14, 2008 Steering Committee meeting.*

*These third draft conservation measures will be discussed at the October 31, 2008 Steering Committee meeting.*

## Introduction

The habitat restoration conservation measures are organized into five categories—floodplain, freshwater intertidal marsh, brackish intertidal marsh, channel margin, and riparian habitat restoration conservation measures. Restored freshwater intertidal marsh as used in this handout corresponds to the tule and cattail dominated elements of the BDCP tidal freshwater emergent wetland natural community; restored riparian forest and scrub is an element of the BDCP valley riparian natural community. Shallow subtidal aquatic habitats[1] are anticipated to be restored incidentally with restoration of intertidal marshes and correspond to elements of the BDCP tidal perennial aquatic natural community.

The following information is provided with each conservation measure following the conservation measure description.

> **Rationale.** This section describes the justification for proposing the conservation measure. Rationale statements are primarily directed at identifying the covered species and ecosystem benefits that would be expected with implementing the conservation measure. The identified benefits are based on scientific literature and expert opinion as expressed by HRPTT members, as provided by experts requested to present information to the HRPTT on selected topics, and relevant expert opinion expressed in other BDCP venues (e.g., working groups and other technical teams).

> **Implementation timeframe.** This section describes the BDCP implementation period (i.e., near-term or long-term) that is likely the most appropriate period for

[1] Elevations considered suitable for shallow subtidal aquatic habitat include lands with elevations extending >0-6 feet below the intertidal zone. Lands within the shallow subtidal aquatic habitat zone may be elevated to elevations suitable for restoration of intertidal marsh habitat.

implementing the measure. The BDCP near-term implementation period refers to the period from issuance of BDCP permits to completion of the around-Delta conveyance facilities and the BDCP long-term implementation period includes the period from when dual-conveyance operations are initiated over the remainder of the term of the BDCP.

**Implementation considerations.** This section describes restoration design, management, and other relevant items that may need to be addressed by the BDCP Implementing Entity when planning implementation of the conservation measure.

**Resiliency to future change.** This section provides a qualitative assessment of the likely ability of the habitat restored under the conservation measure to continue to provide the desired level of covered species and ecosystem benefits into the future with anticipated changes in environmental conditions with climate change and sea level rise.

**Uncertainties/risks.** This section describes important uncertainties associated with ability of the conservation measure to achieve the desired covered species and ecosystem benefits and the ecological risks that may be associated with implementing the proposed conservation measure. Important uncertainties and risks are those identified in the course of HRPTT deliberations, including results of coarse-level DRERIP evaluations of proposed restoration actions.

**Monitoring and adaptive management considerations.** This section describes monitoring and adaptive management-related elements of the conservation measure, including elements of implementation that may be subject to adaptive management and the types of monitoring that may be appropriate for assessing the effectiveness of the restoration in achieving desired ecological benefits and for informing the adaptive management process. [***Note to reviewers****: The content of this section will be expanded for each conservation measure to provide more specificity regarding monitoring actions and metrics and adaptive management triggers and actions, as appropriate, through future iterations of these materials*.]

**Reversibility.** This section qualitatively assesses the likely ability to reverse the environmental outcomes of the conservation measure, if necessary.

Attachment A, *Restoration Concept Definitions*, provides additional information regarding restoration design requirements and expected ecological outcomes associated with each of the habitat restoration categories.

The information described above for each of the draft conservation measures will be expanded upon and incorporated into appropriate sections of the BDCP Conservation Strategy chapter.

## Floodplain Habitat Restoration Conservation Measures

**Conservation Measure FLOO1.1: Modify the Fremont Weir and the Yolo Bypass to provide for a higher frequency and duration of inundation.** Within the Yolo Bypass/Cache Slough Complex ROA (see Figure 1), floodplain habitat in the Yolo Bypass would be designed and operated to support the physical and biological attributes described in Attachment A. To increase the frequency and duration of inundation of floodplain habitat in the Yolo Bypass, the Fremont Weir would be notched to an elevation of 17.5 feet (NAVD88) and fitted with an operable gate(s) that, when operated, would allow Sacramento River water to flow into the Yolo Bypass when Sacramento River stage at the weir exceeds 17.5 feet. The operable gate(s) would be designed and operated to provide for the efficient upstream and downstream fish passage to and from the Yolo Bypass into the Sacramento River. Other design elements of this measure would include:

- excavation of a canal to convey water past the higher elevation natural levee of the Sacramento River upstream of the new gate at Fremont Weir and past accumulated sediment below the new gate at Fremont Weir to the Tule Canal;
- acquisition of lands, in fee-title and through conservation or flood easements, necessary for restoration of seasonally inundated aquatic habitats and for accommodating future sea level rise;
- removal and replacement of the existing Fremont Weir fish ladder with a new fish passage facility designed to effectively allow for the passage of adult salmonids and sturgeon from the Yolo Bypass past the Fremont Weir into the Sacramento River.
- grading, removal of existing berms or levees, and construction of berms or levees to the extent necessary to improve the distribution (e.g., wetted area) and hydrodynamic characteristics (e.g., residence times, flow ramping and recession) of water moving through the Yolo Bypass, prevent stranding of covered fish species, and to protect property; and
- construction of a structure in the Sacramento River, if needed, in the vicinity of the new weir gate to encourage the passage of juvenile salmonids migrating down the Sacramento River into the Bypass.

The range of frequencies, durations, and periods that the operable gate(s) would be operated to inundate the Yolo Bypass are described in Conveyance Action Parameter 1. To implement this conservation measure, the BDCP Implementing Entity would coordinate with the U.S. Army Corps of Engineers and other flood control entities, as appropriate, to ensure that designs of the modified Fremont Weir, fish passage improvements, bypass improvements, and Fremont Weir operations are compatible with the flood control functions of the Yolo Bypass.

**Rationale:** All BDCP covered fish species are believed to directly or indirectly benefit from seasonally inundated floodplain habitat within the Sacramento River and Delta. Sommer et al. (2003, 2004) found that larval and/or juvenile Chinook salmon, delta smelt, longfin smelt, river lamprey, and splittail seasonally inhabit the Yolo Bypass during periods when the floodplain is inundated. Harrell et al. (2003) found that adult fall-, winter-, and spring-run Chinook salmon, splittail, delta smelt, and white sturgeon inhabit the Yolo Bypass when inundated. The floodplain supports spawning habitat for splittail and juvenile rearing habitat for juvenile Chinook salmon, steelhead, and sturgeon. Analyses of the annual trends in juvenile splittail abundance have shown substantially increased juvenile abundance in wet years. Increased splittail production in wet years is hypothesized to be the result of favorable habitat conditions for successful spawning and early development of larval and juvenile splittail within inundated floodplain habitat (Sommer et al. 2001a). Results of investigations have shown that growth and survival of juvenile fish is improved for those fish rearing in the floodplain compared to those that migrate downstream and rear in the mainstem Sacramento River (Sommer et al. 2001b). Flooding of the bypass also provides surface water connectivity that supports upstream and downstream migration of covered species, as well as production and downstream transport of nutrients, phytoplankton, and zooplankton. During periods when the bypass is flooded, studies have shown relatively high production of zooplankton and macroinvertebrates that serve, in part, as the forage base for many of the covered fish species (Benigno and Sommer 2008). Furthermore, is believed that organic carbon and food production within the flooded bypass is transported downstream into the Cache Slough region of the Delta, and subsequently into the western Delta and Suisun Bay (Schemel et al. 1996, Jassby and Cloern 2000).

Increasing the frequency and duration of floodplain inundation in the Yolo Bypass is expected to reduce the adverse effects of stressors related to food availability, habitat availability, passage, harvest, stranding, predation, and entrainment for the covered fish species by:

- creating additional spawning habitat for Sacramento splittail (Sommer et al.2001a,2002, 2007, 2008, Moyle 2002, Moyle et al. 2004, Feyrer et al. 2006);
- creating additional juvenile rearing habitat for Chinook salmon, Sacramento splittail, and possibly steelhead (Sommer et al.2001a,b, 2002, 2007, 2008, Moyle 2002, Moyle et al. 2004, Feyrer et al. 2006);
- increasing the production of food for rearing salmonids, splittail, and other covered species (Sommer et al. 2001a,b, 2002, 2007, 2008, Moyle 2002, Moyle et al. 2004, Feyrer et al. 2006);

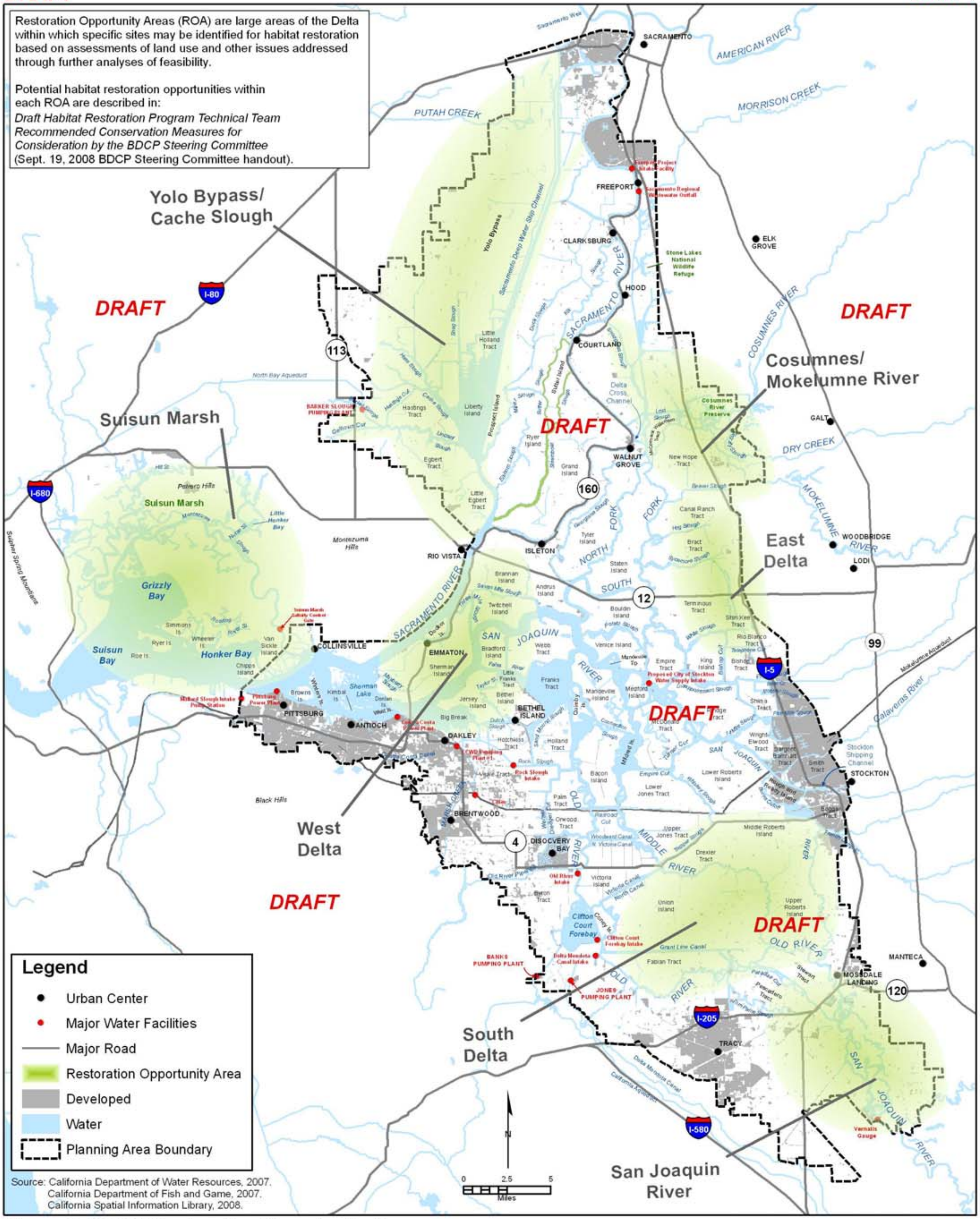


Figure 1. BDCP Restoration Opportunity Areas

- increasing the availability and production of food in the Delta downstream of the bypass for delta smelt, longfin smelt, and other covered species by exporting organic material and phytoplankton, zooplankton, and other organisms produced from the inundated floodplain into the Delta (Mitsch and Gosselink 2000, Moss 2007, Lehman et al. 2008)[2];
- increasing the frequency that floodplain flows transport organic carbon and organisms from existing and future restored intertidal marsh at the downstream end of the bypass into the Delta in support of in-Delta food production for delta smelt, longfin smelt, and other covered species (Mitsch and Gosselink 2000, Moss 2007, Lehman et al. 2008)[2];
- increasing the duration that the floodplain is inundated during periods that the Yolo Bypass is receiving water from both the Fremont Weir and the westside tributaries (e.g., Cache and Putah Creeks);
- reducing losses of Chinook salmon, sturgeon, and other fish species to stranding and illegal harvest by improving passage at the Fremont Weir;
- reducing the exposure and risk of outmigrating juvenile fish migrating from the Sacramento River into the interior Delta through the Delta Cross Channel and Georgiana Slough, thus decreasing the risk for predation losses (Brandes and McLean 2001); and
- reducing the exposure of outmigrating juvenile fish to entrainment at intakes of the proposed North Delta water diversion facilities by passing juvenile fish into the Yolo Bypass upstream of the proposed intake locations.

Increasing the frequency and duration of inundation within the Yolo Bypass is the largest opportunity for increasing inundated floodplain habitat in the North Delta. The Yolo Bypass provides the only opportunity for increasing the frequency and duration of inundation of a floodplain in the Planning Area without restoration of historical floodplain surfaces presently in other land uses. Land use in the Yolo Bypass has developed to be compatible with the existing Yolo Bypass flood regime.

Modification of the Yolo Bypass seasonal floodplain is also compatible with and would provide benefits under proposed water supply operations in both the BDCP near-term implementation period and long-term implementation period with operation of a North Delta diversion facility on the Sacramento River.

**Recommended Implementation Timeframe:** It is anticipated that implementation of this conservation measure could be initiated in the BDCP near-term implementation period.

**Implementation Considerations:** There are numerous challenges to

[2] Generally wetland principles support this rationale (Mitsch and Gosselink. 2000, Moss 2007, Lehman et al. 2008), but there may be indirect effects that create complex responses as illustrated in Jassby's analysis of Bay/Delta phytoplankton production (Jassby 2008).

implementing this measure to improve the Yolo Bypass floodplain habitat. Implementation considerations include:

- coordination with the U.S. Army Corps of Engineers and other flood control agencies to allow notching, construction of an operable gate, excavation of a channel, operation of the Fremont Weir, and modifications to Bypass topography and flow patterns;
- coordination with the Department of Fish and Game on water management affecting the Yolo Wildlife Area;
- coordination with the Yolo Basin Natural Heritage Program to ensure effective implementation of conservation measures under both programs;
- coordination with the Yolo Basin Foundation, Yolo Bypass Working Group, and the Lower Yolo Bypass Planning Forum;
- securing conservation easements, fee title, or other agreements necessary to accommodate changes in patterns of inundation frequency and duration on current land uses;
- the need to construct levees to protect private landholdings that have not been secured through conservation easements;
- ensuring that the design and management of Yolo Bypass floodplain habitats would be compatible and provide synergistic species and ecosystem benefits with restoration of freshwater intertidal marsh habitats in the Cache Slough Complex ROA (see Figure 1 and Conservation Measure FIMA1.1);
- potential for increasing mercury methylation and resuspension and downstream transport of other contaminants;
- opportunities for improving passage through the Yolo Bypass downstream of Fremont Weir, Toe Drain, and Tule Canal;
- opportunities for reducing the potential adverse effects of pesticides/herbicides on agricultural lands by promoting organic farming practices within the Bypass;
- potential effects on existing biological resources; and
- opportunities for providing localized floodplain inundation benefits during periods when Sacramento River stage is below 17.5 feet by forcing water from the Toe Drain onto adjacent lands.

**Resiliency to future changes:** This conservation measure is expected to be resilient to future changes in hydrology and sea levels. With changes in hydrology, the period of inundation is expected to occur earlier in the year than under current conditions (Cayan et al. 2006). The Fremont Weir and Yolo Bypass would continue to accommodate flood flows. Although the frequency, duration, or magnitude of seasonal inundation of the floodplain may vary in the future, the basic functional processes and biological benefits associated with the action would continue into the future over the entire range of anticipated changes in future hydrologic conditions. Sea level rise would be expected to reduce the extent of inundated floodplain at the south end of the bypass and result in tidal emergent wetlands extending into these areas. This tidal emergent wetland would produce organic carbon and organisms in support of food production for covered fish species.

**Uncertainties/risks:** Methylation of mercury may occur in seasonally inundated floodplains and intertidal zones, making methylmercury bioavailable to plants, fish, and wildlife in and downstream of the floodplain (Alpers et al. 2006). Mercury loading from Cache and Putah Creeks and exposure to agricultural pesticides and herbicides may adversely affect habitat productivity. Requirements and the effectiveness of reducing the risk of stranding juvenile fish during floodplain recession require further analysis.

There is some uncertainty regarding the relative biological effects that may occur as a result of increasing seasonal flows through the bypass on habitat conditions, migration rates, and the downstream transport of fish egg and larvae as well as phytoplankton, zooplankton, and organic matter within the Sacramento River within the reach of the mainstem river between the Fremont Weir and Rio Vista. Reduced flows within the mainstem river during the late winter and early spring (i.e., when the bypass would be flooding) have the potential to reduce survival of those organisms that continue to inhabit the mainstem river.

Although the available data supports the biological benefits of increasing the frequency and duration of floodplain inundation, there is uncertainty in the relationship between the seasonal timing and duration of inundation and the benefits for various species.

**Monitoring and adaptive management considerations:** ***[Note to reviewers:*** *this section is a general summary; more detail will be provided in future iterations.]* Implementation of this conservation measure would provide opportunities to adaptively manage flows in the Bypass using the new operable gate(s) in the weir to improve food production and habitat conditions for covered fish species over time based on monitoring results. Basic operational monitoring would include variables such as Sacramento River stage, flow into the Yolo Bypass, water velocities and residence times, water quality, and overall conditions of aquatic habitat within the seasonal floodplain. Physical habitat parameters that would be useful to monitor include the extent of wetted area and water depths, dissolved oxygen concentrations, water temperatures, water velocities and residence times, and other features of the floodplain habitat. In addition to providing information necessary to adaptively manage inundated floodplain habitat conditions, results of monitoring (e.g., monitoring of phytoplankton and zooplankton production relative to residence time and water depth) would help identify ways to improve the design and management of floodplain habitats restored in future years. Additionally, monitoring of covered fish species benefits provided by both the Yolo Bypass and a new Deep Water Ship Channel Bypass (see Conservation Measure FLOO2.1) under various operations would help inform how to co-manage inundation of the bypasses to spatially and temporally optimize benefits for covered fish species. Some additional monitoring considerations under various bypass operations to inform adaptive implementation include:

- extent of phytoplankton, zooplankton, and macroinvertebrate production under various bypass operations;
- load of organic carbon, phytoplankton, zooplankton, and macroinvertebrates exported into aquatic habitats in the Delta;
- effects of floodplain inundation on food production downstream of the bypass;
- effects of floodplain inundation on Delta turbidity;
- effectiveness of the new fish passage facility in providing passage past and reducing stranding at the Fremont Weir;
- incidence of and magnitude of stranding of all life stages of covered fish species;
- shifts in topography over time (e.g., floodplain scouring that create surfaces that pond deep water) that could create stranding risks for covered fish species;
- effects of floodplain inundation on habitat conditions for delta smelt in Cache Slough, the Toe Drain, and other habitat use areas affected by the discharge of water from the bypass;
- effects of various bypass inundation conditions and non-inundation periods on fish abundance, food production and export, organic carbon production and export, toxic concentrations, and other relevant parameters in restored intertidal marshes and adjacent subtidal habitats restored in the Cache Slough area;
- effects on the relative survival, migration, and transport of covered fish species within the mainstem Sacramento River as a function of flows diverted into the Yolo Bypass;
- levels of mercury methylation and biological uptake;
- habitat use by green and white sturgeon and other covered fish species; and
- growth and survival of rearing Sacramento splittail and Chinook salmon.

Additionally, experiments could be conducted to determine if inundating small areas of the bypass floodplain during drier years by placing barriers in the Toe Drain would yield tangible food and habitat benefits for covered fish species.

**Reversibility:** Flow-related effects of this conservation measure are considered to be easily reversible because the BDCP Implementing Entity could choose not to operate the Fremont Weir gate(s), thus maintaining the existing inundation patterns of the Yolo Bypass. Costs related to modification of the existing weir to install an operable gate(s) and re-grading within the bypass, however, could not be recovered. New levees and berms could permanently remove farm land within the footprint of these structures if they are too costly to remove.

**Conservation Measure FLOO2.1: Create and operate a new flood bypass in the Yolo Bypass/Cache Slough Complex ROA to restore seasonally inundated floodplain habitat.** The BDCP Implementing Entity would coordinate flood control planning with the Central Valley Flood Protection Board, California Department of Water Resources (DWR), and U.S. Army Corps of Engineers to assess the desirability and feasibility for creating a new flood bypass located in the Yolo Bypass/Cache Slough Complex ROA (see Figure 1) adjacent to the east levee of the Sacramento River Deep Water Ship Channel. This new flood bypass (hereafter referred to as the Deep Water Ship Channel Bypass) would restore seasonally inundated floodplain habitats for covered fish species and provide flood control benefits. If results of planning studies indicate that construction of a Deep Water Ship Channel Bypass is desirable and feasible, the BDCP Implementing Entity would enter into a cost sharing agreement with the U.S. Army Corps of Engineers for project planning and construction and would assist with securing Congressional authorization and funding for the project. If authorized and funded, the BDCP Implementing Entity would enter into subsequent agreements with the U.S. Army Corps of Engineers and other appropriate agencies governing bypass operations for providing joint flood control and ecosystem benefits and maintenance responsibilities.

The Deep Water Ship Channel Bypass would be designed to reduce flood risks to Clarksburg and the Pocket Area of Sacramento and reduce flood pressures along downstream levees to Rio Vista. If implemented, the bypass would be designed and operated to provide seasonally inundated floodplain habitat for periods of at least 45 days from late-winter through spring during years when sufficient water is available in the Sacramento River for this purpose. Restored floodplain habitat within the bypass would be designed and operated to support the physical and biological attributes described in Attachment A.

Design elements of this measure could include:

- acquisition of lands in fee-title or through conservation easements suitable for restoration of seasonally inundated floodplain habitats and for accommodating future sea level rise;
- construction of a new levee east of the Sacramento Deep Water Ship Channel to contain bypass flows between the new levee and the existing east levee of the Deep Water Ship Channel (the bypass width would be relatively narrow [an estimated 1,000-2,000 feet] to minimize impacts on existing land uses and still provide substantial benefits to covered species);
- construction of an operable gate(s) along the west levee Sacramento River upstream of Freeport designed to pass flows into the bypass and to provide for passage of fish upstream and downstream of the gate(s);
- modify the landform within the bypass to prevent stranding of covered fish species.

- removing levees at the south end of the bypass to provide flow connectivity with the Delta; and
- potentially discontinuing farming within the bypass if the bypass is designed with sufficient flood capacity to provide for the natural establishment and growth of riparian vegetation on the floodplain surface to provide structural and hydrodynamic complexity (the bypass width likely would be too narrow to provide for both farming and the desired level of riparian habitat-associated benefits).

Preliminary assessments of this concept indicate that, based on flows recorded at Freeport from 1984-2007, a gate invert elevation of 6 feet in the vicinity of Freeport would allow at least 3,000 cfs to inundate the floodplain for at least 45 consecutive days in 48 percent of the years . The extent of inundated floodplain would be determined by the width of the bypass, but would be expected to range between 2,000 and 5,000 acres. The range of frequencies, durations, and periods that the operable gate(s) would be operated to inundate the new bypass are described in Conveyance Action Parameter 2.

If construction of the Deep Water Ship Channel Bypass is not deemed desirable and feasible or if funding or authorizations necessary to construct the bypass are not obtained, the BDCP Implementing Entity, in coordination with Fishery Agencies, may terminate this conservation measure. If terminated, remaining funding would be deobligated from this conservation measure and reallocated to augment funding for other effective conservation measures identified in coordination with the Fishery Agencies through the BDCP adaptive management process.

**Rationale:** Flood control agencies are currently planning modifications to the existing Central Valley flood control system, which provides an opportunity for the BDCP Implementing Entity to coordinate with these agencies to explore the desirability and feasibility for constructing and operating a Deep Water Ship Channel Bypass.

Historically seasonally inundated floodplains are believed to have played an important role as spawning and juvenile rearing habitat for salmonids, splittail, sturgeon, and other Central Valley fish. As a result of channelization, levee construction, and reclamation for agriculture and other uses, many of the seasonally inundated floodplains on the Sacramento River (and most other Central Valley rivers) and the Delta are no longer accessible to fish and other aquatic species. As discussed for Conservation Measure FLOO1.1, results of recent studies conducted by Sommer et al. (2003, 2004) and others have shown the biological value of seasonal floodplain habitat. These studies have shown that seasonal floodplains provide important spawning and egg incubation habitat for Sacramento splittail, juvenile rearing habitat for Chinook salmon, steelhead, sturgeon, and others, and increase the availability of nutrients as well as production of phytoplankton, zooplankton, and macroinvertebrates that serve as the basis for the trophic web and important food resources for the covered species.

Increasing seasonal floodplain habitat along the Sacramento River also provides increased connectivity among habitats, an alternative migration route for juvenile and adult fish, and a corridor for the downstream transport of fish and nutrients into the lower Sacramento River and Delta.

Increasing the extent of floodplain habitat within the Delta by creating a Deep Water Ship Channel Bypass is expected to reduce the adverse effects of stressors related to food availability, habitat availability, predation, and entrainment for the covered fish species by:

- creating additional spawning habitat for Sacramento splittail by expanding access to floodplain habitat area and providing in-channel spawning habitat by creating backwaters (Sommer et al.2001a, 2002, 2007, 2008, Moyle 2002, Moyle et al. 2004, Feyrer et al. 2006);
- creating additional rearing habitat for Sacramento Basin runs of Chinook salmon, Sacramento splittail, and possibly steelhead (Sommer et al.2001a,b, 2002, 2007, 2008, Moyle 2002, Moyle et al. 2004, Feyrer et al. 2006);
- increasing the production of food for rearing salmonids, splittail, and other covered species (Sommer et al. 2001a,b, 2002, 2007, 2008, Moyle 2002, Moyle et al. 2004, Feyrer et al. 2006);
- naturally establishing freshwater intertidal marsh at suitable elevations within the bypass as a result of restoring tidal connectivity that will produce organic carbon and food in support of aquatic food web processes;
- increasing the availability and production of food in Delta channels downstream of restored floodplain habitat for delta smelt, longfin smelt, and other covered species by exporting organic material and phytoplankton, zooplankton, and other organisms produced from the inundated floodplain into the Delta (Mitsch and Gosselink 2000, Moss 2007)[2];
- reducing the exposure and risk of outmigrating juvenile fish migrating from the Sacramento River into the interior Delta through the Delta Cross Channel and Georgiana Slough, thus decreasing the risk for predation losses (Brandes and McLain 2001, USFWS unpubl. data, Burau pers. com.); and
- reducing the exposure of outmigrating juvenile fish to entrainment at intakes of the proposed North Delta water diversion facilities by passing juvenile fish into the new bypass upstream of the proposed intake locations.

In addition to providing benefits for the covered fish species, riparian habitats if allowed to establish within the new floodplain would substantially increase valley elderberry longhorn beetle habitat and Swainson’s hawk nesting habitat.

**Recommended Implementation Timeframe:** This conservation measure would be implemented in the BDCP long-term implementation period to accommodate the time necessary to coordinate planning with responsible agencies and local land owners and to fund, plan, authorize, and permit construction of the Deep Water

Ship Channel Bypass. Planning and coordination efforts with responsible agencies and local landowners, however, could be initiated in the near-term implementation period.

**Implementation Considerations:** Implementation considerations include:

- coordination with the U.S. Army Corps of Engineers and other flood control agencies to obtain permits to allow for 1) use of the east Sacramento River Deep Water Ship Channel levee to serve as the west levee of the new bypass, 2) construction of a new levee that would serve as the east levee of the new bypass, and 3) levee modifications along the Sacramento River at the upstream end of the new bypass to accommodate the construction and operation of a new operable gate(s).
- coordination with local landowners;
- securing conservation easements, fee title, or other agreements necessary to address the effects of seasonal inundation on current land uses;
- designing the flood capacity of new floodplains to allow for the natural establishment and growth of native woody riparian vegetation;
- potential for increasing mercury methylation and resuspension and downstream transport of other contaminants; and
- potential for short-term mobilization of toxic compounds from newly inundated agricultural lands.

**Resiliency to future changes:** This conservation measure is expected to be resilient to future changes in hydrology and sea levels. With changes in hydrology, the period of inundation is expected to occur earlier in the year than under current conditions (Cayan et al. 2006). Although the frequency, duration, or magnitude of seasonal inundation of the floodplain may vary in the future, the basic functional processes and biological benefits associated with the action would continue into the future over the entire range of anticipated changes in future hydrologic conditions. The the operable gate(s) could be used to regulate seasonal flows and floodplain inundation in response to future changes in Sacramento River hydrology. Sea level rise would be expected to reduce the extent of inundated floodplain at the south end of the bypass and result in tidal emergent wetlands extending into these areas. This tidal emergent wetland would produce organic carbon and organisms in support of food production for covered fish species.

**Uncertainties/risks:** Methylation of mercury may occur in seasonally inundated floodplains and intertidal zones, making methylmercury bioavailable to plants, fish, and wildlife in and downstream of the floodplain (Alpers et al. 2006). Exposure to agricultural pesticides and herbicides may impact habitat productivity in the first few periods that the restored floodplain is inundated. Requirements and the effectiveness of reducing the risk of stranding juvenile fish during floodplain recession require further analysis.

Uncertainty also exists regarding the relative biological effects that may occur as a result of providing seasonal flows through a new flood bypass on habitat conditions, migration rates, and the downstream transport of fish eggs and larvae as well as phytoplankton, zooplankton, and organic matter within the mainstem Sacramento River. Reduced flows within the mainstem of the Sacramento River during the late winter and early spring when the bypass would be flooding have the potential to reduce survival of those organisms that continue to inhabit the mainstem river.

Although the available data supports the biological benefits of increasing the frequency and duration of floodplain inundation along the Sacramento River, there is uncertainty in the relationship between the seasonal timing, duration of inundation, and the benefits for various species.

**Monitoring and adaptive management considerations:** ***[Note to reviewers:*** *this section is a general summary; more detail will be provided in future iterations.]* Implementation of this conservation measure would provide opportunities to adaptively manage flows in the new bypass using the operable gate(s) to improve food production and habitat conditions for covered fish species over time based on monitoring results. Basic operational monitoring would include variables such as Sacramento River stage, flow into the Yolo Bypass, water velocities and residence times, water quality, and overall conditions of aquatic habitat within the seasonal floodplain. Physical habitat parameters that would be useful to monitor include the extent of wetted area and water depths, dissolved oxygen concentrations, water temperatures, water velocities and residence times, and other features of the floodplain habitat. Opportunities for adaptive management include assessing the effectiveness of seasonal floodplain habitat restoration designs and the ability of native riparian vegetation to successfully establish on the new floodplain surface. Monitoring the establishment of riparian vegetation would provide information necessary for determining the need to control the establishment of non-native vegetation or plant native vegetation to promote development of native riparian forest and scrub habitats. Additionally, monitoring of covered fish species benefits provided by inundation of the Deep Water Ship Channel Bypass and the Yolo Bypass (see Conservation Measure FLOO1.1) under various operations would help inform how to co-manage inundation of the bypasses to spatially and temporally optimize benefits for covered fish species. Some additional monitoring considerations to inform adaptive implementation include:

- phytoplankton and zooplankton production on the inundated floodplain;
- load of organic carbon, phytoplankton, zooplankton, and macroinvertebrates exported into aquatic habitat in the Delta;
- effects of floodplain inundation on food production and water quality in downstream areas;

- incidence of and magnitude of stranding of all life stages of covered fish species;
- shifts in topography over time (e.g., floodplain scouring that create surfaces that pond deep water) that could create stranding risks for covered fish species;
- effects on the relative survival, migration, and transport of covered fish species within the mainstem Sacramento River as a function of flows diverted into the new bypass;
- effects of floodplain inundation on Delta turbidity;
- habitat use by green and white sturgeon, salmon, steelhead, and other covered fish;
- levels of mercury methylation and resuspension of contaminants, and biological uptake; and
- growth and survival of rearing Sacramento splittail and Chinook salmon.

**Reversibility:** Construction of the new bypass would be very difficult to reverse because of the high capital costs associated with construction of new levees and construction of an operable gate(s) and associated levee modifications.

Flow-related effects of this conservation measure are considered to be easily reversible because the BDCP Implementing Entity could choose not to operate the gate(s). Costs related to modification of the existing levee to install an operable gate(s), construction of the east bypass levee, modifications to the west Deep Water Ship Channel levee (if needed), and re-grading within the new bypass, however, could not be recovered. The new levee could permanently remove farm land within the levee footprint if it is too costly to remove.

**Conservation Measure FLOO2.2: Restore floodplain habitat along __ miles of the San Joaquin River from Vernalis to Mossdale.** The BDCP Implementing Entity would coordinate flood control planning with the Central Valley Flood Protection Board, California Department of Water Resources (DWR), and U.S. Army Corps of Engineers to assess the desirability and feasibility for setting back levees along the San Joaquin River from Vernalis to Mossdale to restore seasonally inundated floodplain habitats for covered fish species and provide flood control benefits. If results of planning studies indicate that setting back levees along this reach of the San Joaquin River is desirable and feasible, the BDCP Implementing Entity would enter into a cost sharing agreement with the U.S. Army Corps of Engineers for project planning and construction and would assist with securing Congressional authorization and funding for the project. If authorized and funded, the BDCP Implementing Entity would enter into subsequent agreements with the U.S. Army Corps of Engineers and other appropriate agencies governing levee and floodway maintenance responsibilities.

Located within the South Delta ROA (see Figure 1), this conservation measure would expand the flood capacity of the existing constricted flood control channel downstream of

Vernalis to Mossdale by setting back levees along the San Joaquin River to expand the floodplain to allow flood waters to attenuate, improving access of juvenile fish, such as Chinook salmon and steelhead, to seasonally inundated floodplain habitat, and reducing flood risk to properties upstream and downstream. If implemented, restored floodplain habitat along the San Joaquin River would be designed and operated to support the physical and biological attributes described in Attachment A. Implementation would require acquisition of lands in fee-title or through conservation easements within the footprint of the expanded floodway and levees.

Floodplain habitat would be restored by setting back levees along the San Joaquin River and removing all or large sections of the existing levees. The extent that levees would be set back and the extent of floodplain restored would primarily be dependent on the extent of restored floodplain that could be inundated under __ year flood events as modeled for hydrological conditions expected with climate change. Initial hydrodynamic modeling under existing hydrologic conditions suggests that, on average, new floodplain habitat areas could be inundated for at least 30 consecutive days from late winter to early spring on average once every 5.5 years (i.e., 18% of years). The new floodplain area would be contoured, if needed, to reduce and avoid the potential for stranding of juvenile and adult fish following inundation events.

The channel within the restored floodplain reach would be modified where practicable to create low velocity habitat areas designed to provide spawning habitat for splittail and rearing habitat for splittail and salmonids. Within the restored floodplain, farming potentially would be discontinued and riparian vegetation would be allowed to naturally establish and the channel would be allowed to meander between the new levees through the natural processes of erosion and sedimentation (the width of setback levees likely would be too narrow to provide for both farming and the desired level of riparian habitat-associated benefits).

If setting back levees along this reach of the San Joaquin River is not deemed desirable and feasible or if funding or authorizations necessary to construct the bypass are not obtained, the BDCP Implementing Entity, in coordination with Fishery Agencies, may terminate this conservation measure. If terminated, remaining funding would be deobligated from this conservation measure and reallocated to augment funding for other effective conservation measures identified in coordination with the Fishery Agencies through the BDCP adaptive management process.

**Rationale:** Flood control agencies are currently planning modifications to the existing Central Valley flood control system, which provides an opportunity for the BDCP Implementing Entity to coordinate with these agencies to to explore the desirability and feasibility for setting back levees along this reach of the San Joaquin River.

Increasing the extent of floodplain habitat by setting back levees along the San Joaquin River from Vernalis to Mossdale is expected to reduce the adverse effects of stressors related to food and habitat availability for the covered fish species by:

- creating additional spawning habitat for Sacramento splittail by expanding floodplain habitat area and providing in-channel spawning habitat by creating backwaters (Sommer et al. 2001a, 2002, 2007, 2008, Moyle 2002, Moyle et al. 2004, Feyrer et al. 2006)

- creating additional rearing habitat for San Joaquin Basin runs of Chinook salmon, Sacramento splittail, and possibly steelhead (Sommer et al.2001a,b, 2002, 2007, 2008, Moyle 2002, Moyle et al. 2004, Feyrer et al. 2006);
- increasing the production of food for rearing salmonids, splittail, and other covered species (Sommer et al. 2001a,b, 2002, 2007, 2008, Moyle 2002, Moyle et al. 2004, Feyrer et al. 2006);
- increasing the availability and production of food in Delta channels downstream of restored floodplain habitat for delta smelt, longfin smelt, and other covered species by exporting organic material and phytoplankton, zooplankton, and other organisms produced from the inundated floodplain into Delta channels (Mitsch and Gosselink 2000, Moss 2007)[2]; and
- increasing habitat complexity by allowing the natural establishment and growth of woody riparian vegetation that will provide inputs of large woody debris into the river channel and provide overhead cover.

In addition to providing benefits for the covered fish species, riparian habitats established within the new floodplain habitat would be expected substantially increase habitat for Swainson’s hawk, riparian brush rabbit, valley elderberry longhorn beetle, delta button celery, and delta tule pea.

**Recommended Implementation Timeframe:** This conservation measure would be implemented in the BDCP long-term implementation period to accommodate the time necessary to coordinate planning with responsible agencies and local land owners and to fund, plan, authorize, and permit construction of the set back levees and demolition of existing levees. Planning and coordination efforts with responsible agencies and local landowners, however, could be initiated in the near-term implementation period. Furthermore, it would not be desirable to restore floodplain in the south Delta until after completion of the around-Delta conveyance facilities to minimize adverse effects of South Delta SWP and CVP pumping operations on the functions of the restored habitat.

**Implementation Considerations:** Implementation considerations include:

- coordination with the U.S. Army Corps of Engineers and other flood control agencies to allow for 1) the removal of flood control levees and the construction of new flood control levees setback from San Joaquin River;
- coordination with local landowners;
- designing the flood capacity of setback levees to allow for the natural establishment and growth of native woody riparian vegetation;
- ensuring that designs would be compatible and provide synergistic species and

ecosystem benefits with restoration of floodplain habitats along Old River or Middle River (see Conservation Measure FLOO2.4) and freshwater tidal marsh habitats in the South Delta ROA (see Figure 1 and Conservation Measure FIMA1.4);

- potential for increasing mercury methylation and resuspension and downstream transport of other contaminants;
- potential for short-term mobilization of toxic compounds from newly inundated agricultural lands;
- potential for aggravating low DO in the Stockton Deep Water Ship Channel if late floods produce large amounts of algae or decaying organic material that are transported into the Ship Channel;
- opportunities for increasing the frequency of inundation of the restored floodplain in future years if changes in upstream operations increase San Joaquin River flows entering the Delta; and
- potential for increased inundation frequency and duration with future changes in hydrology resulting from climate change.

**Resiliency to future changes:** Setback levees would be designed to accommodate future changes in hydrology and sea level rise and, thus, would be expected to be fairly resilient to future changes in these conditions. With changes in hydrology, the frequency of floodplain inundation would be expected to increase and period of inundation could be expected to occur earlier in winter year than under current conditions (Cayan et al. 2006). Sea level rise could reduce the extent of inundated floodplain in downstream restored habitat area as sea level rises. The lost floodplain habitat, however, would be expected to develop as tidal marsh, which would produce organic carbon and organisms in support of food production for covered fish species.

**Uncertainties/risks:** Methylation of mercury may occur in seasonally inundated floodplains and intertidal zones, making methylmercury bioavailable to plants, fish, and wildlife in and downstream of the floodplain (Alpers et al. 2006). Exposure to agricultural pesticides and herbicides may impact habitat productivity in the first few periods that the restored floodplain is inundated. Requirements and the effectiveness of reducing the risk of stranding juvenile fish during floodplain recession require further analysis.

**Monitoring and adaptive management considerations:** ***[Note to reviewers:*** *this section is a general summary; more detail will be provided in future iterations.]* Opportunities for adaptive management include assessing the effectiveness of in-channel backwater and seasonal floodplain habitat restoration designs and the ability of native riparian vegetation to successfully establish on new floodplain surfaces and along the channels. Monitoring the establishment of riparian vegetation would provide information necessary for determining the need to control the establishment of non-native vegetation or plant native vegetation to promote development of native riparian forest and scrub habitats. Monitoring of restored floodplain habitats would also provide information that would be useful in restoring floodplains in other locations. Some of the monitoring considerations include:

- phytoplankton and zooplankton production on the inundated floodplain and changes in in-channel phytoplankton and zooplankton production associated with increasing the complexity of in-channel habitat;
- load of organic carbon, phytoplankton, zooplankton, and macroinvertebrates exported into aquatic habitat in the Delta;
- effects of floodplain inundation on food production and water quality in downstream areas;
- effects of floodplain inundation on Delta turbidity;
- habitat use by green and white sturgeon, salmon, steelhead, and other covered fish;
- levels of mercury methylation and resuspension of contaminants, and biological uptake;
- covered fish species use of restored backwaters; and
- growth and survival of rearing Sacramento splittail and Chinook salmon.

**Reversibility:** The restoration actions described under this conservation measure would be very difficult to reverse because of the high capital costs associated with construction of new levees and the removal of existing levees.

**Conservation Measure FLOO2.3: Restore floodplain habitat along __ miles of the San Joaquin River from Mossdale to French Camp Slough.** The BDCP Implementing Entity would coordinate flood control planning with the Central Valley Flood Protection Board, California Department of Water Resources (DWR), and U.S. Army Corps of Engineers to assess the desirability and feasibility for setting back levees along the San Joaquin River from Mossdale to French Camp Slough to restore seasonally inundated floodplain habitats for covered fish species and provide flood control benefits. If results of planning studies indicate that setting back levees along this reach of the San Joaquin River is desirable and feasible, the BDCP Implementing Entity would enter into a cost sharing agreement with the U.S. Army Corps of Engineers for project planning and construction and would assist with securing Congressional authorization and funding for the project. If authorized and funded, the BDCP Implementing Entity would enter into subsequent agreements with the U.S. Army Corps of Engineers and other appropriate agencies governing levee and floodway maintenance responsibilities.

Located within the South Delta ROA (see Figure 1), this conservation measure would increase seasonally inundated floodplain habitat and expand the flood capacity of the existing flood control channel downstream of Mossdale to French Camp Slough by setting back levees along the San Joaquin River. Restored floodplain habitat would be designed and operated to support the physical and biological attributes described in Attachment A. Implementation would require acquisition of lands in fee-title or through conservation easements within the footprint of the expanded floodway and levees.

Floodplain habitat would be restored by setting back levees along the San Joaquin River and removing all or large sections of the existing levees. The extent to which levees would be setback and the extent of floodplain habitat restored would primarily be dependent on the extent of restored floodplain that could be inundated under __ year flood events as modeled for hydrological conditions expected with climate change and land surface elevations. The new floodplain area would be contoured, if needed, to reduce and avoid the potential for stranding of juvenile and adult fish following inundation events. Ground surface elevations along tidal reaches may need to be elevated to allow natural establishment of tidal freshwater wetland and riparian habitat.
The channel within the restored floodplain reach would be modified where practicable to create lower velocity habitat areas designed to provide spawning habitat for splittail and rearing habitat for splittail and salmonids. Within the restored floodplain, farming potentially would be discontinued and riparian vegetation would be allowed to naturally establish and the channel would be allowed to meander between the new levees through the natural processes of erosion and sedimentation (the width of setback levees likely would be too narrow to provide for both farming and the desired level of riparian habitat-associated benefits).

If setting back levees along this reach of the San Joaquin River is not deemed desirable and feasible or if funding or authorizations necessary to construct the bypass are not obtained, the BDCP Implementing Entity, in coordination with Fishery Agencies, may terminate this conservation measure. If terminated, remaining funding would be deobligated from this conservation measure and reallocated to augment funding for other effective conservation measures identified in coordination with the Fishery Agencies through the BDCP adaptive management process.

**Rationale:** Flood control agencies are currently planning modifications to the existing Central Valley flood control system, which provides an opportunity for the BDCP Implementing Entity to coordinate with these agencies to to explore the desirability and feasibility for setting back levees along this reach of the San Joaquin River.

Increasing the extent of floodplain habitat by setting back levees along the San Joaquin River from Mossdale to French Camp Slough is expected to reduce the adverse effects of stressors related to food and habitat availability for the covered fish species by:

- creating additional spawning habitat for Sacramento splittail by expanding floodplain habitat area and providing in-channel spawning habitat by creating backwaters (Sommer et al. 2001a, 2002, 2007, 2008, Moyle 2002, Moyle et al. 2004, Feyrer et al. 2006)

- creating additional rearing habitat for San Joaquin Basin runs of Chinook salmon, Sacramento splittail, and possibly steelhead (Sommer et al.2001a,b, 2002, 2007, 2008, Moyle 2002, Moyle et al. 2004, Feyrer et al. 2006);
- increasing the production of food for rearing salmonids, splittail, and other covered species (Sommer et al. 2001a,b, 2002, 2007, 2008, Moyle 2002, Moyle et al. 2004, Feyrer et al. 2006);
- increasing the availability and production of food in Delta channels downstream of restored floodplain habitat for delta smelt, longfin smelt, and other covered species by exporting organic material and phytoplankton, zooplankton, and other organisms produced from the inundated floodplain into Delta channels (Mitsch and Gosselink 2000, Moss 2007)[2]; and
- increasing habitat complexity by allowing the natural establishment and growth of woody riparian vegetation that will provide inputs of large woody debris into the river channel and provide overhead cover.

In addition to providing benefits for the covered fish species, riparian habitats established within the new floodplain habitat along the San Joaquin River would be expected substantially increase habitat for Swainson's hawk, riparian brush rabbit, valley elderberry longhorn beetle, delta button celery, and delta tule pea.

**Recommended Implementation Timeframe:** This conservation measure would be implemented in the BDCP long-term implementation period to accommodate the time necessary to coordinate planning with responsible agencies and local land owners and to fund, plan, authorize, and permit construction of the set back levees and demolition of existing levees. Planning and coordination efforts with responsible agencies and local landowners, however, could be initiated in the near-term implementation period. Furthermore, it would not be desirable to restore floodplain in the south Delta until after completion of the around-Delta conveyance facilities to minimize adverse effects of South Delta SWP and CVP pumping operations on the functions of the restored habitat.

**Implementation Considerations:** Implementation considerations include:

- coordination with the U.S. Army Corps of Engineers and other flood control agencies to allow for the removal of flood control levees and the construction of new flood control levees setback from San Joaquin River;
- coordination with local landowners;
- designing the flood capacity of new floodplains to allow for the natural establishment and growth of native woody riparian vegetation;
- ensuring that designs would be compatible and provide synergistic species and ecosystem benefits with restoration of floodplain habitats along Old River or Middle River (see Conservation Measure FLOO2.4) and freshwater tidal marsh habitats in the South Delta ROA (see Figure 1 and Conservation Measure FIMA1.4);

- potential for increasing mercury methylation and resuspension and downstream transport of other contaminants;
- potential for short-term mobilization of toxic compounds from newly inundated agricultural lands;
- potential for aggravating low dissolved oxygen in the Stockton Deep Water Ship Channel if late floods produce large amounts of algae or decaying organic material that are transported into the Ship Channel;
- opportunities for designing the floodway to increase the tidal prism such that tidal velocities and mixing are increased sufficiently to improve dissolved oxygen levels in the Stockton Deep Water Ship Channel;
- opportunities for increasing the frequency of inundation of the restored floodplain in future years if changes in upstream operations increase San Joaquin River flows entering the Delta; and
- potential for increased inundation frequency and duration with future changes in hydrology resulting from climate change.

**Resiliency to future changes:** Setback levees would be designed to accommodate future changes in hydrology and sea level rise and, thus, would be expected to be fairly resilient to future changes in these conditions. With changes in hydrology, the frequency of floodplain inundation would be expected to increase and period of inundation could be expected to occur earlier in winter year than under current conditions (Cayan et al. 2006). Sea level rise could reduce the extent of inundated floodplain in downstream restored habitat area as sea level rises. The lost floodplain habitat, however, would be expected to develop as tidal marsh, which would produce organic carbon and organisms in support of food production for covered fish species. Proposed restored tidal marsh upstream of Stockton would be expected to establish further upstream in the floodplain as sea level rises.

**Uncertainties/risks:** Methylation of mercury may occur in seasonally inundated floodplains and intertidal zones, making methylmercury bioavailable to plants, fish, and wildlife in and downstream of the floodplain (Alpers et al. 2006). Exposure to agricultural pesticides and herbicides may impact habitat productivity in the first few periods that the restored floodplain is inundated. Requirements and the effectiveness of reducing the risk of stranding juvenile fish during floodplain recession require further analysis.

**Monitoring and adaptive management considerations:** ***[Note to reviewers:** this section is a general summary; more detail will be provided in future iterations.]* Opportunities for adaptive management include assessing the effectiveness of in-channel backwater and seasonal floodplain habitat restoration designs and the ability of native riparian vegetation to successfully establish on new floodplain surfaces and along the channels. Monitoring the establishment of riparian vegetation would provide information necessary for determining the need to control the establishment of non-native vegetation or plant native vegetation to promote development of native riparian forest and scrub habitats. Monitoring of restored floodplain habitats would also provide information that would be useful in restoring floodplains in other locations. Some of the monitoring considerations include:

- phytoplankton and zooplankton production on the inundated floodplain and changes in in-channel phytoplankton and zooplankton production associated with increasing the complexity of in-channel habitat;
- load of organic carbon, phytoplankton, zooplankton, and macroinvertebrates exported into aquatic habitat in the Delta;
- effects of floodplain inundation on food production and water quality in downstream areas;
- effects of floodplain inundation on Delta turbidity;
- habitat use by green and white sturgeon, salmon, steelhead, and other covered fish;
- levels of mercury methylation and resuspension of contaminants, and biological uptake;
- covered fish species use of restored backwaters; and
- growth and survival of rearing Sacramento splittail and Chinook salmon.

**Reversibility:** The restoration actions described under this conservation measure would be very difficult to reverse because of the high capital costs associated with construction of new levees and the removal of existing levees.

**Conservation Measure FLOO2.4: Restore between __ and __ acres of inundated floodplain habitat in the South Delta Restoration Opportunity Area.** Within the South Delta ROA (see Figure 1), inundated floodplain habitat would be restored on Fabian Tract along Old River or on Union Island and Upper Roberts Island along Middle River. The location of restored floodplain habitat would depend on the location and design of the selected conveyance pathway and operations for the through-Delta component of the dual conveyance facility. Floodplain habitat would be restored along the river that would provide the most substantial species and ecosystem benefits with the selected through-Delta conveyance configuration. Restored floodplain habitat would be designed and operated to support the physical and biological attributes described in Attachment A.

Design elements of this conservation measure could include:

- acquisition of lands in fee-title or through conservation easements suitable for restoration of intertidal and subtidal habitats and for accommodating future sea level rise;

- setting back levees along the selected river corridor and removing the existing levees or large sections of the existing levees;
- discontinuing farming within the setback levees and allowing riparian vegetation to naturally establish on the floodplain; and
- re-contouring the restored floodplain surface, if needed, to avoid potential for stranding of juvenile and adult fish following inundation events.

**Rationale:** Increasing the extent of floodplain habitat is expected to reduce the adverse effects of stressors related to food and habitat availability for the covered fish species by:

- creating additional spawning habitat for Sacramento splittail by expanding floodplain habitat area (Sommer et al.2001a, 2002, 2007, 2008, Moyle 2002, Moyle et al. 2004, Feyrer et al. 2006);
- creating additional rearing habitat for Sacramento splittail, runs of Chinook salmon from the San Joaquin River and other eastside tributaries, and possibly steelhead (Sommer et al.2001a,b, 2002, 2007, 2008, Moyle 2002, Moyle et al. 2004, Feyrer et al. 2006);
- increasing the production of food for rearing salmonids, splittail, and other covered species (Sommer et al. 2001a,b, 2002, 2007, 2008, Moyle 2002, Moyle et al. 2004, Feyrer et al. 2006);
- increasing the availability and production of food in the Delta downstream of restored floodplain habitat for delta smelt, longfin smelt, and other covered species by exporting organic material and phytoplankton, zooplankton, and other organisms produced from the inundated floodplain into the Delta (Mitsch and Gosselink 2000, Moss 2007)[2]; and
- increasing hydrodynamic and structural complexity within the channel by allowing the natural establishment and growth of woody riparian vegetation that would provide inputs of large woody debris into the river channel and provide overhead cover.

Improving in-channel habitat complexity along the Old or Middle River corridors would be expected to reduce the predation risk to covered fish species and improve connectivity between San Joaquin River habitats and Delta habitats for passage of juvenile salmonids outmigrating from the San Joaquin River and eastside tributaries.

In addition to providing benefits for the covered fish species, restored riparian habitats associated with creating new floodplain habitat in the South Delta ROA (see Figure 1) would be expected to substantially increase habitat for Swainson's hawk, riparian brush rabbit, valley elderberry longhorn beetle, delta button celery, and delta tule pea.

**Recommended Implementation Timeframe:** This conservation measure would not be implemented until after completion of the around-Delta conveyance facilities to minimize adverse affects of South Delta SWP/CVP pumping operations on the functions of the restored habitat. Restoration planning and design could be initiated in the near-term implementation period.

**Implementation Considerations:** Implementation considerations include:

- selecting the location for floodplain restoration (Fabian Tract, Union Island, or Middle Roberts Island) is dependent on the through-Delta corridor (i.e., Old River or Middle River, or both rivers) selected for dual operations and therefore the relative influence of South Delta SWP/CVP pumping operations on the restored habitat;
- coordination with the Department of Water Resources and local reclamation districts to allow for the removal of flood control levees and the construction of new flood control levees setback from the selected river corridor;
- designing the flood capacity of new floodplains to allow for the natural establishment and growth of native woody riparian vegetation;
- ensuring that designs would be compatible and provide synergistic species and ecosystem benefits with restoration of floodplain habitats along the San Joaquin River (see Conservation Measure FLOO2.1) and freshwater intertidal marsh habitats in the South Delta ROA (see Figure 1 and Conservation Measure FIMA1.4);
- potential for increasing mercury methylation;
- potential for short-term mobilization of toxic compounds from newly inundated lands;
- the likelihood that restoration of habitat could increase entrainment risk for covered fish species at the SWP and CVP pumping facilities;
- the likelihood that substantial proportions of food and organic material exported from restored floodplains would be entrained at the SWP and CVP pumping facilities;
- opportunities for increasing the frequency of inundation of the restored floodplain in future years if changes in upstream operations increase San Joaquin River flows entering the Delta; and
- potential for increased inundation frequency with future changes in hydrology resulting from climate change.

**Resiliency to future changes:** This conservation measure is expected to be somewhat resilient to future changes in the hydrograph and sea level. With changes in the hydrograph, the frequency of inundation would be expected to increase and inundation could occur earlier in the year than under current conditions (Cayan et al. 2006). Sea level rise could reduce the extent of inundated floodplain in downstream restoration areas. The floodplain habitat inundated by

# Handout #3

sea level rise, however, would be expected to develop into tidal marsh, which would produce organic carbon and organisms in support of food production for covered fish species.

**Uncertainties/risks:** Methylation of mercury may occur in seasonally inundated floodplains and intertidal zones, making methylmercury bioavailable to plants, fish, and wildlife in and downstream of the floodplain (Alpers et al. 2006). Exposure to residual agricultural pesticides and herbicides may impact habitat productivity in the first few periods that the restored floodplain is inundated. It is uncertain whether or not flows sufficient to inundated restored floodplain habitats would be of sufficient magnitude to provide substantial benefits for covered fish species during periods floodplains are inundated and the SWP and CVP pumping facilities are in operation.

**Monitoring and adaptive management considerations:** ***[Note to reviewers:** this section is a general summary; more detail will be provided in future iterations.]* Opportunities for adaptive management are related to assessing the effectiveness of restored floodplain to develop as functional habitat for covered species and to produce food and organic material in support of food web processes. Adaptive management considerations include assessing the need for further actions to improve species benefits if indicated through monitoring (e.g., control of non-native fish predators if survival of outmigrating salmonids using the corridor is not improved). Monitoring the establishment of riparian vegetation on the restored floodplains and along the channel would also provide information useful to restoring floodplains in other locations. Some of the monitoring considerations include:

- phytoplankton and zooplankton production on the inundated floodplain and changes in in-channel phytoplankton and zooplankton production associated with increasing the complexity of in-channel habitat;
- load of organic carbon, phytoplankton, zooplankton, and macroinvertebrates exported into aquatic habitat in the Delta;
- natural establishment and growth of riparian vegetation;
- effects of floodplain inundation on food production and water quality in downstream areas;
- effects of floodplain inundation of Delta turbidity;
- habitat use by green and white sturgeon, salmon, and other covered fish species;
- levels of mercury methylation and biological uptake; and
- growth and survival of rearing Sacramento splittail and Chinook salmon.

**Reversibility:** This conservation measure would be difficult to reverse because of the high capital costs associated with construction of new levees and the removal of existing levees.

## Freshwater Intertidal Marsh Habitat Restoration Conservation Measures

**Conservation Measure FIMA1.1. Restore a mosaic of __ to __ acres of freshwater intertidal marsh, shallow subtidal aquatic, and transitional grassland habitat within the Yolo Bypass/Cache Slough Complex Restoration Opportunity Area.** Restored freshwater intertidal marsh and shallow subtidal aquatic habitats would be designed to support the physical and biological attributes described in Attachment A. The mosaic of habitats would include at least __ acres of freshwater intertidal marsh habitat. Areas suitable for restoration include, but are not limited to, Haas Slough, Hastings Cut, Lindsey Slough, Barker Slough, Calhoun Cut, Liberty Island, Little Holland, the Westlands property, Shag Slough, Little Egbert Tract, and Prospect Island. Design elements of this conservation measure could include:

- acquisition of lands in fee-title or through conservation easements suitable for restoration of intertidal and subtidal habitats and for accommodating future sea level rise;
- breaching levees to provide for tidal exchange with lands being restored and construction of new levees to provide flood protection for adjacent landowners as appropriate;
- modifying ditches and cuts to encourage the development of a dendritic system of tidal channels based on local hydrology, sized appropriately for the tidal prism being conveyed;
- restoring stream functions of erosion and sedimentation (e.g., Ulatis Flood Control channel) to improve spawning conditions for delta smelt and other fish and macroinvertebrates; and
- planting tules before breaching levees to raise ground surface elevations suitable for tidal marsh restoration on subsided lands (e.g., Little Egbert Tract).

**Rationale:** Restoring freshwater intertidal marsh and shallow subtidal aquatic habitats within the Cache Slough Complex is expected to reduce the adverse effects of stressors related to food availability and habitat availability for the covered fish species by:

- increasing rearing habitat area for Chinook salmon, Sacramento splittail, and possibly steelhead (Healey 2001, Brown 2003);
- increasing the production of food for rearing salmonids, splittail, and other covered species (Kjelson et al. 1982, Siegel 2007);
- increasing the availability and production of food in the Delta downstream of Rio Vista by exporting organic material from the marsh plain and

phytoplankton, zooplankton, and other organisms produced in intertidal channels into the Delta (Siegel 2007);

- locally providing areas of cool water refugia for delta smelt (C. Enright pers. comm.);
- increasing the extent of habitat available for colonization by Mason's lilaeopsis; and
- increasing the extent of habitat for giant garter snake, California black rail, and tricolored blackbird.

Additionally, the Cache Slough Complex encompasses a substantial area of land with elevations suitable for freshwater tidal marsh restoration that would involve few impacts on infrastructure or permanent crops relative to other areas of the north Delta.

**Recommended Implementation Timeframe:** It is anticipated that implementation of this conservation measure could be initiated in the BDCP near-term implementation period.

**Implementation Considerations:** Implementation considerations include:

- the need to coordinate with the Solano County HCP to ensure effective implementation of conservation measures under both programs;
- feasibility for subsidence reversal using tule plantings or other techniques to raise ground surface elevations before breaching levees;
- ensuring compatibility with flood control functions of the Yolo Bypass;
- ensuring that designs would be compatible and provide synergistic species and ecosystem benefits with proposed restoration of floodplain habitats in the Yolo Bypass and a new Deep Water Ship Channel Bypass as described under Conservation Measures FLOO1.1 and FLOO2.1, respectively;
- coordination with land owners, the Lower Yolo Bypass Planning Forum, and other conservation planning efforts;
- the need to incorporate design features and management strategies to preclude or minimize the establishment of *Egeria* and other undesirable non-native species;
- the need to incorporate design features that will promote the natural establishment of marsh-associated covered plant species;
- consideration for the effects of restoration-induced dampening of the tidal range on subsequent marsh restoration designs;
- potential for increasing mercury methylation and resuspension of contaminants;

- locating and designing levee breaches to maximize the development of intertidal marsh and minimize hydrodynamic conditions that favor non-native predatory fish;
- potential effects on existing populations of covered plant species;
- determining the appropriate allowable land uses and management activities on transitional grasslands conserved to accommodate future sea level rise; and
- the need to address the likely adverse effects of the Barker Slough Pumping Plant intake on entrainment of food produced from and fish inhabiting restored marshes before restoring habitats south of Lindsey Slough.

**Resiliency to future changes:** This conservation measure is expected to be resilient to future changes in hydrology and sea levels. Conserving higher elevation transitional grassland habitat along the margins of restored intertidal marsh would provide sufficient lands to accommodate the upslope establishment of intertidal marsh as sea level rises.

**Uncertainties/risks:** Restoration of subtidal aquatic habitats could result in infestation by non-native submerged aquatic vegetation and increase the abundance of non-native predators or vulnerability of covered fish species to predation. Methylation of mercury may occur in intertidal zones, making methylmercury bioavailable to plants, fish, and wildlife in and downstream of restored marshes (Alpers et al. 2006). It is uncertain if altering habitat conditions in this area could adversely affect delta smelt spawning in this area if salinity gradients, turbidity, or temperature conditions that support delta smelt habitat are degraded as a result of restoration actions. Additionally, there could be a short-term risk associated with mobilizing pesticides, herbicides, and other contaminants into the Delta following initial introduction of tidal flow onto agricultural lands.

**Monitoring and adaptive management considerations:** ***[Note to reviewers:** this section is a general summary; more detail will be provided in future iterations.]* Opportunities for adaptive management are related to assessing the effectiveness of restored marshes and adjacent shallow subtidal habitats to develop as functional covered species habitats and to produce food and organic carbon in support of food web processes. Results of monitoring the development of early marsh restorations would help inform improvements in the design and management of subsequent marsh restoration projects. Results of monitoring early restorations could also be used to develop cost effective management techniques, if needed, to control the establishment of non-native species in restored marshes. Some of the monitoring considerations include:

- type and extent of use by covered fishes;
- extent of phytoplankton, zooplankton, and macroinvertebrate production in marsh channels;

- load of organic carbon, phytoplankton, zooplankton, and macroinvertebrates produced in emergent marshes and subsequently exported into the Delta;
- extent of native vegetation relative to non-native vegetation on the marsh plain;
- extent of native aquatic vegetation relative to non-native aquatic vegetation;
- growth and survival of rearing Sacramento splittail and Chinook salmon in shallow subtidal aquatic habitats;
- change in abundance of non-native predatory fish species;
- ongoing use of the Cache Slough complex by spawning delta smelt;
- the establishment of habitat conditions suitable for the natural establishment of marsh-associated covered plant species; and
- levels of mercury methylation and biological uptake.

**Reversibility:** This conservation measure would be difficult to reverse because it would require re-construction of levees to re-isolate restored habitat areas from tidal flow and pumping to remove water from reclaimed habitat areas.

**Conservation Measure FIMA1.2: Restore a mosaic of __ to __ acres of freshwater intertidal marsh, shallow subtidal aquatic, and transitional habitat within the Cosumnes/Mokelumne ROA.** Restored freshwater intertidal marsh and shallow subtidal aquatic habitats would be designed to support the physical and biological attributes described in Attachment A. The mosaic of habitats would include at least __ acres of freshwater intertidal marsh habitat. Areas suitable for restoration within the Cosumnes/Mokelumne ROA (see Figure 1) include McCormack-Williamson Tract, New Hope Tract, Canal Ranch Tract, Bract Tract, Terminous Tract north of State Highway 12, and lands adjoining Snodgrass Slough, South Stone Lake, and Lost Slough. Design elements of this conservation measure could include:

- acquisition of lands in fee-title or through conservation easements suitable for restoration of intertidal and subtidal habitats and for accommodating future sea level rise;
- constructing levees to isolate deeply subsided lands and protect private property;
- planting tules or placing fill material to raise elevations of shallowly subsided lands,
- creating channels to promote the development of tidal channels; and
- breaching levees to reintroduce tidal exchange to currently leveed lands.

If the eastern alignment of an around-Delta conveyance facility is constructed, the canal levees may be incorporated into the design of intertidal emergent wetland restoration. For example, in locations where the conveyance canal is located at elevations at or below elevations suitable for restoration of intertidal marsh, marsh may be restored to the east of canal levee, with the canal levee forming the western boundary of the restored marsh.

**Rationale:** Restoring freshwater intertidal marsh and shallow subtidal aquatic habitats within the Cosumnes/Mokelumne River ROA (see Figure 1) is expected to reduce the adverse effects of stressors related to food and habitat availability for the covered fish species by:

- increasing rearing habitat area for Sacramento splittail and Cosumnes and Mokelumne River fall-run Chinook salmon and possibly steelhead (Healey 2001, Brown 2003);
- increasing the production of food for rearing salmonids, splittail, and other covered species migrating to and from the Cosumnes and Mokelumne Rivers (Kjelson et al. 1982, Siegel 2007);
- increasing the availability and production of food in the east and central Delta by exporting organic material from the marsh plain and phytoplankton, zooplankton, and other organisms produced in intertidal channels into the Delta (Siegel 2007);
- locally providing areas of cool water refugia for delta smelt (C. Enright pers. comm.);
- increasing the extent of habitat available for colonization by Mason's lilaeopsis, and
- increasing the extent of habitat for giant garter snake, California black rail, and tricolored blackbird.

**Recommended Implementation Timeframe:** Restoration of marsh could be initiated during the BDCP near-term implementation period at locations within this ROA that would not be affected by or would be dependent on construction of an around-Delta conveyance facility (e.g., McCormack-Williamson Tract). Locations for marsh restoration within this ROA that would be affected by or would be dependent on construction of an around-Delta conveyance facility would be implemented in the the BDCP long-term implementation period.

**Implementation Considerations:** Implementation considerations include:

- the feasibility for subsidence reversal using tule plantings or other technique to raise ground surface elevations before breaching levees;
- ensuring compatibility with flood control functions of north Delta levees and channels (e.g., McCormack-Williamson Tract);
- restoration effects on upstream and downstream flood risk;
- the need to incorporate design features and management strategies to preclude or minimize the establishment of non-native submerged aquatic vegetation and other undesirable non-native species;

- locating and designing levee breaches to maximize the development of intertidal marsh and minimize hydrodynamic conditions that favor non-native predatory fish;
- the need to incorporate design features that will promote the natural establishment of marsh-associated covered plant species;
- consideration for the effects of restoration-induced dampening of the tidal range on subsequent marsh restoration designs;
- potential for increasing mercury methylation and resuspension of contaminants;
- compatibility with the footprint and facilities associated with an around-Delta conveyance facility;
- determining appropriate allowable land uses and management activities on transitional grasslands conserved to accommodate future sea level rise;
- securing fee title or easements for implementing restoration; and
- designing habitat restorations to protect privately owned lands within the ROA.

**Resiliency to future changes:** This conservation measure is expected to be fairly resilient to future changes in hydrology and sea levels. Conserving higher elevation transitional grassland habitats along the margins of restored marsh will provide sufficient lands to accommodate the upslope establishment of intertidal marsh as sea level rises. If the alignment of an around-Delta conveyance facility is upslope of restored habitats, however, the area available for accommodating sea level rise may be constrained.

**Uncertainties/risks:** Restoration of subtidal aquatic habitats could result in infestation of non-native submerged aquatic vegetation and increase the abundance of non-native predators or vulnerability of covered fish species to predation. Methylation of mercury may occur in intertidal zones, making methylmercury bioavailable to plants, fish, and wildlife in and downstream of restored marshes (Alpers et al. 2006). Additionally, there could be a short-term risk associated with mobilizing pesticides, herbicides, and other contaminants into the Delta following initial introduction of tidal flow onto agricultural lands.

**Monitoring and adaptive management considerations:** ***[Note to reviewers:*** *this section is a general summary; more detail will be provided in future iterations.]* Opportunities for adaptive management are related to assessing the effectiveness of restored marshes to develop as functional covered species habitats and to produce food and organic carbon in support of food web processes. Results of monitoring the development of early marsh restorations would help inform improvements in the design and management of subsequent marsh restorations. Results of monitoring early restoration projects could also be used to develop cost effective management techniques, if needed, to control the establishment of non-native species in restored marshes. Some of the monitoring considerations include:

- type and extent of use by covered fishes;
- extent of phytoplankton, zooplankton, and macroinvertebrate production in marsh channels;
- load of organic carbon, phytoplankton, zooplankton, and macroinvertebrates produced in marshes and subsequently exported into the Delta;
- extent of native vegetation relative to non-native vegetation on the marsh plain;
- extent of native aquatic vegetation relative to non-native aquatic vegetation;
- change in abundance of non-native predatory fish species;
- growth and survival of rearing Sacramento splittail and Chinook salmon in shallow subtidal aquatic habitats;
- the establishment of habitat conditions suitable for the natural establishment of marsh-associated covered plant species; and
- levels of mercury methylation and biological uptake.

**Reversibility:** This conservation measure would be difficult to reverse because it would require construction of new levees to re-isolate restored habitat areas from tidal flow and pumping to remove water from reclaimed habitat areas.

**Conservation Measure FIMA1.3: Restore a mosaic of __ to __ acres of intertidal marsh and shallow subtidal aquatic habitat within the West Delta Restoration Opportunity Area.** Restored freshwater intertidal marsh and shallow subtidal aquatic habitats would be designed to support the physical and biological attributes described in Attachment A. The mosaic of habitats would include at least __ acres of freshwater intertidal marsh habitat. Areas suitable for restoration include Decker Island, portions of Sherman Island, Jersey Island, Bradford Island, Twitchell Island, and Brannon Island, and along portions of the north bank of the Sacramento River where elevations and substrates are suitable. The purpose of restoring intertidal marsh in the west Delta is to provide a continuous corridor of habitat and food productivity linking current and future restored habitat in the Cache Slough Complex with habitat in Suisun Marsh and Bay and to provide intertidal marsh habitat within the anticipated future eastward position of the low salinity zone with sea level rise.

Design elements of this conservation measure are anticipated to include:

- placing fill material on shallowly subsided restoration sites to raise land surfaces to elevations suitable for restoration of intertidal marsh[3];
- planting tules, or other techniques, to raise ground surface elevations suitable for intertidal marsh restoration on shallowly subsided portions of islands and breaching levees when target elevations are achieved;
- breaching and setting back levees to provide for tidal exchange with restored habitats; and
- excavating channels and/or creating berms to encourage the development of dendritic channel networks within restored marshes.

**Rationale:** Restoring freshwater intertidal marsh and shallow subtidal aquatic habitats is expected to reduce the adverse effects of stressors related to food and habitat availability for the covered species by:

- increasing rearing habitat area for Chinook salmon, Sacramento splittail, and possibly steelhead (Healey 2001, Brown 2003);
- improving future habitat areas for delta smelt and longfin smelt within the anticipated eastward movement of the low salinity zone with sea level rise;
- increasing the production of food for rearing salmonids, splittail, and other covered species (Kjelson et al. 1982; Siegel 2007);
- increasing the availability and production of food in the western Delta and Suisun Bay by exporting organic material via tidal flow from the marsh plain and organic carbon, phytoplankton, zooplankton, and other organisms produced in intertidal channels into the Delta (Siegel 2007);
- locally providing areas of cool water refugia for delta smelt (C. Enright pers. comm.);
- increasing the extent of habitat available for colonization by Mason's lilaeopsis; and
- increasing the extent of habitat for California black rail and tricolored blackbird.

Lands within the West Delta ROA (see Figure 1) represent the only location to implement intertidal marsh restorations within the anticipated future location of the low salinity zone with sea level rise. A substantial proportion of the suitable restoration sites in this area are in public ownership.

**Recommended Implementation Timeframe:** This conservation measure could be initiated in the BDCP near-term implementation period and continue to be implemented over the term of the BDCP as restoration opportunities are identified.

[3] Sources of fill material could include dredge material from ongoing dredging operations and dredge spoils and sand deposits on Decker Island, Brannon Island, and other nearby suitable sites.

**Implementation Considerations:** Implementation considerations include:

- the availability of suitable fill material and feasibility for subsidence reversal;
- consideration for the effects of restoration-induced dampening of the tidal range on subsequent marsh restoration designs and local tidal hydrodynamics;
- the need to design levees and provide elevations suitable to accommodate future sea level rise;
- locating and designing levee breaches to maximize the development of intertidal marsh and minimize hydrodynamic conditions that favor non-native predatory fish;
- coordination with Delta levee programs to ensure that restored habitats are protected from adverse effects that could be associated with future levee failures;
- determining the appropriate allowable land uses and management activities on transitional grasslands conserved to accommodate future sea level rise;
- the need to incorporate design features and management strategies to preclude or minimize the establishment and abundance of undesirable non-native species;
- potential for increasing mercury methylation and resuspension of contaminants;
- the need to incorporate design features that will promote the natural establishment of marsh-associated covered plant species; and
- the likelihood for removal of food produced from restored intertidal marshes by non-native clams.

**Resiliency to future changes:** The resiliency of this conservation measure to accommodate future sea level rise is limited because of the extent of subsidence in the west Delta. It is expected, however, that, to the extent practicable, restoration designs would incorporate elements that would provide land surface elevations sufficient to accommodate the upslope establishment of marsh over time as sea level rises.

**Uncertainties/risks:** Restoration of subtidal aquatic habitats could result in establishment of *Egeria* and other non-native plants that reduce the ecological benefits for restored subtidal aquatic habitats to covered species. The abundance of non-native predators and competitor abundance could increase and the ability to control these species is uncertain. Methylation of mercury may occur in intertidal zones, making methylmercury bioavailable to plants, fish, and wildlife in and downstream of restored marshes (Alpers et al. 2006). Large scale levee failures, in the central Delta could reduce species and ecosystem benefits associated with restored marshes in the west Delta depending on the effects of changed hydrodynamic conditions on tidal range and salinity gradients in the west Delta. There could be a short-term risk associated with mobilizing pesticides, herbicides, and other contaminants into the Delta following initial introduction of tidal flow onto agricultural lands.

**Monitoring and adaptive management considerations:** ***[Note to reviewers:*** *this section is a general summary; more detail will be provided in future iterations.]* Opportunities for adaptive management are related to assessing the effectiveness of restored marshes to develop as functional covered species habitats and to produce food and organic carbon in support of food web processes. Results of monitoring the development of early marsh restoration projects would help inform improvements in the design and management of subsequent marsh restorations. Results of monitoring early restorations could also be used to develop cost effective management techniques, if needed, to control the establishment of non-native species in restored marshes. Some of the monitoring considerations include:

- type and extent of use by covered fishes;
- extent of phytoplankton, zooplankton, and macroinvertebrate production in marsh channels;
- load of phytoplankton, zooplankton, and macroinvertebrates exported into the Delta and Suisun Bay;
- extent of food produced from restored habitats that are consumed by non-native clams;
- extent of native vegetation relative to non-native vegetation in the restored marsh;
- extent of native relative to non-native submerged aquatic vegetation;
- change in abundance of non-native predatory fish species;
- effects of habitat restoration on salinity gradients in the west Delta;
- levels of mercury methylation and biological uptake;
- organic carbon production in restored marshes and export to the Delta and Suisun Bay; and
- growth and survival of rearing Sacramento splittail and Chinook salmon in shallow subtidal aquatic habitats.

**Reversibility:** This conservation measure would be difficult to reverse because reversing the measure would require construction of new levees to re-isolate restored habitat areas from tidal flow.

**Conservation Measure FIMA1.4: Restore a mosaic of __ to __ acres of intertidal marsh, shallow subtidal aquatic, and transitional grassland habitat within the South Delta Restoration Opportunity Area.** Restored freshwater intertidal marsh and shallow subtidal aquatic habitats would be designed to support the physical and biological attributes described in Attachment A. The mosaic of habitats would include at least __ acres of freshwater intertidal marsh habitat. Suitable sites for restoring freshwater intertidal marsh include Fabian Tract, Union Island, Middle Roberts Island, and Lower Roberts Island. Sites selected for restoration would be depend on the location and design of the selected conveyance pathway and operations for the through-Delta component of the dual conveyance facility. Selected sites would be those that would provide substantial species and ecosystem benefits with the selected through-Delta conveyance configuration.

Design elements of this conservation measure could include:

- planting tules or other techniques to raise currently subsided ground surface elevations suitable for intertidal marsh restoration on shallowly subsided portions of islands and breaching levees when target elevations are achieved;
- scalping higher elevation portions of islands to provide fill for placement on subsided portions of islands to raise surface elevations;
- breaching and setting back levees to provide for tidal exchange with restored habitats;
- constructing cross levees where appropriate to protect property and preclude inundation of deeply subsided portions of islands;
- locating and designing levee breaches to maximize the development of intertidal marsh and minimize hydrodynamic conditions that favor non-native predatory fish; and
- excavating channels to initiate development of dendritic channel networks within restored marshes.

**Rationale:** Restoring freshwater intertidal marsh and shallow subtidal aquatic habitats is expected to reduce the adverse effects of stressors related to food availability and habitat availability for the covered species by:

- increasing rearing habitat area for Sacramento splittail, Chinook salmon produced in the San Joaquin River and other eastside tributaries, and possibly steelhead (Healey 2001, Brown 2003);
- increasing the production of food for rearing salmonids, splittail, and other covered species (Kjelson et al. 1982; Siegel 2007);
- increasing the availability and production of food in the Delta and Suisun Bay by export from the south Delta of organic material via tidal flow from the new marsh plain and organic carbon, phytoplankton, zooplankton, and other organisms produced in new intertidal channels (Siegel 2007);
- locally providing areas of cool water refugia for delta smelt (C. Enright pers. comm.);
- increasing the extent of habitat available for colonization by Mason's lilaeopsis; and

- increasing the extent of habitat for California black rail and tricolored blackbird.

Additionally, in conjunction with dual conveyance operations, marsh restoration in the south Delta could expand the current distribution of delta smelt into formerly occupied habitat areas.

**Recommended Implementation Timeframe:** This conservation measure would need to be implemented following completion of the around-Delta facilities to minimize adverse affects of through-Delta operations on restoration benefits. Restoration planning, however, could be initiated in the near-term implementation period.

**Implementation Considerations:** Implementation considerations include:

- selecting the location for habitat restoration (Fabian Tract, Union Island, Middle Roberts Island, or Lower Roberts Island) is dependent on the through-Delta conveyance corridor (i.e., Old River or Middle River) selected for dual operations and therefore the relative influence of South Delta SWP/CVP pumping operations on the restored habitat;
- opportunities for designing intertidal marsh restoration along the San Joaquin River to increase the tidal prism such that tidal velocities and mixing are increased sufficiently to improve dissolved oxygen levels in the Stockton Deep Water Ship Channel;
- feasibility of raising land surface elevations using tule plantings or other techniques to raise ground surface elevations before breaching levees;
- consideration of the effects of restoration-induced dampening of the tidal range on local tidal hydrodynamics and subsequent marsh restoration designs;
- coordination with Delta levee programs to ensure that restored habitats are protected from adverse effects that could be associated with future levee failures;
- locating and designing levee breaches to maximize the development of intertidal marsh and minimize hydrodynamic conditions that favor non-native predatory fish;
- ensuring that designs for restored intertidal marshes along the San Joaquin River would be compatible and provide synergistic species and ecosystem benefits with proposed restoration of adjoining floodplain habitat upstream of French Camp Slough as described under Conservation Measure FLOO2.1;
- net level of species and ecosystem benefits that can be achieved with dual conveyance operations;
- potential for increasing mercury methylation and resuspension of contaminants;

- determining the appropriate allowable land uses and management activities on transitional grasslands conserved to accommodate future sea level rise;
- the need to incorporate design features and management strategies to preclude or minimize the establishment and abundance of undesirable non-native species;
- the need to incorporate design features that will promote the natural establishment of marsh-associated covered plant species; and
- securing fee title or easements for implementing restoration; and
- designing habitat restorations to protect privately owned lands within the ROA.

**Resiliency to future changes:** This conservation measure is expected to be fairly resilient to future changes in hydrology and sea level. Conserving higher elevation transitional grassland habitats along the margins of restored marsh will provide sufficient lands to accommodate the upslope establishment of intertidal marsh as sea level rises.

**Uncertainties/risks:** Restoration of subtidal aquatic habitats could result in establishment of *Egeria* and other non-native plants that reduce the ecological benefits of restored marsh for covered species. The abundance of non-native predator and competitor abundance could increase and the ability to control them is uncertain. Methylation of mercury may occur in intertidal zones, making methylmercury bioavailable to plants, fish, and wildlife in and downstream of restored marshes (Alpers et al. 2006). Large scale levee failures in the central Delta could reduce species and ecosystem benefits associated with restored marshes in the south Delta depending on the effects of changed hydrodynamic conditions on tidal range and salinity gradients.

**Monitoring and adaptive management considerations:** *[**Note to reviewers:** this section is a general summary; more detail will be provided in future iterations.]* Opportunities for adaptive management are related to assessing the effectiveness of restored marshes to develop as functional covered species habitats and to produce food and organic carbon in support of food web processes. Results of monitoring the development of early marsh restorations would help inform improvements in the design and management of subsequent marsh restorations. Results of monitoring early restorations could also be used to develop cost effective management techniques, if needed, to control the establishment of non-native species in restored marshes. Some of the monitoring considerations include:

- type and extent of use by covered fishes;
- extent of phytoplankton, zooplankton, and macroinvertebrate production in marsh channels;

- load of phytoplankton, zooplankton, and macroinvertebrates exported into the central and west Delta;
- organic carbon production in restored marshes and exported to the central and west Delta;
- levels of mercury methylation and biological uptake;
- extent of native vegetation relative to non-native vegetation at marsh surface;
- change in abundance of non-native predatory fish species;
- effects of through-Delta operations on the amount of organic carbon and food produced from restored marshes that is successfully exported to the central and west Delta;
- extent of native relative to non-native aquatic vegetation; and
- growth and survival of rearing Sacramento splittail, Chinook salmon, and other covered fish species in shallow subtidal aquatic habitats.

**Reversibility:** This conservation measure would be difficult to reverse because reversal would require construction of new levees to re-isolate restored habitat areas from tidal flow.

**Conservation Measure FIMA1.5: Restore a mosaic of __ to __ acres of intertidal marsh, shallow subtidal aquatic, and transitional grassland habitat within the East Delta Restoration Opportunity Area.** Restored freshwater intertidal marsh and shallow subtidal aquatic habitats would be designed to support the physical and biological attributes described in Attachment A. The mosaic of habitats would include at least __ acres of freshwater intertidal marsh habitat. Areas suitable for restoration in the East Delta ROA (see Figure 1) include Terminous Tract south of State Highway 12, Shin Kee Tract, Rio Blanco Tract, and Bishop Bract. Design elements of this conservation measure could include:

- acquisition of lands in fee-title or through conservation easements suitable for restoration of intertidal and subtidal habitats and for accommodating future sea level rise;
- constructing levees to isolate deeply subsided lands and protect property;
- planting tules or placing fill material to raise elevations of shallowly subsided lands;
- creating channels and/or creating berms to encourage the development of dendritic tidal channels; and
- breaching levees to reintroduce tidal exchange to leveed lands.

If the eastern alignment of an around-Delta conveyance facility is constructed, the canal levees may be incorporated into the design of intertidal emergent wetland restoration. For example, in locations where the conveyance canal is located at elevations at or below elevations suitable for restoration of intertidal marsh, marsh may be restored to the east of canal levee, with the canal levee forming the western boundary of the restored marsh.

**Rationale:** Restoring freshwater intertidal marsh and shallow subtidal aquatic habitats within the East Delta ROA (see Figure 1) is expected to reduce the adverse effects of stressors related to food and habitat availability for the covered fish species by:

- increasing rearing habitat area for Sacramento splittail and San Joaquin Chinook salmon and possibly steelhead (Healey 2001, Brown 2003);
- increasing the production of food for rearing salmonids, splittail, and other covered species (Kjelson et al. 1982, Siegel 2007);
- increasing the availability and production of food in the east and central Delta by exporting organic material from the marsh plain and phytoplankton, zooplankton, and other organisms produced in intertidal channels into the Delta (Siegel 2007);
- locally providing areas of cool water refugia for delta smelt (C. Enright pers. comm.);
- increasing the extent of habitat available for colonization by Mason's lilaeopsis, and
- increasing the extent of habitat for giant garter snake, California black rail, and tricolored blackbird.

**Recommended Implementation Timeframe:** It is anticipated that this conservation measure would be implemented in the BDCP long-term implementation period because the design of restored freshwater intertidal marshes would be influenced by the construction of a new around-Delta conveyance facilities.

**Implementation Considerations:** Implementation considerations include:

- the feasibility for subsidence reversal using tule plantings or other techniques to raise ground surface elevations before breaching levees;
- the need to incorporate design features and management strategies to preclude or minimize the establishment of *Egeria* and other undesirable non-native species;
- locating and designing levee breaches to maximize the development of intertidal marsh and minimize hydrodynamic conditions that favor non-native predatory fish;
- the need to incorporate design features that will promote the natural establishment of marsh-associated covered plant species;
- consideration for the effects of restoration-induced dampening of the tidal range and local tidal hydrodynamics on subsequent marsh restoration

designs;
- the footprint and facilities associated with an around-Delta conveyance facility;
- potential for increasing mercury methylation and resuspension of contaminants;
- determining the appropriate allowable land uses and management activities on transitional grasslands conserved to accommodate future sea level rise; and
- securing fee-title or easements and the protection of  privately own lands within the ROA.

**Resiliency to future changes:** This conservation measure is expected to be fairly resilient to future changes in hydrology and sea level. Conserving higher elevation transitional grassland habitats along the margins of restored marsh would provide lands to accommodate the upslope establishment of intertidal marsh as sea level rises. If the alignment of an around-Delta conveyance facility is upslope of restored habitats, however, the area available for accommodating sea level rise may be constrained.

**Uncertainties/risks:** Restoration of subtidal aquatic habitats could result in infestation of non-native submerged aquatic vegetation and increase the abundance of non-native predators and vulnerability of covered fish species to predation. Methylation of mercury may occur in intertidal zones, making methylmercury bioavailable to plants, fish, and wildlife in and downstream of restored marshes (Alpers et al. 2006). Additionally, there could be a short-term risk associated with mobilizing pesticides, herbicides, and other contaminants into the Delta following initial introduction of tidal flow onto agricultural lands.

**Monitoring and adaptive management considerations:** *[**Note to reviewers:** this section is a general summary; more detail will be provided in future iterations.]* Opportunities for adaptive management are related to assessing the effectiveness of restored marshes to develop as functional covered species habitats and to produce food and organic carbon in support of food web processes. Results of monitoring the development of early marsh restoration projects would help inform improvements in the design and management of subsequent marsh restorations. Results of monitoring early restorations could also be used to develop cost effective management techniques, if needed, to control the establishment of non-native species in restored marshes. Some of the monitoring considerations include:

- type and extent of use by covered fishes;
- extent of organic carbon, phytoplankton, zooplankton, and macroinvertebrate production in marsh channels;

- load of organic carbon, phytoplankton, zooplankton, and macroinvertebrates exported into the Delta;
- extent of native vegetation relative to non-native vegetation on the marsh plain;
- extent of native submerged aquatic plants relative to non-native submerged aquatic vegetation;
- change in abundance of non-native predatory fish species;
- growth and survival of rearing Sacramento splittail, Chinook salmon, and other covered fish species in shallow subtidal aquatic habitats;
- the establishment of habitat conditions suitable for the natural establishment of marsh-associated covered plant species; and
- levels of mercury methylation and biological uptake.

**Reversibility:** This conservation measure would be difficult to reverse because it would require construction of new levees to re-isolate restored habitat areas from tidal flow and pumping to remove water from reclaimed habitat areas.

## Brackish Intertidal Marsh Habitat Restoration Conservation Measures

**Conservation Measure BIMA1.1 Restore a mosaic of __ to __ acres of brackish intertidal marsh, shallow subtidal aquatic, and transitional grassland habitat within the Suisun Marsh Restoration Opportunity Area.** Restored brackish intertidal marsh would be designed to support the physical and biological attributes described in Attachment A. The Suisun Marsh Habitat Management, Preservation, and Restoration Plan (in development) currently provides for restoring 6,000-9,000 acres of brackish intertidal marsh (S. Chappell pers. comm.). Under this conservation measure, additional brackish intertidal marsh would be restored opportunistically through amendments to the Suisun Marsh Habitat Management, Preservation, and Restoration Plan over the term of the BDCP as lands become available for restoration. Habitat would be restored as a mosaic of brackish intertidal marsh, shallow subtidal aquatic, and transitional grassland habitats of which at least __ acres would be brackish intertidal marsh. Anticipated actions to restore brackish intertidal marsh habitat include:

- acquisition of lands in fee-title or through conservation easements suitable for restoration of intertidal and subtidal habitats and for accommodating future sea level rise from willing landowners;
- planting tules or other techniques to raise elevations of shallowly subsided lands;
- reconnecting disconnected remnant sloughs to Suisun Bay and removing remnant slough dikes to reintroduce tidal connectivity to slough watersheds to restore tidal marsh; and

- breaching dikes to reintroduce tidal exchange to diked lands.

Hydrodynamic modeling conducted for the Suisun Marsh Restoration Plan (J. DeGeorge pers. comm.) indicates that restoring marsh north of Montezuma Slough would shift the low salinity zone westward and restoring marsh at sites adjacent to Suisun Bay would shift the low salinity zone eastward, potentially adversely affecting delta smelt habitat and water quality in the west Delta. Consequently, implementation of marsh restoration projects in north and south Suisun Marsh would likely be sequenced such that these potential effects would be minimized.

As described in Conveyance Action Parameter 7, future reoperation or removal of the Montezuma Slough Salinity Control Gate would increase benefits of restoring brackish intertidal marsh in Suisun Marsh by increasing access for covered fish species to existing and restored tidal aquatic habitat within a large area of Suisun Marsh.

**Rationale:** Suisun Marsh is located in the low salinity zone of the estuary which serves as a corridor for upstream and downstream passage by migratory fish such as salmon and steelhead, as rearing habitat for species such as delta and longfin smelt, splittail, and sturgeon. Suisun Marsh is also located in the area of the estuary that has high production of phytoplankton, zooplankton, and macroinvertebrates. Suisun Marsh historically functioned as a complex of shallow, tidally inundated, brackish water marshes, wetlands, and adjacent channels. Construction of dikes that isolate low elevation habitat from the surrounding channels and brackish waters have been used to create managed freshwater wetlands, primarily for the benefit of waterfowl. As part of the Suisun Marsh Habitat Management, Preservation, and Restoration Plan and expanded as part of BDCP, diked wetland areas would potentially be returned to brackish water tidal habitat accessible to fish and other aquatic species. These shallow water low saline habitats are expected to provide high quality estuarine habitat that would benefit covered fish, other aquatic species, and wildlife directly as habitat but would also serve to benefit the estuary through the production of nutrients, phytoplankton, zooplankton, macroinvertebrates, and organic carbon. Re-establishing large areas of aquatic habitat within the marsh would also maximize habitat connectivity between Yolo Bypass/Cache Slough and important estuarine habitat within Suisun Marsh and Suisun Bay.

Restoring brackish intertidal marsh within Suisun Marsh is expected to reduce the adverse effects of stressors related to food and habitat availability for the covered species by:

- increasing rearing habitat area for Chinook salmon, Sacramento splittail, and possibly steelhead (Healey 2001, Siegel 2007);
- increasing the production of food for rearing salmonids, splittail, and other covered species (Kjelson et al. 1982);
- increasing the availability and production of food in Suisun Bay by exporting organic material via tidal flow from the marsh plain and phytoplankton,

zooplankton, and other organisms produced in intertidal channels into the Bay;

- locally providing areas of cool water refugia for delta smelt (C. Enright pers. comm.);
- reducing periodic low dissolved oxygen events associated with the discharge of waters from lands managed as seasonal freshwater wetlands that would be restored as brackish intertidal marsh (Siegel 2007, C. Enright pers. comm.);
- increasing the extent of habitat available for colonization by Suisun marsh aster and soft-bird's beak; and
- enhancing and increasing the extent of salt marsh harvest mouse and Suisun shrew habitat.

Additionally, the Suisun Marsh ROA (see Figure 1) encompasses a substantial area of land with elevations suitable for intertidal marsh restoration that would involve few impacts on infrastructure or permanent crops relative to the availability of suitable lands within the Delta.

**Recommended Implementation Timeframe:** This conservation measure could be initiated in the BDCP near-term implementation period and be implemented over the term of the BDCP as restoration opportunities are identified.

**Implementation Considerations:** Implementation considerations include:

- coordination with the Solano Multi-Species Habitat Conservation Plan and the Suisun Marsh Habitat Management, Preservation, and Restoration Plan to ensure effective implementation of conservation measures among the plans;
- feasibility for subsidence reversal using tule plantings or other techniques to raise ground surface elevations before breaching levees;
- consideration for the effects of restoration-induced dampening of the tidal range and local tidal dynamics on subsequent marsh restoration designs;
- the need to incorporate design features and management strategies to preclude or minimize the establishment and abundance of undesirable non-native species;
- the need to incorporate design features that will promote the natural establishment of marsh-associated covered plant species;
- locating and designing levee breaches to maximize the development of intertidal marsh and minimize hydrodynamic conditions that favor non-native predatory fish;
- evaluating the impact of likely removal of food produced from restored brackish intertidal marshes by clams;
- effects of operation of the salinity control gates on species and ecosystem benefits provided by restored marshes;
- potential for increasing mercury methylation and resuspension of

contaminants;

- determining the appropriate allowable land uses and management activities on transitional grasslands or managed seasonal wetlands conserved to accommodate future sea level rise;
- selecting restoration lands and implementing restoration in a sequence that minimizes adverse effects of breaching/removing dikes on position of the low salinity zone; and
- securing fee-title or easements from willing private landowners and the protection of privately lands within the ROA.

**Resiliency to future changes:** This conservation measure is expected to be fairly resilient to future changes in hydrology and sea level. The landward margins of Suisun Marsh border higher elevation transitional grassland habitats that would provide sufficient lands for the upslope re-establishment of brackish intertidal marsh as sea level rises and inundates marshes restored in those locations. Sediment modeling conducted for existing proposed restorations in Suisun Marsh also indicate that sediment supplies entering the marsh from tributaries may be sufficient to allow the marsh plain south of Montezuma Slough to accrete at rates that would keep pace with sea level rise (C. Enright, pers. comm.).

**Uncertainties/risks:** Restoration of subtidal aquatic habitats could result in establishment of non-native plants that reduce the ecological benefits of restored marsh for covered species. Non-native predator and competitor abundance could increase and the ability to control them is uncertain. Initial studies have indicated that sediment supplies are likely sufficient to allow for subsided lands south of Montezuma Slough to accrete to form marsh plain. If restored habitats are designed around this assumption and sediment supplies are not sufficient, restored habitats would not provide the desired covered species benefits and could increase the abundance of predators and competitors, adversely affecting covered fish species. Altering existing habitat conditions in this area could potentially adversely affect delta smelt habitat if salinity gradients, turbidity, or temperature conditions change significantly as a result of restoration actions.

**Monitoring and adaptive management considerations:** ***[Note to reviewers:*** *this section is a general summary; more detail will be provided in future iterations.]* Opportunities for adaptive management are related to assessing the effectiveness of restored marshes to develop as functional covered species habitats and to produce food and organic carbon in support of food web processes. Results of monitoring the development of early marsh restoration projects would help inform improvements in the design and management of subsequent marsh restorations project. Results of monitoring early restorations could also be used to develop cost effective management techniques, if needed, to control the establishment of non-native species in restored marshes. Some of the monitoring considerations include:

- type and extent of use by covered fishes;
- extent of organic carbon, phytoplankton, zooplankton, and macroinvertebrate production in marsh channels;
- load of organic carbon, phytoplankton, zooplankton, and macroinvertebrates exported into Suisun Bay;
- extent of food produced from restored habitats that are consumed by clams;
- extent of native marsh vegetation relative to non-native vegetation;
- change in abundance of non-native predatory fish species;
- effects of habitat restoration on salinity gradients and local tidal hydrodynamics in the western Delta;
- growth and survival of rearing Sacramento splittail, Chinook salmon, and other covered species in shallow subtidal aquatic habitats.

**Reversibility:** This conservation measure would be difficult to reverse because reversal would require construction of new dikes to re-isolate restored habitat areas from tidal flow.

## Channel Margin Habitat Restoration Conservation Measures

**Conservation Measures CHMA1.1. Support development and implementation of levee construction and maintenance designs that incorporate aquatic, intertidal marsh, and riparian habitat features.** The BDCP Implementing Entity would coordinate with DWR, Central Valley Flood Protection Board, and U.S. Army Corps of Engineers to track planned levee construction and maintenance activities. The BDCP Implementing Entity would participate in planning processes for the construction of new levees, or maintenance of existing levees, located along important habitat areas for covered fish species (e.g., fish migration corridors). These activities will help ensure that levee designs incorporate features that would benefit covered fish species, minimize adverse effects of the actions on covered fish species, and avoid potential adverse effects of proposed actions on the ecological functions provided by existing and planned BDCP conserved habitats.

**Rationale:** Improperly designed levees could increase habitat for non-native predators, attract covered fish species, and thus contribute to increased predation losses of covered fish species. Properly designed levees can support habitat for salmonids and splittail. Riparian and emergent vegetation provide cover and rearing habitat for covered fish species and organic carbon inputs into adjacent channels (U.S. Fish and Wildlife Service 2004).

**Implementation timeframe:** This measure could be implemented in the BDCP near-term implementation period and for the duration of the BDCP.

**Implementation Considerations:** Implementation considerations include establishing a process that effectively engages the Implementing Entity in DWR, Central Valley Flood Protection Board, and U.S. Army Corps of Engineers levee-related planning processes.

**Resiliency to future changes:** If levees are sufficiently high and properly designed to support vegetation, then riparian vegetation could move up the levee face with the anticipated rising sea level.

**Uncertainties/risks:** There are uncertainties related to designing levee habitat features that would improve habitat conditions for covered fish species and degrade habitat conditions for non-native predatory fish. Restoring aquatic levee habitats potentially increase the predation risk for covered fish species.

**Monitoring and adaptive management considerations:** ***[Note to reviewers:*** *this section is a general summary; more detail will be provided in future iterations.]* It is anticipated that lead agencies would include provisions for adaptive management and monitoring in their levee planning documents. Adaptive management opportunities could include monitoring the effectiveness of various levee habitat design components and, based on monitoring results, adjusting levee habitat designs to improve benefits for covered species. Some of the monitoring considerations include:

- monitoring the use of aquatic levee habitats by covered fish species and non-native predatory fish;
- the natural establishment and regeneration of emergent marsh and riparian vegetation on levee slopes; and
- the extent of zooplankton and macroinvertebrate production along restored channel margin habitats compared to unvegetated levees.

**Reversibility:** Intertidal marsh and riparian habitat components of this measure are moderately reversible as riparian vegetation established on or adjacent to levees could be removed if necessary for levee repair, maintenance, or other reasons. Reversing structural habitat design features (e.g., submerged low rock benches), however, would be difficult.

**Conservation Measures CHMA1.2. Provide for the establishment of native riparian woody vegetation and emergent vegetation on BDCP constructed levees.** BDCP site-specific habitat restoration designs may require the construction of new levees (e.g., setback levees to restore floodplain habitat area). The BDCP Implementing Entity would design such levees to incorporate design features that would provide for the establishment of riparian and tidal emergent vegetation along low elevation surfaces (e.g., levee benches).

**Rationale:** Improperly designed levees could increase habitat for non-native predators, attract covered fish species, and contribute to increased predation losses of covered fish species. Properly designed levees can support and enhance habitat for salmonids, splittail, and other covered fish species. Riparian vegetation provides cover for covered fish species, and provides organic carbon inputs into adjacent channels (U.S. Fish and Wildlife Service 2004).

**Implementation timeframe:** This measure could be implemented in the BDCP near-term implementation period and for the duration of the BDCP.

**Implementation Considerations:** Implementation considerations include coordinating with the U.S. Army Corps of Engineers, DWR, and other flood control agencies to ensure that BDCP levee designs, as applicable, comply with levee flood control standards.

**Resiliency to future changes:** If levees are sufficiently high and properly designed to support vegetation, then riparian vegetation could move up the levee face with the anticipated rising sea level.

**Uncertainties/risks:** There are uncertainties related to designing levee habitat features that would improve habitat conditions for covered fish species and degrade habitat conditions for non-native predatory fish. Restoring aquatic levee habitats potentially increase the predation risk for covered fish species.

**Monitoring and adaptive management considerations:** *[**Note to reviewers:** this section is a general summary; more detail will be provided in future iterations.]* Adaptive management opportunities could include monitoring the effectiveness of various levee habitat design components and, based on monitoring results, adjusting levee habitat designs to improve benefits for covered species. Some of the monitoring considerations include:

- monitoring the use of aquatic levee habitats by covered fish species and non-native predatory fish;
- the natural establishment and regeneration of riparian vegetation on levee slopes; and
- the extent of zooplankton and macroinvertebrate production along restored channel margin habitats compared to unvegetated levees.

**Reversibility:** Riparian habitat components of this measure are moderately reversible as riparian vegetation established on or adjacent to levees could be removed if necessary for levee repair, maintenance, or other reasons. Reversing structural habitat design features (e.g., submerged low rock benches), however, would be difficult.

**Conservation Measure CHMA1.3: Enhance channel margin habitats along __ to __ miles of Steamboat and Sutter Sloughs to improve habitat conditions for covered fish species.** Steamboat and Sutter Sloughs (see Figure 1) are thought to serve as important rearing habitat and movement corridors for juvenile salmonids outmigrating from the Sacramento River (J. Burau pers. comm.). Habitat conditions for covered fish species would be enhanced along__ to __ miles of Steamboat Slough and __ to __ miles of Sutter Slough. The purpose of this measure is to improve the growth and survival of juvenile salmonids that use these habitat areas.

Design elements for this conservation measure could include:

- modifying channel geometry to improve hydrodynamic and structural complexity for native species;
- establishing woody riparian vegetation along banks that do not support woody riparian vegetation; and
- reducing the abundance of non-native fish predators and competitors.

Following implementation of habitat enhancements, the BDCP Implementing Entity may undertake actions to encourage the transport of juvenile salmonids into Steamboat and Sutter Sloughs if monitoring results indicate that survival and growth of juvenile salmonids that rear and pass through Steamboat and Sutter Sloughs is substantially higher than under current conditions. Increasing the proportion of juvenile salmonids transported into the sloughs could be accomplished either by reorienting the upstream mouth of Steamboat Slough and/or Sutter Slough to the Sacramento River or constructing structures in the Sacramento River channel near the upstream mouths of the sloughs that would guide the movement of fish into Steamboat and Sutter Sloughs. To undertake this action, the BDCP Implementing Entity would need to coordinate with and receive approvals from the U.S. Army Corps of Engineers to either modify the project levees or construct an in-channel structure.

**Rationale:** Enhancing Steamboat and Sutter Sloughs as fish migration corridors is expected to increase the survival and growth of outmigrating Sacramento River salmonids by:

- increasing the quality of rearing habitat area for Sacramento River salmonids (J. Burau pers. comm., Siegel 2007);
- reducing the risk for predation on covered fish species by non-native fish predators (J. Burau pers. comm.); and
- reducing the risk for entrainment of juvenile salmonids by providing a migration corridor that bypasses the intakes of a new north Delta diversion point, the Delta Cross Channel, and Georgiana Slough.

**Recommended Implementation Timeframe:** It is anticipated that some habitat improvements described in this conservation measure could be implemented in the BDCP near-term implementation period. Improvements that would change channel geometry or affect flood control functions of these sloughs would likely be implemented in the BDCP long-term implementation period to accommodate coordinating planning efforts with local, state, and federal flood control agencies.

**Implementation Considerations:** Implementation considerations include:

- the relative efficacy of various predatory fish control methods;
- appropriate modifications to the channel geometries of Steamboat and Sutter Sloughs that could effectively improve habitat conditions for juvenile salmonids and other covered species and degrade habitat conditions for non-native predatory fish; and
- coordination with the U.S. Army Corps of Engineers and other flood control agencies to allow for: 1) modifications to project levees or placement of in-channel structures to improve transport of juvenile salmonids into Steamboat and Sutter Sloughs and 2) modifications to the channel geometry of the sloughs.

**Resiliency to future changes:** This conservation measure is expected to be fairly resilient to future changes in hydrology and sea levels because the types of habitat improvements are such that they would be expected to continue to provide greater benefits for juvenile salmonids than under future conditions without the improvements.

**Uncertainties/risks:** The efficacy of the proposed restoration actions for increasing survival and growth of juvenile salmonids by reducing predation risk is uncertain, particularly if flow velocities are substantially reduced as a result of increasing flows into the Yolo Bypass and operating a new Delta diversion.

**Monitoring and adaptive management considerations:** ***[Note to reviewers:*** *this section is a general summary; more detail will be provided in future iterations.]* Opportunities for adaptive management are related to assessing the effectiveness of restoration actions in improving the survival and growth of juvenile salmonids passing through the sloughs by improving habitat conditions and reducing predation and entrainment risk. Results of monitoring could help inform the BDCP Implementing Entity of subsequent opportunities to improve these sloughs as salmonid rearing habitats and migration corridors. Implementation of this conservation measure would also afford the opportunity to test fish predator control techniques to identify the most efficacious methods for controlling predator populations. Some of the monitoring considerations include assessing the:

- change in survival and growth of juvenile salmonids using the sloughs relative to current conditions;
- effectiveness of channel geometry designs for improving salmonid rearing habitat and degrading non-native predatory fish habitat;
- effectiveness of predatory fish control methods; and
- effectiveness of channel modifications for increasing the transport of juvenile salmonids into the sloughs.

**Reversibility:** This conservation measure could be difficult to reverse depending on the magnitude and nature of channel modifications.

## Riparian Habitat Restoration Conservation Measures

**Conservation Measure RIPA1.1. Restore between __ and __ acres of riparian forest and scrub communities as a component of restored floodplain, freshwater intertidal marsh, and channel margin habitats.** As described in Attachment A, the design of restored floodplain, freshwater intertidal marsh, and channel margin habitats [see Conservation Measures FLOO 1.1, FLOO2.1-2.4, FIMA1.1-1.5, BIMA1.1, CHMA1.1 and 1.2] will incorporate restoration of riparian habitats as described below.

**Floodplain Habitat Restoration.** To the extent consistent with flood control requirements, restored floodplain habitat areas will allow for the natural establishment and growth of woody riparian vegetation on portions of restored floodplains that support appropriate soils and hydrology. At floodplain restoration sites that function hydrologically as flood bypasses (e.g., the Yolo Bypass), riparian vegetation is expected to establish along margins of existing and created drains and channels and other locations with suitable hydrology. In bypasses co-managed for habitat and flood control benefits, locations where riparian vegetation is allowed to establish would be limited to areas where the presence of riparian vegetation would not compromise flood control standards or hydraulic capacity of the flood control bypass.

Riparian habitat would be allowed to naturally establish in floodplain habitat areas that are restored by setting back levees to expand the extent of the floodplain subject to overbank flow.

**Freshwater Intertidal Marsh Restoration.** Woody riparian vegetation will be allowed to naturally reestablish along the upper elevation margins of restored intertidal marsh habitats where soils and hydrology are suitable, including segments of stream channels that drain into restored marshes.

**Channel Margin Habitat Restoration.** As described under Conservation Measure CHMA1.2, BDCP levees will be designed to provide for the establishment and growth of riparian vegetation along levees. Levees constructed and maintained by other entities that incorporate "green" levee components would also increase the extent of riparian habitat within the Planning Area by allowing for the establishment and growth of riparian vegetation on levee surfaces.

**Rationale:** Restoring riparian forest and riparian scrub habitats is expected to provide the following ecosystem and covered species benefits:

- increasing the extent of valley elderberry longhorn beetle habitat and nesting habitat for Swainson's hawk and yellow breasted chat;

- increasing the extent of shaded riverine aquatic cover and increasing instream cover by through contributions of instream woody material (U.S. Fish and Wildlife Service 2004);
- providing inputs of organic material (e.g., leave and twig drop) in support of aquatic foodweb processes;
- increased production and export of terrestrial invertebrates into the aquatic ecosystem (Nakano S. and M. Murakami 2001); and
- increasing cover for rearing juvenile salmonids and Sacramento splittail.

**Recommended Implementation Timeframe:** It is anticipated that elements of this conservation measure would be implemented in both near-term and long-term BDCP implementation period.

**Implementation Considerations:** Implementation considerations include ensuring that designs for the floodplain, intertidal marsh, and channel margin habitat restorations described under Conservation Measures FLOO 1.1, FLOO2.1-2.4, FIMA1.1-1.6, BIMA1.1, CHMA1.1 and 1.2 provide for the restoration of at least __ acres of riparian forest and scrub habitat and the potential need for periodic control of non-native invasive plant species. Additionally, current and future U.S. Army Corps of Engineer policies regarding the establishment and maintenance of woody riparian vegetation on Project levees and floodways would need to be considered in determining locations restoring riparian habitats. Other implementation considerations for this conservation measure are included under implementation considerations for Conservation Measures FLOO 1.1, FLOO2.1-2.4, FIMA1.1-1.5, BIMA1.1, CHMA1.1 and 1.2.

**Resiliency to future changes:** Restored riparian habitats are expected to be fairly resilient to future changes in hydrology and sea level rise because habitats will be restored within large sites that would be expected to provide a sufficient range of site characteristics (e.g., elevation and soil gradients) to allow for the ongoing reestablishment of riparian vegetation in response to changes in hydrologic and sea level conditions over time.

**Uncertainties/risks:** Allowing for the natural establishment of native riparian vegetation could result in the establishment of riparian habitats dominated by non-native invasive species.

**Monitoring and adaptive management considerations:** *[Note to reviewers: this section is a general summary; more detail will be provided in future iterations.]* Opportunities for adaptive management include improving the design and management of restored floodplain, channel margin, and freshwater intertidal marsh to provide for the successfully establishment, growth, and benefits of restored riparian habitats based on monitoring of the development of previously restored riparian habitats. For example, if the natural establishment and growth of native riparian vegetation is substantially impaired by competition with non-native plants, restoration projects may need to provide for the control of non-native plants or require that riparian plantings be installed to improve restoration success. Some of the monitoring considerations include assessing the:

- use of restored riparian habitats by valley elderberry longhorn beetle, Swainson's hawk, yellow-breasted chat, and riparian brush rabbit;
- factors governing the natural establishment and growth of native riparian vegetation over a range of site conditions associated with restored floodplain, channel margin, and intertidal marsh habitat areas;
- the need to control non-native plants to provide for the natural establishment of native riparian vegetation; and
- ability for native riparian vegetation to reestablish in patterns that provide desired ecosystem and covered species benefits.

**Reversibility:** The reversibility of riparian habitat restorations are the same as described for each of the ROA restoration actions described under Conservation Measures FLOO 1.1, FLOO2.1-2.4, FIMA1.1-1.5, BIMA1.1, CHMA1.1 and 1.2.

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# Attachment A. Restoration Concepts for Habitats

## Definitions of Restoration Concepts

This attachment describes the floodplain, intertidal marsh, and channel margin restoration concepts developed by the Habitat Restoration Program Technical Team (HRPTT). These descriptions are intended to provide guidance to the BDCP Implementing Entity for planning habitat restoration actions and to initially define the range of physical and biological conditions that must be present in restored habitat areas in order for the restoration to be considered successful. The draft information presented in the restoration concept descriptions will be developed further and incorporated into the BDCP Conservation Strategy chapter. Each description includes the following information:

**Restoration Variables:** Brief descriptions of the key physical parameters that can be manipulated through restoration design and operations to restore habitat under the concept.

**Design Targets:** Narrative description of the desired physical and biological conditions that are expected to develop in restored habitat areas as a result of manipulating restoration variables.

**Desired Ecological Benefits:** Brief descriptions of covered fish species stressor effects expected to be reduced with implementation of the restoration concept.

**Potential Performance Criteria (monitoring needs and adaptive management triggers):** Physical and biological parameters that can be measured and that are indicators of the extent of desired ecological functions to be provided by habitats restored under the concept. The performance criteria represent the range of indicators that may be appropriate to monitor to assess the effectiveness of restored habitats in achieving desired covered species and ecosystem benefits. Results of monitoring may be used to trigger adaptive management responses through the BDCP adaptive management process to improve the effectiveness of restored habitats to provide desired benefits.

**Key Uncertainties:** Brief descriptions of major unknowns with respect to designing habitat restorations and benefits that are expected to be afforded by restoration habitats.

**Potential Ecological Risks:** Brief descriptions of potential unintended adverse physical and biological impacts that could be associated with implementing the restoration concept.

## Floodplain Restoration Concept

### Restoration Variables

- Seasonal timing of inundation
- Interannual frequency of inundation
- Spatial extent of inundation
- Depth of inundation
- Water velocity
- Connectivity with intertidal marsh and open water habitats
- Accessibility to migrating fish
- Design related to stranding risk and fish passage
- Vegetation type and cover
- Dry season land use (compatible farming practices)
- Grading/slope

### Design Targets

#### Inundated Floodplain

- Shallow with highly variable depth (2 feet deep on average)
- Adequate hydraulic residence time to promote primary and secondary food production and export and turbidity export (number of days to produce desired food resources)
- Average velocities of about 1.5 foot/sec, but highly variable spatially and temporally
- Duration of inundation about 30-45 days
- Relatively large area (>1,000 acres) to accrue substantive benefit to fish populations
- Stranding avoided through good drainage
- Provides for passage around weirs or other inflow control structures
- Minimized risk for problem levels of methyl mercury and other contaminants
- Inundated during periods that favor native fish and disfavor non-native fish predators – generally late winter to early-mid spring
- Hydrodynamic variability through floodplain cross-section via heterogeneous topography

- Flows exit floodplain via a channel system that, where possible, flows through intertidal marsh towards open water
- Natural connectivity to adjacent uplands to provide transitional habitats and accommodate species movement

**Dry Floodplain**

- Minimized use of persistent pesticides that are toxic to aquatic organisms
- Cover and type of residual standing crop biomass (for floodplains with flood protection function) or riparian and perennial vegetation (for floodplains without flood protection function)
- Allow for the natural establishment of woody riparian vegetation to the extent consistent with desired land uses and flood control requirements

**Desired Ecological Benefits**

- Primary and secondary production
- Primary and secondary production export to Delta
- Export of allochthonous material to Delta
- Substantial increase in high quality splittail spawning and rearing habitat and Chinook salmon (all runs) and steelhead rearing habitat relative to existing in-Delta habitat conditions
- Reduction in stranding/poaching losses of adult sturgeon and salmonids below Fremont Weir
- Improved habitat connectivity between upstream and downstream habitats
- Improved survival/escapement of juvenile salmonids
- Improved turbidity conditions (?)

**Potential Performance Criteria (possible monitoring needs and adaptive management triggers)**

- Extent of phytoplankton/zooplankton/macroinvertebrate production on floodplain
- Extent of phytoplankton/zooplankton/macroinvertebrate exported to the Delta
- Growth rate of juvenile salmonids on floodplains
- Proportion of outmigrating juvenile salmonids accessing floodplain habitats (by run)
- Extent of splittail spawning

- Extent of native fish stranding
- Extent of successful upstream passage of adult salmonids and sturgeon
- Extent of mercury methylation
- Contaminant load exported to Delta
- Extent of habitat connectivity along migratory routes for anadromous fishes

**Key Uncertainties**

- Proper depth for optimizing fish habitat conditions and food production
- Proper inundation duration/residence time for optimizing fish growth and survival and food production
- Conditions necessary for the natural establishment of channel-associated covered plant species in floodplains restored by setting back levees
- Benefits of floodplain inundation to sturgeon, particularly juveniles, are undocumented

**Potential Ecological Risks**

- Mercury methylation
- Establishment of non-native invasive species into created habitat



## Freshwater Intertidal Marsh Restoration Concept

**Restoration Variables**

- Spatial distribution of restored habitats within the Delta
- Extent, location, and configuration of restored habitat
- Amplitude of tidal exchange
- Size and location of levee breaches
- Channel cross sectional profile (elevation of marsh plain, topographic diversity, depth, and slope)
- Intertidal marsh channel density

**Design Targets**

- Dominated by native freshwater emergent vegetation (predominantly tules,)

# Handout #3

- Presence of sinuous, dendritic channel networks of high density
- Sufficient tidal exchange to promote primary and secondary production and its export into the aquatic food web
- Located throughout the Delta for optimal use by and benefit to covered species
- Located where it can filter non-point source pollution from surface or subsurface infiltration
- High velocity, shallow channels to potentially prevent establishment of non-native submerged aquatic vegetation that supports non-native predator habitat
- Large tidal connectivity to open water areas to minimize steep flow velocity gradients that promote establishment of non-native submerged aquatic vegetation and provide predatory fish habitats
- Natural connectivity to adjacent uplands to provide transitional habitats and accommodate species movement
- Accessible to fish, but does not trap fish
- Connectivity with other intertidal marshes and with floodplain, open water, channel margin, and low gradient upland habitats
- Located such that other stressors (e.g., diversions) do not substantially reduce functions beneficial to covered species
- Designed to allow localized reductions in water temperature though nocturnal thermal reduction

**Desired Ecological Benefits**

- Primary and secondary production
- Primary and secondary production export to Delta channels
- Reduced summer/fall water temperature through nocturnal thermal exchange and reintroduction of cooled water to Delta waterways
- Filter for contaminants or site for transformation of contaminants
- Splittail and salmonid rearing habitat
- Potential delta smelt, longfin smelt, and splittail spawning habitat

**Potential Performance Criteria (possible monitoring needs and adaptive management triggers)**

- Type and extent of use by covered fishes
- Extent of in-marsh phytoplankton/zooplankton/macroinvertebrate production
- Extent of phytoplankton/zooplankton/macroinvertebrate exported into the Delta

- Extent of native vegetation relative to non-native vegetation at marsh surface
- Extent of native relative to non-native submerged aquatic vegetation
- Extent of organic carbon production and export to Delta channels

**Key Uncertainties**

- Ability to control non-native submerged aquatic vegetation and fish
- Ability to restore native plant species (e.g., Delta tule pea)
- Availability of adequate sediment supply and rate of tule growth for marsh accretion
- Extent and effectiveness for providing aquatic covered species and ecosystem benefits
- Effects of increased dampening of the tidal range as marsh restorations are implemented on the ability to implement subsequent restorations
- Effect of freshwater tidal marsh restoration on water quality and hydrodynamics upstream and downstream

**Potential Ecological Risks**

- Possibility of establishment of non-native invasive species into restored habitats
- Depending on location, benefits may be reduced by diversions (project and non-project)

## Brackish Intertidal Marsh Restoration

**Restoration Variables**

- Extent, location, and configuration of restored habitat
- Distribution along salinity gradient
- Amplitude of tidal exchange
- Delta freshwater outflow
- Size and location of dike breaches
- Channel cross sectional profile (elevation of marsh plain, topographic diversity, depth, and slope)
- Intertidal marsh channel density

**Design Targets**

- Dominated by native brackish marsh vegetation (e.g., pickleweed, saltgrass)
- Presence of sinuous, dendritic channel networks of high density
- Adjacent to higher elevation uplands to accommodate future with sea level rise
- Primarily low marsh
- Sufficient tidal exchange to promote primary and secondary production and its export into the estuarine food web
- Natural connectivity to adjacent uplands to provide transitional habitats and accommodate species movement
- Restore habitats that provide a range of salinity gradients
- Accessible to fish, but does not trap fish
- Connectivity with other intertidal marshes and with floodplain, open water, channel margin, and upland habitats
- Located such that other stressors (e.g., diversions) do not substantially reduce functions beneficial to covered species
- Designed to allow localized reductions in water temperature though nocturnal thermal reduction

**Desired Ecological Benefits**

- Primary and secondary production
- Primary and secondary production export to Suisun Bay
- Reduced summer/fall water temperature through nocturnal thermal exchange and reintroduction of cooled water to Delta waterways
- Filter for contaminants or site for transformation of contaminants
- Splittail, salmonid, and sturgeon rearing habitat

**Potential Performance Criteria (possible monitoring needs and adaptive management triggers)**

- Type and extent of use by covered fishes
- Extent of in-marsh phytoplankton/zooplankton/macroinvertebrate production
- Extent of phytoplankton/zooplankton/macroinvertebrate exported into Suisun Bay
- Extent of native vegetation relative to non-native vegetation at marsh surface

- Extent of organic carbon production and export into Suisun Bay

**Key Uncertainties**

- Ability to control non-native fish (e.g., inland silversides)
- Ability to restore native plant species (Suisun Marsh aster and soft bird's-beak)
- Availability of adequate sediment supply for marsh accretion
- Extent and effectiveness for providing aquatic covered species and ecosystem benefits
- Effects of increased dampening of the tidal range as marsh restorations are implemented on the ability to implement subsequent restorations
- Effect of brackish tidal marsh restoration on the position of the low salinity zone

**Potential Ecological Risks**

- Possibility of establishment of non-native invasive species into restored habitat

## Channel Margin Habitat Restoration Concept

**Restoration Variables**

- Spatial distribution, extent, and location within the Delta
- Length of restored habitat along channel margins
- Cross sectional profile (elevation of habitat, topographic diversity, width, variability in edge and bench surfaces, depth, and slope)
- Amount and distribution of installed large woody debris
- Extent of shaded riverine aquatic cover and vegetation needed to provide future inputs of large woody debris

**Design Targets**

- Incorporate large woody debris in banks (i.e., complex structure refugia)
- Provide range of hydrodynamic conditions to benefit natives and minimize the colonization of non-native submerged aquatic vegetation and predators
- Provide woody riparian vegetation to create overhead cover and refuge from predators in roots
- Located and configured to connect to existing patches of habitat

- Minimize use by predatory fish
- Minimize occurrence of non-native submerged aquatic vegetation
- Located along fish movement corridors and rearing habitats

**Desired Ecological Benefits**

- Improved local and diurnal water temperatures at a local scale
- Splittail spawning habitat
- Splittail and salmonid rearing habitat
- Source of allochthonous material
- Phytoplankton/zooplankton/macroinvertebrate production
- Increased hydrodynamic complexity in channels

**Potential Performance Criteria (possible monitoring needs and adaptive management triggers)**

- Type and extent of use by covered fishes
- Type and extent of use by non-native predatory fish
- Extent of overhead cover and woody riparian vegetation
- Extent of native vegetation relative to non-native vegetation
- Extent of phytoplankton/zooplankton/macroinvertebrate production

**Key Uncertainties**

- Cost:benefit ratio associated with improving channel margin habitats along levees

**Potential Ecological Risks**

- Possibility of establishment of non-native invasive species into created habitat