HRCM 4:
Yolo/Cache Slough Complex ROA
Tidal Marsh & Shallow Subtidal Restoration

Scientific Evaluation Worksheet

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Action

Restore between 5,000 and 11,000 acres to tidal action and vegetated tidal marsh and shallow sub tidal habitat in the Yolo Bypass/Cache Slough Complex ROA (in addition to Liberty Island and Little Holland Tract). *(Evaluate both 5,000 and 11,000 acres)*.

Evaluation Team

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Action Description and Clarifying Assumptions

The evaluation team was asked to consider two restoration scenarios as follows:

5,000-Acre Option Extent

Haas Slough A & B; Shag Slough; and Egbert A & B.

11,000-Acre Option Extent

Areas suitable for restoration include, but are not limited to: Haas Slough (A & B); Hastings Cut; Lindsey and Barker Sloughs and Calhoun Cut (Egbert A & B); Liberty Island, Little Holland, Westland's property, Shag Slough, Little Egbert Tract, and Prospect Island.

Restoration would include a combination of: (1) vegetated marsh plain; (2) tidal channel networks with depths that are shallow to medium subtidal; and (3) shallow subtidal open water in the deeper portions of the restoration sites. Achieving the 5,000 or 11,000 acre restoration target would involve restoring *some* but not all of the sites noted above.

Figure 1 and Table 1 depict the different habitat types that would be expected to result from tidal reintroduction in the Yolo/Cache ROA based on existing elevations. Elevations are reported in the current federal geodetic datum (land surface elevation) of the North American Vertical Datum of 1988 (NAVD88). Elevations are grouped relative to *existing* local tide heights as reported by the National Ocean Service for the Rio Vista station (NOS 941-5316). BDCP modeling has shown that tide ranges will be reduced with implementing tidal reintroduction projects but we have not attempted to integrate those modeling findings at this time. It should also be noted that existing intertidal areas for Liberty, Little Holland and Westlands' property are combined. Sea level rise is indicated by the abbreviation (SLR).

A brief description of each elevation category depicted in Table 1 is provided below the table. Descriptions of the plant community composition associated with the elevation categories listed in Table 1 come from the DRERIP Tidal Marsh Conceptual Model (Kneib et al 2008), findings of the CALFED Integrated Regional Wetland Monitoring Pilot Project (www.irwm.org), and the DRERIP Aquatic Vegetation Conceptual Model (Anderson 2008).

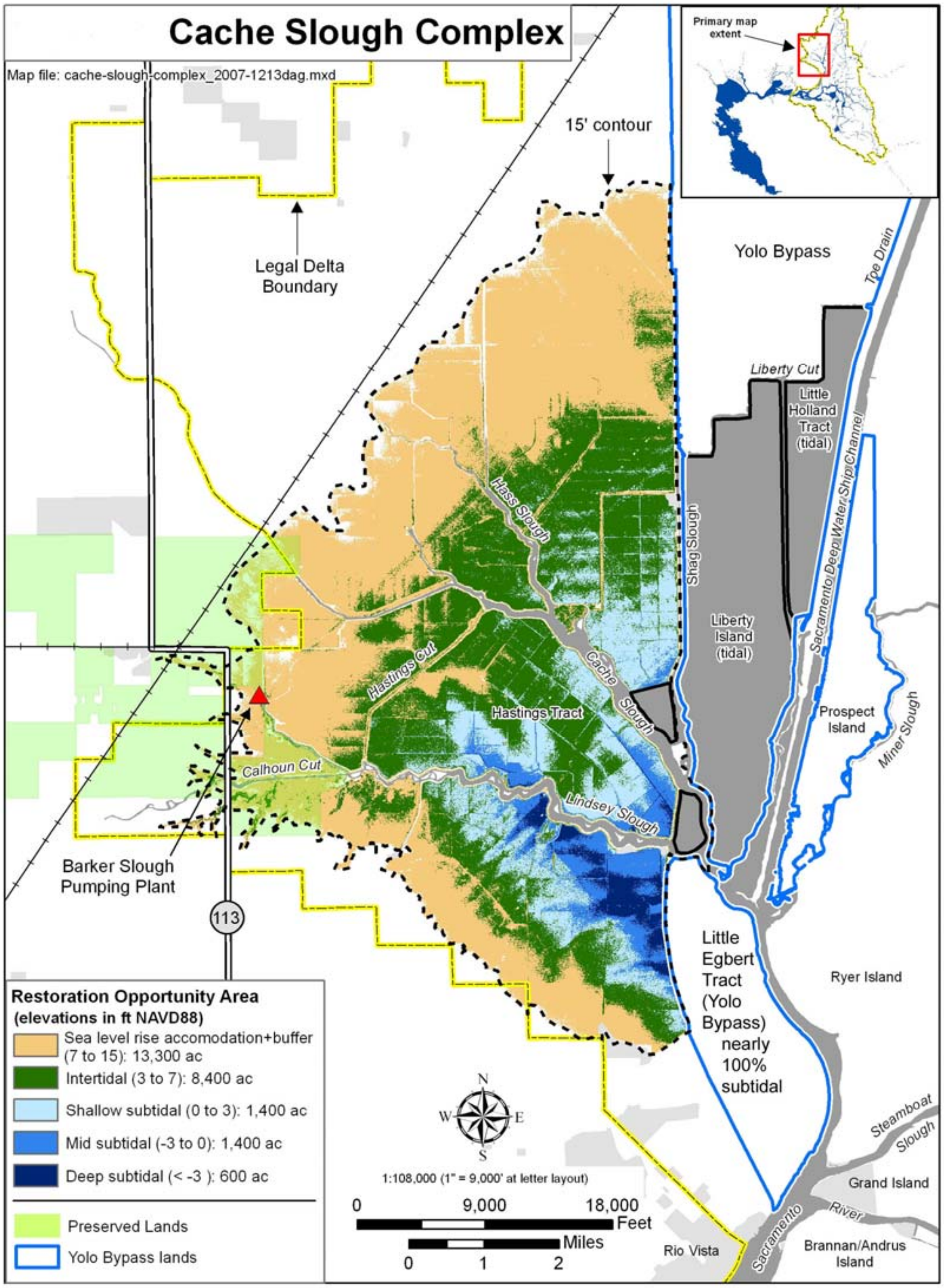
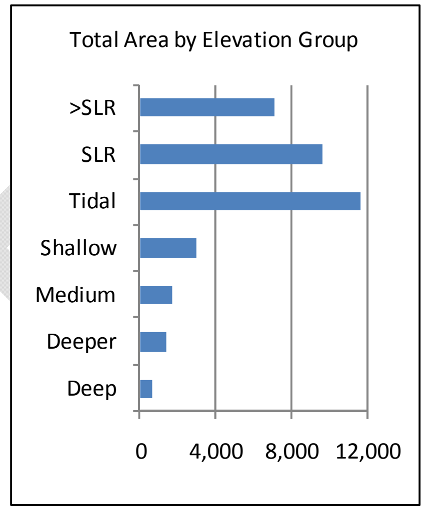


Figure 1. Topography of proposed restoration areas.
Lands shown in green (intertidal) and blue (sub tidal) plus Little Egbert Tract and Prospect Island (both mostly sub tidal) comprise the larger, 11,000-acre option. *Source: Stuart Siegel 2008.*

Table 1.

Total Area Available at BDCP Sites Considered, by Elevation Group

Site (5K option only)	Total (ac)	Area (ac) by Elevation Group (ft NAVD88) > SLR (>12')	SLR (7-12')	Tidal (3-7')	Subtidal Shallow (0-3')	Medium (-3-0')	Deeper (-6--3')	Deep (<-6')
Egbert A	4,644	3,323	1,034	276	2	3	3	4
Egbert B	7,107	1,496	1,455	1,687	1,541	779	51	97
Haas A	1,900	431	989	457	5	2	4	11
Haas B	1,233	489	728	16				
Hastings Cut	7,721	872	2,139	3,343	936	181	63	187
Little Egbert	3,457	67	381	536	312	725	1,196	240
Prospect	1,818	59	181	1,480	46	14	8	30
Shag	6,859	267	2,651	3,731	64	28	30	87
Total	34,738	7,003	9,558	11,527	2,907	1,732	1,356	656
% of total		20%	28%	33%	8%	5%	4%	2%
% of tidal, subtidal				63%	16%	10%	7%	4%



* Data provided by SAIC 2/2/09 with corrected Little Egbert data 2/6/09

1) **Above SLR** (sea level rise): elevations above the currently projected upper end of sea level rise. These areas would be expected to remain as uplands over the long term after tidal reintroduction. These areas could support seasonal wetlands and upland habitats utilized by species that also use the marsh (e.g., birds, small mammals, reptiles, amphibians).

2) **SLR**: elevations that are within the currently projected upper end of sea level rise and thus would be expected to become inundated over time after tidal reintroduction as sea level rises. These areas could support a mix of seasonal wetlands, uplands, upland-wetland transition, infrequently inundated tidal marsh at the lowest elevations, and in the future increased extent of tidal marsh as sea level rises.

3) **Tidal**: elevations that are within the current local tide range of mean lower low water (MLLW) (3 ft NAVD88) to mean higher high water (MHHW) (7 feet NAVD88). This elevation category would be dominated over time by a diverse suite of emergent marsh plants showing some zonation patterns relative to elevation and thus inundation regime.

4) **Shallow Subtidal**: elevations that are between MLLW and 3 feet below local MLLW (0 to 3 ft NAVD88). This elevation category would be dominated by open water with tule vegetation extending into its shallowest regions; also subject to colonization by submerged aquatic vegetation in low-energy areas with suitable substrate.

5) **Medium Subtidal**: elevations that are 3 to 6 feet below local MLLW (-3 to 0 ft NAVD88). This elevation category would be open water and subject to colonization by submerged aquatic vegetation in low-energy areas with suitable substrate; SAV would have a greater probability of occurrence at shallower depths with more light penetration.

6) **Deeper Subtidal**: elevations that are 6 to 9 feet below local MLLW (-6 to -3 ft NAVD88). This elevation category would be open water and subject to colonization by submerged aquatic vegetation in low-energy areas with suitable substrate only in areas with high light penetration.

7) **Deep Subtidal**: elevations that are more than 9 feet below local MLLW (below -6 ft NAVD88). This elevation category would be open water and subject to colonization by submerged aquatic vegetation in low-energy areas with suitable substrate only in areas with extremely high light penetration.

Approach

1. Breach levees to provide for tidal exchange with lands being restored; breaches will be of sufficient length not to limit water motion into and out of restored habitat.
2. Modify 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.
3. Restore stream functions of erosion and sedimentation (e.g., Ulatis Flood Control channel) to improve spawning conditions for Delta smelt and other fish and macro invertebrates.
4. On subsided lands (e.g., Little Egbert Tract), plant tules before breaching levees to raise ground surface to elevations suitable for tidal marsh restoration.

Intended Outcomes as Stated in Conservation Measure

1. Increase rearing habitat area for Chinook salmon, Sacramento splittail, and possibly steelhead.
2. Increase the production of food for rearing salmonids, splittail, and other covered species.
3. Increase 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.
4. Locally provide areas of cool water refugia for Delta smelt.

Conceptual Model Information Regarding Intended Outcomes

The Outcomes tables document the following linkages between tidal marsh restoration efforts generally in the Delta and the specific cause-effect relationships implied in the Action:

1. Rearing habitat is a stated outcome for habitat quantity and quality (specifically, water quality). It is a driver for Delta smelt, longfin smelt, splittail, and white and green sturgeon. The higher turbidity levels of Cache Slough region compared to other Delta locations (see Schoellhamer et. al., 2007) improves habitat suitability for Delta smelt.
2. Exported production is a stated outcome. It is a driver for Delta smelt, steelhead, and white and green sturgeon.
3. Cool water refugia is not integrated into the Outcomes table. To the extent that “water quality” implies temperature (it usually implies salinity unless otherwise stated) then it is captured.

Assumptions

Provided in BDCP Conservation Measure

1. Barker Slough Pumping Plant is relocated such that it does not adversely affect benefits of restoration.

Added by Evaluation Team

1. Barker Slough Pumping Plant relocation also eliminates potential conflicts between drinking water supplies and increased organic carbon in the water column.
2. Other large agricultural intakes in the area will be relocated such that they do not adversely affect benefits of restoration.
3. Levee breaches will be large enough not to cause muted tides within a restoration site.
4. Levee breaches will be large enough to avoid steep velocity gradients (eddies) that promote fish predation.
5. Approach #2 includes the excavation of subtidal dendritic channel networks, recognizing that down cutting through prior agricultural fields is unlikely.
6. The time frame for realizing restoration benefits depends upon the approaches used. Reversal of subsidence on restored areas can take several years to a decade or more depending on starting elevations. The accretion rate depends on sediment supply and biomass accretion which depends on site-specific conditions. Sediment supply in the Delta is generally very low. Cache Slough and Suisun Marsh generally have higher concentrations of sediment than other Delta locations (Schoellhamer et. al., 2007).
7. Efforts to reverse subsidence before active restoration would be focused on the more deeply subsided portions of these landscapes, i.e., lands more than 6 feet below low tide. To speed up the subsidence reversal process, an alternative method would be to separate low-lying areas with new levees and reconnect those areas after subsidence reversal is accomplished.
8. Prior to implementation, a complete Phase I Environmental Assessment with on-site sampling to assess legacy and other soil contaminants (i.e. mercury and pesticides) would be conducted.
9. The frequency, magnitude, and duration of Yolo Bypass flooding would be the same as current existing conditions.

Problem(s) with Action as Written:

1. The conservation measure would benefit from an explicit recognition that restoration of tidal marsh functions on subsided landscapes, especially those subsided below emergent vegetation elevations, will take many years to many decades. In the interim, the region will function as a shallow intertidal habitat.
2. The evaluation should consider alternative approaches for shallowly subsided lands. Approach #4 indicates one approach – pre-breach tule planting on the subsided areas. The approach should also consider leaving some part of the restored area as shallow sub tidal habitat, as the Action itself states “tidal marsh and shallow sub tidal habitat”. Each approach leads to a different outcome on different time scales. See assumption #8 above.
3. It is unlikely that intertidal mudflats will develop in the Delta because dominant intertidal emergent vegetation species in the Delta can grow throughout the tidal

range and just into shallow sub-tidal elevations (Brown 2003, Simenstad et al 2000 as cited in Schoellhamer et. al., 2007, page 26).

4. Because rearing habitat for juvenile fish by necessity includes local availability of food, the evaluation team merged the first two Intended Outcomes (rearing habitat and local food) into one outcome.
5. As currently written, approach #3 (stream functions) is not clear. The Evaluation Team doubts this watershed is large enough to provide significant sedimentation. Therefore, this approach is not included in this evaluation.

Scale of Action:

Large for both acreage options.

Rationale:
This is a large scale restoration action due to its spatial extent. As listed in Table1 below, the Delta currently has approximately 21,600 acres of tidal marsh habitat (baseline). Additionally 67,000 acres of diked and other lands have been identified as potentially restorable to tidal marsh (neglecting effects of restoration on reducing tidal range). The proposed 5,000 and 11,000 acre restoration options would increase marsh acreage 23% and 51% (respectively) above current conditions. Significant amounts of the 67,000 acres of identified restorable lands are highly constrained such that they could not be restored in the near term (South Delta and Netherlands alone account for 31,000 acres of the 67,000 acres). Therefore, this action also represents an important part of the potentially restorable tidal marsh lands.

Table 2. Summary of Tidal Marsh Acreages

Area	**Acreage**	**Source**
Delta (entire Delta proper)	738,000	DWR, 2009
Historic tidal marsh/wetlands in Delta	525,000	TBI, 2002
Current extent of tidal marsh/wetlands in Delta.	21,600	TBI, 2002
Restorable intertidal lands within Delta.	67,000	CA DVSP, 2008, Table 1, p.77.
Proposed Cache Slough tidal marsh restoration (this action)	5,000 or 11,000	BDCP, 2009

Evaluation Summary Tables

Summary tables listing magnitude and certainty scores for each outcome, by species are provided in the Outcome Summary Table Appendix at the end of this worksheet. Details regarding each of the listed scores, and the rationales for the scores are provided in the discussion of positive and negative outcomes herein.

Outcomes with Direction of Change Uncertain

The outcomes listed below could be either positive or negative (the direction of change is not certain).

- P/N1. Slough turbidity changes as it affects Delta smelt food locating capacity. This outcome was not evaluated. The team believes there is a relationship but lack of data precludes evaluation (we don't know whether the sign would be positive or negative).
- P/N2. Increased velocities in larger sloughs may alter the energetics of covered fish species. Velocities will increase in some parts of the Delta and decrease in other parts. The direction of change is not known.

Outcomes with Zero Magnitude

- OP1: Increase rearing habitat and local food production for Eastside and San Joaquin Chinook salmon, fall run.
- OP2a: Locally provide areas of cool water refugia for winter-run salmon.
- OP2b: Locally provide areas of cool water refugia for late fall-run salmon.

Other Potential Positive Outcomes Identified, Not Evaluated

When BDCP originally crafted this action, they identified the four potential positive outcomes listed below. The Evaluation Team was instructed to focus evaluation efforts on covered fish species. Since the four outcomes consider species other than covered fish, the team did not evaluate these outcomes.

- OP1. Increase giant garter snake habitat
- OP2. Increase Mason's lilaeopsis habitat
- OP3. Increase habitats for resident native fish (blackfish, Sacramento perch, tule perch)
- OP4. Increase habitats for birds
- OP5: Reduce low velocity-associated salmonid predation pressure in Sutter and Steamboat sloughs (see details in Appendix C)

Other Potential Negative Outcomes Identified, Not Evaluated

During the course of this evaluation, the team identified one potential negative outcome that it did not evaluate due to lack of time. It is recommended that this potential outcome be evaluated at some point in the future when additional time is available.

- ON1. Pesticide use for mosquito control. Tidal marsh provide habitat for mosquito larvae and adults. Since this restoration action will increase tidal marsh habitat, it will also increase the availability of habitat for mosquitoes. County environmental health departments are authorized to utilize pesticides to the extent necessary to manage mosquitoes in order to protect public health and prevent west nile and other viruses. Sacramento, San Joaquin, and other Delta counties have active mosquito management programs that include the application of pesticides on marsh habitats. The effect such pesticide use may have on the flora and fauna in the restored marsh and connected areas have not been evaluated in this worksheet.

Relation to Existing Conditions

Significant changes to hydrodynamics due to Cache Slough restoration have been simulated by the BDCP modeling team (BDCP 2009. and John DeGeorge, pers. comm.). The one-dimensional model results combine Cache Slough restoration with other core elements including modification of the Fremont Weir and new North Delta diversion. The two-dimensional modeling simulated multiple restoration areas at one time in some cases. For this particular evaluation, only altered hydrodynamics in response to Cache Slough restoration are considered. In this section, the evaluation team primarily considers the Cache Slough restoration on its own merits. However, some comments on the integration of Cache Slough restoration and Yolo bypass flow augmentation are also provided.

In general, opening hydraulic connections to formerly diked lands will dissipate tidal energy on a regional (in this case, nominally northwest Delta) scale. Reductions in tidal range and redistribution of tidal flows and associated tidal velocity may also be observed.

While the modeling of Cache Slough restoration includes the north Delta diversion and intermittent Fremont Weir flow, the influence of these elements on tidal range is thought to be minimal (BDCP 2009).

Cache Slough restoration decreases regional tidal range, with generally more reduction near, and less reduction far from the project. The magnitude and aerial extent of decrease is also a function of project acreage, hydraulic connection attributes, the restoration volume or accommodation space, and the roughness characteristics of the site.

Tidal stage range in Cache Slough and the Liberty Island area is estimated to decrease by up to 0.75 feet from its current range of about 4 feet. Simulated changes in Sacramento River stage range downstream of Cache Slough (near Rio Vista) are similar. Upstream, Sacramento River stage range is estimated to be reduced by approximately 0.5 ft. More of the tidal range reduction will on the high tides than the low tides. Sutter, Steamboat, and Georgiana Slough stage changes are anticipated to be similar to that at Freeport.

The magnitude and duration of tidal inundation on newly restored sites is a function of the particular configuration of the project. It is expected that the site will evolve geomorphically over time. Project evolution will be characterized by sediment and vegetation accretions that will reduce accommodation space. This may have the effect of increasing regional tidal range once again. However, along the trajectory of change over time, the balance of forces may yet reduce tidal range further while the site still has most of its initial accommodation space, but also becomes highly frictional as emergent vegetation begins to dominate the tidal fringes. The evolving balance between the tidal prism and the frictional characteristics of the site ultimately determines how regional stage and tidal flow will be affected over time (Friedrichs et al. 2001, Culberson et al. 2003).

Tidal restoration in Cache Slough ROA differentially influences regional tidal flow and velocity depending on channel proximity to the restoration area. In general, tidal flow and velocity increases in Cache Slough as much as 30,000 cfs, because it conveys flow to the increased accommodation space created by the restoration. Tidal flow increases despite the reduced tidal range because there is now slightly less asymmetry between stage and velocity phasing (peak flood and ebb flows occur ~1 hour later). Tidal flow at Rio Vista increases from approximately +/- 100,000 cfs to approximately +/- 130,000 cfs. Modeling suggests that peak tidal velocity will increase 30-40% to accommodate the added flow. This will likely be a transient effect until the channel scours to a new dynamic equilibrium between bed shear stress and sediment cohesion properties.

Tidal flow variability is dramatically decreased upstream of Cache Slough in concert with diminished tidal range. While net flow remains the same, variability of tidal flow at Freeport is decreased from approximately 4,000-15,000 cfs to +6,000-14,000 cfs (simulated spring tide, mid June 2002) (BDCP, 2009). Closer to Cache Slough, Sutter Slough flow range diminishes from +/-2,000-5,500 cfs to +1,000-4,500 cfs. Sutter Slough and Steamboat Slough also no longer exhibits bi-directional flow at their heads, and diminished bi-directional flow downstream. This is important because it reduces or stops the ability of salinity (or other scalars) to disperse upstream.

The hydrodynamic changes described above can be broadly used to describe changes under either the 5,000 or 11,000 acres restoration scenarios, with the magnitude of change corresponding to the acreage restored. Tidal dampening and/or conveyance restrictions appear to increase as more acres are restored, limiting the extent of inundation; further hydrodynamic modeling would be needed to confirm or reject and quantify this effect.

Overview of Productivity Import-Export

The purpose of this section is to discuss the general concepts around productivity in the restored tidal marshes and shallow open water and availability of primary productivity to the aquatic food web within and outside of restoration sites. Available productivity is one of the main intended positive outcomes of this conservation measure. Factors that influence biological productivity include resource availability (e.g., light, nutrients), import-export dynamics (biological and physical), invasive species, and predator-prey relationships As restoration sites evolve over time, the nature and relative magnitude of these factors may change. Climate change and sea level rise will introduce additional dynamics (Callaway et al, 2007).

Freshwater tidal marshes are among the most productive ecosystems globally. The efficiency with which organic material produced at the base of the food web will reach covered fish species has a large influence on the potential positive benefits of tidal marsh restoration. The DRERIP tidal marsh model (Kneib et. al., 2008) hypothesizes that the most prevalent form of carbon bioavailable to the aquatic food web is exported from tidal marshes in the form of small fish, a concept referred to as the "trophic relay". In addition, the Conservation Measure includes restoration of emergent vegetated tidal marsh, shallow sub tidal channel networks within the restored tidal marshes, and adjacent shallow sub tidal open water areas. See Figure 2 below for a schematic representation of a generic tidal marsh.

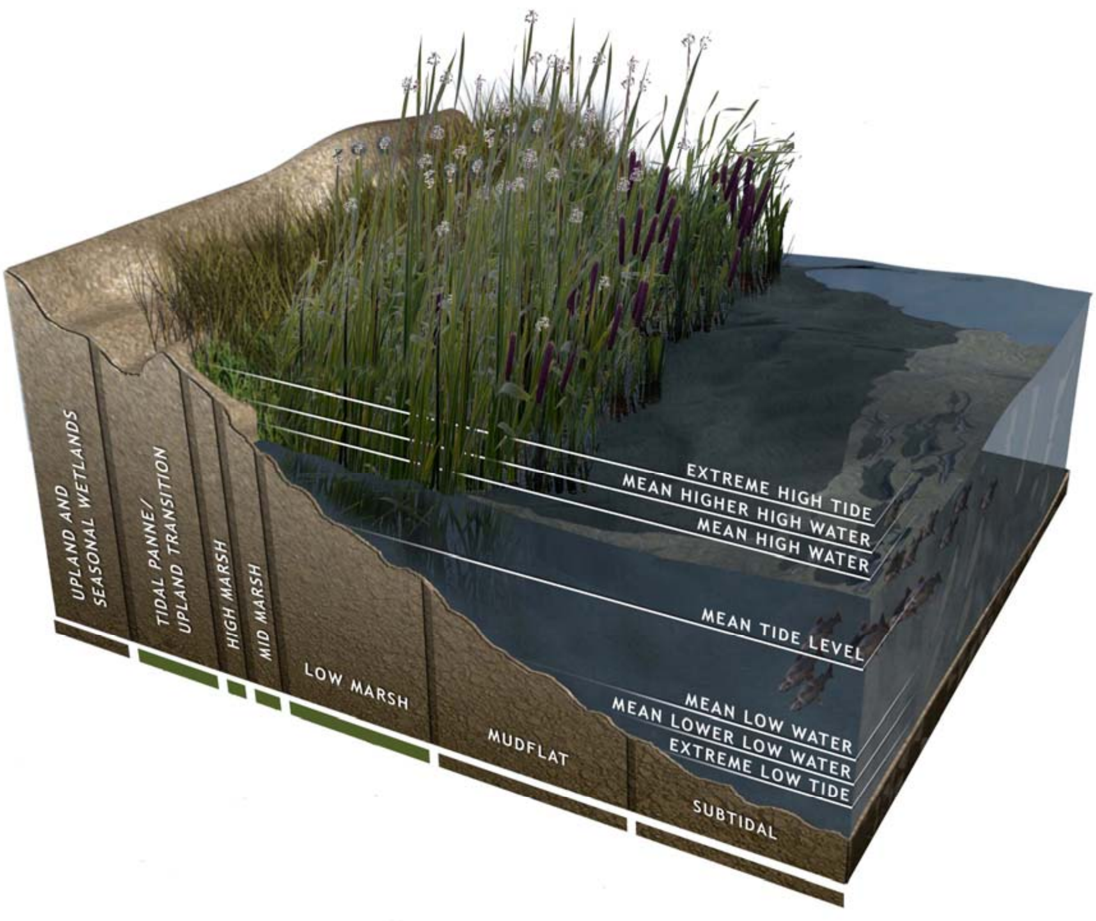


Figure 2. Typical cross section through a marsh.

Tidal marshes generally are net producers of organic matter because of high primary production by marsh plants, epiphytes, submerged and floating vegetation, and phytoplankton. This material is available to support local foodwebs and provide food energy for invertebrates, fish, and other animals. Tidal marshes can both import and export organic carbon in dissolved or particulate, living and nonliving, and bioavailable or refractory forms. However, much of the organic matter exported is in the dissolved form which provides less direct benefit to the estuarine foodweb because the organic matter is not very bioavailable and the microbial foodweb that can use this material is inefficient (Sobczak et al. 2005). Newly created or restored marshes, or marshes that are mainly subtidal, may accrete organic soil and thereby bury organic matter (Kneib et. al., 2008).

An intended outcome is the export of organic matter, based on the assumption that marsh restoration will increase production of phytoplankton and other bioavailable forms. Experiments to stimulate phytoplankton production in natural water bodies have been conducted to investigate nutrient limitation and to explore the possibility of stimulating production of fish. These studies include lake fertilization experiments (Schindler 1977, Carpenter et al. 1995) and iron addition experiments in the ocean (Chisholm et al. 2001). The general conclusion of such studies is that natural ecosystems are complex and that consequences of any change in forcing, whether from nutrient enrichment or alteration of trophic structure, can be difficult to predict (Carpenter et al., Chisholm et al. 2001). This suggests that forecasts of gains in export of productivity from the restored marshes should be made cautiously.

When net flow rates are low, the movement of individual foodweb components depends on tidal exchange and the concentration gradient, affected in turn by source and loss rates in and outside the marsh, and the swimming of organisms. For example, marshes produce particulate detritus that is then available for export, but marshes can also import detritus through particle trapping by marsh plants. Data shows that net phytoplankton production is highest in shallow water because phytoplankton production requires light (Thompson 2000). Although this implies the potential for export there is little quantitative information to support this, and the degree of export depends critically on shallow-deep system connectivity (Cloern 2007 and Monsen et al 2007) and the local phytoplankton growth-loss balance (Lucas et.al. 2009). For example, establishment of invasive clams or mussels in the shallow subtidal regions or marsh channels (Outcome N1B) may increase local phytoplankton loss rates and thus convert restored areas into food sinks instead of sources. Similarly, planktivorous fish in marshes may consume zooplankton at a higher rate than occurs outside the marsh, resulting in a concentration gradient favoring net import of zooplankton. Thus, the restored marsh may or may not export phytoplankton, zooplankton, or other organic matter to the broader foodweb.

Role of Restoration Stage, Sedimentation, and Biomass Accumulation, and Sea Level Rise: Inundation regime (depth, frequency, and duration of flooding) and salinity are the two most dominant controls of tidal marsh ecology (Callaway et al, 2007). Inundation regime is controlled mainly by marsh elevations relative to the tides, with the Delta having a relatively significant seasonal riverine influence. Restored marshes will increase in elevation over time through sediment accretion and biomass accumulation. Accretion rates are not well documented in the Delta but what little information exists suggests generally low rates with high variability (data from BREACH and Integrated Regional Wetland Monitoring Pilot Project), though the Yolo Bypass provides somewhat more sediment (see Schoellhamer et. al., 2007, Simenstad 2000 and Reed 2002) that should benefit restoration in the Cache-Yolo area compared to other Delta locations.

Role of *Corbicula* in Affecting Exported Production: The outcome in terms of organic carbon production depends critically on whether freshwater clams (*Corbicula*) become established in the vicinity of the restored area (Lopez et al. 2007). If they become established and abundant either within marsh channels or in river channels in the vicinity of the marsh or in shallow sub tidal restored areas, they may consume most of the phytoplankton carbon produced there and remove it from the pelagic food web. See Outcome N1c below.

Role of Residence Time in Affecting Productivity Levels: Residence time refers to the time that a particle of water or some constituent of water remains in a water body. This concept is applied here more as a broad concept than a specifically measured quantity (see Monsen et al. 2002 for a discussion of residence time). When the movement of water in the Delta slows either because of lower net flow or reduced tidal velocities, residence time increases (see Kimmerer and Nobriga 2008). With the decrease in inflow to the Delta due to the export of water from the Sacramento River, and the decrease in north-to-south flow of water toward the south Delta export pumps, residence time generally will increase.

The speed of exchange between the Cache Slough restoration area and the rest of the Delta would be influenced by the tidal range, freshwater flow, the physical configuration of the breaches, and how that configuration changed over time. Hydrodynamic modeling results suggest that waters in the Cache Slough area after restoration would have relatively long residence times due to limited mixing in the tidal marsh areas, despite increased exchange of tidal flows in the main connecting channels. When the Yolo Bypass floods, mixing might increase and residence time would be inversely related to the flow rate. The amount of food produced in an area and the fate of this food depends on residence time as well as the local growth-loss balance (Lucas et. al. 2009). When residence time is long, food production can be high but little is exported. When residence time is very short, little production results. Intermediate residence times can maximize the production and export of foodweb organisms, but the magnitude of that export is unknown.

Potential Positive Ecological Outcome(s)

Outcome P1: Increase rearing habitat and local food production

As indicated at the beginning of this worksheet under the section entitled "Problems with Action", the team decided to merge two Intended Outcomes (rearing habitat and local food) into one outcome, P1, as shown below because rearing habitat for juvenile fish by necessity includes local availability of food. This outcome includes food (both primary and secondary production) produced within the vegetated marsh, within marsh channels, and within the subtidal areas adjacent to the vegetated marsh.

P1a. Delta smelt

General Observations: The aquatic food web supporting Delta smelt production is a primary component of habitat suitability that affects Delta smelt growth rates, health, fecundity, and mortality (page 21 in Nobriga and Herbold, 2008). The food web supporting Delta smelt is based on the production of pelagic zooplankton.

Historically, Delta smelt had a larger spawning range as compared with their spawning range in recent years. In some recent years, the Cache Slough area appears to have supported a substantial portion of spawning and rearing Delta smelt (page 11 in Nobriga and Herbold, 2008). Maintenance of suitable habitat conditions in the Cache Slough region is very important to conservation of this species and it is possible (though not at all certain) that habitat conditions for Delta smelt in this area can be improved; however, without restoration of spawning/rearing conditions in other locations (maintenance of spatial distribution and diversity), Delta smelt will remain in great peril of extinction.

Delta smelt are believed to be food limited for at least some life stages (Herbold and Nobriga 2008, page 9). In summary, food resources for Delta smelt would be produced within the restored marsh habitat, and the combination of physical space and food production would constitute habitat for Delta smelt.

Food generated on this site might be lost to invasive clams. This phenomenon is described in detail in Negative Outcome N1b. Predation (especially if it is facilitated by colonization of SAV) may also eliminate any beneficial effect of this action.

Magnitude = 3 - Medium: If implemented, this action is expected to produce a sustained minor population level effect on Delta smelt. The benefit of the action is expected to vary over time depending on the Delta smelt population distribution. When Delta smelt are distributed in many areas of the Delta, the overall population will derive a relatively minor benefit from this localized action. However, if the population is constrained to the Cache Slough area, the relative benefit from this action may increase.

One of the major concerns for Delta smelt relates to their narrow geographic distribution. The maximum suspected spawning range for Delta smelt (i.e. all localities where gravid or early larval fish have been detected) is small enough that this species is at risk of extinction due to localized catastrophic or demographic events (see Rosenfield 2002); this risk is exacerbated by their short life span and semleparous life history. In fact, the geographic range of Delta smelt appears to have decreased in recent years and, during

low outflow years, may be limited to just a few sites (this year, in the Northern Delta, Montezuma and west Delta), totaling just a few square kilometers. Increasing the Delta smelt population without increasing their geographic range (meaning available spawning and rearing habitat within the Delta) addresses only a portion of the threats to Delta smelt.

An additional factor contributing to the medium magnitude score for this outcome is that under circumstances described in the conceptual model (which may no longer hold, as discussed above) the production of habitat here would affect only a portion of the life cycle and the outcome will only benefit a fraction of the population.

Certainty = 2 - Low: The value of food produced on site is related to how much of that food makes it into the adjacent channels and to the suitability of the adjacent open-water regions to continue supporting Delta smelt. Both of these are uncertain. The food available to Delta smelt in directly adjacent channel and open-water habitats depends on how much of the zooplankton produced in the region is consumed by fish that actually forage there. The ability of Delta smelt to compete for available zooplankton is influenced by how well the habitat meets its physiological and behavioral needs.

Corbicula establishment could reduce the productivity benefits of the restoration to Delta smelt. See Negative Outcome N1b. If SAV starts to become established in a restoration site, there also may be an increase in the rate of predation on Delta smelt by several predators during the period SAV begins to establish. If SAV becomes well established, Delta smelt will not occupy the site with much frequency. Thus, poorly designed restoration could dissuade Delta smelt from using the north Delta as extensively as they do currently.

P1b. Longfin smelt

General Observations: Rearing longfin smelt larvae and juveniles are infrequently found in this area at low abundances according to Rosenfield, 2008 and data from the 20mm survey (http://www.delta.dfg.ca.gov/data/20mm/CPUE_Map.asp) and the tow-net survey (http://www.delta.dfg.ca.gov/data/townet/CPUE_Map.asp).

Magnitude = 1 - Minimal: The effect of this action on longfin smelt is expected to be negligible. Tidal marsh is not considered "rearing habitat" for longfin smelt. Although larvae are generally found near the water column surface (Rosenfield, 2008 p.5), where

they might access shallow habitats, juveniles can adjust their position in the water column (Rosenfield, 2008, p.6) and tend to concentrate in deepwater environments (Rosenfield and Baxter 2007). Only a very small proportion of late-stage longfin smelt larvae would be expected to occur in shallow tidal environments.

In addition, longfin smelt are rarely detected above Rio Vista on the Sacramento River (Wang 1991; R. Baxter, CDFG, unpublished data). Recent survey data (in years 2008 and 2009) have shown longfin smelt larvae to be more common in this area (e.g. Smelt Survey; http://www.delta.dfg.ca.gov/data/sls/CPUE_Map.asp; and 20mm survey, http://www.delta.dfg.ca.gov/data/20mm/CPUE_Map.asp). It is possible that the very small proportion of larvae-transitioning-to-juvenile longfin smelt rearing in this area may benefit from food items produced locally.

Certainty = 2 - Low: The scientific certainty about achieving any benefit is low. Sampling rarely detects longfin smelt in the Cache Slough complex and, when they are detected (generally larvae or very small juveniles), abundances are extremely low. In addition, establishment of *Corbicula*, SAV and/or predators on the restoration site could eliminate any net benefits to covered fish species. See Negative Outcome N1b.

P1c. Chinook salmon and steelhead

General considerations that apply to all the salmonids are described below followed by run-specific magnitude and certainty evaluations. The DRERIP Salmonid conceptual model indicates the value of estuarine rearing varies across runs (see Williams and Rosenfield, In preparation page 15).

General Seasonality of Delta Use: Juveniles of most runs migrate during winter through spring.

Role of Outmigrant Size in Duration of Delta Use: Larger outmigrants generally rear for shorter periods in the lower estuary before moving to the ocean. Life histories that include rearing upstream (including in-rivers and on floodplains) produce large outmigrants that are believed to derive less benefit from restoration of rearing habitat in the Delta.

Temperature: Salmonids are sensitive to warm water. Average daily water temperatures from May to September in the vicinity of this restoration (as indicated by those at IEP monitoring station RSAC 101) regularly exceed 20-21 degrees C, beyond which sublethal effects accumulate (Myrick and Cech 2004; Richter and Kolmes 2005). With warming that may occur under climate change, these temperatures are expected to occur in this area with some frequency during April and October as well. Steelhead, fall run Chinook salmon, and spring run Chinook salmon are typically present in the Delta

during some of these months and value of Cache/Yolo tidal marsh restoration to these runs would be reduced because of the warmer water.

Role of Delta in Overall Life-History of Salmonids: Delta rearing is one relatively short period in the overall life of salmonids and is not believed to be a key limiting factor for spring run, winter run, late-fall run or steelhead. Other factors such as upstream spawning and rearing habitats and water diversion structures and operations are more important in the overall life history for these salmonids (Williams and Rosenfield, In preparation).

Food Productivity to Support Rearing: Factors affecting food productivity described in this worksheet indicate that salmonids would find food resources in the Cache Slough area. The benefits of this productivity would accrue more to smaller migrants and when water temperatures support growth and smoltification (Williams and Rosenfield, In preparation).

Predator Exposure: Estuarine habitats that support salmonid rearing potentially also support predator populations, including (in particular) introduced Centrarchids that prefer shallow slow-moving freshwater environments. Increasing the residence time of salmonids in the Delta (by increasing rearing habitat) may also increase exposure to predator populations – the number of predatory fish in the Delta is much higher now than it was historically because of the introduction of Centrarchid and other non-native predators and maintenance of conditions that support those predators.

P1c1. Chinook salmon, Sacramento, winter run

General Observations: Winter-run juveniles move through the northern Delta from late-summer through winter. Winter-run life history strategy is unique. Because they may rear for several months in upstream environments, they are not expected to utilize the estuary extensively for rearing. Winter-run will consume the types of zooplankton produced in this restoration (under the assumed condition). Most winter-run migrate through this area when temperatures are cool enough to support rearing.

Magnitude = 2 - Low: The Salmonid life history conceptual model (Williams and Rosenfield, In preparation, page 16) states that "Spring Chinook, or at least the Butte Creek population, pass quickly through the Delta, so habitat restoration there seems unlikely to do much for them. The same is probably true for late fall Chinook and for steelhead. The presumed benefit of this conservation measure is the provision of food resources for outmigrating smolts. The benefits provided by proposed restoration action for winter run are equivocal.

The magnitude of this benefit for winter-run Chinook is low because of their comparatively large size when they migrate through the Estuary and because it is unlikely that they are limited by the extent of rearing habitat. Winter run are believed to grow little in the Delta. The Salmonid model suggests a moderate impact of this kind of habitat on competition, which may have a moderate impact on growth. However, both of these impacts are highly speculative. Winter-run have the smallest population of any Chinook salmon run in this system and they have access to the same estuarine habitats as the other runs. Also, their migratory season overlaps little with the more populous spring and fall run migrations. Thus, growth limitation due to inter- or intra-population competition for habitat in the Estuary is least likely for this run among all the Central Valley Chinook populations.

Food limitation is not considered a major limitation on survival in this life stage. Limitations on spawning and rearing habitat upstream are far more important to winter-run Chinook salmon conservation than putative habitat limitations in the Delta.

Certainty = 1 - Minimal: No direct studies of this run's habitat use in estuarine habitats have been published. Establishment of *Corbicula*, SAV, or predatory fish populations could limit, if not eliminate the productivity benefits of the restoration to Chinook salmon. See Negative Outcome N1b. Predation by invasive predators (especially if it is facilitated by colonization of SAV) may also eliminate any beneficial effect of this action.

P1c2. Chinook salmon, Sacramento, spring run

General Observations: Spring-run juveniles move through the northern Delta from winter through spring.

Magnitude = 2 - Low: The DRERIP Salmonid conceptual model (Williams and Rosenfield, In preparation, page 16, states that "Spring Chinook, or at least the Butte Creek population, pass quickly through the Delta, so habitat restoration there seems unlikely to do much for them. The same is probably true for late fall Chinook, and for steelhead".

The salmonid model's evaluation focused on one spring run population (Butte Creek). In fact, many juveniles from other populations migrate at a smaller size than Butte Creek juveniles. They migrate at about the same time as fall-run and thus may experience competition with fall run. So, this restoration may alleviate competition for a segment of the population. Williams and Rosenfield (In preparation) indicates moderate benefits of increasing rearing habitat.

Benefits are limited to those emigrants rearing in this habitat in the early-mid spring, before temperatures in this region increase above optimal rearing threshold (12-16 degrees C, Marine and Cech 2004).

Certainty = 2 - Low: There are no direct studies of spring-run Chinook salmon habitat use in this ecosystem. Driver-Linkage-Outcome (i.e. conceptual model) indicates variability (inter-population and inter-annual) in the relationship between habitat volume-density-competition and growth.

Given the temperature limitations and differences in life history among spring-run populations, the Evaluation Team can be moderately certain that the maximum positive magnitude of this impact from this action is low; however, there is relatively low certainty that there will be any beneficial impact at all. Establishment of *Corbicula*, could limit if not eliminate the productivity benefits of the restoration to Chinook salmon. See Negative Outcome N1b. Predation by invasive predators (especially if it is facilitated by colonization of SAV) may also eliminate any beneficial effect of this action.

P1c3. Sacramento Chinook salmon, fall run

Magnitude = 3 – Medium: The conceptual model (Williams and Rosenfield, In preparation, page16), states that "Fall Chinook […] could benefit strongly from tidal marsh restoration". Fall Chinook enter estuarine habitats at a small size and the text anticipates benefits from additional rearing/growth opportunities. Fall-run will consume the types of zooplankton produced in this restoration (under the assumed condition). However, the benefits that may accrue to fall run Chinook are uncertain because it is possible that the "ocean type" life history strategy of this run minimizes Delta residency in favor of rapid migration to the ocean (NMFS 2009, p12 Citing MacFarlane and Norton 2001).

Fall-run juveniles move through the northern Delta from winter through spring. Fall run rearing in this proposed restoration site during late spring will probably be impacted by high temperatures.

This outcome will benefit only the Sacramento portion of the fall-run population. Please note that the eastside Chinook salmon run is discussed in Appendix C.

Certainty = 2 - Low: Sacramento fall run Chinook use of fresh water tidal and sub-tidal environments is documented in other systems but is not well studied in this system – possibly because this kind of habitat is limiting in this system.

The effect of global climate change on water temperatures in this area during Sacramento River fall run migration period also decrease the window of time during each year when restoration will produce benefits. The temperatures experienced in this area during late spring and summer indicate that only a portion of the Sacramento River fall-run population will benefit from this action.

Other factors create uncertainty as to the benefits of this measure for this population. *Corbicula* establishment could limit if not eliminate the productivity benefits of the restoration to Chinook salmon. See Negative Outcome N1b. Similarly, establishment of predators or SAV that supports predation could eliminate most or all of the benefits created by this measure.

P1c4. Chinook salmon, Sacramento, late fall run

General Observations: Late-fall run juveniles move through the northern Delta from early fall through spring. The fisheries biology community is currently debating whether late fall run Chinook exhibit separate reproduction from fall run. As that debate has not yet been settled, this evaluation presents late fall run as a distinct run.

Magnitude = 1 - Minimal: Late fall-run will consume the types of zooplankton produced in this restoration (under the assumed condition). Most late-fall run migrate through this area when temperatures are cool enough to support rearing. The discussion of drivers and outcomes in the figures of Williams and Rosenfield, (In preparation) indicates that tidal marsh has a low impact on competition and competition in this area has a low impact on growth.

Certainty = 1 - Minimal: The importance of growth in estuarine environments is unstudied for this run. Text concerning drivers, linkages, and outcomes in the conceptual model indicates low certainty of impact.

Establishment of *Corbicula* could limit, if not eliminate the productivity benefits of the restoration to Chinook salmon. See Negative Outcome N1b. Predation by invasive predators (especially if it is facilitated by colonization of SAV) may also eliminate any beneficial effect of this action.

P1c5. Steelhead

Magnitude = 1 - Minimal: Steelhead juveniles migrate through the Delta during a six month period from January to June. However, most migration occurs in a two-month window, "mainly in April and May" (Williams and Rosenfield, In preparation, page 34). Steelhead rearing in this proposed restoration site during and after May will probably be impacted by high temperatures and negative impacts could become more common with global warming.

The Salmonid conceptual model regarding estuarine – growth, shows a low impact of this kind of habitat on competition – competition may have a moderate impact on growth. The restoration of tidal marsh habitat will impact only steelhead from Sacramento Basin.

Certainty = 1 - Minimal: There is no direct research on the use of shallow estuarine habitat by steelhead in the Delta system. Any effect will be limited to the Sacramento population and to those times of year when temperatures are not too high in the target area.

Establishment of *Corbicula*, could limit, if not eliminate, the productivity benefits of the restoration to Chinook salmon. See Negative Outcome N1a, b, and c. Predation by invasive predators (especially if it is facilitated by colonization of SAV) may also eliminate any beneficial effect of this action.

P1d. Splittail

Magnitude = 3 - Medium: Additional tidal marsh acreage in the Cache Slough region would be expected to help rearing of juvenile splittail, particularly due to the restoration site's proximity to the Yolo Bypass, a major spawning location for Sacramento splittail. Post-spawners coming off the Yolo Bypass might benefit. The marsh may also provide dry period spawning habitat when the bypass is flooded less frequently (Kratville 2008). Splittail are benthic fish which forage during the day. Adult splittail typically consume detritus (60-79%), mysid shrimp (2-24%), Corbula (6%), salmon eggs, worms, and invertebrates. Larval and juvenile splittail are typically found on the floodplain and while there they consume small rotifers, cladocerans, chironomid larvae, zooplankton, and copepods (Kratville 2008). To the extent that tidal marsh supports the production of these types of food resources and to the extent that these food resources are available at a time and location that is accessible to splittail, the proposed restoration may offer some food benefits during the limited time window when the fish would be in Cache Slough and moving towards the more brackish areas of Suisun Marsh.

Certainty = 2 - low: The ultimate effect this action will have on splittail population abundance is uncertain because while this restoration will increase opportunities for rearing juveniles, rearing habitat does not appear to be a limiting factor in splittail abundance compared to floodplain inundation (Kratville 2008). The bulk of the adult splittail population resides in brackish areas of Suisun Marsh (Kratville 2008). The freshwater Cache Slough marsh will only provide habitat for juvenile fish migrating into

Suisun Marsh. It might not provide a new population center or increase the number of fish making it to Suisun Marsh.

Outcome P2: Increase food production for local consumption by green and white sturgeon

Magnitude = 2 -Low: Information on juvenile sturgeon diets and physical habitat needs in the Delta is limited. Juvenile sturgeons of other species located in other systems do feed on drifting insects. This area of the Delta will not provide extensive intertidal-mud bottoms as found in lower portions of the estuary. Since the former farm fields on this proposed shallow sub tidal restoration site will remain comparatively hard for many years (such as at Liberty Island and Little Holland Tract), it could take considerable time for conditions that support the growth of soft bottom benthos (organisms) to develop. These soft bottom benthos are a food resource for the sturgeon.   Most habitat limitations for sturgeon appear to occur outside of the restoration area (i.e. upstream and downstream), as described on pages 4, 8, 9 in Israel and Klimley, 2008 and pages 19-21 of Israel et. al., 2009.

Certainty = 1 - Minimal: Most of the available information on sturgeon diets and predator/prey relationships is based upon other species of sturgeon, located outside of this system. It is unknown to what extent adult sturgeon historically used fresh water tidal marsh for foraging. The impact to individual sturgeon may be low but the loss of fresh water tidal marsh in the Delta may have lowered the carrying capacity of the entire system for sturgeon. See pages 4, 8, 9 in Israel and Klimley, 2008 and pages 19-21 Israel et. al., 2009 for more detail.

Outcome P3: Food resources produced on the restored marsh will be exported and contribute to food availability downstream of Rio Vista.

General Observations: Outcome P1 above addresses the potential for restoration to produce increased food resources locally within the restoration area (both in the marsh and in adjacent open water). Outcome P3 described below deals explicitly with the potential for food resources (phytoplankton, zooplankton, insects, and small fish) to be exported out of the restoration area and become available to covered species downstream of Rio Vista.

The Tidal Marsh and Foodweb models [Kneib et. al., 2008, page 9 and Durand, 2008, section 2.16)] provide a general indication that there may be a linkage between tidal marsh habitat as a driver and increases in availability and production of food resources as an outcome, but that the mechanism for this linkage may be movement by fish. The tidal marsh conceptual model also states that freshwater tidal marshes are net exporters of high-quality organic production (page 2 in Kneib et. al., 2008).   See also Dame et al. 1986, Kimmerer and McKinnon 1989, Kneib 1997, Lucas et al. 2009.

There was disagreement within the evaluation team regarding the magnitude and certainty of expected benefits of tidal reintroductions with regard to the export of food (phytoplankton, zooplankton, insects, and small fish) to areas downstream of Rio Vista and the likely benefits to covered fish species. In the spirit of presenting the scientific discourse, both points of view are captured below.

Two key questions discussed were: (1) can we predict the sign of the flux of productivity (i.e. will the restoration area be a source or a sink for primary and secondary productivity); and (2) will there be adequate advection to move material out of the restoration area and downstream to Rio Vista (assuming the restoration area is a source of productivity, as opposed to a sink). Additional information and analyses is needed to better answer these key questions. To develop this additional information, the team recommends future development of a Tropho-dynamic model as described in the section on page 40 entitled "Research Needs".

Viewpoint #1

Estuaries are open systems that comprise interconnected yet spatially heterogeneous habitat. Connectivity of these functionally variable habitats is a key design consideration for sustaining biological diversity on degraded landscapes (Cloern, 2007, Friedrichs et al. 2001). Channel habitats downstream of Rio Vista are deeper, light limited, heterotrophic pelagic habitats. In contrast, the proposed Yolo/Cache Slough restoration is shallow intertidal/subtidal, and not nutrient limited. It is likely to comprise autotrophic habitat from which excess productivity could enhance regional pelagic carrying capacity if phytoplankton and a range of secondary production types is exported downstream (Lopez et al. 2006). The export, or water connectivity rate, is key. Regional ecosystem production efficiencies occur when the water connectivity rate between shallow and deep habitats is similar to autotrophic habitat phytoplankton growth rates (Cloern 2007).

Without flow augmentation, the Yolo/Cache area would exhibit variable seasonal water connectivity with channels downstream of Rio Vista. When the Bypass is strongly flowing, complete water exchanges occur on short timescales. In contrast, when the Bypass is dry, water connectivity depends on tidal dispersion that may be minimal due to distances (Cache Slough to Rio Vista) greater than tidal excursion length. On the tail end of hydrographs when the Bypass is draining (usually in Spring), hydraulic connectivity could be near optimal for extended periods. These periods overlap well with native fish usage of deep channels downstream of Rio Vista (see conceptual models for Delta smelt, longfin smelt, and salmonids).

With flow augmentation (e.g. a Fremont Weir notch), water connectivity between Yolo/Cache and Rio Vista could be tuned to provide near optimal connectivity for much longer periods and across a greater number of years (from roughly 1 in 4 years at present to 1 in 2 years as proposed). In this case, the rate of water connectivity would be exactly known since transport to Rio Vista would be advective. The magnitude of the productivity subsidy will keenly depend on how flow augmentation is routed through the restoration area. For maximum subsidy, Yolo/Cache water inputs would be routed in ways that tend to spatially equalize phytoplankton and zooplankton concentration gradients. Adaptive management experiments would elucidate transport strategies that maximize regional ecosystem efficiencies.

The single greatest impediment to realizing these exported productivity benefits would be the colonization by invasive clams that, if established in large numbers, could divert much of the phytoplankton and zooplankton productivity. Clams would exert a greater detrimental effect during tidal dispersion periods (no Yolo outflow and long local residence times) and a lesser detrimental effect during advective transport periods (with Yolo outflow and short local residence times).

Magnitude = 3-4 – Moderate to High: Without advective connection, restoration will still have significant productivity benefits to covered fish species and to many other species due to providing large areas of highly functional habitat in conjunction with restoration elsewhere that collectively provide fish species a range of options that spread risk through exploiting available resources when they are present. Refer to Ted Sommers, IEP Esutarine Ecology Team or CAERS poster. In addition, these areas would export that productivity through the "trophic relay" concept described in the tidal marsh conceptual model (fish export the productivity).

With advective connectivity driven by current and proposed Yolo Bypass flows, productivity will be exported strongly during periods of Yolo flow, generally in the February to May time period. These time periods are identified as very crucial to many covered species. Under current conditions, Yolo floods roughly 1 in 4 years. The Yolo Conservation Measure proposes to increase this frequency to 1 in 2 years. Under either condition, advective-driven transport of Cache Slough productivity will provide important and very substantial productivity contributions to larger geographic regions of the northwestern Delta.

Certainty = 3 – Moderate: Certainty is reduced by the potential for establishment of invasive clams that could consume substantial portions of phytoplankton and hinder zooplankton productivity. These effects would be greater during time periods without Yolo flows through the Cache Slough complex.

Viewpoint #2

Net primary production is highest in shallow water (given the excellent light resources and plentiful nutrients). However, the additional primary production that results from this restoration may be limited due to short residence time. The positive impact of food production also atenuates with distance. Export off the restored marsh will be non-existent when Yolo Bypass is not flowing. When Yolo Bypass is flowing, the additional small quantity of organic matter may (uncertain probability) be exported downstream. However, there is little quantitative information to support the idea that this phytoplankton will be exported downstream. The degree of phytoplankton export is critically dependent on whether clams become established in the shallow subtidal regions or marsh channels, climate change, and other factors (Callaway et al 2007). Dissolved organic carbon, by far the largest component of the organic pool, is very likely exported from marshes. However, for the most part, DOC supports bacterial production and relatively little of the bacteria supports the open-water foodweb of which pelagic fish participate. Established tidal marshes can both import and export organic carbon in dissolved or particulate (living and nonliving) form. The overall net flux of organic carbon must be out of the marsh to the extent that high plant productivity within the marsh exceeds local burial. The direction of the flux of a given constituent across the marsh-channel interface depends on the net flow (i.e., through freshwater runoff through the marsh), the concentration gradient, affected in turn by source and loss rates in and outside the marsh, and the swimming of organisms. For example, marshes produce organic detritus that is then available for export. However, marshes can also import detritus through particle trapping by marsh plants. Zooplankton may be zooplankton sinks because of consumption in the marsh by planktivorous fish (Dean et al. 2005). In some marshes, fish may be important carriers of organic carbon from the marsh to open waters.

Please note that potential modifications to weirs and other water management structures in Cache Slough could alter hydrologic patterns and thereby change residence time and other factors that affect food productivity (i.e. the scores presented below would need to be updated accordingly).

Magnitude = 1 to 2 – Minimal to Low: The implied relationship is that restoring 5,000 to 11,000 acres of tidal marsh will export nonliving and living organic matter including plankton and fish, thereby supporting foodwebs of the upper estuary. An implicit assumption is that any increase in the area of shallow habitat would result in enhanced plant productivity some of which would be exported.

When the Yolo Bypass is flowing, the Cache Slough area may export organic matter, but the additional productivity due to the marsh restoration will be limited because of the short residence time. At other times, relatively little of the production from within the Cache Slough area is likely to be exported.

Certainty = 1 -Minimal: The sign of the signal is difficult to determine, except for total organic carbon, most of which is dissolved. Although dissolved organic carbon (DOC) will likely flow out of the marsh, fluxes of other components may be in or out (Kneib et. al., 2008, page 9).

Outcome P4: Provide local cool water refugia for Delta smelt and rearing salmonids

Temperature in a water body is determined by the balance between gains and losses of heat. Heat is gained from solar radiation and from conduction and convection between water and air, and lost through conduction, convection, evaporation, and infrared radiation. Heat is also gained or lost during mixing of water bodies. All of these processes depend on physical drivers such as current and wind speeds and tidal fluctuations, and on the physical configuration of the water body and landforms.

The fundamental physics of heat transfer is well understood (Malamud-Roam 2000, Stacey and Monismith 2008, Enright 2008), and the large-scale temperature fluctuations in a water body can be predicted to some degree. However, small-scale fluctuations depend critically on local conditions and can be somewhat more difficult to predict.

The temperature of a shallow water body will roughly track air temperature. However, very shallow bodies of water are susceptible to rapid changes in temperature because of small thermal mass and relatively large radiative gains and losses of heat. Thus, the water on a marsh plain at midday will be much warmer than that in an adjacent channel, whereas water on the same plain at night will be cooler.

In Suisun Marsh, the higher-high tide occurs near midnight, resulting in substantial cooling by radiation, conduction, and evaporation (Enright 2008). The result was substantial spatial and temporal variation in water temperature in the marsh channels. It is reasonable to suppose that fish under thermal stress would seek out and remain in cooler water in an area of spatially heterogeneous temperature. This cooling may occur in any mature marsh exposed to a similar tidal regime. The extent to which it will occur, and the extent to which Delta smelt and salmon will actually take advantage of it, are unknown.

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P4a. Delta smelt

Magnitude = 2 - Low: Thermal stresses for Delta smelt in this location occur typically in May and June, so some potential for a benefit exists. Most Delta smelt are not in the Cache Slough area during summer.

Certainty = 1 - Minimal: The basis for our understanding is a single unpublished study in Suisun Marsh. The extent to which this effect may transfer to the restoration site, and to which Delta smelt and salmon will take advantage of it, cannot be predicted.

P4b. Chinook Salmon

The following describes expected benefits to Spring run, Fall run, and Steelheed. Winter run and late-fall run are discussed in Appendix B.

P4b1: Spring run salmon

Magnitude = 2- Low.
Beneficial effect occurs for only a portion of the salmonid population passing through this region during a particular and narrow window of time. This outcome modifies Outcome P1 (creation of habitat). In evaluating that outcome, benefits of this action were interpreted in the light of unfavorable temperature conditions that occur in the area during late-spring and summer. To the extent that the tidal flooding/cooling phenomenon occurs on this restoration site (a function of geography and restoration design and site elevations) during the period of potential thermal stress (May through end of summer), it may provide some relief from the effects of thermal stress *for those salmon runs that migrate through this region at this time (fall and spring run and steelhead).* That benefit impacts only the proportion of the population that migrates at this time and only the proportion of the population that migrates through this area (i.e. not all fall run or all steelhead). Although the team suggests a magnitude score of 2, for this outcome there is some debate within team as to whether this action's cool water refugia will offer any benefit at all. Chinook salmon using this area during late spring are probably on their way out of the estuary, and if it is too warm they will probably move on. The existence of thermal refugia (if it occurs in the area) may not make much difference to the salmon.

Certainty = 1-Minimal
As noted above, certainty is reduced due to a great dependence on highly variable ecosystem processes. While a reasonable understanding at the general level is prevalent, the range of data needed to evaluate at the action scale is lacking.

P4b2: Fall run salmon

Magnitude = 2- Low.
Beneficial effect occurs for only a portion of the salmonid population passing through this region during a particular and narrow window of time. This outcome modifies Outcome P1 (creation of habitat). In evaluating that outcome, benefits of this action were

interpreted in the light of unfavorable temperature conditions that occur in the area during late-spring and summer. To the extent that the tidal flooding/cooling phenomenon occurs on this restoration site (a function of geography and restoration design and site elevations) during the period of potential thermal stress (May through end of summer), it may provide some relief from the effects of thermal stress *for those salmon runs that migrate through this region at this time (fall and spring run and steelhead).* That benefit impacts only the proportion of the population that migrates at this time and only the proportion of the population that migrates through this area (i.e. not all fall run or all steelhead). Although the team suggests a magnitude score of 2, for this outcome there is some debate within team as to whether this action's cool water refugia will offer any benefit at all. Chinook salmon using this area during late spring are probably on their way out of the estuary, and if it is too warm they will probably move on. The existence of thermal refugia (if it occurs in the area) may not make much difference to salmon.

Certainty = 1-Minimal
As noted above, certainty is reduced due to a great dependence on highly variable ecosystem processes. While a reasonable understanding at the general level is prevalent, the range of data needed to evaluate at the action scale is lacking.

P4b3: Steelhead

Magnitude = 2- Low.
Beneficial effect occurs for only a portion of the salmonid population passing through this region during a particular and narrow window of time. This outcome modifies Outcome P1 (creation of habitat). In evaluating that outcome, benefits of this action were interpreted in the light of unfavorable temperature conditions that occur in the area during late-spring and summer. To the extent that the tidal flooding/cooling phenomenon occurs on this restoration site (a function of geography and restoration design and site elevations) during the period of potential thermal stress (May through end of summer), it may provide some relief from the effects of thermal stress *for those salmon runs that migrate through this region at this time (fall and spring run and steelhead).* That benefit impacts only the proportion of the population that migrates at this time and only the proportion of the population that migrates through this area (i.e. not all fall run or all steelhead).

Certainty = 1-Minimal
As noted above, certainty is reduced due to a great dependence on highly variable ecosystem processes. While a reasonable understanding at the general level is prevalent, the range of data needed to evaluate at the action scale is lacking.

Potential Negative Ecological Outcome(s)

Outcome N1: Establishment of harmful invasive species

Harmful invasive species have the potential to cause two types of adverse effects. First is to worsen conditions relative to the existing baseline; i.e., creating an attractive nuisance. Second is to detract from achieving the positive benefits the action could provide. The magnitude and certainty scores below are based upon an assessment relative to the potential for conditions to become worse than the existing baseline.

N1a. Submerged Aquatic Vegetation (SAV)

General Observation: As described in the conceptual model, the establishment of SAV is controlled by local flow conditions and substrates (Anderson, In Preparation). Many aspects of SAV physiology are influenced by local flow conditions including turbidity and to some extent flow velocity which if too high can scour suitable substrate precluding SAV establishment. In nearby Liberty Island where turbidities are generally higher due to wind wave action and the substrate is a compacted old farm field, SAV is restricted to shallow near shore areas and narrow shallow sloughs (Ustin et al. 2008). If turbidities are high in the restoration area then SAV establishment and growth may be reduced to levels similar to those at Liberty Island. If not, there is the potential for SAV amounts similar to those at overgrown regions of the central and southern Delta. The substrates in the Cache Slough area would be restored farm field hardpan bottoms, which may not be conducive to establishment of SAV. The initial establishment of SAV is an intermediate outcome and the development of a large sustainable SAV population is the final outcome.

Please note that establishment of SAV reduces the certainty that the positive outcome, P1 will occur. This has been noted in the scoring for P1.

Magnitude = 3 - Medium: For this outcome, the baseline condition is that much of the existing 21,600 acres of Delta tidal marsh is infested with submerged aquatic vegetation (Ustin, 2008). The risk of a restored a tidal marsh becoming infested with SAV is significant. Large, sustainable populations of SAV will produce significant changes in water quality (turbidity, pH, DO and temperature), or water flow characteristics (velocity and direction), which in turn can affect the quantity and quality of sediments (Anderson, In Preparation). Eventually, the clarity of water at the site will increase by lowering velocities and allowing particulates to settle out of the water column. This increased water clarity could increase predation of fish entering the site from outside areas (i.e. predators now have greater visual range). One type of predator, Centrarchid fish, is strongly associated with SAV and increased Centrachid populations may create a population sink for native fish at this location, as discussed in N1b, below. In summary, this action may worsen conditions beyond that of baseline conditions and small to moderate fractions of all the covered fish species may experience highly significant but localized effects due to SAV. Given the rarity of Delta smelt, the impact of SAV establishment could be particularly significant on this species if conditions similar to the South Delta are created here.

Certainty = 2 - Low: The initial colonization and ultimate patch distribution of SAV on the substrate is uncertain. As the substrate softens over time, it may be more conducive to SAV establishment and growth (i.e. bed characteristics are described as a driver in the conceptual model – see Anderson, In Preparation). It is well documented that the physical structure of SAV facilitates slower water velocities which allows sediment particles to settle, thereby reducing turbidity, locally and creating a positive feedback loop for more SAV establishment (Anderson, In Preparation). The effect of specific restoration site substrate, how those substrates may change over time after restoration, and the role of flow velocity at these locations is not well understood.

N1b. Centrarchids

General Observations: Centrarchid fish, as an assemblage, cover a range of ecological niches in the Delta. They are competitors for resources as well as predators on native fish. The magnitude of this effect is dependent on the assemblage of centrarchids that invade and the size of the populations. This is in turn partially dependent on the amount of SAV invasion into the restored system.

Please note that establishment of centrachids reduces the certainty that the positive outcome, P1 will occur. This has been noted in the scoring for P1.

Magnitude = 3 - Medium: For this outcome, the baseline condition is that much of the existing 21,600 acres of tidal marsh are excellent habitat for Centrarchid fish where they are associated with adjacent deeper water. This is illustrated by the large number of Bass Tournaments that occur in the Delta. The Delta is a stop on the national professional bass fishing circuit with $100,000 prizes. This action could worsen conditions beyond that of baseline. Centrachids are a concern because they prey upon and compete for food and other resources with native covered fish. Establishment of centrarchids in conjunction with SAV is well documented in the Delta (Brown and Michniuk 2007; Grimaldo et al. 2004; Nobriga and Feyrer 2007; Nobriga et al. 2005). Centrarchid fish would likely become established in this area as they have in other areas of the Delta where flows are more tidal than riverine (Brown and Michniuk 2007). The magnitude score reflects the possible impact that these fish could have given evidence from the southern Delta. Delta smelt are believed to spawn in the Cache Slough area and an increase in populations of Centrarchids could have impacts on nearly every life stage of Delta smelt and other native fishes. Given the rarity of Delta smelt, the impact of Centrachids could be particularly significant.

Certainty = 2 -Low: The spatial extent of a Centrarchid population(s) after initial colonization and the subsequent impacts to local native fish use once established are not well understood. Their abundance and presumed impact on native fish is greatest in areas of large, dense patches of SAV (Brown and Michniuk 2007).

N1c. *Corbicula*

Consequences of *Corbicula* establishment. If established, *Corbicula* would likely have a significant effect on food web dynamics because it consumes phytoplankton in shallow areas (Lopez et al. 2007). *Corbicula*'s consumption of primary productivity represents a significant limiting factor throughout the Delta that could greatly reduce productivity benefits of restoration efforts (Thompson et al., In revision, page 12). No local studies have been undertaken to indicate whether *Corbicula* feeding has reduced zooplankton populations either through competition or direct predation (Thompson et al., In revision, page 11).

Probability and extent of potential establishment. *Corbicula* are prolific reproducers and colonizers of newly available habitats in salinities below 2 ppt. Source populations can come from elsewhere within the Delta or from upstream tributary populations. *Corbicula* can establish on soft and hard substrates and on vegetation and they can colonize intertidal zones as well as deeper water. (*Corbicula* model). Based upon the biology of the species and the physical setting of the restoration site, the probability of *Corbicula* establishment in the Cache Slough restoration areas appears to be high, but ultimately cannot be predicted, partially due high variability in environmental conditions.

Recent very limited *Corbicula* monitoring data from Liberty Island shows that they are present at Liberty Island, with greater abundance in areas with coarser substrate (sand-cobble), small abundance in hard clay substrate, and minimal abundance in soft sediment substrates (Errin Kramer-Wilt, pers. comm. 2009). These data are preliminary and not yet peer reviewed and a part of an ongoing study so findings may change.

Potential Control Options. There are no stressors identified that can limit the success of *Corbicula*. However, salinity can limit the spatial distribution of this species and food limitation is a source of stress (Thompson et. al., In revision, pages 8 and 13). The *Corbicula* conceptual model indicates that the only meaningful method to control their presence or abundance is salinity. This control method would require salinity intrusions into the Cache Slough area of sufficient duration and at the appropriate times of year to have a meaningful effect. The conceptual model does not specify the duration and timing which might be most effective during recruitment. Water temperatures may influence the effectiveness of both recruitment and control measures.

Please note that establishment of *Corbicula* reduces the certainty that the positive outcome, P1 will occur. Establishment of *Corbicula* would consume much of the positive benefits that were previously discussed above under positive outcomes. This has been noted in the scoring for P1.

Magnitude = 1 – Minimal
For this outcome, the baseline condition is that much of the Delta is infested with *Corbicula*. The restoration of tidal marsh that eventually becomes infested with *Corbicula* would not represent a significant change above baseline conditions. This restoration will introduction of *Corbicula* (and its associated phytoplankton cababilities) to a geographic location where it is not currently located. This action may add 5,000 or 11,000 acres of potential *Corbicula* habitat. See also text above.

Certainty = 2 - Low. See text above.

N1d. Inland Silversides Effects on Delta and Longfin Smelt

General Observations: Inland silversides (*Menidia beryllina*) are highly tolerant of warm water and variable salinity and are trophic generalists compared to Delta smelt (Moyle 2002). Inland silversides are the most numerous fish in shallow Delta habitats (Nobriga et al. 2005, Brown and May 2006). Page 3 of Nobriga and Herbold 2008 includes intraguild competition with inland silversides as one of the top five in-Delta stressors to Delta smelt. Inland silversides are thought to be a major predator of Delta smelt eggs (Bennett and Moyle 1996 and Bennett 2005 in Nobriga and Herbold 2008 page 12). In the laboratory, inland silversides reduce Delta smelt size relative to controls when they are reared together (Bennett 2005).

Inland silversides are also treated in the longfin smelt model. Moyle (2002, in Rosenfield 2008) suggested that based on timing of arrival in the Estuary and subsequent longfin population response, inland silverside might have had a major impact on longfin population dynamics. However, the model states that inland silverside prefer shallow water habitats where juvenile and sub-adult longfin are rare, thus, their impact as predators of juvenile and sub-adult longfin is probably slight (Rosenfield 2008, pg. 17). Spawning locations for longfin are unknown, so it is not known whether competition from inland silverside for spawning territory is a factor in their decline.

However, Delta smelt evolved with other intraguild competitors, including longfin smelt, and have survived with striped bass (introduced in 1879). Interaction between silversides and Delta smelt in the wild may be limited because Delta smelt typically inhabit offshore environments, while inland silversides typically inhabit shoreline habitats. Increased shoreline habitat would presumably increase the carrying capacity for inland silversides. However, predator-prey interaction between Delta smelt and inland silversides in the wild is speculative. Silversides may eat Delta smelt eggs or larvae if the eggs and larvae occur on the shorelines. It has not been shown that inland silversides reduce calanoid copepods (Nobriga and Herbold 2008, page 32), so they may not effectively compete with Delta smelt for prey.

Magnitude = 2 - Low: Inland silversides are the most abundant fish in shallow-water habitats in many areas of the Delta and may currently contribute to local depletions of zooplankton otherwise available to native fishes within these areas. Additionally, they may prey on embryos of species who lay eggs in these shallow areas (Moyle 2002). The crash of Delta smelt populations coincided with invasions of inland silversides into the estuary (Bennett and Moyle 1996). This action may change conditions relative to baseline by attracting (via restored marsh) a nuisance (inland silversides). This conservation measure will increase the local inland silverside population by providing additional shoreline breeding habitat. Because of the high existing abundance of inland silversides, the incremental increase in breeding habitat and thus population size above current conditions is considered small and the magnitude of this effect is considered to be low relative to baseline. Further, differential habitat selection (offshore environments for inland silverside) is expected to reduce the interspecific competition effects.

Certainty = 2 - Low: Understanding of interaction between Inland silversides and Delta smelt in the wild is low, particularly in regards to egg predation by inland silversides. Spatial interactions with longfin smelt are also uncertain.

Outcome N2: Local contaminant effects

General Observations, methyl mercury: Although current methylmercury levels on Liberty Island (analogue for future state of areas to be restored) are relatively low (Slotton et al. 2002, Alpers et. al., 2008, figure 5), there is potential for enhanced production of methylmercury in areas of high marsh that will be inundated infrequently (only during highest tides). The process of drying out between wetting events tends to oxidize species of sulfur, iron, carbon, and mercury, leading to higher potential to form methylmercury upon rewetting. Once formed, methylmercury biomagnifies in the aquatic food web and ecological effects may occur in some sensitive species. Thus, the specific geomorphology of restoration sites and in particular the degree to which shallow depressions and poorly drained areas of high marsh are part of the restoration projects directly influences the degree of mercury methylization.

General Observations, other contaminants: Past land use determines risk of other contaminants: lead risk in areas with significant hunting, e.g., pheasant farms or duck clubs. Risk of residual pesticides (e.g., pyrethroids) in areas used for agriculture in past 2 years, which suggests that if these pesticides were used, allowing for a 2 year lag period between application and tidal restoration would be a prudent mitigation measure. Selenium contamination from the San Joaquin Valley isn't an issue in the Cache Slough area.

N2a1. Methyl mercury, covered fish species

General Observations: Alpers et. al., 2008 (Table 2 and associated text) describes the relevant issues.

Magnitude = 1 - Minimal: No toxicological studies have been conducted with any of the covered species regarding acute toxicity. Mercury concentrations in covered fish species are compared here against concentrations producing mortality in other fish species. Mercury concentrations in ppm-wet weight for white sturgeon, Chinook salmon and Steelhead collected during 2006 were 0.165-0.279, 0.094-0.396 and 0.06-0.13, respectively ((Melwani et al. 2007). No tissue data for either longfin or Delta smelt were found. Assume both species will have tissue concentrations similar to other fish taxa living one year and feeding primarily on zooplankton. Mercury concentrations in juvenile threadfin shad and juvenile largemouth bass in the Delta are 0.012-0.076 and 0.035-0.230, respectively (Slotton et al., 2006). In comparison death in rainbow trout (steelhead) in laboratory studies occurred at 4-ppm wet weight and the NOAEC for death in Brook trout at 2.7 ppm (in Wiener and Spry, 1996). Conclusion: about a 10X safety factor exists between fish tissue concentrations measured in the Delta and values reported to cause mortality in lab studies.

Regarding chronic toxicity, again no toxicological studies exist with any of the target species. Therefore, we have compared reported tissue concentration for individual species against known laboratory effects in other taxa. Decreased feeding efficiency and some hormones response changes have been observed at 0.25-0.27 ppm wet weight (page 30 of Alpers et. al., 2008). Decreases in growth have occurred in fathead minnows at 0.6-0.7 ppm (Hammerschmidt et al., 2002) and in juvenile walleye at 2.4 ppm (Friedmann et al., 1996). In conclusion, some up/down regulation of genes and alterations in feeding behavior are possible in the most contaminated individuals.

Certainty = 2 - Low: Limited tissue data available for most target species but large safety factor regarding acute toxicity. Limited toxicological data available for most of the important sub-lethal processes and none of this has been collected on species of interest.

N2a2. Methyl mercury, non-covered species

Magnitude = 2 - Low: Fifty-eight percent of Forster's terns in San Francisco Bay are at risk of reproductive impairment from consuming fish with elevated mercury levels (Ackerman et al, 2008). Although no Forster's Terns nest in Delta, mercury levels in small fish consumed by terns are higher in parts of the Delta such as the Yolo Bypass than in the San Francisco Bay. This suggests other bird species filling the Forster's tern niche in the Delta may be at risk.

In laboratory studies, mink have reproductive failure and die when fed fish diets of 0.5 and 1-ppm mercury, respectively (Dansereau et al. 1999). For comparison, mercury concentrations in 64% of largemouth bass, 23% of white catfish, and 35% of channel catfish caught in the Bay-Delta watershed have between 0.23 and 0.93 ppm mercury (Davis et al., 2008). Although the geometry of the high marsh area is poorly understood, evidence suggest a sustained minor population effect.

Most of the studies were conducted in the South San Francisco Bay and Petaluma River marshes with a focus on species native to that area, specifically Clapper and Black rail (endangered and threatened, respectively) (see also Grenier et al. 2002). These studies have shown that rails seem particularly susceptible to methyl mercury. Although neither of these species occurs in the Delta, the related Virginia rail (not a listed species) is present.

Biogeochemical processes create varying conditions and a subset of these conditions promotes mercury methylation and this is the key factor used in evaluating the magnitude of this actions effect. Mercury methylation in tidal wetlands is driven in large part by geomorphology and the resulting inundation regime. Methyl mercury production needs approximately one to four weeks of dryness to re-set the biogeochemical conditions necessary for mercury methylation (specific time frame not determined; table 2 in Alpers et. al., 2008). Available restoration lands in the Cache Slough complex all have a relatively uniform and very gradual slope from the uplands to the tidal

waterways, suggesting relatively little potential for providing the geomorphic setting needed for extensive high marsh plain that is most susceptible to methyl mercury production. However, available topographic data have not been analyzed to the level necessary to describe the setting more precisely.

Certainty = 2-3 Low - Medium: Scientific understanding of methylmercury effects on some bird and mammal species is high, based on peer-reviewed studies conducted in the San Francisco Bay and elsewhere. However, methylmercury effects on other bird, reptile, and mammal species are unknown. The nature of this outcome is also greatly dependent on highly variable ecosystem processes.

N2a3. Methyl mercury, human health

Magnitude = 2 - Low: Fish consumption advisories for the Delta recommend that children under the age of 17 and women of child bearing age consume no largemouth bass or smallmouth bass, spotted bass or Sacramento pikeminnow, and others should limit their consumption of these species to one meal a month (Gassel et al. 2007, 2008). Between 10,000 and 20,000 fishermen in the Delta are presently eating fish with more than 10X the recommended methylmercury (Klasing and Brodberg, 2008) and could experience some sub lethal mercury poisoning (personal communication, Dr Fraser Shilling). Action could increase mercury content of sport fish.

The probability of increased methyl mercury production and export into the food web is the same as that described above for target and non-target species.

Certainty = 3 - Medium: Uncertain magnitude and direction of change in mercury content of sport fish, although levels are more likely to increase than decrease. For a given increase in mercury content of sport fish, risk to human health is quantified based on peer-reviewed studies (Gassel et al. 2007, 2008). Unknown how many anglers would access the project area and what fish they would catch and consume.

The role of restoration projects under this Conservation Measure in contributing to mercury levels in fish species consumed by humans needs to be explored in relation to other mercury sources for those fish species.

N2b1. Residual pesticides and herbicides, covered fish species

General Observations: Pesticide use for calendar year 2007 (DPR, 2008) indicates that 104 pounds of total pyrethroids and pyrethrins were used during 2007 in the Cache Slough area. Possible presence of legacy pesticides from 1960s (e.g. DDT) is unknown. More recent (illicit) use of DDT is likely given the presence of non-degraded forms of DDT in sediment (http://www.bdat.gov, accessed 2008 by P. Green, UC Davis). Pyrethroids are 20x more toxic compared to some other pesticides (organochlorides). They persist in the sediment and degrade in one or two years. Pyrethoids represent several individual pesticides out of about 300 pesticides used during 2007 (DPR, 2008).

Magnitude = 1-2: Mminimal- Low: To the extent that pyrethroids or pyrethrins were used in the area to be flooded, significant toxicity could occur within 1-2 years of application. After ~2 years, near-total degradation should occur. DDT and metabolites could cause reduction of insect populations and bioaccumulation in target fish species (and some non-target bird species).

Certainty = 1 - Minimal: The toxicity of various pesticides is not completely understood. Although some peer-reviewed studies for selected life stages of certain fish exist, there is not much data for covered fish species. The nature of this outcome is highly dependent on highly variable ecosystem processes affecting the fate (degradation) and transport of pesticides.

N2b2. Residual pesticides and herbicides, non-covered wildlife species

General Observations: Pesticide use for calendar year 2007 (DPR, 2008) indicates that 104 pounds of total pyrethroids and pyrethrins were used during 2007 in the Cache Slough area. More recent (illicit) use of DDT is likely given the presence of non-degraded forms of DDT in sediment (http://www.bdat.gov, accessed 2008 by P. Green, UC Davis). Pyrethroids are 20x more toxic compared to some other pesticides (organochlorides). They persist in the sediment and degrade in one or two years. Pyrethoids represent several individual pesticides out of about 300 pesticides used during 2007 (DPR, 2008).

Magnitude = 1-2 Minimal to low: To the extent that pyrethroids or pyrethrins were used in the area to be flooded, significant toxicity could occur within 1-2 years of application. After approximately two years, near-total degradation should occur. DDT and metabolites could cause reduction of insect populations and bioaccumulation in covered fish species (and some non-covered bird species).

Certainty = 1 - Low: The toxicity of various pesticides is not well understood. A limited number of peer-reviewed studies for certain life stages of selected fish species exist. However, there is not much data for covered fish species available (Werner et. al., 2008). The effect that tidal marsh restoration will have on the availability of residual pesticides is greatly dependent on highly variable ecosystem processes affecting the fate (degradation) and transport of pesticides. Additionally, legacy pesticides from 1960s (e.g. DDT) may be present on the restoration site and more recent (illicit) use is unknown.

Outcome N3: Contaminant resuspension

Analysis of resuspension affects considers two separate physical settings: the restoration marsh sites and the adjacent tidal sloughs. The restored marsh sites are not likely to experience much scour, since the adjacent tidal channels would be excavated as part of construction and the hard farm fields are not expected to scour easily. Adjacent tidal sloughs, which are typically comprised of more erodible substrate, may experience more scour both the bed and banks.

N3a. Mercury, methyl mercury

General Observations: The relationship between tidal marsh restoration as a driver of potential contaminant resuspenion is supported by facts outlined in the DRERIP Mercury model (Figures 4, 7, and 8 and associated text in Alpers et. al., 2008).

Magnitude = 1 - Minima: The degree of scouring manifested on pre-project soils depends on hydrodynamics and this could be a short-term phenomenon as channels reach geomorphic equilibrium. Concentrations of total mercury and methylmercury in sediment is relatively low pre-project on the Cache / Prospect Slough areas, compared with other parts of Delta (Heim et al. 2007). Methylmercury concentrations have the potential to increase on high-elevation portions of the marsh (infrequently wetted zone) and this mercury has the potential for export to downstream environments.

Certainty = 2 - Low: The certainty of this outcome is low due to the dependence on highly variable ecosystem processes affecting the fate (e.g. photo degradation) and transport of methylmercury.

N3b. Residual pesticides and herbicides

General Observations: Werner and Oram, 2008, Figure 1, indicates that tidal marsh restoration is a driver for the resuspension of residual pesticides and herbicides.

Magnitude = 1 -Minimal: The degree of scouring occurring on pre-project soils depends on hydrodynamics and it could be a short-term phenomenon as channels reach geomorphic equilibrium. Acute and chronic toxicity effects of some recently used pesticides (e.g. pyrethroids) and legacy pesticides (e.g. DDT) have been documented for some covered fish species and some non-covered species (fish, invertebrates, mammals, humans) (Werner et. al., 2008, pages 16-25).

Certainty = 1 - Minimal: There is a minimal degree of certainty about this outcome because concentrations of recently used pesticides (e.g. pyrethroids) and legacy pesticides (e.g. DDT) are largely unknown on the soils of proposed project area.

Outcome N4: Scour of spawning habitat for Delta smelt and other covered species

General Observations: Breaching levees for tidal restoration affects the hydraulic geometry of adjacent channels, both landward and seaward of the site (Hood 2004). In particular, levee breaching for tidal restoration can be expected to increase the tidal prism through distributary channels downstream of restoration areas. Downstream distributary channels will therefore exhibit transient increases in tidal velocity that, in turn, increase bed shear stress and bed erosion. Preliminary modeling of Cache Slough restoration indicates that the cross-section average tidal velocity in downstream channels will increase to greater than ~3ft/s (Munevar 2009). Depending on the materials, sandy silt material would likely be eroded rather rapidly toward a new (deeper) dynamic equilibrium that balances the increased tidal prism. In-channel island marsh fragments and fringing marsh along the channel edge may also erode; though likely more slowly. Erosion will selectively remove finer sediment from the bed. In summary, the proposed levee breach(es) will change the geomorphic/hydrological configuration of the site. This change in configuration will alter tidal currents, increasing them in some places and decreasing them elsewhere. This could erode or redistribute sediments used during spawning of Delta and longfin smelt (Dinehart, 2002).   Since scientists do not actually know where native fish spawn or on what, it is very difficult to ascertain the importance of this effect.

N4a: Delta smelt

Magnitude = 4 - High: Tidal forcing energy is a zero sum game in the Delta. Tidal restorations will cause regional shifts of tidal range, prism, and velocity. Downstream distributary channels from new restoration areas may experience increased tidal prism with transient increase in tidal velocity and bed shear stress. In situ sediment will be eroded until the hydraulic geometry achieves dynamic equilibrium with the new tidal prism. The eroded sediment will be transported to lower energy channels that will become transient sediment sinks until their hydraulic geometry adjusts to the new lower tidal energy. The re-organization of sediment sources and sinks for Yolo-Cache Slough restorations may be confined to the northwest Delta.

During water year types with poor conditions for Delta smelt, Cache Slough appears to be a seriously important habitat area for this species. It is possible that Cache Slough currently represents one of the few areas where substrate availability, suitable hydrodynamics, and fish productivity overlap. Alteration of the hydrodynamics and substrate positioning in this region has the potential for catastrophic effects to Delta smelt (see Rosenfield, J.A. 2002).

Certainty = 1 - Minimal: Little is known about native delta resident fish spawning, especially with respect to the detail of egg placement and attachment to vegetation or sediment substrate. No one has even seen an emplaced Delta smelt egg. Some evidence suggests Delta smelt may use sandy sediment. Within an annual cycle, most of the sediment redistribution will have occurred and a new dynamic equilibrium reached. Progeny spawned in one reach of the lower Sacramento River may find that section deepened and the sediment characteristics changed with a year. It is not possible to predict whether sediment redistribution will occur at a location that is suitable as Delta smelt habitat (i.e. salinity or turbidity conditions etc).

Sediment transport processes are qualitatively understood but difficult to quantify. Erosion is more difficult to quantify than deposition.

N4b: Longfin Smelt

Magnitude = 2 – 3: Low to Medium: Rationale is similar to the information provided above in N4a Delta smelt.

Certainty = 1 - Minimal: Rationale is similar to the information provided above in N4a Delta smelt.

Important Gaps in Information and/or Understanding

Data needed to more fully evaluate tidal marsh restoration actions:

- A study of predator-prey-habitat interactions for Centrarchid fish.
- Striped bass model is needed to compile and synthesize life history information. This should also include a research study of predator-prey-habitat interactions.
- Expected retention time on restored tidal areas to understand likely productivity and food export potential to local sloughs.
- Predation rates in Cache slough vicinity to understand baseline predation pressure in this region.
- More spatially comprehensive hydrodynamics to understand whether changed flow patterns will reduce or simply redistribute predator pressure.
- Hydrologic and sediment information about turbidity levels, duration, and consequences on species as related to the following: Increased ability for Delta smelt to locate food due to increased turbidity from increased velocities in larger channels.
- *Corbicula* monitoring data from previous restoration sites in the Delta, such as Liberty Island or Little Holland Tract, would provide greater information about the probability of colonization on this Cache Slough site.
- Better data on where and when Delta smelt lay their eggs would better allow us to assess the potential impact of inland silverside predation.
- Analysis of factors contributing the success or failure of other past tidal marsh restoration actions in the Delta.
- Liberty Island is often referred to as a model of a successful restoration project. Monitoring data and new bathymetric data from Liberty Island should be fully analyzed to determine the features that makes it successful and to consider how to apply those features to other restoration projects in the Delta. Specifically, the bathymetric data could be turned into a Digital Elevation Model (DEM) and combined with the habitat type mapping (i.e. vegetation and open water) to illustrate how the restoration provides habitat for covered and other species. This would include documenting the quality of existing LiDAR data for the vegetation mapping.
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To fully evaluate Outcome P5, additional information listed below is needed:

- Data collection and analysis of the relative predation rate of salmon migrating through Cache slough compared with other areas of the Estuary (e.g. can it be estimated in even a qualitative sense?).
- Data collection and analysis of whether relevant predatory species would be displaced by the expected changes in hydrodynamics in these sloughs.
- Modeling of a situation in which predators are displaced from the sloughs, and analysis of whether this would result in a reduced predator population in this region, or whether predators would simply relocate to another part of the migration corridor where hydrodynamics are more suitable (i.e. what is the new distribution of low velocity/tidally influenced habitat that could be suitable to predators?).
- Data collection and analysis of whether other predatory species (i.e. pikeminnow and striped bass, which prefer riverine habitats) benefit from the altered hydrodynamics and occupy Sutter and Steamboat sloughs.

Research Needs

Run (and life-history) specific studies of Central Valley Chinook salmon and studies of steelhead use of tidal marsh habitats would be extremely valuable to defining magnitude of impacts to these populations and increasing certainty. Various tools (including genetic markers and otolith signatures of population origin) could be used to asses both growth and survival of salmonids in tidal marsh habitats as well as changes in life history characteristics (survival and fecundity) over the course of the life cycle that arise from residence in tidal marsh habitats. Currently, all of the evidence for benefits of tidal marsh on salmonids comes from steelhead and fall run populations located well to the north (where high temperatures and invasive predators are not as problematic). Translating these results to all Central Valley salmonid populations is unwarranted and could lead to disastrous "restoration" projects.

In addition, data on nutrient flow from the marsh plain to juvenile fish rearing in the adjacent channels is essential to determining the value of restored marshes as a food source for pelagic fish larvae (i.e. longfin and Delta smelt).

Greater understanding and more research is needed about the availability and production of food in tidal marshes. Export of organic material from the marsh plain and phytoplankton, zooplankton, and other organisms produced in intertidal channels into the Delta has not been studied.

Potential negative effects of methylmercury exposure on covered fish species remain largely unknown. Based on published studies involving other (non-targeted) fish species, there is reason for concern regarding possible chronic effects caused by methylmercury exposure, including: endocrine disruption, reduced reproductive success, reduced predator avoidance, and reduced feeding efficiency. (See Mercury Conceptual Model, Alpers et al. 2008, Table 4, page 30). Research is especially needed to determine possible effects caused by exposure during early life stages.

A better understanding is needed regarding the relationship of mercury methylation to the duration of wetting and drying events in areas that are intermittently inundated (i.e. tidal marsh and floodplain). Laboratory and field studies of mercury cycling involving sediments in tidal marsh and floodplain environments should quantify the duration of drying time and the extent of dryness necessary to change the oxidation-reduction character of iron, sulfur, carbon, and mercury in sediments such that microbial activity associated with mercury methylation is enhanced.

Tropho-dynamic model of ecological interactions linking primary production to the food web structure and production flows into, through, and out of the tidal marsh system.

Landscape-level models that address the effects of variation in structural features of the tidal marsh environment (e.g., tidal channel complexity, channel width, channel length, edge: area ratios, etc.) on the population or production dynamics of specific plants and animals.

Reversibility

No/Hard: The following on-the-ground actions would be needed to reverse this action:

1) levees would need to be reconstructed
2) newly created tidal sloughs would have to be regraded
3) sites would have to be dewatered
4) wetland vegetation would have to be removed
5) monitoring pre, during, and post construction

Although this reconstruction is technically possible, there would be significant financial and regulatory costs. Prior to action reversal, the following planning activities would be needed:

1) geotechnical evaluations for levee reconstruction
2) engineering design
3) evaluate land use options for areas subject to subsidence reversal actions
4) environmental permitting and associated agency ESA consultation,
5) mitigation planning

Levee repair costs are estimated to range between $1,000 and $9,000 per linear foot (Snow 2006).

Opportunity for Learning

High: Implementation of this project can be designed such that different engineering designs can be compared. Numerous physical and biological components can be monitored and ideally, the monitoring data would be used to assess and refine modeling simulations of the restoration. Monitoring questions/data collection could address: marsh function, use of marsh by plant and animal species, abundance/influence of non-native species in restored areas, evolution of marsh habitat including patterns of change, and affect on MeHg levels. It is assumed that monitoring and learning would be part of a comprehensive adaptive management program.

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Appendices:

Appendix A Summary Tables Organized by Outcome

Table A1. Positive Outcomes

Outcome	Magnitude	Certainty
P1. Increase rearing habitat and local food production		
a. Delta smelt	3	2
b. Longfin smelt	1	2
c1. Chinook, Sac, winter run	2	1
c2. Chinook, Sac, spring run	2	2
c3. Chinook, fall run		
1. Sacramento River	3	2
c4.Chinook, Sac, late fall run	1	1
c5.Steelhead	1	1
d.Splittail	3	2
P2. Increase food production for:		
a. Green sturgeon	2	1
b. White sturgeon	2	1
P3. Increase availability and production of food downstream of Rio Vista	Viewpoint 1: 3-4	Viewpoint 1: 3
	Viewpoint 2: 1	Viewpoint 2: 1
P4. Provide local cool water refugia.		
a: Delta smelt	2	1
b1: Spring-run,	2	1
b2. Fall-run Salmon	2	1
b3. Steelhead.	2	1

Table A2. Negative Outcomes

Outcome	Magnitude	Certainty
N1. Establishment of harmful invasive species		
a. SAV	3	2
b. Clams	2-3	2
c. Centrarchids	3	2
d. Inland silversides	2	2
N2. Local contaminant effects		
a. Methyl mercury		
1. Covered fish species	1	2
2. Non-covered species	2	2-3
3. Human health	2	3
b. Residual pesticides, herbicides		
1. Covered fish species	1-2	1
2. Non-covered species	1-2	1
N3. Contaminant resuspension and export		
a. Mercury, methyl mercury	1	2
b. Residual pesticides, herbicides	1	1
N4. Scour of spawning habitat for Delta smelt or other covered species.	4	1

Appendix B: Other Potential Positive Outcomes Identified, Not Evaluated

Outcome OP5: Reduce low velocity-associated salmonid predation pressure in Sutter and Steamboat sloughs

Preliminary hydrodynamic modeling indicates that tidal velocities will be damped in Sutter and Steamboat Sloughs with the restoration of tidal action to 5,000 -11,000 acres of habitat in the Cache Slough region (Munevar, pers. comm.). This change in hydrodynamics may make Sutter and Steamboat Sloughs less hospitable to certain predators of salmonids (i.e. those that prefer low velocity and/ or tidal environments). Also, the altered hydrodynamics may reduce the encounter rate with predators that remain, once riverine conditions become established. Predation of salmonid juveniles moving through these two sloughs may be high, however, the studies needed to reach a definitive conclusion have not been conducted. This hypothetical outcome cannot be vetted without additional information about relative predation rates, potential for predators to be displaced, and potential benefits predators may reap from the altered hydrodynamic conditions. These information needs are detailed in the "Important Gaps in Information and/or Understanding" section located in this worksheet.

Appendix C - Outcomes With Zero Magnitude

Outcome OP1a: Increase rearing habitat and local food production for Eastside and San Joaquin Chinook salmon, fall run.

Magnitude = 0 for East Side and San Joaquin River

Fall-run juveniles move through the northern Delta from winter through spring. Fall run rearing in this proposed restoration site during late spring will probably be impacted by high temperatures.

This outcome will benefit only the Sacramento portion of the fall-run population.

Certainty = 2 - Low: Fall run Chinook use of fresh water tidal and sub-tidal environments is documented in other systems but is not well studied in this system – possibly because this kind of habitat is limiting in this system.

The effect of global climate change on water temperatures in this area during Sacramento River fall run migration period also decrease the window of time during each year when restoration will produce benefits. The temperatures experienced in this area indicate that only a portion of the Sacramento River fall-run population will benefit from this action.

Other factors create uncertainty as to the benefits of this measure for this population. *Corbicula* establishment could limit if not eliminate the productivity benefits of the restoration to Chinook salmon. See Negative Outcome N1b. Similarly, establishment of predators or SAV that supports predation could eliminate most or all of the benefits created by this measure.

OP2a: Locally provide areas of cool water refugia for winter-run salmon.

Magnitude = 0- Zero.
There will be no benefits of this restoration to winter-run salmon because this run passes through the region during a window of time when temperatures are not believed to be highly stressful to salmonids.

Certainty = 1-Minimal
As noted above, certainty is reduced due to a great dependence on highly variable ecosystem processes. While a reasonable understanding at the general level is prevalent, the range of data needed to evaluate at the action scale is lacking.

OP2b: Locally provide areas of cool water refugia for late fall-run salmon.

Magnitude = 0- Zero.
There will be no benefits of this restoration to late fall-run salmon because this run passes through the region during a window of time when temperatures are not believed to be highly stressful to salmonids

Certainty = 1-Minimal
As noted above, certainty is reduced due to a great dependence on highly variable ecosystem processes. While a reasonable understanding at the general level is prevalent, the range of data needed to evaluate at the action scale is lacking.

Appendix D: Background information on Hydrologic Processes

About Hydrologic Connectivity: Exchange of materials (i.e. import-export balance) between the Cache Slough area and the western Delta is controlled by a number of factors including the following:

- Site hydrologic connection including size, location, and number of levee breaches; levee lowering; emergent vegetation; channel network geometry
- seasonal variation in tidal versus riverine characteristics at the lower end of the Yolo Bypass,
- enlargement of local sloughs through scour,
- other restoration projects locally and elsewhere in the Delta, and
- water exports.

Individual components of the organic matter flux may go into or out of the marsh and the region depending on the net flow, flow velocities, concentration gradients, trapping by vegetation, and the swimming of organisms relative to currents.

About Scour and its potential affect on Delta native fish: Estuary channel geometry reflects the dynamic interaction between channel morphology and physical forcings including wind, waves, tidal currents, and river discharge. The fundamental geomorphic function of estuaries is to attenuate the energy of physical forcings (Orr et al. 2003). One way this is accomplished is by transporting sediment from high to low energy areas in ways that tend to distribute and attenuate wave energy (Pethick 1996).

Sediment on the bed is characterized by particle size, density, and organic content (Schoellhamer et al. 2008). Higher energy channels like the lower Sacramento River where Delta smelt may spawn, tend to have sandy sediment and contain moving bed forms (Dinehart, 2002).

Given this understanding, a potential negative consequence of tidal restoration is loss or relocation of spawning habitat for Delta smelt or other covered species. Since there is a finite amount of tidal energy in the Delta, newly created restoration areas that increase downstream distributary channel energy will also cause reduction in tidal energy elsewhere. Near region reduction of tidal range and tidal velocity can be expected to vary as a function of distance from the site. Eroded sediments from the immediate downstream distributary channel may therefore be deposited relatively nearby, and perhaps even on the newly restored land.

Little is known about native delta resident fish spawning, especially with respect to the detail of egg placement and attachment to vegetation or sediment substrate. Some evidence suggests Delta smelt may use sandy sediment. Since the time from egg laying to spawn is about a fortnight, the transient erosion of bed sediment may not affect a particular spawn. However, within an annual cycle, most of the sediment redistribution will have occurred and a new dynamic equilibrium reached. Progeny spawned in one reach of the lower Sacramento River may find that section deepened, and the sediment characteristics changed with a year. However, it is not possible to predict whether the sediment will be redistributed to a location that is also suitable as Delta smelt habitat. If sandy substrates were to be moved to locations that do not have suitable Delta smelt habitat (i.e. salinity or turbidity is not quite right) then this could pose a serious obstacle to smelt reproduction and livelihood.

			Viewpoint 1		Viewpoint 2	
Outcome Code	**Covered Spp.**	**Description**	**Magnitude**	**Certainty**	**Magnitude**	**Certainty**
		Positive Outcomes				
P3	All	Food resources produced on the restored marsh will be exported and contribute to foood availability downstream of Rio Vista	1-2	1		
P4b	chinook salmon	Provide local cool water refugia for delta smelt and rearing salmonids	2	1		
P4a	delta smelt	Provide local cool water refugia for delta smelt and rearing salmonids	2	1		
P1a	delta smelt	Increase rearing habitat and local food production	3	2		
P1c3	Fall-run Chinook salmon, Sac.	Increase rearing habitat and local food production	3-4	3	1-2	1
P2	Green & White Sturgeon	Increase food production for local consumption by green and white sturgeon (added by evaluation team).	2	1		
P1c4	Late Fall-run Chinook Salmon, Sac.	Increase rearing habitat and local food production	1	1		
P1b	Longfin smelt	Increase rearing habitat and local food production	1	2		
P1d	splittail	Increase rearing habitat and local food production	3	2		
P1c2	Spring-run Chinook Salmon	Increase rearing habitat and local food production	2	2		
P1c5	steelhead	Increase rearing habitat and local food production	1	1		
P1c1	Winter-run Chinook Salmon	Increase rearing habitat and local food production	2	1		

Outcome Code	Covered Spp.	Description	Magnitude	Certainty	Magnitude	Certainty
Negative Outcomes						
N3a	All	Contaminate Resuspension Hg	1	2		
N2b1	All	Local toxicity from residual pesticides and herbicides: e.g. pyrethroids:	1-2	1		
N2a1	All	Potential for mercury methylation and local bioaccumulation	1	2		
N1d	All	Establishment of Inland silversides that will prey or compete or alter habitat conditions for covered fish.	2	2		
N1c	All	Establishment of centrarchids that will prey or compete or alter habitat conditions for covered fish.	3	2		
N1b	All	Establishment of undesirable clams species that will compete with or alter habitat conditions for covered fish.	1	2		
N1a	All	Establishment of undesirable SAV will alter habitat conditions for covered fish.	3	2		
N4a	delta smelt	Increased velocities in larger channels could scour spawning habitat for Delta smelt and/or habitat for other covered species.	4	1		
N2a3	Human health	Potential for mercury methylation and local bioaccumulation	2	3		
N4b	Longfin smelt	Increased velocities in larger channels could scour spawning habitat for Delta smelt and/or habitat for other covered species.	2-3	1		
N2b2	Wildlife	Local toxicity from residual pesticides and herbicides: e.g. pyrethroids:	1-2	1		
N2a2	Wildlife	Potential for mercury methylation and local bioaccumulation	2	2-3		

Viewpoint 1 Advective-driven transport of Cache Slough productivity will provide important and very substantial productivity contributions to larger regions of the northwestern Delta.

Viewpoint 2 Export from the restored marsh will be non-existent when Yolo Bypass is not flowing therby limiting productivity contributions beyond the restoration area.

Outcome Code	Covered Spp.	Description	Viewpoint 1 Magnitude	Viewpoint 1 Certainty	Viewpoint 2 Magnitude	Viewpoint 2 Certainty
Positive Outcomes						
P2a	All	INCREASE 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.	3-4	3	1-2	1
P3b	Chinook Salmon	LOCALLY PROVIDE AREAS OF COOL WATER REFUGIA (FEB-JUN) FOR DELTA SMELT AND SALMON.	2	1		
P3a	Delta smelt	LOCALLY PROVIDE AREAS OF COOL WATER REFUGIA (FEB-JUN) FOR DELTA SMELT AND SALMON.	2	1		
P1a	Delta smelt	Increase rearing habitat area (including physical and biotic attributes) for covered fish species	1	1		
P1c	Fall-run Chinook salmon	Increase rearing habitat area (including physical and biotic attributes) for covered fish species	1	2		
P1d	Splittail	Increase rearing habitat area (including physical and biotic attributes) for covered fish species	3	3		
P1b	steelhead	Increase rearing habitat area (including physical and biotic attributes) for covered fish species	1	2		

Outcome Code	Covered Spp.	Description	Magnitude	Certainty	Magnitude	Certainty
Negative Outcomes						
N4a	All	Resuspension and export of mercury and methylmercury to downstream areas	1	2		
N3b	All	Local effects of contaminants including toxicity from residual pesticides and herbicides: e.g. pyrethroids	1-2	1		
N3b	All	Contaminate Resuspension - Residual pesticides and herbicides	1	1		
N3a	All	Local effects of contaminants including toxicity from residual pesticides and herbicides: e.g. pyrethroids	1-2	1		
N2a	All	POTENTIAL FOR MERCURY METHYLATION AND LOCAL BIOACCUMULATION TO AFFECT WILDLIFE: N2-A - TARGET SPECIES, N2-B, NON-TARGET WILDLIFE SPECIES, N2-C, HUMAN HEALTH.	1	2		
N1b	All	Establishment of undesirable species (such as Centrachids) that will prey or compete or alter habitat conditions for covered fish.	4	2		
N1a	All	Establishment of undesirable species (such as egeria,) that will prey or compete or alter habitat conditions for covered fish.	3	2		
N1c	All	Establishment of undesirable species (such as Corbicula) that will prey or compete or alter habitat conditions for covered fish.	1	2		
N1d	Delta smelt	Establishment of undesirable species (such as Inland Silversides) that will prey or compete or alter habitat conditions for covered fish.	2	2		
N2c	Human health	POTENTIAL FOR MERCURY METHYLATION AND LOCAL BIOACCUMULATION TO AFFECT WILDLIFE: N2-A - TARGET SPECIES, N2-B, NON-TARGET WILDLIFE SPECIES, N2-C, HUMAN HEALTH.	2	3		
N2b	Wildlife	Potential for mercury methylation and local bioaccumulation to affect wildlife: N2-A - Target species, N2-B, Non-target wildlife species, N2-C, Human health.	3	2-3		

Viewpoint 1 Advective-driven transport of Cache Slough productivity will provide important and very substantial productivity contributions to larger regions of the northwestern Delta.

Viewpoint 2 Export from the restored marsh will be non-existent when Yolo Bypass is not flowing therby limiting productivity contributions beyond the restoration area.