March 17, 2017

Submitted via email: commentletters@waterboards.ca.gov

Ms. Jeanine Townsend
Clerk to the Board
State Water Resources Control Board
P.O. Box 100
Sacramento, CA 95812-2000

Subject: Comment Letter – 2016 Bay Delta Plan Amendment and SED

The State Water Contractors ("SWC") appreciate this opportunity to provide comments regarding the State Water Resources Control Board's ("Water Board") September 2016 Recirculated Draft Substitute Environmental Document in Support of Potential Changes to the WQCP for the San Francisco Bay-Sacramento San Joaquin Delta Estuary, San Joaquin River Flows and Southern Delta Water Quality ("Draft SED"), and proposed amendments to the 2006 Water Quality Control Plan ("WQCP"). The SWC submit these comments on behalf of itself and its 27 member agencies.

The Draft SED is technically and legally flawed. The SWC provided a detailed explanation of our concerns with the Draft SED in a comment letter that the SWC filed jointly with SLDMWA in 2013. Those comments were not addressed in the 2016 Draft SED. As a result, we are resubmitting the SWC's March 2013 joint comment letter on the draft SED as Attachment A because the comments and issues raised in 2013 remain applicable. The SWC are also providing specific comments on 2016 Draft SED groundwater analysis. (See Attachment B.)

For emphasis, the SWC are reiterating and expanding our prior comments related to two specific issues: (1) use of unimpaired flow as a compliance metric, and, (2) imposition of permit conditions on the State Water Project (SWP) and Central Valley Project (CVP) to install temporary barriers in the south Delta.

I. Unimpaired Flow is an Inappropriate Metric.

The Water Board continues to propose flow actions based on the unimpaired flow concept. The SWC believe that unimpaired flow is an inappropriate metric for setting water quality objectives. Detailed support for our position was provided in response to the initial draft SED in 2013. (See Attachment A). Recent advances in science further support our position on unimpaired flow; these advances are summarized in our December 15, 2016, comment letter to the Water Board regarding its working draft Phase II WQCP Technical Basis Report (provided as Attachment C) and incorporated by reference. The currently proposed WQCP amendments and use of unimpaired flow as a compliance metric is incongruent as described below.

A. Unimpaired flow is not a proxy for pre-development or "natural" flow.

Best available science shows that unimpaired flow from the upstream San Joaquin River tributaries is not an appropriate measure for natural flow on the valley floor or in the Delta. For example, see recent supporting scientific work by Howes et al. (2015)[1] on the evapotranspiration from natural vegetation that was present in the Delta and Central Valley, work by Fox et al. (2015)[2] that quantifies the expected mix of vegetation in the Delta and Central Valley under natural or pre-development conditions, and work by Huang (2016)[3] that utilized the above-cited work to compare annual and seasonal unimpaired and natural Delta outflow estimates. Huang found, similar to Fox et al. (2015), that unimpaired outflow estimates are a very inaccurate proxy for natural outflow estimates, significantly overestimating natural flows, because natural flows were not subject to the confines of levees, dams, and other anthropogenic development and as such, spread over greater areas of the basin. Given that the best available science shows unimpaired flow to be an inappropriate indicator of natural flow on the valley floor or in the Delta, proposed flow standards should be justified based on flow function and not on purported benefits of unimpaired flows, which do not emulate natural conditions, nor provide the same functions. Thus, using unimpaired flow criteria as an accounting tool cannot be:

- Justified as a means to improve habitat conditions through restoration of natural flow conditions, functions, etc.

- Used as a justification for the need to increase required flows on the valley floor and/or in the Delta.

- Used as a baseline from which to measure annual or seasonal trends in flows on the valley floor or in the Delta.

B. The Water Board's proposal to "sculpt flows" is analytically disconnected from concept of mimicking the hydrograph.

The unimpaired flow compliance metric is based on DWR's calculation as a means to define a pool of water for adaptive management for the intended purpose of "sculpting" flows. The recirculated Draft SED does not identify the types of actions needed to "sculpt" flows, and therefore it is unclear how the Water Board intends to implement the flow actions. The SWC recommend that the Draft SED be revised to provide examples of flow types being proposed, as well as the conceptual model that the Water Board would be evaluating in its adaptive management plan. The Draft SED cites literature supporting the idea that a percent of the natural hydrograph

[1] Howes, D.J., Fox, P., and Hutton, P.H. (2015). Evapotranspiration from Natural Vegetation in the Central Valley of California: Grass Reference-Based Vegetation Coefficients and the Dual Crop Coefficient Approach, Journal of Hydrologic Engineering, DOI: 10.1061 / (ASCE) HE.1943-5584.0001162.

[2] Fox, P., Hutton, P.H., Howes, D.J., Draper, A.J., and Sears, L. (2015). Reconstructing the Natural Hydrology of the San Francisco Bay-Delta Watershed, Hydrology and Earth System Sciences, 19, 4257-4274.

[3] Huang, G. (2016). Estimates of Natural and Unimpaired Flows for the Central Valley of California: Water Years 1922-2014, California Department of Water Resources, Bay-Delta Office, March, Draft.

be preserved as a method for restoring the Delta ecosystem. However, the Water Board is really proposing a plan where it would "sculpt" flows, not necessarily in proportion to unimpaired flows. Therefore, the cited literature does not support the intended action. It should be further noted, as the water contractors and others explained during the 2012 Water Board workshops, the literature relevant to using unimpaired flows as a restoration tool cautions that the outcome, particularly in highly altered systems, is highly uncertain. For example, see Poff et al. (1997)[4], Poff and Zimmerman (2010)[5], Pierson et al (2002)[6], and Bunn and Arthington (2002)[7].

C. The Water Board's proposal is not a "functional flow."

During a recent Water Board workshop, there was a definitional discussion about what is a "functional flow." The SWC have been discussing the need for functional flows for many years, so knowing that there is a misunderstanding regarding the use of this term is informative. Based on the literature, the SWC define a functional flow as supporting a specific ecological function that is relevant to one or more native fish species. It requires investigating conditions under which native fish evolved, how those conditions have changed, and what can be done to restore those conditions within the context of today's highly altered system. Historically, the water and landscape were much more interconnected with high flows spilling out onto the landscape creating spawning and rearing habitat, and feeding the rivers as flows slowly drained back into the main channels carrying nutrients, detritus, and lower trophic organisms produced in these nutrient rich, often shallow and slow moving waters, among other important functions. Merely putting more water down rip-rap lined levees does not re-create these historical conditions. The best opportunities for restoring functional flows may be in areas where some remnant of the pre-development environment still exists, like floodplains, or in the restoration of these land-water connections elsewhere (see SFEI 2014[8]). In the highly altered Central Valley and Delta, the unimpaired flow concept is not the same as functional flow or natural flow, as it would merely provide for transport functions (i.e., increasing the depth and velocity of water in leveed and rip rapped channels) without providing for other important functions such as turbidity, nutrients, detritus and appropriate temperatures.

The Water Board should reconsider the information provided in these attachments and revise the proposed amendments to the 2006 WQCP and Draft SED accordingly.

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[4] Poff, N.L., Allen, D., Bain, M.B., Karr, J.R., Prestegaard, K.L., Richter, B.D., Spaerks, R.E., Stromberg, J.C. (1997) The Natural Flow Regime: A Paradigm for River Conservation and Restoration. *BioScience*, 47:11.

[5] Poff, N.L., and J.K.H. Zimmerman. 2010. Ecological Responses to Altered Flow regimes: A Literature Review to Inform the Science and Management of Environmental Flows. *Freshwater Biology* 55: 194: 205.

[6] Pierson, H.A., and M. Vayssieres. (2010) Benthic assemblage variability in the Upper San Francisco Estuary: 1 27-year retrospective. San Francisco Estuary and Watershed Science, 8(1).

[7] Bunn, SS., and A.H. Arthington. (2002) Basic Principles and Ecological Consequences of Altered Flow Regimes and Aquatic Biodiversity. *Environmental Management* 30: 492-507.

[8] San Francisco Estuary Institute (2014) A Delta Transformed, ecological functions, spatial metrics, and landscape change in the Sacramento-San Joaquin Delta, prepared for the California Department of Fish and Wildlife and Ecosystem Restoration Program.

II. The implementation of temporary agricultural barriers to address water levels should be reconsidered.

The Water Board's proposal includes continued installation of the temporary agricultural barriers, and even provides some analysis of permanent agricultural barriers. The Water Board should reconsider the continuation of the agricultural barrier program to address water level issues.

The Draft SED reports that the maximum potential effect of combined SWP-CVP pumping is 1.5 ft. on the high tide and .75 ft. on the low tide. (Draft SED at p. 5-37.) The Draft SED further reports that the barriers increase water levels by 1 ft. to 2 ft. (*Ibid.*) This shows the relatively minor effect of maximum combined SWP-CVP pumping on south Delta water levels. It further illustrates the over mitigation of water level effects provided by the barriers.

The Draft SED does not consider the current environmental effect of the barriers on the environment, including the fishery, as it is an existing condition. However, the Water Board should consider whether the barriers have unintended biological effects, and whether those effects are justified in light of the negligible effect that SWP-CVP exports have on water levels. The Water Board should also consider if there are other feasible alternatives to barriers.

The Water Board should reconsider the continuation of the temporary agricultural barrier program, adopting alternative implementation measures such as irrigation management (scheduling), consolidating diversions and extending agricultural pumps.

III. The implementation of temporary agricultural barriers to address interior south Delta salinity should be reconsidered.

The Water Board continues to propose permit conditions on the SWP-CVP to install temporary barriers to provide salinity control in the south Delta. This proposal is based on the flawed conclusion that, "EC values in the southern Delta are affected primarily by…the combined CVP and SWP pumping influencing salinity in the southern Delta…." (Draft SED at p. 5-44.) As the SWC explained in its comments on the prior SED (Attachment A), and as DWR and Reclamation have demonstrated on numerous occasions over the last three decades, the SWP-CVP are unable to control salinity at all locations in the south Delta. In our 2013 comment letter, the SWC provided a CD containing DWR's extensive DSM2 modeling that specifically analyzed the effects of the SWP-CVP on water quality, water levels, and circulation with and without the temporary barriers. The SWC believe that its prior letter, with attachments, sufficiently demonstrate that SWP-CVP operations cannot control water quality in the area east of the SWP-CVP pumping facilities, in the vicinity of Old River at Tracy River Bridge. In other areas of the south Delta, particularly near the SWP-CVP pumping facilities, the operation of the SWP-CVP maintains conditions significantly fresher than would exist without the projects.

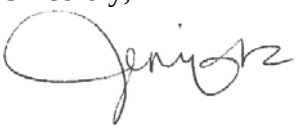
The Water Board's implementation plan for south Delta salinity standards should not allocate responsibility to the SWP-CVP, and should not require the installation of agricultural barriers. The Draft SED identifies other sources of water quality degradation and those sources should be the Water Board's focus during the implementation phase.

IV. The SWC support voluntary agreements.

The SWC support the Water Board's consideration of voluntary agreements as an implementation mechanism in the amended WQCP to help achieve the water quality objectives to benefit various beneficial uses. To the extent that the Water Board would like to discuss alternative actions that are achievable and likely to provide targeted benefits, the SWC would be pleased to participate in such discussions. The SWC and its members are involved in many collaborative scientific efforts, scientific studies (including field work), and habitat restoration projects. The SWC have been, and will continue to take proactive steps to improve Delta water quality and the Delta ecosystem, and would be willing to partner with the Water Board to find achievable and resilient solutions.

We look forward to continuing the dialog with the Water Board with the shared goal of developing an effective, viable and integrative proposal for the San Francisco Bay-Sacramento San Joaquin Delta Estuary.

Sincerely,



Jennifer Pierre
General Manager

Attachments

Public Hearing (3/20/13)
Bay-Delta Plan SED
Deadline: 3/29/13 by 12 noon

San Luis & Delta-Mendota Water Authority

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3-29-13
SWRCB Clerk

March 29, 2013

Via Email: *commentletters@waterboards.ca.gov*
Via Hand-Delivery

Members of the State Water Resources Control Board
Attn: Ms. Jeanine Townsend, Clerk to the Board
1001 "I" Street, 24th Floor
P.O. Box 100
Sacramento, CA 95814

Re: Comment Letter – Bay-Delta Plan SED

Dear Board Members:

The San Luis & Delta-Mendota Water Authority and State Water Contractors, Inc., on behalf of and in conjunction with each of their member agencies (herein "Public Water Agencies"),[1] appreciate this opportunity to provide comments on: (1) the draft Substitute Environmental Document in Support of Potential Changes to the Water Quality Control Plan for the San Francisco Bay-Sacramento/San Joaquin Delta Estuary: San Joaquin River Flows and Southern Delta Water Quality ("SED" or "draft SED"), and (2) the draft Southern Delta Agricultural Water Quality Objectives and draft Lower San Joaquin River Fish and Wildlife Flow Objectives and the draft Program of Implementation for those objectives,[2] (together "draft amendments").

The draft amendments to the Water Quality Control Plan for the San Francisco Bay-Sacramento/San Joaquin Delta Estuary ("Bay-Delta Plan"), as identified in the SED, substantially improve upon the draft objectives and programs of implementation presented in the April 1, 2011, revised notice of preparation. The draft amendments also reflect important changes to the Bay-Delta Plan. Noteworthy improvements and changes are:

1. Updated analyses of the southern Delta salinity levels that will provide for the "reasonable" protection of agricultural beneficial uses;

2. Elimination from the program of implementation the intent to condition the water rights of the U.S. Bureau of Reclamation ("Reclamation") and the Department of

[1] See Attachment 1 for a description of the Public Water Agencies.
[2] This comment letter provides comments on the draft objectives and draft programs of implementation, as identified in Appendix K of the draft SED.

Water Resources ("DWR") on compliance with interior southern Delta salinity objectives, measured in the San Joaquin River at Brandt Bridge, Old River near Middle River, and Old River at Tracy Road Bridge; and

3. Elimination of water level and circulation narrative objectives.

Those three changes are required to ensure the objectives and programs of implementation are consistent with the best available science and the law, and the Public Water Agencies support them.

The process to develop potential changes to the Bay-Delta Plan and analyze potential changes in a draft SED presents an important opportunity for the State Water Resources Control Board ("State Water Board") to improve its understanding (and the collective understanding of interested parties) of the water quality impairments impacting beneficial uses of the waters of the Bay-Delta estuary. It also presents an opportunity to explicitly assess "all demands being made and to be made on those waters and the total values involved, beneficial and detrimental, economic and social, tangible and intangible." (Water Code, § 13000.) Unfortunately, the draft amendments and the draft SED do not take full advantage of this opportunity and there are several legal, evidentiary and analytical defects with the draft amendments and draft SED. Attached hereto are detailed comments, which are incorporated herein by this reference. In this cover letter, the Public Water Agencies highlight a few critical defects with the draft amendments and draft SED.

1. The Draft Lower San Joaquin River Flow Objectives And Program Of Implementation Are Based On Two Underlying Premises Which Lack Evidentiary And Analytical Support

- *Unsupported Premise # 1*: Flows Can Be Managed To "Mimic the Natural Hydrographic Conditions" In A Highly Altered Ecosystem

- *Unsupported Premise # 2*: An "Unimpaired Flow" Regime Will Support And Maintain Viable Native Fish Populations

The staff has recommended that the State Water Board establish a narrative flow objective for the February-June period. The draft program of implementation contends that the beneficial uses will be better protected by establishing flows that "more closely mimic the natural hydrographic conditions." (Draft SED, App. K, at p. 3.) However, the scientific literature does not support the conclusion that more flow will necessarily provide environmental benefits and increase salmon viability. The results of the studies are mixed, particularly in highly altered systems. (Poff *et al.* 1997; Hart and Finelli 1999; Bunn and Arthington 2002; Poff and Zimmerman 2010.) As Poff, *et al.* 1997 explains:

> Most rivers are highly modified, of course, and so the greatest challenges lie in managing and restoring rivers that are also used to satisfy human needs. Can reestablishing the natural flow regime serve as a useful management and restoration goal? We believe that it can, although to varying degrees, depending on

> the present extent of human intervention and flow alteration affecting a particular river.

Accordingly, when Poff, *et al.* discusses restoration projects, it is in the context of providing targeted flows for the purpose of attaining specific ecological benefits. The general restoration literature review in Appendix C of the SED does not address the extent to which the flows being proposed here (as opposed to flows as a general concept) may provide fishery benefits through restored flow functions. Conversely, the analysis in Chapter 7 of the SED (which focuses on potentially significant negative effects) indicates that many of the benefits that sometimes occur in other systems are not expected to materialize here under any of the alternative implementation measures (e.g., no floodplain inundation, no increased turbidity, no sediment (gravel) transport, etc.). Without any analysis showing expected improvements in specific ecological functions, the draft amendments and SED lack the information to support a conclusion that the preferred Lower San Joaquin River flow alternative is necessary to obtain the narrative water quality objective.

2. The Draft Substitute Environmental Document Does Not Fully Or Sufficiently Analyze All Aspects Of The Southern Delta Salinity Objectives

The best available science supports a finding that some level of an increase in the southern Delta agricultural salinity objectives would reasonably protect agricultural beneficial uses. However, the Public Water Agencies are not expressing a position on what specific level of salinity concentration is reasonable because the draft SED is missing important information, information that is needed to allow the State Water Board to determine the amount of increase that is reasonably protective given "all demands being made and to be made on those waters and the total values involved, beneficial and detrimental, economic and social, tangible and intangible." (Water Code, § 13000.)

For Southern Delta Agriculture, The Certainty Of Impacts Is Not Adequately Characterized: Chapter 11 of the draft SED show crops grown in the southern Delta will be fully protected with salinity objectives of 1.0 EC, during all months of the year. The draft SED projects that, even if the southern Delta salinity objectives were increased to 1.4 EC, farmers within the southern Delta would realize only a 5 percent reduction in dry bean yields (assuming 20 percent leaching fraction, and minimum precipitation) and a 3 percent reduction in almonds (assuming 15 percent leaching fraction, and minimum precipitation). (Draft SED, at p. 11-30.) Those impacts are based on analysis with highly conservative assumptions – for example, the analysis: (1) does not meaningfully account for the availability of low salinity water in the winter and spring; and (2) the analysis does not meaningfully account for changes in salt tolerance that occurs as plants mature. As a result, the impacts identified in the draft SED likely overstate the impacts that farmers in the southern Delta would realize if the southern Delta salinity objectives were increased to 1.4 EC.

No Monetization Of Potential Impacts To Southern Delta Agriculture: Crops grown in the southern Delta will be fully protected with an increase in the salinity objectives of to 1.0 EC, and therefore there is no need to monetize impacts under that alternative. However, as noted above, the draft SED identifies a 5 percent reduction in dry bean yields and 3 percent reduction in almond yields. Those impacts, assuming they would occur, are not monetized. The Public Water Agencies attempt to do that, based on information available to them.

In 2007, south Delta farmers cultivated 2,998 acres of dry-beans and 2,860 acres of almonds. (Draft SED, App. E, at p. 12 [citing San Joaquin County Ag Commissioner].) The per-acre value for dry-beans was approximately $1,140 and for almonds was $3,690. (San Joaquin County Ag Commissioner 2007 Report.) As a worst case scenario and based on information from the San Joaquin County Ag Commissions, the economic impact of a 5 percent reduction in dry beans and 3 percent reduction in almonds would be approximately $171,000 and $317,000, respectively (or collectively $488,000 annually). That calculation has not been performed by staff or presented for consideration by the State Water Board.

No Consideration Of The Comparative Costs Of Implementing The Southern Delta Salinity Objective: The draft SED does not compare the estimated $488,000 in costs to southern Delta agriculture associated with the proposed salinity objective of 1.4 EC to the burden placed on those under the draft program of implementation. If it did, the draft SED would demonstrate, for example, that the annual costs to Reclamation and DWR associated with installation of the temporary barrier program alone are more than an order of magnitude greater than the costs associated with reduced agricultural production. The annual cost of the temporary barrier program approximates $6,000,000. Additional costs are associated with other actions that would be required under the program of implementation, including monitoring and special studies. Again, those costs have not been previously presented. This point is made notwithstanding the information discussed below which demonstrates that the responsibility proposed for assignment to Reclamation and DWR is unreasonable and unlawful.

No Consideration Of Impacts Of The Southern Delta Salinity Objective On Water Service Providers: The draft SED does not analyze what, if any, water quality impacts would occur to water exported by the CVP and the SWP. Salinity in source water supplies can cause corrosion, unpleasant taste and odor, economic impacts to utilities and their customers, and constraints on water recycling and groundwater management programs. Bromide, one component of salinity, can produce harmful disinfection byproducts in drinking water such as bromate and trihalomethanes (THMs), which are known human carcinogens. Water service providers may experience increased costs to minimize or avoid those impacts by blending lower quality water or incorporating additional treatment facilities or processes. However, these options may not be available or technical or economically feasible for all water service providers. As the quality of a water source changes, the ability to blend and treat water changes. The draft amendments and draft SED fail to analyze whether such impacts will occur, or the associated costs to water suppliers to mitigate such impacts if they do occur.

3. The Draft Program Of Implementation For The Southern Delta Salinity Objectives Addresses Matters Outside Of The State Water Board's Water Quality Planning Authority That Will Impair Fundamental Rights Without Affording Due Process

The draft program of implementation for the southern Delta salinity objectives pre-determines water rights conditions and assigns to specific water right holders responsibility for implementation of the salinity objectives. However, what water right conditions, if any, are necessary to implement the salinity objectives must be considered and determined in an adjudicative water right proceeding, which affords water right holders due process. The draft program of implementation unlawfully conflates the State Water Board's quasi-legislative water

quality planning authority with its quasi-adjudicatory water rights authority. It would condition fundamental water rights without providing the procedural protections mandated by law. [3]

4. In Addition To Exceeding The State Water Board's Water Planning Authority, The Assignment Of Responsibility In The Draft Program Of Implementation For The Southern Delta Salinity Objectives Is Inequitable And Does Not Reflect Adequate Consideration Of The Factors Contributing To Southern Delta Salinity Concentrations

In several places, the draft SED acknowledges that multiple factors influence salinity concentrations in the southern Delta, including: San Joaquin River inflow; tidal action; diversions of water by the SWP, CVP, and local water users; municipal and agricultural return flows; and channel capacity. The draft SED correctly notes that operations of the CVP and SWP either have no impact or improve salinity concentrations in the southern Delta. Overall, however, the draft SED contains an incomplete and unbalanced analysis of the salinity issue, and the draft program of implementation unlawfully and inequitably assigns responsibility for addressing salinity in the southern Delta almost entirely to the CVP and SWP.

The SED Analyses Do Not Reflect Significant Reductions in Selenium And Salt Loads: The draft SED lacks any meaningful discussion of the substantial reductions in selenium and salt loads resulting from drainage management actions on the westside of the San Joaquin Valley. From Water Year 1995 to Water Year 2012, those actions reduced selenium loads by 94 percent (11,875 lbs to 750 lbs) and salt loads by 84 percent (237,530 tons to 38,400 tons). The draft SED should recognize that effort and progress and should look to others to address salt concentrations, before any new burdens are placed on the agricultural interests on the westside of the San Joaquin Valley, whether directly or through conditions on CVP water rights.

The Draft Program Of Implementation Assigns Responsibility To Reclamation And DWR When Neither Operations Of The CVP Nor SWP Facilities Contribute To Salinity Impairment In The Southern Delta: The assignment of responsibility in the draft program of implementation is not commensurate with the factors contributing to salinity concentrations in the southern Delta. The draft program of implementation assigns significant responsibility to Reclamation and DWR to install barriers, to conduct monitoring, and to prepare, fund, and conduct special studies, in spite of modeling results showing that pumping of water from the Delta by the CVP and SWP have a neutral or sometimes beneficial effect on salinity in the southern Delta, have uncertain but likely no more than limited impacts on water levels,[4] and have no adverse impact on circulation.

5. Conclusions

The Public Water Agencies welcome an opportunity to work with the State Water Board to address the comments raised in this letter and the attached detailed comment letter. The revisions needed to address the comments will result in an improved Bay-Delta Plan, a plan which is consistent with the best available science, addresses the multiple sources of impacts to water

[3] The same comment applies to the draft Lower San Joaquin River flow objectives and related draft program of implementation as well.

[4] Modeling suggests that in-Delta pumping operations of CVP and SWP has very limited impacts on water levels in the southern Delta. However, that modeling does not consider the impact of other factor, such as reductions in Delta inflow, local water users, or in-Delta land reclamation.

quality in the Lower San Joaquin River and southern Delta, and ultimately strikes a balance between competing demands for the water involved.

Sincerely Yours,

Daniel G. Nelson
Executive Director
San Luis & Delta-Mendota Water Authority

Terry L. Erlewine
General Manager
State Water Contractors

cc: Members of the State Water Resources Control Board

Attachment 1 - Description of the Public Water Agencies
Attachment 2 – Detailed Comments on Draft Amendments to the Bay-Delta Plan and Draft SED
Attachment 3 – List of References
Attachment 4 - Relevant Legal Standards and Rules
Attachment 5 – Discharges By Grasslands Bypass Project

Attachment 1
(Description of the Public Water Agencies)

The State Water Contractors, Inc. ('SWC") organization is a nonprofit mutual benefit corporation that represents and protects the common interests of its 27 member public agencies in the vital water supplies provided by California's State Water Project ("SWP"). Each of the member agencies of the State Water Contractors holds a contract with the California Department of Water Resources to receive water supplies from the SWP. Collectively, the SWC members deliver water to more than 25 million residents throughout the state and more than 750,000 acres of agricultural lands. SWP water is served from the San Francisco Bay Area, to the San Joaquin Valley and the Central Coast, to Southern California. The SWC's members are: Alameda County Flood Control and Water Conservation District Zone 7; Alameda County Water District; Antelope Valley-East Kern Water Agency; Casitas Municipal Water District; Castaic Lake Water Agency; Central Coastal Water Authority; City of Yuba City; Coachella Valley Water District; County of Kings; Crestline-Lake Arrowhead Water Agency; Desert Water Agency; Dudley Ridge Water District; Empire-West Side Irrigation District; Kern County Water Agency; Littlerock Creek Irrigation District; Metropolitan Water District of Southern California; Mojave Water Agency; Napa County Flood Control and Water Conservation District; Oak Flat Water District; Palmdale Water District; San Bernardino Valley Municipal Water District; San Gabriel Valley Municipal Water District; San Gorgonio Pass Water Agency; San Luis Obispo County Flood Control & Water Conservation District; Santa Clara Valley Water District; Solano County Water Agency; and Tulare Lake Basin Water Storage District.

The San Luis & Delta-Mendota Water Authority ("Authority") is a joint powers authority, established under California's Joint Exercise of Powers Act. (Gov. Code, § 6500 *et seq*.) The Authority is comprised of 29 member agencies, 27 of which hold contractual rights to water from the federal Central Valley Project ("CVP"). The Authority member agencies have historically received up to 3,100,000 acre-feet annually of CVP water for the irrigation of highly productive farm land primarily along the San Joaquin Valley's Westside, for municipal and industrial uses, including within California's Silicon Valley, and for publicly and privately managed wetlands situated in the Pacific Flyway. The areas served by the Authority's member agencies span portions of seven counties encompassing about 3,300 square miles, an area roughly the size of Rhode Island and Delaware combined. The Authority's members are: Banta-Carbona Irrigation District; Broadview Water District; Byron Bethany Irrigation District (CVPSA); Central California Irrigation District; City of Tracy; Columbia Canal Company (a Friend); Del Puerto Water District; Eagle Field Water District; Firebaugh Canal Water District; Fresno Slough Water District; Grassland Water District; Henry Miller Reclamation District #2131; James Irrigation District; Laguna Water District; Mercy Springs Water District; Oro Loma Water District; Pacheco Water District; Pajaro Valley Water Management Agency; Panoche Water District; Patterson Irrigation District; Pleasant Valley Water District; Reclamation District 1606; San Benito County Water District; San Luis Water District; Santa Clara Valley Water District; Tranquillity Irrigation District; Turner Island Water District; West Side Irrigation District; West Stanislaus Irrigation District; and Westlands Water District.

Attachment 2

(Detailed Comments on Draft Amendments to the Bay-Delta Plan and Draft SED)

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Attachment 2

(Detailed Comments on Draft Amendments to the Bay-Delta Plan and Draft SED)

I. SPECIFIC COMMENTS ON THE DRAFT SOUTHERN DELTA SALINITY OBJECTIVES, THE DRAFT LOWER SAN JOAQUIN RIVER FLOW OBJECTIVES AND THE RELATED PROGRAMS OF IMPLEMENTATION

The Public Water Agencies provide specific comments regarding: (1) the draft Southern Delta Agricultural Water Quality Objectives ("draft SDWQ objectives" or "draft salinity objectives") and related draft Program of Implementation ("draft salinity POI" or "draft POI"); and (2) the draft Lower San Joaquin River Fish and Wildlife Flow Objectives ("draft LSJR flow objective" or "draft flow objective") and related draft Program of Implementation ("draft flow POI" or "draft POI"), as identified in Appendix K of the Draft Substitute Environmental Document in Support of Potential Changes to the Water Quality Control Plan for the San Francisco Bay-Sacramento/San Joaquin Delta Estuary: San Joaquin River Flows and Southern Delta Water Quality ("SED" or "draft SED").

A. Legal And Evidentiary Defects Of The Draft Southern Delta Agricultural Salinity Objectives And Related Program Of Implementation

1. The Draft Salinity Objectives Fail To Adequately Consider The Section 13241 Factors

In establishing water quality objectives that provide "reasonable protection" of beneficial uses, Water Code section 13241 requires the State Water Resources Control Board ("State Water Board") consider the following factors, among others: (1) "[p]ast, present, and probable future beneficial uses of water;" (2) "[w]ater quality conditions that could reasonably be achieved through the coordinated control of all factors which affect water quality in the area;" and (3) "[e]conomic considerations." (Water Code, § 13241, subd. (a), (c), (d).) The draft SDWQ salinity objectives fail to reflect adequate consideration of these factors.

a. The Draft Salinity Objectives Do Not Consider The Extent Of Past, Present, And Probable Future Beneficial Uses Of Water

When considering what water quality objectives will provide a reasonable level of protection for agricultural uses in the southern Delta, the starting point must be defining the beneficial use. (Water Code, § 13241 subd. (a).) To do that, the State Water Board must consider the water rights asserted by southern Delta agricultural interests. That consideration is critical, as many assert riparian water rights, and, with regard to those asserted water rights, in Decision 1641, the State Water Board found:

1. On average, insufficient water is available to supply the southern Delta in Below Normal, Dry and Critical Dry years in August, September and October.

2. On average, sufficient water is available in September only in Wet Years.

3. Insufficient water is available in July during 16 percent of years, in August during 56 percent of years, in September during 78 percent of years, and in October during 70 percent of years.

> To the extent that other instream water users are making riparian use of water, and to the extent that all southern Delta lands are not riparian, water is available to southern Delta water users less often than assumed herein.
>
> Based on this analysis, riparian rights to the waters of the San Joaquin River are inadequate to meet the agricultural demands in the southern Delta in some months of many years. Because a riparian right holder's water right cannot exceed the natural flow, it follows that whenever there is inadequate natural flow to meet their demands, southern Delta riparian right holders cannot be injured if they are deprived of water that exceeds the natural flow.

(D-1641, at p. 33). Conversely, when there is inadequate natural flow to support riparian diversions, there is no riparian beneficial use of that water that requires protection. The draft amendments to the Water Quality Control Plan for the San Francisco Bay-Sacramento/San Joaquin Delta Estuary ("Bay-Delta Plan") do not reflect that circumstance, nor do the draft amendments consider the availability of water for southern Delta agricultural water users asserting other water rights.

b. <u>The Draft Salinity Objectives Do Not Consider The Water Quality Conditions That Could Reasonably Be Achieved Through The Coordinated Control Of All Factors Affecting Water Quality</u>

The draft salinity POI reveals that the draft salinity objectives were developed without adequate consideration of the water quality conditions that could reasonably be achieved through the coordinated control of *all factors* affecting water quality. (*See* Draft SED, App. K.) The draft SED states that "[s]alinity levels in the southern Delta are affected primarily by the salinity of water flowing into the southern Delta from the SJR near Vernalis and evapo-concentration of salt in water that is diverted from and discharged back into southern Delta channels for agricultural purposes [within the southern Delta]." (Draft SED, App. C, at p. 4-7; *see Id*. at pp. 13-7 – 13-10.) This statement acknowledges that multiple factors affect salinity concentrations in the southern Delta. Yet, the draft salinity POI reveals that the 1.0 EC objectives were developed with the assumption that the salinity objectives would be achieved by imposing significant responsibility on the U.S. Bureau of Reclamation ("Reclamation"). As proposed, Reclamation would be obligated to meet a salinity level of 0.7 EC at Vernalis, to provide "assimilative capacity" for downstream diversions and discharges. (*See* Draft SED, App. K.) Similarly, the draft POI states that "DWR and USBR's water rights will be conditioned to require the development and implementation of a Comprehensive Operations Plan to fully address the impacts of SWP and CVP export operations on water levels and flow conditions that *might affect* assimilative capacity for local sources and evapo-concentration of salinity in the southern Delta." (*Ibid*.)

The Department of Water Resources ("DWR") submitted the results of DSM2 modeling that specifically analyzes the effect of pumping by the CVP and SWP on water quality, water levels, and circulation with and without the temporary barriers.[5] The modeling results demonstrate that CVP and SWP operations usually have no effect on salinity in the southern Delta,

[5] The referenced DWR modeling results are contained on the "References" CD, which the Public Water Agencies provided by hand-delivery to the State Water Board.

and, at times, have a positive effect by lowering salinity concentrations. The models also demonstrate that null zones, which are commonly used as an indicator of poor circulation, occur with the same general frequency and duration with or without CVP and SWP pumping. In addition, spikes in salinity in the southern Delta may not be attributable to poor circulation because salinity sometimes spikes during high flow periods in the absence of null zones. The modeling also demonstrates that CVP and SWP pumping has a small and ephemeral impact on water levels in the southern Delta of approximately 6-8 inches for just a few hours per day. In contrast, the temporary barriers raise water levels well above levels that would occur without CVP and SWP pumping.[6]

Indeed, the draft SED acknowledges this effect of operations of the CVP and SWP. For instance, the SED states that "[h]igher CVP and SWP pumping . . . have a large effect on southern Delta salinity as higher pumping brings more Sacramento River water across the Delta to the export pumps and results in lower salinity." (Draft SED, at p. 2-37.) In addition, the draft SED itself clearly demonstrates that the salt loadings in the Lower San Joaquin River ("LSJR") and southern Delta are not attributable to the CVP or SWP pumping, but rather result from a host of other factors, including agricultural return flows in the southern Delta. (E.g., Draft SED, at 13-7 – 13-10.) Yet, by assuming assignment of responsibility to Reclamation and DWR, the draft amendments ignore the actions that could be taken by other entities that actually contribute to salt concentrations in the southern Delta. The State Water Board should not make the same mistakes it has made in the past, by taking too narrowly focusing and failing to consider all of the factors that affect water quality in developing water quality objectives.[7]

c. The Draft Salinity Objectives Do Not Adequately Consider The Economic Costs Associated With The Draft Objectives

(i) Economic Costs Associated With Agricultural Yield Reductions

The draft SED explains that the "State Water Board based the southern Delta EC objectives on the calculated maximum salinity of applied water which sustains 100% yields of two important salt sensitive crops grown in the southern Delta (beans and alfalfa) in conditions typical of the southern Delta." (Draft SED, App. C, at p. 4-2.) However, this approach to establishing the salinity objectives fails to consider and compare the economic costs and benefits of implementing specific salinity objectives. In other words, this approach fails to provide the State Water Board with the information necessary to consider whether it is "reasonable" to establish salinity

[6] Indeed, if the State Water Board is concerned about the impact of water levels on irrigation in the southern Delta, it would be far more cost effective and appropriate to study alternatives such as altering the timing of irrigation pumping in the southern Delta, or changing the location of pumps or siphons that experience issues with fluctuating water levels.

[7] *See U.S. v. SWRCB* (1986) ["Racanelli "] 182 Cal.App.3d 82. In *Racanelli*, the court concluded that "the Board made no effort to protect against water quality degradation by [] users [other than Reclamation and DWR] namely, upstream diverters or polluters. As a consequence, the Board erroneously based its water quality objectives upon the unjustified premise that upstream users retained unlimited access to upstream waters, while the projects and Delta parties were entitled only to share the remaining water flows." (*Id.* at p. 118.) The court stated that "the Board cannot ignore other actions which could be taken to achieve Delta water quality, such as remedial actions to curtail excess diversions and pollution by other water users." (*Id.* at p. 120.) The draft salinity objective and draft POI reflect the same mistakes found in *Racanelli*—the faulty and narrow presumption that the CVP and SWP will be held responsible for supporting the diversions and discharges of other entities.

objectives that provides 100% protection for agricultural beneficial uses of water in light of the economic costs associated with the responsibilities assigned in the draft POI. For example, the draft SED acknowledges that revising the salinity objectives could involve costs to dischargers complying with a NPDES discharge permit, waste discharge requirements, or complying with a TMDL that is established for protecting agricultural beneficial uses. (Draft SED, at p. 18-3.) Those are important considerations. However, the draft SED fails to account for other costs, such as the costs associated with mandating the installation and operation of the temporary barriers and conducting the studies and monitoring identified in the draft POI. These costs are necessary considerations.

In light of economic considerations, higher salinity objectives would provide "reasonable" levels of water quality protection for agricultural beneficial uses in the southern Delta. In fact, the evidence in the administrative record shows that even with the conservative assumptions that likely result in an overstatement of impacts, salinity objectives of 1.4 EC would result in only minor yield reductions in the most sensitive crops and would have a relatively minor economic impact on agriculture. The draft SED states:

> [T]here is a 5 percent yield reduction for Dry Bean irrigated with 1.4 dS/m water, with *minimum* amount of precipitation and a leaching fraction of 20 percent. When the median level of precipitation is used, the yield decline is less than 1 percent. For Almonds, the yield decline is 3 percent with a leaching fraction of 15 percent and *minimal precipitation*; with the median level of precipitation the yield decline is less than 1 percent. For Alfalfa there was no yield decline under the 15 percent leaching fraction with minimal precipitation.

(Draft SED, at p. 11-30, italics added.) Those conclusions alone could support changes in the salinity objectives. However, such a decision should be informed by the additional information discussed immediately below.

The 2007 Annual Crop Report ("2007 Crop Report"), prepared by the San Joaquin County Agricultural Commissioner's Office and cited in the draft SED (App. E) indicates that, as of 2007, there were 2,860 acres of almonds within the South Delta Water Agency's service area and 2,998 acres of dry beans. (Draft SED, App. E, at p. 12, Table 2.2.) The average value per acre of dry beans was approximately $1,141/acre. Assuming that the yield for dry bean would be reduced by 5 percent when irrigated with 1.4 EC water, (Draft SED, at p. 11-30), such a reduction would correspond to an approximate $57.00 reduction in the value of an acre of dry bean. Assuming the 5% yield reduction occurs on all of the 2,998 acres of dry bean, the yield reduction would correspond to a regional loss in value of approximately $171,000 annually. Similarly, the 2007 Crop Report indicates that the average value per acre of almonds was $3,690. Assuming that the yield for almonds would be reduced by 3 percent when irrigated with 1.4 EC water, (Draft SED, at p. 11-30), such a reduction would correspond to a $110.00 reduction in the value of an acre of almonds. Assuming the 3% yield reduction occurs on all of the 2,860 acres of almonds, the yield reduction would correspond to a regional loss in value of approximately $317,000 annually. Therefore, the combined estimated regional loss in value for yield reductions in almonds and dry beans from irrigating with 1.4 EC water would be approximately $488,000.00 annually.

While salinity objectives of 1.4 EC are estimated to result in less than a half a million dollars annually in economic impacts to southern Delta agricultural revenues, changes in the salinity

objectives could significantly affect the economic costs associated with actions contemplated in the draft program of implementation. For example, the estimated annual cost of operating the temporary barrier program, which is currently a condition of DWR and Reclamation's water rights to implement the existing salinity objectives and which is identified as a condition that will continue to be imposed to implement the draft 1.0 EC objective, is approximately *$6 million/year*. Yet, as demonstrated, it would be unlawful to require installation of the temporary barriers, to conduct additional studies, or to undertake other measures since those mandates cannot be imposed through water quality planning and neither CVP nor SWP pumping causes any introduction of salts into the waters of the southern Delta. But even if such mandates were lawful, the cost to implement the barriers (and conduct additional monitoring and studies) far outweighs any incremental benefit to agricultural crop yields resulting from lower salinity. The relative economic costs and benefits of implementing specific salinity objectives are precisely the type of "economic considerations" that the State Water Board must evaluate when considering the draft amendments.

(ii) Economic Costs Associated With Impacts To Municipal Water Service Providers

The SED fails to analyze all direct and indirect impacts to municipal water service providers that would result from implementing the southern Delta agricultural salinity objectives. Salinity in source water supplies can cause corrosion, unpleasant taste and odor, economic impacts to utilities and their customers, and constraints on water recycling and groundwater management programs. Bromide, one component of salinity, can produce harmful disinfection byproducts in drinking water such as bromate, which is a known human carcinogen. Water service providers may experience increased costs to minimize or avoid those impacts by blending lower quality water or incorporating additional treatment facilities or processes. However, these options may not be available or technical or economically feasible for all municipal service providers. As the quality of a water source changes, the ability to blend and treat that water changes. The draft amendments and draft SED fail to analyze these reasonably foreseeable impacts and associated costs to water suppliers to mitigate them.

2. The Draft Program Of Implementation Illegally Conflates The State Water Board's Legislative Water Planning Function And Its Adjudicative Water Right Function

The State Water Board performs dual functions—its legislative function of developing and amending water quality control plans and its adjudicatory function of allocating water rights. Consideration and determination of what, if any, water right conditions are necessary to implement *new* water quality objectives must be performed in an adjudicative proceeding. (*See Racanelli*, *supra*, 182 Cal.App.3d at p.113 ["in undertaking to allocate water rights, the Board performs an adjudicatory function."].) The draft SED acknowledge this rule and repeatedly asserts that the State Water Board will consider any necessary changes to water rights to implement the amendments to the water quality control plan in a later water right proceeding.[8] Unfortunately,

[8] See e.g. Draft SED at p. 1-1 ["Subsequent Phase III proceedings will consider and assign responsibility for implementing measures to achieve the water quality objectives established in Phase I and Phase II, including changes to water rights or other implementation actions."]; *Id.* at p. 1-2 ["This update of the 2006 Bay-Delta Plan, which describes the actions needed to protect the Bay-Delta ecosystem, does not affect the water rights of anyone either within or outside the Delta. Any changes to water rights that may be needed to implement the plan will be considered in future proceedings."]; *Id.* at p. 1-7 [the "State Water Board's Phase III would specifically identify the water rights that could be modified as a result of

the draft amendments pre-determine many water right conditions. For example, the draft POI pre-determines that DWR and Reclamation's water rights *will be* conditioned to: 1) develop and implement a Comprehensive Operations Plan to address how SWP and CVP operations "might affect the assimilative capacity for local sources of salinity in the southern Delta;" 2) develop and implement a special monitoring study to characterize water level, flow and salinity conditions in the southern Delta; 3) to require continued operations of the agricultural barriers program; and 4) develop a monitoring and reporting protocol to provide the data necessary to assess attainment of the salinity objectives. (Draft SED, App. K.) Such an approach illegally conflates the State Water Board's legislative water quality planning function with its adjudicative water rights function and fails to provide the targeted water right holders with the procedural protections and due process provided by an *adjudicative* water right proceeding.

a. <u>The State Water Board Cannot Decide To "Continue" To Condition The Water Rights Of Reclamation And DWR To Implement Water Quality Objectives During This Quasi-Legislative Water Quality Planning Process</u>

The "guiding principle" in any water right proceeding commenced to implement a water quality control plan is that the State Water Board's power to act in such a water rights proceeding "is constrained by the terms of the plan it is implementing." (*State Water Resources Control Bd. Cases* (2006) 136 Cal.App.4th 674, 729 at p. 729.) The draft SDWQ salinity objectives would amend the existing southern Delta salinity objectives in the Bay-Delta Plan (0.7 EC April-August and 1.0 September-March) to require 1.0 EC year-round. (Draft SED, App. K, at p. 1 of 5; Bay-Delta Plan at p. 13.) Therefore, the inquiry in any water right proceeding commenced to implement a new salinity objectives would be: "what water right conditions, if any, are necessary to implement the 1.0 dS/m salinity objective." Thus, because the State Water Board would be seeking to implement a new salinity objective, it must perform a new evaluation and determination of the water right conditions, if any, necessary to implement those salinity objectives, in a water right proceeding.

Although the draft salinity objectives would effectively eliminate the 0.7 EC salinity objectives that currently exist in the Bay-Delta Plan, the draft POI assumes that some of the existing water right conditions imposed to implement the 0.7 EC salinity objectives will continue. The draft POI states:

> In order to maintain current protective salinity levels in the southern Delta, *USBR's water rights will continue to be conditioned to require* compliance with a salinity level of 0.7 deciSiemens per meter (dS/m) from April through August and 1.0 dS/m from September through March in the San Joaquin River at the Airport Way Bridge near Vernalis.

(Draft SED, App. K, at p. 2 of 5, italics added.)[9] Also, the draft POI states:

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adopting and applying the program of implementation for the LSJR flow objectives analyzed in this SED as part of Phase 1."]; App. C at p. 1-1 ["Any changes to water rights consistent with the revised program of implementation will be considered in a subsequent adjudicative proceeding."].

[9] See e.g. Draft SED at p. 11-2, Table 11-1 [water quality within the southern Delta under SDWQ Alternatives 2 and 3 "is expected to remain unchanged as USBR would be responsible for complying with the same salinity requirements that currently exist at Vernalis."]; at p. 11-18 [the "program of implementation for the numeric salinity objectives contained in SDWQ Alternatives 2 and 3 includes continued U.S. Bureau of Reclamation (USBR) compliance with the Vernalis salinity requirement currently established in the 2006 Bay-Delta Plan and implemented through D-1641."]; at p. ES-15 [the

> *DWR and USBR's water rights will be conditioned to require* continued operations of the agricultural barriers at Grant Line Canal, Middle River, and Old River at Tracy, or other reasonable measures, to address the impacts of SWP and CVP export operations on water levels and flow conditions that might affect the assimilative capacity for local sources and evapo-concentration of salinity in the southern Delta.

(Draft SED, App. K, at p. 2 of 5, italics added.) However, the State Water Board cannot pre-determine the water right conditions necessary to implement the salinity objectives, and the draft POI's assumption that the State Water Board will continue to require the water right conditions imposed to implement the Bay-Delta Plan is contrary to law.

b. <u>An Adjudicative Water Right Proceeding Is Necessary To Provide Due Process To Water Right Holders</u>

A right to appropriate water is recognized as a private property right and "once rights to use water are acquired, they become vested property rights." (*Racanelli Decision*, *supra*, 182 Cal.App.3d at p. 101.) The Constitution prohibits a state from depriving any person of property "without due process of law." (Sec. 1, Amendment XIV, U.S. Constitution.) Thus, appropriative water rights "cannot be infringed by others or taken by governmental action without due process and just compensation." (*Racanelli Decision*, *supra*, 182 Cal.App.3d at p. 101.) Therefore, the procedural protections provided by law with respect to appropriative water rights are necessary to ensure that due process is provided by the State. The draft POI for the salinity objectives deprives Reclamation and DWR, their respective contractors, including members of the Public Water Agencies, and likely others of due process by attempting to impose water right conditions through this legislative water quality planning process.

An adjudicative water right proceeding provides additional procedural protections to water right holders that are not provided in the legislative water quality planning process. For example, in an adjudicative water right proceeding, each party has the right to call and examine witnesses, to cross-examine opposing witnesses, and to rebut evidence against him or her. (Gov. Code § 11513, subd. (b); Gov. Code, § 11425.10, subd. (a); 23 C.C.R. § 648, subd. (b) [listing applicable procedures in State Water Board adjudicative proceedings].) In addition, the decision issued in a water right proceeding must include "a statement of the factual and legal basis of the decision . . .." (Gov. Code, § 11425.10, subd. (a); 23 C.C.R. § 648, subd. (b).) These procedural rights, and others provided for in adjudicative proceedings, ensure that parties to such proceedings receive due process and an opportunity to contest the State Water Board's evidence. If adopted, the draft POI for the SDWQ salinity objectives would deprive Reclamation and DWR, their respective contractors, including members of the Public Water Agencies, and likely others of these procedural rights by pre-determining the conditions that will be placed on water rights, prior to providing the due process afforded in an adjudicative water right proceeding.

In addition, the State Water Board is held to a higher evidentiary standard in making water rights decisions than it is in developing water quality control plans. In reviewing the State Water Board's legislative actions, such as amendments to a water quality control plan, the courts apply a

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"program of implementation for SDWQ Alternatives 2 and 3 would require USBR to continue complying with the existing 2006 Bay-Delta Plan 0.7 dS/m EC objective at Vernalis April–August and 1.0 dS/m September–March as a 30-day average. This would help maintain assimilative capacity downstream of Vernalis into the interior southern Delta during the main growing season"].

deferential standard of review and a court will "'uphold the agency action unless the action is arbitrary, capricious or lacking in evidentiary support.' [Citation.]" (*Racanelli Decision*, *supra*, 182 Cal.App.3d at p. 113.) In contrast, in reviewing the validity of water right permit conditions imposed through an adjudicative proceeding, the courts must determine whether "the conditions are supported by 'precise and specific reasons founded on tangible record evidence.' [Citation.]" (*Id*. at p. 115.) Also, an administrative agency is required to make findings that bridge the analytic gap between the raw evidence and the ultimate decision when it issues an adjudicative decision, but not when it issues a legislative decision. (*Id*. at p. 114.) Thus, the nature of the proceeding determines the evidentiary standard the State Water Board must meet and adjudicatory actions provide more protection for the parties and rights affected by the agency action, by providing a more demanding evidentiary standard.

3. Assignment Of Responsibility For Implementing The Salinity Objectives Should Be Commensurate With A Party's Contribution To Salinity

The draft SED states that the "goal of the Preferred SDWQ Alternative is to protect agriculture through new numeric objectives and a program of implementation that places responsibility on the USBR, DWR, and others, *commensurate with their contributions to the southern Delta salinity impairments*." (Draft SED, at p. ES-3, italics added.) However, nowhere does it explain why it is appropriate to require Reclamation to provide "assimilative capacity" downstream of Vernalis. Nor does it explain why it is appropriate to require Reclamation and DWR to install, operate and maintain barriers, conduct the specified monitoring, and conduct the specified studies. There is also no valid basis for imposing permit conditions on the CVP and SWP, including those that require the Reclamation and DWR, and likely the Public Water Agencies, to fund monitoring and studies, install temporary barriers. (Draft SED, App. K.) It is beyond reasonable dispute that multiple factors affect the concentration of salinity in the waters of the San Joaquin River and southern Delta. Indeed, the draft SED acknowledges that salinity conditions in the southern Delta "are affected by various factors including low flows, salts imported to the SJR Basin in irrigation water, municipal discharges, groundwater percolation, poor circulation and water diversion and discharges from agricultural drainage." (*Id*.; Draft SED at p. ES-6 [listing additional factors]; *Id*. at p. 1-7 [same].) Thus, it is inconsistent with the goal of the Preferred SDWQ Alternative, unreasonable, and unlawful to require Reclamation to provide assimilative capacity or to require Reclamation and DWR to install, operate and maintain barriers, conduct the specified monitoring, and conduct the specified studies.

4. The Assignment Of Responsibility For Implementing The Salinity Objective Must Reflect The Substantial Reduction In Salt Discharge Upstream Of Vernalis

The SED extensively discusses the topic of salinity in the San Joaquin River, but the SED omits decades of successful efforts to reduce salinity loading in the San Joaquin River from lands irrigated with CVP water. The contribution of salinity to the San Joaquin River from lands irrigated with CVP water have changed considerably since the State Water Board last closely examined San Joaquin salinity standards in the 1995 Water Quality Control Plan amendments and in D-1641. At the time the State Water Board adopted D-1641, there was a concern that the Vernalis salinity objective would not be met. Indeed, Reclamation "acknowledged that on occasion salinity objectives at Vernalis will not be met under its plan." (D-1641, at p. 80.) The State Water Board found that "the actions of the CVP are the principal cause of the salinity concentrations exceeding the objectives *at Vernalis*." (*Id.* at p. 83, italics added.) The effect of CVP-

related irrigation and other activities is very different today, something the draft SED does not sufficiently acknowledge.

There have been no exceedances of the salinity objective at Vernalis since D-1641 was adopted. The Grasslands Bypass Project ("GBP") has achieved substantial reductions in salt discharges to the San Joaquin River. The GBP is regulated through waste discharge requirements issued by the Central Valley Regional Water Quality Control Board ("Central Valley Regional Board"), an important fact not mentioned in the description of the project. (Draft SED, at p. 1-13.) The GBP gathers subsurface drain water from some 90,000 acres of farmland located west of Firebaugh, California, lands that are irrigated with CVP water. As the draft SED explains, the GBP routes the drain water around wetlands and wildlife refuges. The GBP uses a portion of the San Luis Drain to convey the drain water to Mud Slough, which is tributary to the San Joaquin River. The SED acknowledges that the GBP "improves water quality in the wildlife refuges and wetlands, sustains the productivity of 97,000 acres of farmland, and fosters cooperation between area farmers and regulatory agencies in drainage management reduction of selenium and salt loading." (Draft SED, at p. 1-13.) The regulations and agreements governing the GBP require further dramatic drainage reductions that will continue to reduce discharges of salinity, while drainage management through the project will allow viable agriculture to be maintained. Appendix F to the SED, in a description of the baseline conditions for salinity modeling, says that "SWRCB recognizes that . . . the salinity upstream of the Merced is likely to be substantially reduced by the Grasslands drainage project (for selenium removal)." (Draft SED, App. F at p. 1-114.)

Absent from the draft SED, however, is any acknowledgement that the level of salinity that the GBP discharges to Mud Slough and hence to the San Joaquin River have already been substantially reduced. The reductions in salt discharge achieved by the GBP from water years 1995 through 2012 are presented in the table included with these comments as Attachment 5. As shown in Attachment 5, from 1995 to 2012 the GBP reduced the annual salt discharge to Mud Slough by 84%, from 237,530 tons to 38,400 tons. The GBP reduced the total volume of drain water discharged to Mud Slough by 82%, from 57, 574 acre-feet to 10,485 acre-feet. And the GBP reduced the annual discharge of selenium over this period by 94%, from 11,875 lbs. to 750 lbs. The GBP removed all discharges from the 97,000 acres into Salt Slough.

We have been unable to find any narrative in the draft SED describing these dramatic reductions in load from the GBP since 1995. Figure F.2-1b in the SED does depict combined salt load from Mud and Salt sloughs by month, from 1985 through 2010, but is on such a scale that the reductions in loading over time from the GBP are not readily apparent. The approximately 200,000 ton reduction in annual salt load reaching the San Joaquin River from the GBP from 1995 to the present amounts to a 19% reduction in the average salt load at Vernalis, which recently totals approximately 1 million tons per year. Figure F.2-1g in the SED depicts salt load at Vernalis. Like Figure F.2-1b, the scale in Figure F.2-1g does not reveal the reductions in salt loading at Vernalis by the GBP, nor does the narrative related to Figure F.2-1g mention these reductions. Any modeling or presentation of salinity in the San Joaquin River should reflect current conditions and trends–especially where they are supported by data indicating that the trends are likely to continue, in part in response to existing regulation. Failure to include such information in modeling will result in inaccurate information being considered by decision-makers. In particular, modeling current conditions is critical, given Westside farmers' already significant reductions in salt discharges.

Finally, other programs on the west side of the San Joaquin Valley are addressing salinity on lands not within the GBP. The Irrigated Lands Regulatory Program ("ILRP") includes measures addressing drainage discharges from irrigated agricultural lands that reach the San Joaquin River. The ILRP initially requires monitoring and data collection that will guide later management. In addition to program requirements for monitoring the discharge of salts, priority management practices, such as installation of drip irrigation and tailwater recirculation systems to avoid sediment discharges, are expected to have incidental but immediate benefits in reducing discharges of salts. The ILRP, along with the waste discharge requirements for the GBP, will be used to implement the TMDL for salinity in the lower San Joaquin River. Reclamation has entered into and is updating a Management Agency Agreement with the Central Valley Regional Board that is engaging stakeholders, including state and federal refuges, among others, in the development of a real time program for managing discharges to address salinity concerns.

In sum, much has changed since adoption of the 1995 WQCP and D-1641 regarding the CVP's contribution to salinity in the San Joaquin River upstream of Vernalis. There have been no exceedances of the standard at Vernalis since D-1641 was adopted. The GBP has achieved substantial reductions in salt discharges from agricultural lands irrigated with CVP water. These reductions in salinity discharges upstream of Vernalis, which are not described in the SED, should be made known to policymakers and the public. This information will help inform decisions about what salinity reduction measures are feasible, and the relative progress that has been made since adoption of the 1995 WQCP to address various sources of salinity in the south Delta. Such information is essential to developing sound amendments to the existing water quality control plan, including to the program of implementation.[10]

B. Legal And Evidentiary Defects Of The Draft Lower San Joaquin River Flow Objective & Related Program Of Implementation

1. Flow Is Not A Proper Parameter For A Water Quality Objective Under Porter-Cologne

The draft LSJR flow objective is unlawful because flow is a not a proper parameter for a water quality objective. "Water quality objectives" are defined in the Porter-Cologne Act as the

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[10] Two additional comments related to discharges of salt are.

Page 2-36, Paragraph 2.6.4 Water Quality and Water Quality Objectives: This paragraph describes contributions of salinity to the Lower San Joaquin River including boron, selenium and pesticides. The Lower San Joaquin River has been removed from the 303(d) list of impaired water bodies for selenium which is the main constituent of concern for the GBP. In 2010, 40.4 miles of the San Joaquin River from the Merced River to the Delta were removed from the 303(d) list because selenium objectives were being met. The EPA has identified the GBP as a "Success Story" because of these improvements. (water.epa.gov/polwaste/nps/success319/ ca_san.cfm).

Page 5-15 Salinity and Water Temperatures: The second paragraph on this page discusses the use of releases of water from New Melones to maintain water quality objectives of the San Joaquin River. The need for releases from New Melones for this purpose has been reduced significantly over time because of the reduced discharge of salinity from the GBP to the San Joaquin River, which results in lower salinity levels at Vernalis. An analysis in Chapter 6 of the GBP Annual Report 2008-2009 indicates that prior to water year 1997 273,440 acre-feet of fresh water would have been required to dilute the average annual volume of drainage water from the Grassland Drainage Area to meet the Vernalis standard. During the period of the project through 2009 the theoretical annual volume of water needed to dilute the drainage water from the Grassland Drainage Area was reduced to 60,580 acre-feet, or a reduction from the pre-project average of over 200,000 acre-feet. This represents a significant savings of water that now can be used for other purposes.

"limits or levels of water quality constituents or characteristics which are established for the reasonable protection of beneficial uses of water or the prevention of nuisance within a specific area." (Water Code, § 13050, subd. (h).) Temperature, pH, dissolved solids, pathogens, dissolved oxygen, and chemical constituents such as pesticides are all examples of "water quality constituents or characteristics." Flow, by contrast is the physical *movement* of water in a watercourse. While flow may affect water quality, flow is not a water *quality* constituent or characteristic of the water. Flow is therefore outside the scope of a water quality objective as defined in section 13050, subd. (h). The State Water Board's current task is to consider potential amendments to water quality objectives. Questions of flow may be properly addressed as part of implementation, in a water rights proceeding.

The Porter-Cologne Act defines "quality of the water" separately and differently from its definition of "water quality objectives." "Quality of the water" is defined as the "chemical, *physical*, biological, bacteriological, radiological, and other properties and characteristics of water which affect its use." (Cal. Wat. Code, § 13050, subd. (g), emphasis added.) Flow, and volume too, are physical properties of a water body. By contrast, the definition of "water quality objective" does not include the term "physical."

Notably, the defined term "quality of the water" is not used in the provisions of the Water Code that govern water quality control plans. Instead, it appears in a provision of the Water Code that prohibits the commingling of transferred water resulting in a diminution of the quality of the water (Water Code, § 1810), and in a provision that defines a "project" in the context of groundwater basin protection (Water Code, § 12921.3). The term also appears in provisions pertaining to specific projects and entities. For example, section 5901 addresses the deterioration of the quality of the waters of the Upper Klamath River Basin, sections 13951 and 13952 address waste disposal affecting the quality of waters in Lake Tahoe, and sections 50903 and 60230 enable small reclamation districts and water replenishment districts, respectively, to take certain actions to protect the quality of local waters. The Legislature's choice to use a term that includes physical properties in some contexts, but not in the water quality control plan provisions, is a strong indicator that it did not intend for plans to define objectives using physical properties of a water body such as flow.

There are sound policy and practical reasons for excluding properties such as flow and volume from water quality control plans. As discussed above, water quality control plans and water rights proceedings are subject to differing standards and requirements. The distinction between the two is breached when water quality objectives are expressed in terms of flow, because that can predetermine what water rights may be affected and by how much, without the benefit of due process.

The term "quality of the water" appears in only one reported California case. (*State Water Resources Control Board Cases*, *supra*, 136 Cal.App.4th at p. 699.). In that case, the court said that "[w]ater flow can be regulated as a water quality objective because, as the Board explained in the 1995 Bay-Delta Plan, 'the rate and quantity of flow . . . are physical properties or characteristics of the water' which 'have an impact on the beneficial uses of' water in the Bay-Delta." (Id. at p. 701 [citing Water Code, § 13050, subd. (g)].) This was *dictum*, however, because no party in that case challenged the State Water Board's authority to set flow-based objectives, which were adopted following the Delta Accord. Further, the court did not explain how the definition of "quality of the

water" it quoted could be substituted for the pertinent and materially different definition of "water quality objective" provided in Water Code section 13050(h).

The 1995 Bay-Delta Plan illustrates that for many years the State Water Board has taken the position that it may set flow objectives in a water quality control plan, despite the definition of "water quality objective" in section 13050(h). Assuming *arguendo* that the State Water Board's interpretation is not contrary to section 13050(h), it is still unlawful for failure to comply with the California Administrative Procedure Act, California Government Code §§ 11340 *et seq.* ("APA"). A "regulation" within the meaning of the APA includes "every rule, regulation, order, or standard of general application or the amendment, supplement, or revision of any rule, regulation, order, or standard adopted by any state agency to implement, interpret, or make specific the law enforced or administered by it, or to govern its procedure" (Gov. Code, § 11342.600). Under the APA, a promulgating agency "must comply with the procedures for formalizing such regulation, which include public notice and approval by the Office of Administrative Law. . ." (*County of Butte v. Cal. Emergency Medical Services Authority, Inc.* (2010) 187 Cal.App.4th 1175, 1200 [internal quotations and citations omitted].) In *Tidewater Marine Western, Inc. v. Bradshaw* (1996) 14 Cal.4th 557, 571, the California Supreme Court explained that a regulation is subject to the APA if it has two principal identifying characteristics: (1) "the agency must intend its rule to apply generally, rather than in a specific case;" (2) "the rule must 'implement, interpret, or make specific the law enforced or administered by [the agency], or . . . govern [the agency's] procedure.'" (Citing Gov. Code, § 11342, subd. (g).) The State Water Board's claim of authority to include flow as a water quality objective meets these criteria. Yet, the State Water Board has never formally adopted a regulation setting forth its expanded definition of water quality objectives. Accordingly, a water quality objective defined by flow would be based on an underground regulation, and hence invalid. (*Niles Freeman Equipment v. Joseph* (2008) 161 Cal.App.4th 765 [citing *Kings Rehabilitation Center, Inc. v. Premo* (1999) 69 Cal.App.4th 215, 217.].)

2. <u>The Draft Program Of Implementation Fails To Consider And Balance Competing Beneficial Uses Of Water</u>

In developing water quality objectives, the State Water Board is directed to consider *all* competing demands for water in determining what is a reasonable level of water quality protection .(Water Code, § 13000.) In the *State Water Resources Control Bd. Cases*, the court described the Board's duty to consider and balance competing beneficial uses of water as follows:

> In formulating the 1995 Bay–Delta Plan, the Board set out "to attain the highest water quality which is reasonable, considering *all* demands being made on the water of the [Bay–Delta]." (1995 Bay–Delta Plan, p. 14, italics added.) While the Board had a duty to adopt objectives to protect fish and wildlife uses and a program of implementation for achieving those objectives, in doing so *the Board also had a duty to consider and protect all of the other beneficial uses to be made of water in the Bay–Delta, including municipal, industrial, and agricultural uses.* It was for the Board in its discretion and judgment to balance all of these competing interests in adopting water quality objectives and formulating a program of implementation to achieve those objectives.

(*State Water Resources Control Bd. Cases*, *supra*, 136 Cal.App.4th at p. 778, second italics added.) Thus, the State Water Board has a duty to both protect fish and wildlife beneficial uses and other beneficial uses of water in developing flow objectives. Unfortunately, the draft SED fails to

identify the State Water Board's duty to balance competing beneficial uses as one of the stated goals in developing the flow objective.[11] The draft POI does not effectuate the State Water Board's duty to balance the competing beneficial uses of water because it provides for an "unimpaired" flow regime that would require significant reductions in water diversions for other beneficial uses.

It is unclear how the State Water Board can fulfill its statutory duty to consider and balance competing demands for water in developing water quality objectives if the draft SED fails to evaluate those competing beneficial uses of water. The draft SED asserts that "unimpaired flow" can be used as a "straightforward means to assist in balancing the competing uses of water" and that the "35 percent unimpaired flow requirement would strike a balance between providing water for the protection of fish and other competing uses of water, including agriculture and hydropower generation." (Draft SED, at pp. ES-2, ES-3.) Yet, the draft SED reveals that the draft POI's flow regime of 35 percent of unimpaired flow would have significant impacts on other beneficial uses of water. For example, the draft SED concludes that the preferred flow alternative will have significant and unavoidable impacts on agricultural supply and recreation. (*See* Draft SED, at pp. ES-48, ES-49; *see also* Water Code, § 13050, subd. (f) [identifying agricultural supply and recreation as beneficial uses of water].) The draft SED also fails to quantify any fishery benefits of these proposed additional flows under today's physical and biological conditions. Given the recent extremely low salmon survival in the southern Delta (regardless of there being high flows), any fishery benefits are at best highly speculative.

In light of the impacts to other beneficial uses of water, it is unclear how the draft POI's "unimpaired flow" regime satisfies the State Water Board's duty to consider and balance the competing beneficial uses of water in developing water quality objectives. The draft SED states that "[f]low needed for the protection of fish and wildlife beneficial uses will be balanced against flow needs for other beneficial uses of water including: agriculture and hydropower production." (Draft SED, App. C, at p. 3-62.) The draft POI does not reflect a balanced approach to the protection of all beneficial uses of water in the plan area.

3. <u>The Draft Narrative Flow Objective And Program Of Implementation Lack A Strong Technical Basis</u>

a. <u>Applying The Unimpaired Flow Metric Does Not "Mimic The Natural Conditions To Which Native Fish Were Adapted"</u>

The fundamental basis of the draft narrative flow objective is the presumption that an increased magnitude of instream flows that "mimic" actual seasonal hydrologic conditions during the later winter and spring each year will likely result in an increase in the abundance and survival of juvenile and adult Chinook salmon and steelhead. The draft SED asserts that:

> [S]cientific evidence indicates that in order to protect fish and wildlife beneficial uses in the SJR basin, including increasing the populations of SJR basin fall-run Chinook salmon and Central Valley steelhead to sustainable levels, changes to the

[11] One of the stated "goals" of the draft salinity objectives is to "balance actions needed to reasonably protect southern Delta agricultural beneficial uses with the needs for water to meet other beneficial uses of water." (Draft SED, at p. ES-11.) However, the draft SED does not identify a similar "balancing" goal for the LSJR flow objectives. (See Draft SED, at p. ES-10.)

> current flow regime of the SJR basin are needed. Specifically, a more natural flow regime from the salmon bearing tributaries (Stanislaus, Tuolumne, and Merced Rivers) is needed during the February through June time frame.

(Draft SED, App. C, at p. 3-2.) However, the draft SED overlooks that "unimpaired flow" is not, and cannot be, the same as a "natural" flow regime in a highly modified ecosystem such as the Bay-Delta. The draft SED also states that "[u]sing a river's unaltered hydrographic conditions as a foundation for determining ecosystem flow requirements is well supported by scientific literature." (*Id*. at p. 3-41.) This statement fails to acknowledge that "unimpaired flow" is not the same as "unaltered hydrographic conditions" because the physical structure of the streams, rivers, and the Bay-Delta estuary has been so altered that unimpaired flow conditions will not reflect or mimic the "natural" hydrographic conditions that existed in the predevelopment era. The "unimpaired flow" regime is a simplistic short-hand approach that attempts to provide more variability in flow, but such a flow regime will not approximate "natural flow," nor will it restore the complex habitat that native fish species are adapted to or many of the functions that predevelopment flows may have provided.

First, draft POI measures would modify the hydrograph in the lower reaches of these tributaries, the San Joaquin River and Delta, all of which are highly altered. The SED should explain that even to the extent the percent of the unimpaired hydrograph approach may approximate natural hydrology in the upper tributaries, the draft POI measures would modify the hydrograph in unnatural ways in the lower reaches of these tributaries, the San Joaquin River and Delta.

Second, the draft POI only includes a portion of the year, even though the existing standard includes flows in October. The draft SED does not provide an adequate explanation for why excluding nearly half of the year's hydrograph still represents "natural" conditions. Juvenile steelhead rear within in the San Joaquin River tributaries year-round and require suitable instream flows and cold water temperatures, particularly in the late spring, summer, and fall to support their growth and survival. Similarly, adult fall-run Chinook salmon adults migrate into the San Joaquin River system in the fall (September-December) where they spawn and eggs incubate. Providing instream flows and maintaining suitable cold water for salmon spawning and egg incubation is critical to their reproductive success and subsequent abundance (year class strength). While it may be true that additional flow in the spring could be biologically beneficial, limiting changes in flow to less than half the year is not "natural."

Third, the draft POI describes a process where the Executive Director could decide in any year to deviate from the pattern of the hydrograph based on an exercise of his or her discretion indicating that a different flow would benefit the fishery. (Draft SED, App. K.) The SED provides no discussion of the types of habitat and biological monitoring data, rationale, or analyses that would be used as the technical basis for modifying the instream flow schedule within a year. The reservation of authority for the Executive Director further deviates from a "natural" pattern.

Fourth, while the calculated percent of the unimpaired hydrograph approach may approximate natural flow patterns in the tributaries below the dams, it does not do so downstream on the San Joaquin River and in the south Delta. Once flow enters the valley, it cannot be considered "natural" as the current channel configuration and physical environment are drastically transformed from historic conditions. Levees, channelization, and land use changes

have dramatically altered the relationship between instream flows and seasonal floodplain and wetlands inundation on the lower San Joaquin River and Delta from historic conditions. The functional relationships and biological benefits to juvenile salmonid rearing on intermittently inundated habitat in the basin no longer mimic natural processes or conditions that are part of the implied foundation for the unimpaired flow strategy. Today's highly altered conditions are relevant because the seasonal timing and magnitudes of flow under historic conditions were highly modified through interactions with channels, wetlands and floodplains, groundwater recharge, consumptive use by native vegetation, and evaporation. These interactions moderated the timing and magnitude of outflow, and dictated localized hydrodynamic patterns. These interactions also affected the functions that these flows provided; functions that are not necessarily replicated by equivalent flows through today's channels.

The recent SFEI Report, Sacramento-San Joaquin Delta Historical Ecology Investigation: Exploring Pattern and Process, contains a detailed description of the historic south Delta. The report describes the physical environment as well as the likely historic hydrograph, as follows:

> The South Delta is defined by the distributaries and meanders of the San Joaquin River upstream of the central Delta. At the landscape scale, the south Delta historically presented an array of tidal wetlands interwoven with distributary riverine channels and non-tidal floodplains across a broad transitional zone, or ecotone. Early travelers encountered rivers that were formable only late in the season, often with dense willow and oak riparian forest along their banks. Beyond forested natural levees, the land surface sloped away to meet a matrix of perennial wetlands (dominated by tule, Schoenoplectus spp.), patches of sedges and grasses, perennial and intermittent ponds, and overflow channels. This floodplain was challenging to traverse for much of the year, owing to annual inundation.

(SFEI, South Delta, at p. 309.) The SFEI report further describes 12,000 acres that once were comprised of an extensive mosaic of wetlands and adjacent upland habitat types of the south Delta, generally defined as extending from Roberts and Union Islands to the Stanislaus River. (*Ibid*.)

The historic hydrograph on the San Joaquin River was also different than on the Sacramento River, as follows:

> The south Delta marked the terminus of the San Joaquin River, a large riverine system that frequently overflowed its banks to fill numerous secondary channels, ponds, and floodplain wetlands. It conveyed floodwaters that spread and inundated land sometimes several feet in depth before much of it entered downstream tidal channels in the central Delta. In contrast to the more rainfall-event driven hydrograph of the Sacramento River, winter floods were less frequent on the San Joaquin, with flooding typically snowmelt-driven. The resulting hydrograph was characterized by fewer peak flood events and exhibited a gradual rise of river stage in the late spring and early summer…Also different from the northern flood basins, the south Delta floodplains were apparently less isolated from the river by natural levees (presumably related, in part, to the lower flood peaks and sediment supply in comparison to the Sacramento River). This greater hydrologic connectivity was maintained through multiple side channel systems that

> made floodplain hydrology more responsive to river stages and enabled water to pass through the system with relative speed. Masses of woody debris obstructed the main channels at certain locations, such as Old River near the present day Fabian Tract, affecting flows and habitat complexity. The combination of these factors meant that floodwaters in wetland complex, likely associated with the many secondary side channels and oxbow lakes. The comparison to the lower Sacramento River riparian forests, a greater proportion seems to have been composed of willows and other shrubs, as opposed to oaks and sycamores.

(SFEI, South Delta, at pp. 312-313.)

As a result of the changes that have occurred from historic conditions to present, making releases based on the calculated hydrograph will not result in the timing or magnitude of flows described above nor will it "mimic" the historic functions that instream flows supported for juvenile salmonid rearing and other biological processes. Similarly, the outflow from the San Joaquin River to the ocean will not approximate "natural" or historic conditions. This means that the through-Delta flows targeting improved juvenile salmon passage cannot be defined as "natural." The draft amendments and draft SED do not adequately reflect these facts.

There are ways to calculate historic or "natural" Delta outflows. During last year's Phase II workshops, Dr. Paul Hutton presented one estimate of historic outflow calculated by Dr. Phyllis Fox and Dr. Dan Howes. They used the landcover published in Chico (2003) as a representation of historic vegetation. Next, they calculated the evapotranspiration of each landcover type (using two different estimation methods) and then multiplied the evapotranspiration rate by the acreages of each vegetation type. Finally, they added up the total estimated water loss from evapotranspiration and subtracted that volume from Delta inflow to estimate the contribution of San Joaquin River flows to Delta outflow. Admittedly, this initial method is somewhat crude as it only provides an estimate of average annual Delta outflow, and does not account for seasonal variability or annual or interannual hydrologic variation.

Since the Phase II workshops, the Public Water Agencies have continued to refine tools for calculating historic or "natural" Delta inflow and outflow. The Public Water Agencies are developing a simple water balance model that estimates natural (pre-development) Delta inflows and Delta outflows that would have occurred in the absence of human activity. Both historical and pre-development Delta inflows will be developed to represent a wide range of hydrologic conditions for an 88-year period from 1922 through 2009. Delta outflows will be calculated using a flow mass balance framework, accounting for all in-Delta depletions. Calculations of unimpaired Delta inflows and Delta outflows will extend previous unimpaired flow calculation work undertaken and published by DWR. Specifically, DWR's estimates of unimpaired flows will be modified to account for: (1) valley floor depletion of water supplies through evapotranspiration of native vegetation and riparian lands; (2) bank overflow and detention storage in low-lying areas within the Valley floor; and (3) seasonal variation in groundwater storage. This new modeling effort will make it possible to estimate both seasonal and annual variation in San Joaquin River hydrology and will provide the foundation for a more robust and defensible analysis of alternatives than is currently presented in the SED.

In a second project, the Public Water Agencies are collaborating with SFEI and UCD to utilize modeling techniques to evaluate the characteristics of Bay-Delta salinity transport

associated with "natural" Bay-Delta hydrology. The goal of this effort is to develop an UnTRIM model based on a three-dimensional mesh for the Bay-Delta representing bathymetry and topography under "natural" conditions. The value of this effort is to support restoration efforts by developing an understanding of the functions and processes provided under a natural flow regime, and to be able to compare and contrast unimpaired flow calculations. Results of this modeling will be used, in part, as the foundation for designing habitat restoration projects that mimic natural flow-habitat functions.

b. There Is A Lack Of Evidentiary And Analytical Support For The Draft Program Of Implementation's Proposed Flow Regime

While flows are important for ecological functions and physical processes that support native fish populations, it does not follow that an "unimpaired flow" regime in a highly altered watershed and estuary will provide the conditions needed to support those biological and ecosystem processes. The draft SED does not contain an analysis establishing that the salmonid population viability factors (e.g., abundance, spatial extent or distribution, genetic and life history diversity, and productivity) can be achieved by providing flows that mimic the natural hydrograph. Even if this analytical connection had been made, it has not been sufficiently established that the implementation of the draft POI would provide "natural" flows under which the fish evolved and were adapted (e.g., the relative magnitude, duration, timing, and spatial extent of historic flows). As discussed in detail below, the SED fails to provide analytical or evidentiary support for the presumption that the proposed flow regime will support native fish populations.

An "unimpaired flow" regime implemented without careful consideration of the biological and ecosystem processes that the flows are intended to support is unlikely to provide the intended protection for fish and wildlife beneficial uses. Also, an unimpaired flow regime implemented without consideration of how the hydrological system has been altered or without consideration of other habitat needs of native fish populations is unlikely to be an effective approach to restoring and maintaining native fish populations. In addition, factors other than flows or exports are having a dramatic impact on salmon survival in the southern Delta. The survival levels are so low now, that even in the high flow years of 2005, 2006 and 2011 these survival rates (likely altered by increases in predation by invasive species) are not high enough to sustain salmon abundance. In fact, the draft SED's technical report quotes the Independent Panel Review of the VAMP studies with the following: The review panel concludes that "'the very low recent survival rates seem unlikely to be high enough to support a viable salmon population, even with favorable conditions for ocean survival and upstream migration and spawning success for adults' (Hankin, et al. 2010)." (Draft SED, App. C, at p. 3-39.)

4. The Proposed "Adaptive Management" Approach Is Flawed

a. The Proposed Flow Regime Fails To Implement The Draft Narrative Flow Objective

Under the draft program of implementation, the Executive Director would have the authority to change the timing and magnitude of flows within the February – June period each year, provided the total quantity of water dedicated to instream flow releases is not less than the quantity that would be have been dedicated under a percent of the hydrograph approach each year. (Draft SED, App. K.) A newly formed Coordinated Operations Group ("COG") made up of

the fishery agencies (DFW, NMFS, and USWS) would make recommendations to the Executive Director regarding how he or she should schedule each year's reservoir releases. (*Ibid.*) The San Joaquin River Monitoring and Evaluation Program would be responsible for monitoring, implementing special studies, and evaluating the performance of the flow management strategy on the viability of native salmonid populations, including the abundance, spatial extent, diversity, and productivity of fall-run Chinook salmon and steelhead. (*Ibid.*) The practical result of the proposed "adaptive management" structure is that it changes the program of implementation into something other than a percent of the hydrograph approach. Rather than mimicking the actual hydrograph during the February-June period each year, the program of implementation would function more like a water bank where withdrawals can be made at any time throughout the spring (February – June). The total quantity of water available for additional flows is established by the percent of the hydrograph approach, but the timing of flows is established by the Executive Director and the COG. Such an approach results in a failure to satisfy the narrative objective of "…flows that mimic natural hydrologic conditions…." (*Ibid.*) The flows will not be targeting more natural conditions, rather the flows will be whatever the Executive Director orders each year.

b. <u>The Proposed Flow Regime May Be Operationally Infeasible</u>

It may be infeasible to use the percent of unimpaired hydrograph in a real-time forecasting operation, making a 14-day average period particularly confounding. A short averaging period requires precision and real-time information that does not currently exist. This averaging period would be very difficult to implement as reservoir operators and diverters would be asked to make releases in excess of the required percent of the hydrograph based on predictions of what the hydrograph might look like at the end of the season. The SED provides no discussion or analysis of how actual hydrologic variability and uncertainty would be addressed each year when modifying instream flow schedules and magnitudes.

The Public Water Agencies incorporate by reference a presentation by the Department of Water Resources, Francis Chung and Messele Ejeta, titled Estimating California Central Valley Unimpaired Flows, Phase I, workshop: Presentation and Discussion of Draft Technical Report on the Scientific Basis for Alternative San Joaquin Flow and Southern Delta Salinity Objectives, January 6, 2011. The main points from DWR's presentation were as follows:

- The unimpaired hydrograph can be significantly different from the natural flows;
- The unimpaired hydrograph is a conceptual quantity estimated through various means;
- The unimpaired hydrograph is an imprecise estimate, and will require further improvement before being used as an operations flow criterion. This improvement can be made with careful design, time, and expert effort.
- Implementing the proposed flow criteria in real-time operations will require timely acquisition of field data to estimate the unimpaired hydrograph.
- Timely acquisition of field data, and, under certain circumstances, forecasting certain components of the unimpaired hydrograph will pose extra challenges and increase the level of uncertainty and reduce water supply reliability to the SWP and CVP project operations.

Neither the draft POI nor the draft SED provide any description of how the adaptive management process would be implemented on a real-time basis in light of the inherent uncertainty in actual

hydrologic conditions within the basin. Instead, the draft POI and SED assume perfect knowledge of February-June hydrology each year and the ability to adaptively manage variation in monthly instream flows in real-time.

c. The Proposed "Adaptive Management" Is Not True Adaptive Management As Used In A Scientific Framework

Adaptive management in a scientific context is something very different than what is being proposed in the draft POI. The approach outlined in the draft POI is basically water balance accounting and re-allocation of instream flows among months to address hydrologic variability within a year. Such an approach is not true adaptive management. In the proposed adaptive management structure, decision-making is not linked to a rigorous study plan of hypotheses testing and monitoring. There is no process or thresholds for determining when a change in the implementation measure is scientifically appropriate.

Adaptive management provides a means for carrying out and assessing alternative management actions in the face of uncertainty. The adaptive management process, when appropriately implemented, should facilitate testing of management alternatives, evaluation of outcomes, iterative modifications of management actions as new information is developed through monitoring and experimentation, and learning. Adaptive management cannot be used to compensate for a lack of knowledge, the variability and complexity of ecological systems and biological processes affecting salmonid population dynamics, or underestimating sources of uncertainty including socio-political uncertainty. If the State Water Board is going to pursue adaptive management, it needs to follow a true scientific model of monitoring, special studies, and hypotheses testing. To accomplish true adaptive management, the State Water Board must develop a detailed adaptive management plan and associated experimental design for monitoring the performance of the instream flow strategy on metrics of salmonid viability before it adopts an amendment to the Bay-Delta Plan. Such actions cannot be deferred.[12]

5. The Draft Program Of Implementation Would Result InFuture Amendments To The Water Quality Control Plan Without The Procedures Required By Law

The draft POI would effectively allow for amendments of the water quality control plan through an adaptive management program, without complying with the procedural requirements of Porter-Cologne and the APA that are applicable to the promulgation of a water quality control plan. The draft POI states that the "State Water Board has determined that 35 percent of unimpaired flow is required from February through June from each of the Merced, Tuolumne, and Stanislaus Rivers on a 14-day running average, *unless otherwise approved by the State Water Board through the adaptive management framework described below*." (Draft SED, App. K, at p. 3 of 11, italics added.) The draft POI allows a "Coordinated Operations Group" to propose annual adaptive management of flows during the February through June period and the adaptive management

[12] During the State Water Board's Phase II, Workshop 3, Analytical Tools, the Public Water Agencies provided a review of the literature detailing the necessary elements of an adaptive management plan. They incorporate herein by reference the following presentations on the issue of adaptive management: (1) Public Water Agencies' written submittal: Analytical Tools: Technical Assessment Methods for Evaluating Changes to the Delta Plan, Sections 2.1-2.1.9.; (2) Presentation, Mr. Wayne Lifton, Cardno-Entrix, Adaptive Management, Workshop 3; and (3) Presentation, Dr. Ray Hillborn, Life Cycle Models, Decision-Making and Resolving Scientific Uncertainty, Workshop 3.

"does not have to rely on the unimpaired flow percentage method, but instead can use pulse flows or other management approaches, as long at the requisite unimpaired flow percentage [of 25 percent] for the entire February through June period is met." (*Id*. at p. 4 of 11.) In addition, the draft POI allows the State Water Board or the Executive Director of the State Water Board, to approve modifications to the required base flow and percentage of unimpaired flows based on "subsequently developed information . . .." (*Id*. at p. 5 of 11.) These provisions of the draft POI effectively allow the State Water Board and the Executive Director to amend the water quality control plan to require different base flows and a different flow regime. This approach, not only improperly delegates authority to the Executive Director and Coordinated Operations Group, but denies the public procedural protections afforded by law.

Porter-Cologne and the APA require the State Water Board to provide an opportunity for public notice and comment before the State Water Board adopts any amendment to a water quality control plan. Porter-Cologne requires the State Water Board to provide notice of a public hearing and to hold a public hearing regarding a proposed water quality control plan, before adopting any plan. (Water Code, § 13244.) In addition, the State Water Board must comply with the APA procedures applicable to rulemaking prior to the adoption or amendment of a water quality control plan. (23 C.C.R. §§ 649.1, 649(a).) The APA requires that a state agency permit "both oral and written statements, arguments, or contentions" at the public hearing for the rulemaking proceeding and the state agency "shall consider all relevant matter presented to it before adopting, amending, or repealing any regulation." (Gov. Code, § 11346.8, subd. (a).) The APA also prohibits a state agency from adopting or amending a regulation which has been changed from that which was originally made available to the public, unless the change is "nonsubstantial" or "sufficiently related to the original text that the public was adequately placed on notice that the change could result from the originally proposed regulatory action." (Gov. Code, § 11346.8, subd. (c).) These procedural provisions are intended to provide the public with prior notice and an opportunity for comment, before a water quality control plan is amended or adopted. They are also intended to allow the State Water Board (not the Executive Director through a delegation of power)[13] the ability to make informed decisions. The draft POI contemplates an "adaptive management" process that would effectively deny the public important rights and usurps the State Water Board's responsibility to establish objectives, by allowing the flow regime to be determined and approved annually, at the discretion of the Executive Director and Coordinated Operations Group. Such an approach effectively allows the water quality control plan to be amended each year. Such an approach is contrary to the procedures provided for in Porter-Cologne and in the APA. The annual changes would amount to unlawful, underground regulations.

[13] The draft POI allows the Executive Director of the State Water Board to independently approve modifications to the 35% of unimpaired flow regime based on "subsequently developed information" or requests by the newly formed Coordinated Operations Group. (Draft SED, App. K.) Such an approach effectively allows for amendments to the water quality control plan, without any further review or consideration by the State Water Board. This would be an improper delegation of the State Water Board's water quality planning powers and duties. (*See Cal. Assn. of Nursing Homes etc. Inc. v. Williams* (1970) 4 Cal.App.3d 800, 813 [agency's incorporation of standards developed outside of the rule-making process without independent consideration of the underlying evidence and without public or judicial access to that evidence transgresses fundamental demands for the adoption of administrative regulations].) In fact, the Water Code expressly prohibits a regional water quality control board from delegating any of its powers and duties related to the issuance or modification of any water quality control plan to its executive officer. (Water Code, § 13223, subd. (a).) The same prohibition should apply when the State Water Board is modifying or issuing a water quality control plan pursuant to Water Code section 13170.

6. The Role Of The Implementation Workgroup Must Be Limited

The draft POI provides for the establishment of an Implementation Workgroup to develop recommendations for implementing the new flow requirements while minimizing water supply costs. (Draft SED, at p. ES-12.) The recommendations would be included in an Implementation Plan submitted to the Executive Director. (*Ibid*.) The SED further states, "The implementation plan would then be considered in State Water Board water right proceedings, Federal Energy Regulatory Commission licensing proceedings, or during other implementation actions to achieve the February-June flows." (*Ibid*.)

The draft POI cannot dictate where and how the committee's implementation plan will be considered by future decision-makers, as the decision-makers should exercise their own discretion when considering the evidentiary weight afforded the plan. The committee's implementation plan should also be appropriately qualified as being purely informational, as the State Water Board members must exercise their independent judgment in satisfying their legal obligations, without having their discretion apparently limited by the committee's implementation plan. To avoid the appearance of an inappropriate delegation of the State Water Board's authority to the Implementation Workgroup, the program of implementation and SED should make clear that the State Water Board members will make an independent determination of the appropriate balancing of beneficial uses.

II. SPECIFIC COMMENTS ON SUBSTITUTE ENVIRONMENTAL DOCUMENT

A. The Substitute Environmental Document Does Not Accurately Describe The Bay-Delta Conservation Plan

The SED's description of the Bay-Delta Conservation Plan ("BDCP") is inaccurate. (See, Draft SED, at pp. 1-12 and 7-48.) Several corrections are warranted. First, the water conveyance facilities are only one component of the overall BDCP. Second, the current remanded biological opinions will not be in operation until the "…the new water conveyance infrastructure identified in the Plan becomes operational," (SED at 7-47), rather, the current remanded BiOps will be in effect until new interim BiOps are completed pursuant to the timeline established by the federal court. The BDCP BiOps will be completed at the time of project approval but will not be controlling of water project operations until the new facilities are operational. Third, while the BDCP was developed in collaboration with various entities, the BDCP document is being prepared by the Department of Water Resources, in close coordination with the Departments of Interior and Commerce, and the California Department of Fish and Wildlife.

A more precise description of the BDCP is found in the introduction of the Preliminary Draft BDCP, pp. 1-1 – 1-2, stating:

> The Bay Delta Conservation Plan (BDCP or Plan) sets out a comprehensive conservation strategy for the Sacramento–San Joaquin River Delta (Delta) designed to restore and protect ecosystem health, water supply, and water quality within a stable regulatory framework….
>
> The BDCP serves as a natural community conservation plan ("NCCP) under the state's Natural Community Conservation Planning Act (NCCPA), and a habitat

conservation plan (HCP) under Section 10 of the federal Endangered Species Act (ESA)…

Consistent with the goals of the NCCPA, the BDCP has been designed to mitigate for the effects of the activities proposed in this Plan (covered activities), and to conserve threatened and endangered species in the Plan Area. The Plan also provides substantial public benefits, including helping prevent species from becoming threatened or endangered, improving Delta water quality, and reducing future risks to the Delta from earthquakes, levee failure, and climate change. Funding to achieve these important goals will come from a variety of sources.

B. Legal And Analytical Defects Of The Substitute Environmental Document Related To The Draft Lower San Joaquin River Flow Objectives And Program Of Implementation

1. The SED Fails To Describe The Various Flow Regimes That Are Possible Under the Draft Program Of Implementation And Fails To Analyze The Potential Impacts Of Those Flow Regimes

The SED does not provide any analysis of the potential environmental effects of the range of possible flow patterns the Executive Director may order in the future, thereby rendering the SED legally inadequate. The SED should have evaluated a prescribed range of possible alternative management actions that could be taken by the Executive Director, and the potential environmental effects of those actions (e.g., effects on upstream coldwater pool management in each reservoir and the ability to maintain suitable water temperatures to support oversummering juvenile steelhead) and provide sufficiently cold water (less than 56 F) for fall-run Chinook salmon spawning and egg incubation in the fall (e.g., October-December)). The SED also should have explained the biological circumstances and underlying scientific basis for modifying instream flow schedules or magnitudes when such deviation would be justified.

The proposed "adaptive management" approach fails to include any protection against the Executive Director ordering flows in excess of the designated percent of the hydrograph, which is reasonably foreseeable if excess releases are ordered early in the year and then (like this year) the hydrology turns very dry. The program of implementation analyzed in the SED only requires that not less than the total quantity of water be dedicated to flow, not more. The SED does not address the potential adverse impacts to other beneficial uses of water, reductions in coldwater pool, or reservoir carryover storage under circumstances when predictions of the unimpaired hydrology and associated instream flow schedule result in greater releases than prescribed under the flow alternatives.

2. The SED Fails To Provide A Sufficient Analytical Link Between Flow Function And Expected Benefit For Salmonids And The Proposed Implementation Program

The SED fails to provide a legally or scientifically sufficient analytical link between the proposed narrative objective and implementation flows, and potential flow derived benefits for salmonids. The fundamental basis of the narrative objective is that an increased magnitude of instream flows that mimic actual seasonal hydrologic conditions during the later winter and spring each year is predicted to result in an increase in the abundance and survival of juvenile and adult

Chinook salmon and steelhead. However, the SED does not contain an analysis establishing that the salmonid population viability factors (e.g., abundance, spatial extent or distribution, genetic and life history diversity, and productivity) can be achieved by providing flows that mimic the natural hydrograph. Even if this analytical connection had been made, it has not been sufficiently established that the implementation of the proposed SED flow alternatives would provide "natural" flows under which the fish evolved and were adapted (e.g., the relative magnitude, duration, timing, and spatial extent of historic flows).

Appendix C of the SED describes two general categories of expected benefits from the percent of unimpaired flow approach: (1) additional flow is needed to significantly improve production (abundance) of fall-run Chinook salmon [upstream]; and (2) the primary influence on adult abundance is flow 2.5 years earlier during the juvenile rearing and outmigration life phase (Kjelson et al 1981; Kjelson and Brandes 1989; AFRP 1995; Baker and Morhardt 2001; Brandes and McLain 2001; Mesick 2001b; Mesick and Marston 2007; Mesick 2009); Mesick 2010 a-d [downstream]). (Draft SED, App. C, at p. 3-29.) However, the draft SED provides only a high level, and incomplete, review of the literature regarding the unimpaired flow management concept, and fails to link the flows actually being proposed with the flows studied in the literature. In addition, the SED fails to acknowledge the high level of uncertainty and highly variable responses within aquatic communities under the unimpaired flow strategy and the effects of factors such as habitat modifications (e.g., levee construction that alters floodplain inundation, channelization, loss of wetland and riparian vegetation, water storage by dams, cold water pool management and exposure to seasonally elevated water temperatures particularly during the late spring, summer, and fall, groundwater extraction, gravel mining, loss of spawning gravels and habitat complexity, etc.) and changes in biological relationships (e.g., increased risk of predation, exposure to contaminants, influence of hatchery operations, competition for limited suitable spawning and rearing habitat, changes in macroinvertebrate prey composition and abundance, invasive species, etc.).

The SED relies primarily on older flow-survival studies and out-dated assumptions about the primacy of spring smolt outmigrants without considering how the results of those studies comport with the newer studies and data. The SED does not synthesize information from these references and more recent studies into an analytical framework that is then systematically applied to expected results of each of the alternatives to assess the predicted response, and level of uncertainty, in the biological metrics (e.g., juvenile salmon survival, reproductive success, adult abundance, adult escapement, etc.) as part of the evaluation of alternatives. The SED presents no quantitative evaluation of the change in upstream habitat quality or availability for salmonid spawning or juvenile rearing as a function of changes in instream flows under the alternative flow regimes. Further, the SED does not provide any discussion of the poor relationship between spring flow and juvenile survival observed in the VAMP studies since 2006 and the apparent change in the spring flow-adult escapement relationship that is the foundation and technical basis for the SED analyses and findings.

a. Insufficient Linkages With Proposed Flows And Expected Benefits In The Tributaries

Chapter 7 of the SED defers to Appendix C for a description of the biological benefits of the proposed range of implementation flows. However, Appendix C does not include an analysis of the benefits of the proposed flows on the population dynamics of either steelhead or fall-run Chinook salmon; rather Appendix C contains a general description of the biological benefits that

could be expected from a broad range of increased flows, without specifying how the specific flows being proposed would provide anticipated biological benefits. Chapter 7 does not analyze the potential benefits of the proposed implementation flows as Chapter 7 is solely focused on analyzing whether the proposed implementation flows would have any potentially significant negative effects.

When describing potential upstream benefits, Appendix C cites studies where a hydrograph approach was applied in various restoration efforts around the world. (*See, e.g.*, Draft SED, App. C, at pp. 3-41 – 3-42.) The Public Water Agencies provided a review of this literature during the Water Board's Phase II workshops last year and herein incorporate the Public Water Agencies Workshop 1 submittal, Ecosystem Changes to the Bay Delta Estuary: A technical Assessment of Available Scientific Information, sections 6.1 and 6.2, by reference.

Appendix C assumes that all increases in flow will provide measureable improvements in species viability without supporting analyses using data from studies conducted on the San Joaquin River and its tributaries; despite the fact the related literature explains that this is an inappropriate assumption. The literature explains ecosystem response to increased flows are complicated, not a monotonic response to flow alone. As asked and answered in Poff, *et al.* (1997):

> Can reestablishing the natural flow regime serve as a useful management and restoration goal? We believe that it can, although to varying degrees, depending on the present extent of human intervention and flow alteration affecting a particular river [emphasis added].

The literature further explains that it cannot be assumed that additional flow will always provide species benefits. Poff and Zimmerman (2010) reviewed 165 papers related to the natural flow regime. A narrative summary of the reported results from the synthesis of available scientific literature by Poff and Zimmerman (2010) strongly corroborated previous, less comprehensive, reviews that document highly variable ecological responses to all types of flow alteration. The literature review by Poff and Zimmerman (2010) revealed some sensitivity of different ecological groups to alterations in flow magnitudes, but consistent robust statistical relationships were not detected between flows and many important biological responses of the aquatic community. The Poff and Zimmerman (2010) results revealed:

> Macroinvertebrates showed mixed responses to change in flow magnitude, with abundance and diversity both increasing and decreasing in response to elevated flows and to reduced flows. Fish abundance, diversity and demographic rates consistently declined in response to both elevated and reduced flow magnitude. Riparian vegetation metrics both increased and decreased in response to reduced peak flows, with increases reflecting mostly enhanced non-woody vegetative cover or encroachment into the stream channel. [emphasis added.]

Poff and Zimmerman (2010) explained, "Given the alteration of flow regimes is typically confounded with other environmental factors, we would not necessarily expect unambiguous relationships between single measures of flow alteration and ecological response." These confounding relationships have also been observed by other researchers. Bunn and Arthington (2002) describe the uncertainties associated with attempting to restore "natural" flow to promote ecological restoration.

> In writing this review, we often encountered reports of river systems affected by multiple stressors and were unable to definitely separate the impacts of altered flow regimes from those of the myriad of other factors and interactions. How much of an observed decline in species diversity can be attributed directly to modified flow compared to diffuse inputs of nutrients and contaminants? A similar problem occurs in our attempt to unravel the cause and effect of exotic species on aquatic diversity. Is an observed decline in native fish species the result of a modified flow regime or direct impact of an introduced species (or both)? Ecological science is not yet able to answer these questions, important as they are.
>
> Ecologists still have much to learn about the ecological significance of individual flow events and sequences of events, and descriptive science can take us only so far in unraveling these linkages. The advice from aquatic ecologists on environmental flows might be regarded at this point in time <u>as largely untested hypotheses about the flows that aquatic organisms need and how rivers function in relation to flow regime.</u> [emphasis added.]

These studies explain why the Water Board cannot rely on the assumption that a percent of the hydrograph approach has been tried elsewhere without also considering the relative success of those efforts in meeting the desired biological goals and functions, and the potential for success in the San Joaquin River system and south Delta. Ours is a highly altered system, both physically and ecologically, and the relationships between flows and habitat functions for salmonids no longer mimic natural or historic conditions. The expert panel during the 2010 flow proceedings nearly unanimously concluded, flow alone is not likely to restore the system or achieve the goals of salmonid recovery, yet that seems to be the assumption underlying the analysis presented in the SED.

The only place where the actual implementation flows are compared to potential flow-rated benefits to salmonids is in Chapter 7 of the SED. The functions identified in Appendix C that could be enhanced by flow are described qualitatively with no technical support or analysis and include: "native fish communities," food web support, habitat, geomorphic processes, temperature modification, and water quality. (Draft SED, at p. 3-42.) The analysis in Chapter 7 does not support a conclusion that the proposed flows would improve these functions and in fact the SED provides no analyses of, or where analyses are provided, no support for potential beneficial changes in a number of these attributes. For example:

- Chapter 7 concludes that turbidity and gravel mobilization will not be changed significantly: Alternatives 2 and 3 are not expected to affect the frequency of overbank or bed mobilization flows in the Stanislaus, Tuolumne, and Merced Rivers. (Draft SED, at p. 7-105.) The SED states:

  > [P]eak flows would occasionally be sufficient to cause gravel transport in the upper gravel-bedded reaches and some instream bank erosion, but the <u>frequency and magnitude of these events would not be sufficient to cause long-term changes in sediment transport rates</u>. Higher rates of sediment transport are also expected to occur in the lower sand-bedded portions of the major SJR tributaries and the SJR, but the frequency, duration, and

> magnitude of increased suspended sediment and turbidity levels are expected to be minor and within the range of historic levels….

(Draft SED, at p. 7-106, emphasis added.)

Alternative 4 is also expected to remain below the capacities of the existing channels and below thresholds associated with gravel mobilization in the upper reaches of the major SJR tributaries. (Draft SED, at p. 7-106.)

- Chapter 7 concludes that food availability and floodplain inundation will not be changed significantly: The SED concludes that under all alternatives, "the primary processes that alter food web support, including the magnitude and frequency of bed mobilization flows and floodplain inundation flows…are not expected to change substantially…." (Draft SED, at p. 7-114, emphasis added.) While there is "some potential" for increased floodplain inundation on the Tuolumne River "impacts on food availability resulting from changes in flow, nutrient transport, and water quality (food web support) would be less than significant on the major SJR tributaries. (*Ibid*., emphasis added.)

- Chapter 7 concludes that redd and fish stranding will not change significantly: For each alternative, the SED concludes:

> The modeling results…indicate…the potential for significant redd dewatering and fish stranding impacts on the Stanislaus River in March…All other rivers would either result in no change from the baseline with respect to redd dewatering or a reduction in the potential for redd dewatering…Therefore, redd dewatering and stranding impacts on Chinook salmon and steelhead populations in the Stanislaus, Tuolumne, and Merced Rivers under LSJR Alternatives…would be less than significant.

(Draft SED, at pp. 7-111 – 7-112.)

- Chapter 7 does not support a conclusion that water quality will be significantly changed: While the SED concludes that the lower flows of Alternative 2 would result in a significant impact to water quality for juvenile salmonids and other fish species, there is insufficient evidence provided to support this conclusion. In fact, the introductory text indicates that increased flows may be equally likely to increase or decrease pollutants.

> Increased flows would have the potential to increase mobilization and concentration of pollutants in surface waters in the tributaries and LSJR, potentially increasing exposure of aquatic organisms to toxic substances…However, increased flows would also provide benefits to indicator species by diluting existing pollutants in the water column, and any other pollutants that may be mobilized from the sediment on the bottom of the riverbed and along the river channel.

(Draft SED, at p.7-101.)

There is no data provided on existing pollutants levels in the water column versus in sediments on which to draw any conclusion regarding whether flow would have a positive or negative effect on water quality.

The SED conclusions in the remaining categories of flow functions are difficult to interpret because of unsupported assumptions. Nevertheless, all other categories were determined to have a less than significant impact, or a significant and unavoidable impact. What is not evaluated in the SED or its Appendix C is whether the proposed change in flow will result in a measureable improvement in salmonid viability as reflected in improved reproduction, improved survival, increased adult abundance, etc.

b. Insufficient Linkages Between Proposed Flow At Vernalis And Increased Salmonid Survival

Appendix C states that the second rational for the proposed implementation alternatives is that the primary influence on adult abundance is flow 2.5 years earlier during the juvenile rearing and outmigration life phase (Kjelson et al 1981; Kjelson and Brandes 1989; AFRP 1995; Baker and Morhardt 2001; Brandes and McLain 2001; Mesick 2001b; Mesick and Marston 2007; Mesick 2009; Mesick 2010 a-d [downstream]). (Draft SED, App. C, at p. 3-29.)

The studies cited above are based on analyses of old data, many new studies have been completed in more recent years. (See Figure 1.) The SED should have updated the Kjelson regressions to include all of the available data, and then evaluated how the regression is supported (or not supported) by the latest data on escapement, recent VAMP tagging experimental results for juvenile Chinook salmon survival, etc. The SED discusses many of the more recent studies, which illustrates how the flow relationships are uncertain and complicated by other factors, and then apparently ignores the recent studies and relies solely on the older work. As an example of recent data that was overlooked, the SED provides no analysis of flow-survival or flow adult escapement using data collected in recent years (e.g., after 2006) when the juvenile salmon survival has been observed to be consistently low (about 5%) and largely independent of spring flow at Vernalis.

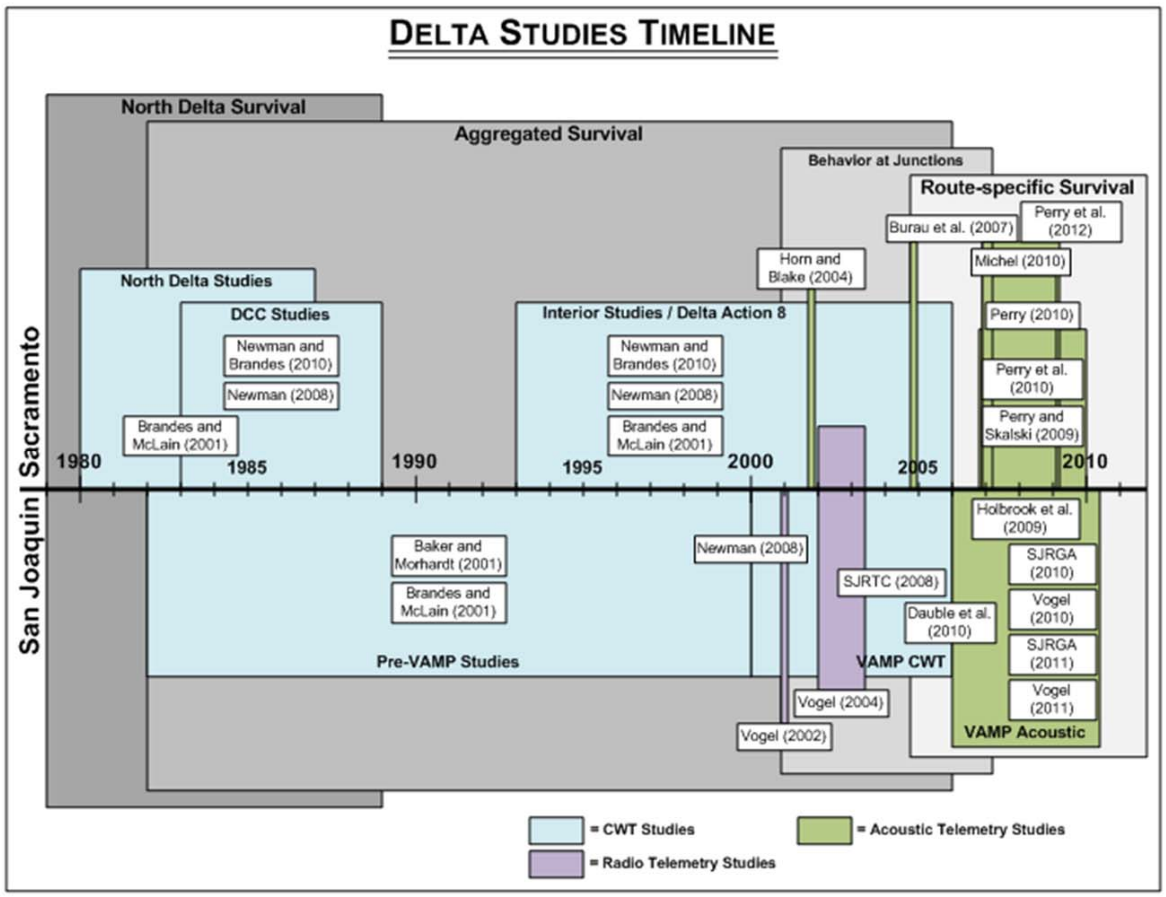

Figure 1. Summary of field studies and data analysis related to lower river and Delta survival studies. Colored rectangles indicate time period for specific field studies. Citations (in small white rectangles) indicate authors and year of reported analysis. The location of citations links the analysis to its data source. Though some studies were published recently, source data were often from more than 10 years old.

In an independent panel review of the VAMP studies, experts concluded: "'the very low recent survival rates seem unlikely to be high enough to support a viable salmon population, even with favorable conditions for ocean survival and upstream migration and spawning success for adults' (Hankin, et al. 2010)." These conclusions do not take into account, but are consistent with ,the recent data from the acoustic tag studies conducted in 2011 and recently summarized at the 2011 Bay Delta Science Conference by the team of Rebecca Buchanan (University of Washington) Patricia Brandes (USFWS) and Kevin Clark (DWR) in a presentation titled "Survival and Route Selection of Juvenile Chinook Salmon in the Southern Sacramento- San Joaquin River Delta – 2012". The acoustic tagging studies were conducted in the last half of May and first half on June in 2011. The flows during these periods were a little more than 10,000 cfs, which are very high flows for the San Joaquin River during these periods historically. Even at these high flows the survival from Vernalis through the Delta to Chipps Island was only 2%. Of extreme interest is that of the fish that survived to Chipps Island, 64% of them came through the CVP Tracy fish screening facility and were trucked around the Delta. This means that the natural fish survival through the Delta Channels in the high flow year of 2011 was less than 1%.

Specific flow regimes could have been quantitatively evaluated by interpreting available data (through 2010) for adult Chinook abundance and San Joaquin River flow 2.5 years earlier.

The SED appears to assume a simple, positive linear response between average spring flows and adult escapement. However, careful analysis reveals this relationship is not linear and is driven largely by a handful of observations of San Joaquin River flows (at Vernalis) greater than 10,000 cfs. The influence of very high flow events is depicted clearly in Figure 2, where a simple linear relationship using all flows years shows a weak positive relationship (R^2<0.36) for March, April and May. In contrast, when observations with average monthly flows greater than 10,000 cfs are excluded, the relationships weakens substantially, particularly for the month of May (R^2=0.04). This distinction is critical because controlled, non-flood flows at Vernalis, even at 60% unimpaired flow, will always be less than 10,000 cfs. The assumed simple linear relationship between spring flow and subsequent spawning escapement, wherein any increase in flows will lead to a proportional increase in Chinook salmon abundance, is not consistent with available data. This strongly implies the assumed simple positive linear relationship is an inadequate basis for flow management. Rather, effective flow regime management requires that the mechanism of the benefit be understood and accounted for. For example, the flow and adult abundance relationship suggests a threshold effect (which develops at flows greater than 10,000 cfs) rather than a simple linear pattern. Thus, flow increases from 1,500 to 3,000 (for example) may yield poorer than expected benefits. The analysis also needs to consider the timing and duration of flow pulses. Such analyses might reveal that a one week duration, large magnitude flow pulse in March would yield greater benefits than four weeks of 5,000 cfs flows in May. This point is made even more significant in light of recent studies showing that early emigrants (fry and parr) contribute substantially (more than 50%) to successful adult spawner abundance.[14]

[14] Sturrock, AM, Johnson, RC, Wikert, JD, Weber, PK, Heyne, T (2012) When to bolt: fry or smolt? Estimating survivorship of juvenile salmon migratory life histories using otolith strontium isotopes. 7th Biennial Bay-Delta Science Conference poster presentation. Sacramento.

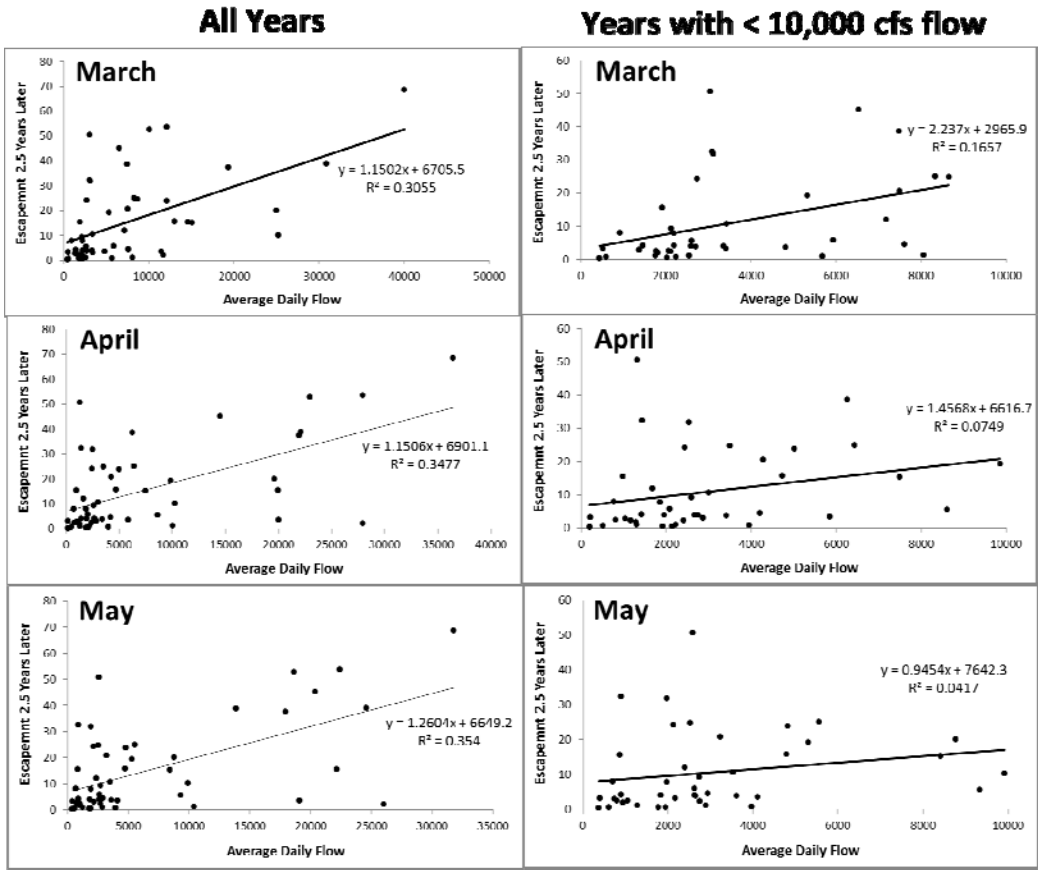

Figure 2. Relationship between average San Joaquin River flow at Vernalis flow and San Joaquin River basin in-river spawning escapement 2.5 years later. Flow data from DayFlow. Spawning abundance data from GrandTab, 1956 through 2010 combined for Merced, Tuolumne and Stanislaus Rivers. Graphs in left column show relationship by month for all years. Graphs in right column show relationship by month including only those years with monthly average flows less than 10,000cfs.

The SED must explain why the newer studies were ignored in favor of the older studies. Moreover, the SED must explain how the proposed implementation flows relate to the body of information that forms the justification for the flow proposal. Stated alternatively, are the implementation flows within the range of flows evaluated in the relevant studies and what is the likelihood that the proposed flows will provide measureable increases in salmonid viability (abundance)?

C. The Alternatives Analyses Is Legally And Analytically Defective

The draft SED must include an "analysis of reasonable alternatives to the project . . .." (23 C.C.R. § 3777, subd. (b)(3).) A substitute environmental document prepared under the State Water Board's certified regulatory program is considered to be the "functional equivalent" of an environmental impact report ("EIR") that would otherwise be required under California Environmental Quality Act ("CEQA"). (*City of Arcadia v. SWRCB* (2006) 135 Cal.App.4th 1392, 1422.) Therefore, the CEQA Guidelines' requirements regarding the range of alternatives that must be analyzed in an EIR are instructive for determining the range of alternatives that must be analyzed in a SED. An EIR must "describe a range of reasonable alternatives to the project, or to the location of the project, which would feasibly attain most of the basic objectives of the project but would avoid or substantially lessen any of the significant effects of the project, and evaluate

the comparative merits of the alternatives." (14 C.C.R. § 15126.6, subd.(a).) An EIR "must consider a reasonable range of potentially feasible alternatives that will foster informed decision-making and public participation." (*Ibid*.) In addition, the Lead Agency "must publicly disclose its reasoning for selecting those alternatives." (*Ibid*.) The range of potential alternatives analyzed in an EIR must "include those that could feasibly accomplish *most* of the basic objectives of the project and could avoid or substantially lessen one or more of the significant effects." (14 C.C.R., § 15126.6, subd.(c), italics added.) Thus, the draft SED must include an analysis of the reasonable alternatives to the draft amendments to the Bay-Delta Plan that: (1) accomplish most of the basic objectives of the project; and (2) could avoid or substantially lessen one or more of the significant effects of the project.

1. The Goals And Objectives Of The Project Are Too Narrowly Drawn And Lead To An Unreasonably Constrained Alternatives Analyses

As part of a legally sufficient project description, CEQA requires a clearly written statement of the objectives sought by the proposed project. (Cal. Code of Regs., tit. 14, §15124(b).) Project objectives are to aid in the development of a reasonable range of project alternatives. (*Ibid*.) But, the SED goals and objectives are too narrowly drawn. The SED goals and objectives unreasonably limit the alternatives to the months of February through June, limit the alternatives to only three of the tributaries in the watershed (the Stanislaus, Tuolumne, and Merced Rivers); and limit flows to those that "…mimic the natural hydrographic conditions to which native fish were adapted." (Draft SED, at p. 3-1.) There are a number of alternatives that could contribute to improved salmon viability but were precluded from consideration because of the overly narrow goals and objectives. For example, there are a number of alternative flow patterns to the "unimpaired flow" regime, as well as non-flow actions, that could provide fishery benefits. These options should have been included as alternatives. Ironically, through the proposed adaptive management program, the SED is contemplating a variety of flows that would not mimic the natural hydrographic conditions, but the SED just fails to include them as alternatives and evaluate the potentially significant environmental effects associated with those flow regimes.

2. The Draft SED Fails To Analyze Reasonable Alternatives To A Flow Objective

The draft SED analyzes a single water quality objective—a flow objective--for the reasonable protection of fish and wildlife beneficial uses. (*See* Draft SED, at p. 3-3 ["LSJR Alternatives 2, 3, and 4 are comprised of a narrative objective and an associated program of implementation."].) This analysis is inadequate because it does not provide an analysis of the "reasonable alternatives" to a flow objective. (23 C.C.R. § 3777, subd. (b)(3).) "Reasonable alternatives" to the flow objective are any alternatives that could accomplish most of the basic goals of the amendments to the water quality control plan. (14 C.C.R., § 15126.6, subd. (c).) In reviewing and amending a water quality control plan, the State Water Board's fundamental goal and statutory mandate is to establish water quality objectives that in its judgment will ensure the "reasonable protection of beneficial uses . . .." (Water Code, § 13241.) Thus, in seeking to establish water quality objectives that will ensure the reasonable protection of fish and wildlife beneficial uses, the State Water Board must take a broad view, and consider a variety of factors, including the environmental characteristics and quality of the waters under consideration. (*Id*.) To achieve the basic goal of providing for the reasonable protection of fish and wildlife beneficial uses, the State Water Board should consider the various water quality characteristics or constituents that affect such beneficial uses and establish reasonable water quality objectives for those characteristics or

constituents. The draft SED fails to analyze reasonable alternatives to a flow objective which could feasibly accomplish the basic goal of providing for reasonable protection of fish and wildlife beneficial uses, and which could avoid or substantially lessen the significant effects of a flow objective. The range of alternatives needs to be expanded to include an analysis of non-flow alternatives that could provide for the reasonable protection of fish and wildlife beneficial uses.

3. The Draft SED Fails To Analyze Reasonable Alternatives To "Mimicking The Natural Hydrograph" Or To The "Unimpaired Flow" Regime

The identified "objectives" or "goals" of the draft amendments to the LSJR flow objectives and associated POI are as follows: (1) to provide flow conditions in the LSJR and three eastside tributaries sufficient to support and maintain the natural production of native fish populations, including "flows that mimic the natural hydrographic conditions" to which native fish species are adapted; (2) to consider relevant factors in establishing the objectives; (3) to provide for adaptive management of flows, while minimizing water supply costs; (4) to provide for appropriate monitoring and evaluation program to inform adaptive management of LSJR flows and future changes to the Bay-Delta Plan; and (5) to provide for coordination of regulatory processes related to LSJR flows. (Draft SED, at p. 3-2.) The first stated goal—to provide flow conditions that support and maintain native fish populations—appears to pre-determine that this goal requires "flows that mimic the natural hydrographic conditions." The assumption that "flows that mimic natural hydrographic conditions" must be part of the goal of supporting native fish populations constrains the alternatives analysis and results in a range of alternatives that merely analyzes various percentages of "unimpaired flow." In fact, the draft SED does not analyze *any* alternative to the draft narrative flow objective; instead it only analyzes different percentages of "unimpaired flow" as alternative programs of implementation.

The draft SED "evaluates four alternatives for LSJR flows during the February-June time frame, including the No Project Alternative (LSJR Alternative 1) and three other LSJR Alternatives (LSJR Alternatives 2, 3, 4)." (Draft SED, at p. ES-11.) However, LSJR Alternatives 2, 3, and 4 all contain the same narrative objective and only differ in terms of the percentage of unimpaired flow specified in the program of implementation for each of the "alternatives." The draft SED states that these "unimpaired flows were selected as alternatives to capture a range of potential flow alternatives that the State Water Board may implement." (Draft SED, at p. ES-12.) However, the draft SED fails to analyze alternatives that do not use the "unimpaired flows" approach. For example, the draft SED fails to explain why the "functional" approach in the existing WQCP, which is based on providing flows for specific ecological and physical processes needed to support native fish populations during certain times of year, is no longer a "reasonable" flow alternative. Nor does the draft SED analyze any alternatives that "mimic the natural hydrographic conditions" by using an approach other than "unimpaired flow." At a minimum, the draft SED must analyze all "reasonable" alternatives that achieve most of the basic goals of the LSJR objectives, if those alternatives could potentially reduce significant impacts. The draft SED fails to analyze whether there are flow alternatives that would support native fish populations and that could potentially reduce the significant impacts to water supply. By limiting the alternatives analyzed to percentages of "unimpaired flow" the draft SED constrains the State Water Board's ability to evaluate whether there are alternative flow regime approaches that could potentially reduce the significant impacts associated with the Preferred LSJR alternative. Alternative approaches could include, for example, approaches that examine the essential physical and ecological processes necessary to support native fish populations and the actions necessary to provide those processes.

4. The Draft SED Fails To Analyze An Alternative That Would Include Flows From The Upper San Joaquin River

All of the LSJR alternatives analyzed in the draft SED involve a program of implementation that requires certain percentages of "unimpaired flow" from three tributaries to the San Joaquin River—the Merced, Tuolumne, and Stanislaus Rivers. (*See* Draft SED, at pp. 3-5 – 3-6; App. K.) The draft SED fails to analyze any LSJR alternative that would include flow requirements from the upper San Joaquin River. However, under the logic of the draft SED, including flows requirements from the upper San Joaquin River is a "reasonable" alternative that could feasibly accomplish the goal of using unimpaired flow as a flow regime, and that could substantially lessen some of the significant impacts related to imposing flow requirements on only the three tributaries. Evidence in the record shows that under unimpaired conditions (1984-2009), the upper San Joaquin River at Friant would have provided 30% of the flow at Vernalis (Draft SED, App. C, at p. 2-24), yet the draft SED does not analyze a single alternative that would require flows from the upper San Joaquin River. In light of the upper SJR's contribution to flow under unimpaired conditions, it is inexplicable why the draft SED does not consider and analyze an alternative that requires flows from this part of the watershed.

5. The Draft SED Lacks Substantial Evidence To Support The Conclusion That There Are No Feasible Alternatives To The Preferred LSJR Alternative

None of the LSJR flow alternatives are feasible because there is no real-time data that would enable water suppliers to manage their diversions on a 14-day running average percentage of unimpaired flow. In addition, there is no substantial technical support for the fundamental assumptions that (1) any percentage of unimpaired flow will mimic the natural hydrograph in the LSJR or three eastside tributaries, or that (2) managing flow at 35%, 40%, or 60% of unimpaired flow will result in any benefit to steelhead, salmon, or other sensitive aquatic species that depend on the LSJR for any part of their life cycles. As stated, the SED must evaluate a reasonable range of feasible alternatives that will actually achieve measurable improvements in or protection of aquatic species beneficial uses.

Nevertheless, in addition to these fatal flaws in the unreasonably narrow range of alternatives, the SED fails to consider LSJR Alternative 2 as a "feasible" alternative that would avoid significant impacts to groundwater, recreation, agriculture, service providers, and energy use and climate change. Thus, even if LSJR Alternative 2 were feasible, which it is not, the SED would have to evaluate it as a means of avoiding otherwise significant impacts of the Preferred LSJR Alternative and Alternatives 3 and 4.

A SED must include "[a]n analysis of reasonable alternatives to the project and mitigation measures to avoid or reduce any significant or potentially significant adverse environmental impacts . . . ." (Cal. Code Regs., tit. 23, § 3777, subd. (b)(3).) This is consistent with the fundamental substantive mandate in CEQA that prohibits public agencies from approving projects with significant environmental effects if "there are feasible alternatives or mitigation measures" that can substantially lessen or avoid those effects. (*Mountain Lion Foundation v. Fish and Game Commission* (1997) 16 Cal.4th 105, 134; see also Pub. Resources Code, § 21002 ["it is the policy of the state that public agencies should not approve projects as proposed if there are feasible alternatives or feasible mitigation measures available which would substantially lessen the significant environmental effects of such projects . . ."].)

In many places, the SED concludes that there are no feasible mitigation measures because the only way to lessen or avoid certain substantial impacts would be to reduce flow, but then concludes that reduced flow is part of another alternative, so it is not a feasible mitigation measure. (E.g., Draft SED, at p. 10-27 ["Requiring less flow cannot be independently applied under LSJR Alternative 3 as a mitigation measure because requiring [less] flow would be inconsistent with the terms of LSJR Alternative 3 . . . ."].) By dismissing other flow regimes as infeasible mitigation measures, the SED ignores the possibility that there may be feasible alternatives that would substantially lessen or avoid the Preferred LSJR Alternative's otherwise significant impacts while achieving most of the project's goals and objectives. (Draft SED, at pp. 20-21 [finding preferred alternative will have significant and unavoidable impact on groundwater because there are no feasible mitigation measures]; 20-24 [same for recreational opportunities]; 20-26 [agricultural resources]; 20-26 -20-27 [service providers]; 20-27 [energy resources and climate change].)

Thus, the Preferred LSJR Alternative has several significant impacts that could be avoided by adopting LSJR Alternative 2, or another feasible alternative that would modify flow to support identified functions and values in the LSJR and tributaries. But the SED lacks substantial evidence that would support a finding that LSJR Alternative 2 is any less feasible than other LSJR alternatives.[15] Instead, the SED relies on the unsupported conclusion that a percentage of LSJR flows from February through June will mimic the natural flow regime and benefit sensitive aquatic species that use or migrate through the LSJR. Thus, in many places, the SED fails to provide substantial evidence that supports the conclusion that the impacts of the Preferred LSJR Alternative (or the impacts of LSJR Alternatives 3 and 4) are significant and unavoidable because it lacks any evidence that LSJR Alternative 2, or another alternative that is based on the best available science, is infeasible or would not achieve most of the goals of the plan.

Ultimately, Phase 1 of the updates to the Bay-Delta Plan should drop the percentage of unimpaired flow alternatives because they cannot be implemented on the proposed 14-day running average, and because there is no technical basis for the assumption that unimpaired flow will protect or benefit sensitive species. Instead, a reasonable range of feasible alternatives that avoid or substantially lessen the impacts of Phase 1 should be formulated based on the best available scientific information about what LSJR flows will actually improve the functions and values needed by steelhead and salmon that rely on the LSJR.

6. The Draft SED Fails To Provide Sufficient Information For The State Water Board To Evaluate Whether There Are Less Costly Alternatives[16]

Before adopting any "major regulation," the State Water Board must evaluate the alternatives to the requirements of the proposed regulation and "consider whether there is a less costly alternative or combination of alternatives which would be equally as effective in achieving increments of environmental protection in a manner that ensures full compliance with statutory mandates within the same amount of time as the proposed regulatory requirements." (Health & Safety Code, § 57005, subd. (a).) A "major regulation" is "any regulation that will have an economic impact on the state's business enterprises in an amount exceeding ten million dollars

[15] None of the LSJR alternatives are feasible as a percentage of unimpaired flow based on a 14-day running average, since there is no real-time data on precipitation and runoff that would enable diverters to operate to meet the objective.

[16] Notwithstanding its placement, the comment raises an independent error with the proposed amendments – a violation of Health and Safety Code section 57005.

($10,000,000) . . .." (*Id.*, subd. (b).) A "regulation" is "every rule, regulation, order, or standard of general application or the amendment, supplement, or revision of any rule, regulation, order, or standard adopted by any state agency to implement, interpret, or make specific the law enforced or administered by it, or to govern its procedure." (Gov. Code, § 11342.600.)

Here, the proposed plan update is a "regulation." (*See SWRCB. Office of Admin. Law* (1993) 12 Cal.App.4th 697, 703 ["a regulation which is part of a water quality control program is a regulation under the APA"], *Id.* at p. 702, fn. 4 [State Water Board conceded that "'water quality control plans adopted pursuant to Porter-Cologne set regulatory standards of general applicability which apply, interpret and make specific the requirements of Porter-Cologne'"].) The proposed update is subject to the requirements of Health and Safety Code section 57005 because the economic impact of that regulation on the state's business enterprises is estimated to be more than ten million dollars. (*See e.g.*, Draft SED, at p. 18-2, Table 18-1 [estimating that LSJR Alternative 3, with 30% unimpaired flow required, would result in $40 million in lost crop revenues annually].) As a result, the State Water Board must evaluate whether there are less costly alternatives that would be equally effective in achieving environmental protection. The State Water Board, however, has not done that. Lesser costly alternatives would likely include alternatives that move past the use of flow to water quality characteristics and constituents (sediment, temperature, etc.) that may be directly affecting the beneficial uses. The State Water Board should not adopt any plan amendments until it has complied with Health and Safety Code section 57005.

D. Specific Comments Regarding Chapter 5 – Water Supply, Surface Hydrology, And Water Quality

1. The Draft SED Confuses The Concepts Of "Unimpaired Flow" And "Natural Flow"

The draft SED states that the "hydrology of the SJR as measured at Vernalis is greatly altered from the unimpaired runoff conditions." (Draft SED, at p. 5-7.) The draft SED describes "unimpaired flow" as the "river flow at a specified location that would occur if all runoff from the watershed remained in the river, without storage or diversion." (*Ibid.*) The draft SED asserts that the "unimpaired monthly hydrology . . . approximate[s] flows of a more natural pattern." (*Ibid.*) This assertion confuses the concepts of "unimpaired flow" and "natural flows" and suggests that "unimpaired flow" approximates "natural flow." However, "unimpaired flow" is a calculation of a hypothetical flow condition that never existed in the Bay-Delta. In contrast, "natural flows" are the actual flow conditions that existed in the Delta during the predevelopment era. Only "natural flow" approximates the flows under which native fish species evolved.

The assertion that "unimpaired flow" approximates "natural" flow patterns ignores the fact that the Bay-Delta and Central Valley is a highly altered ecosystem. In the predevelopment era, historic inflows flooded out the original river channels into wetlands and floodplains that reduced the flood peak and supported vast acreages of natural vegetation. In contrast, any "unimpaired flow" regime would occur in the current, highly modified system, where outflow rushes through rock-lined channels surrounded by levees. The distinction between "unimpaired flow" and "natural flows" was articulated by DWR over 30 years ago during its testimony at the 1987 Bay-Delta Plan hearings:

> Since unimpaired flow estimates assume present channel configurations and levee and flood bypass systems, they are not the same as natural flows (i.e., flows that occurred in a state of nature, before development). Natural flows through the Delta would probably be *far smaller* than unimpaired flows due to consumptive use by extensive natural marshes and riparian areas that were later leveed and reclaimed. Monthly distribution of flows would also be different.

(California Department of Water Resources (DWR) 1987, p. 10, italics added.). The draft SED should be revised to acknowledge and clarify that an "unimpaired flow" regime will not mimic "natural" flow patterns, because the "unimpaired flow" regime would be implemented in a highly modified ecosystem.

2. Regulatory Setting

The draft SED states that the "[r]elevant federal programs, policies, plans or regulations related to water supply, surface hydrology and water quality are described [in section 5.3.1]." (Draft SED, at p. 5-50.) Section 5.3.1 in turn describes the federal Clean Water Action ("CWA"), the Federal Antidegradation Policy and the Raker Act. (*Id*. at pp. 5-50, 5-51.) However, there are federal laws in addition to those described in section 5.3.1 that are relevant to water supply, surface hydrology and water quality. For example, implementation of the federal Endangered Species Act significantly affects water supply in California, by mandating certain flows and restricting water supply diversions. Other federal laws that affect water supply and surface hydrology include federal reclamation law and FERC's licensing program for hydroelectric projects. Section 5.3.1 should be revised to include a discussion of these federal laws and any others that affect water supply, surface hydrology and water quality, either directly or indirectly.

The draft SED states that the "relevant state programs, policies, and regulations related to water supply, surface hydrology, and water quality are described [in section 5.3.2]." (Draft SED, at p. 5-51.) However, there are state laws and programs in addition to those described in section 5.3.2 that are relevant to water supply, surface hydrology and water quality. For example, Fish and Game Code section 5937 requires "[t]he owner of any dam shall allow sufficient water at all times to pass through a fishway, or in the absence of a fishway, allow sufficient water to pass over, around or through the dam, to keep in good condition any fish that may be planted or exist below the dam." In addition, Fish and Game Code section 1602 prohibits any entity from substantially diverting or obstructing the natural flow of any river, stream, or lake without prior notice to the Department of Fish and Wildlife and in some cases, requires conformance with a streambed alteration agreement. Also, the Central Valley Regional Water Board's Irrigated Lands Regulatory Program (ILRP) regulates discharges from irrigated lands within its jurisdiction, including from irrigated lands within the plan area, and this program affects water quality. Section 5.3.2 should be revised to include a discussion of these state laws and programs and any others that affect water supply, surface hydrology and water quality, either directly or indirectly.

E. Specific Comments Regarding Chapter 6 – Flooding, Sediment, And Erosion

1. The Environmental Setting Is Legally Inadequate Because It Lacks Any Description Of Flood Control Storage And Operations For New Don Pedro And New Melones Reservoirs

The environmental setting establishes the environmental baseline against which the project's environmental impacts must be assessed. (Cal. Code Regs., tit. 14, §15125.) The environmental setting must be accurately described in enough detail to enable the State Board, responsible and trustee agencies, and the public to assess the significance of any project alternative's environmental impacts. Generalized references to aspects of the environmental setting are inadequate. (*Galante Vineyards v. Monterey Peninsula Water Mgmt. Dist.* (1997) 60 Cal.App.4th 1109, 1122.)

The rainfall flood control storage and operations for Lake McClure are described, but no similar description is offered for New Don Pedro or New Melones Reservoirs. Instead, the draft SED simply states that "New Don Pedro and New Melones Reservoirs have similar flood control and flood control operating rules." The flood control storage and operations of New Don Pedro and New Melones Reservoirs should be added to the SED since they are key aspects of the environmental baseline. (Draft SED, at p. 6-4.)

2. The Impact Analysis Is Deficient Insofar As It Only Modeled The Flows For The Water Years 1999-2008, When The SED Itself Reveals That Recent Floods Were Recorded In All Three Eastside Tributaries In 1983, 1986, 1995, 1997, And 2006

The SED discloses that recent floods were recorded in the areas of, and high flows were recorded in, each of the three eastside tributaries in 1983, 1986, 1995, 1997, and 2006, and the Merced River experienced high flows in 2005 as well. (Draft SED, at pp. 6-12, 6-13, and 6-16.) However, the State Board only estimated unimpaired flow for water years 1999-2008, claiming without any evidentiary support that "[t]his time frame provides a representative range of flows . . . ." (Draft SED at p. 6-20.) There appears to be no substantial evidence in the record to support this assertion. Given the flood conditions reported in the period between 1983 and 2006, it appears that a broader range of water years is required to provide a representative sample.

Absent a truly representative sample, the analysis of potential flood, sediment and erosion control impacts of the LSJR flow alternatives is fatally flawed, and likely underestimates the potential significance of the impacts. For instance, the SED discloses that "the 1997 flood [on the Tuolumne River] resulted in bank overtopping near Modesto, Waterford, La Grange, and Roberts Ferry . . . ." (Draft SED, at p. 6-13.) Yet 1997 was not included in the "representative" sample of years for modeling and comparison of alternatives to baseline conditions.

3. The Impact Analysis In The SED Impermissibly Fails To Explain To The Reader How The Analysis Was Performed, Or Why Certain Assumptions Were Made

To serve its fundamental purpose as an informational document, an EIR, and thus, a SED, "must include detail sufficient to enable those who did not participate in its preparation to understand and consider meaningfully the issues raised by the proposed project." (*Laurel Heights*

Improvement Assn. v. Regents of the Univ. of California (1988) 47 Cal.3d 376, 404-405.) Accordingly, the SED "must reflect the analytic route the agency traveled from evidence to action." (*Kings County Farm Bureau v. City of Hanford* (1990) 221 Cal.App.3d 692, 733.) "[T]he public and decision-makers, for whom the EIR is prepared, should also have before them the basis for [the agency's opinion] so as to enable them to make an independent, reasoned judgment." (*Santiago Water Dist. V. County of Orange* (1981) 118 Cal.App.3d 818, 831.)

Instead of presenting the evidence and logic underlying the assumptions made in the impact analysis, the SED presents a confusing analysis, and simply refers the reader to Appendix F.1 and Appendix L for an explanation. For instance, according to the SED, the percentage of unimpaired flow requirements "might be waived as a result of public health and safety concerns" when the NOAA action stage of the rivers is reached. (Draft SED, at p. 6-20, emphasis added.) But instead of using the NOAA action levels to model flood flows under the various alternatives, the SED states that "[t]he WSE modeling performed for this chapter, and other chapters, uses monthly flow limits derived from observed flows above which the unimpaired flow requirement no longer applies. The model results are compared to those using the NOAA action stage in Appendix L . . . . The modeling and incorporation of the limits are also discussed in Appendix F.1." (Draft SED, at p. 6-20.)

The same mismatch between how the flood control curves and daily operations would actually be implemented at the three reservoirs under the LSJR flow objective alternatives, and how they were modeled (based on NOAA action levels as a proxy) reappears on page 6-22. Only there, the SED first states that "[a]lthough the monthly reservoir operation during the February-June period would be slightly different under the LSJR alternatives, the same end of month flood control storage space would be maintained and the same daily flood-control releases would be made during major rainfall runoff events, with the same downstream maximum flood-control releases." (*Ibid*., emphasis added.) But in the next sentence the SED inconsistently states that "reservoir storages would often be at the monthly flood control levels in many of the years . . . ." (*Ibid*., emphasis added.) The reference to Appendices F.1 and L are unhelpful in explaining how the two methods compare, or what the comparison supposedly demonstrates, leaving the public and decision-makers in the dark as to whether the analysis and conclusions are actually supported by substantial evidence.

4. The WSE Model Uses Unrealistic Assumptions About The Way Dams Are Operated On The Eastside Tributaries

In Appendix F.1, the SED discloses that the "rule curves" for modeling and establishing downstream flow targets for the LSJR flow objectives were formulated using an unrealistic assumption that diversion dams on the three eastside tributaries are operated based on storage levels at the end of January of each water year.

> To compare the WSE model results with the CALSIM baseline results, several cases were run to determine the approximate percentage of unimpaired flow targets that was most similar to the CALSIM II baseline river flows for each of the three eastside tributaries. This was done by comparing the distributions of the WSE and CALSIM II February–June modeled flows. The target percentage of unimpaired flow for the WSE model was adjusted until the distribution of February-June flows generally matched the CALSIM II flow distribution. The results of CALSIM II February–June flows closely match the WSE model results for the LSJR Alternative 3 flow targets

on the Stanislaus River and for the LSJR Alternative 2 targets on both the Tuolumne and Merced Rivers.

In the second step, the end of January storage verses annual diversion "rule curve" was developed to match the CALSIM II relationship between January storage levels and annual diversions for the major reservoirs on each tributary. The CALSIM II annual diversions were divided by the maximum annual diversion determined for each tributary, resulting in a percent of maximum annual diversion actually delivered each year. This result was then plotted against the January storage for the CALSIM baseline results. The WSE storage-diversion rule-curve was adjusted to provide a similar distribution of annual water supply diversions. The "rule-curve" results in a lower percentage of the maximum annual diversion being delivered when the January storage is lower. In general, substantial cutbacks to diversions are necessary when reservoir storage is less than roughly one half of the full capacity. Using the CALSIM II baseline results as a guide, diversion delivery rule curves were developed that resulted in annual diversions that were similar to those of CALSIM II. The WSE rule curves were also adjusted to match the end-of-September storages (carryover storage) from the CALSIM II model. Minimum allowable storage levels were specified for each reservoir and used as a reference line to tally the number of times storage fell below this level.

(Draft SED, App. F.1 at pp. F.1-20.)

Diversion dams are currently operated by determining the reservoir storage and snowpack prior to the beginning of the growing season, not at the end of January. However, the modeling used to estimate the impacts of the LSJR assumes that the dams will be operated to deliver water based on storage levels at the end of January of each year. (*Ibid*.) This methodology results in unrealistic modeling that undermines the analysis of impacts on a host of resources, including flood control.

Once the State Water Board has revised its modeling to incorporate realistic assumptions about how reservoirs would actually be operated under the various project alternatives, every section that relies on the WSE modeling results will require revision in light of the new modeling results.

5. <u>The Impacts Of LSJR Alternatives 3 And 4 Appear To Be Significant And Unavoidable On The Stanislaus River Because The Percentage Of Monthly Flows Greater Than The Level At Which Seepage Occurs Is Increased Significantly During Certain Months</u>

According to Tables 6-12 and 6-13, LSJR Alternatives 3 and 4 would result in a substantial increase in the percentage of monthly flows greater than 1,500 cfs, which is the level above which the Stanislaus River has experienced seepage. For instance, at Ripon, under the Baseline scenario, the percentage of monthly flows above 1,500 cfs would be 56%, 50%, and 11%. For April, May and June. (Draft SED, at p. 6-22, Table 6-13.) Under LSJR Alternative 3, it would be 30%, 62% and 29%, and under Alternative 4, it would be 70%, 84%, and 52% for the same three months.

Despite these substantial increases in the percentages of monthly flows when seepage would occur, the SED concludes that these impacts are less than significant for LSJR Alternative 3

because "on an annual basis, these flows are the same as baseline." (Draft SED, at p. 6-26.) With respect to Alternative 4, which clearly would exceed baseline by a substantial amount, both in terms of certain months, and on an annual basis, the SED concludes that the substantial increase in seepage into adjacent agricultural land does not take the form of surface inundation, and the flows would not cause additional erosion; therefore, even these substantial monthly and annual increases are less than significant.

The SED therefore either discounts substantial monthly increases by pointing to annual seepage, or it dismisses substantial increases in seepage altogether because no matter the increase, it will not result in inundation or erosion.

F. Specific Comments Regarding Chapter 7 – Aquatic Resources

1. Best Available Science

a. Best Available Science

Many of the sections in Chapter 7 such as those describing species life histories and stressors are poorly documented and many of the finding are not supported by either references or analyses. For example, many of the references cited in support of species descriptions are based on literature from the 1970s and 1980s and do not reference newly published studies and literature. Examples of missing reference citations include, but are not limited to, Maunder and Deriso (2011) delta smelt life cycle, MacNally, *et al.* (2010) and Thompson, *et al.* (2010) on analyses of factors related to trends in pelagic species, Glibert, *et al.* (2011) on the role of ammonia and nutrient ratios as a factor affecting primary production, Merz, *et al.* (2011) on the spatial relationship between salinity gradients and delta smelt geographic distribution, Jeffres, *et al.* (2008) on salmonid habitat use of seasonally inundated floodplains, Rosenfield and Baxter (2007) on population dynamics of longfin smelt, Murphy, *et al.* (2011) on issues related to the use of surrogate species, Bowen, *et al.* (2009) and Bowen and Bark (2010) on results of the Head of Old River non-physical barrier tests, CDFG (2009) status review of longfin smelt, CDFG SALSIM model (2012) for assessing effects of variation in instream flows on fall-run Chinook salmon survival and abundance in the San Joaquin River system, acoustic tag studies conducted in 2011 and recently summarized at the 2011 Bay Delta Science Conference by the team of Rebecca Buchanan (University of Washington) Patricia Brandes (USFWS) and Kevin Clark (DWR) in a presentation titled "Survival and Route Selection of Juvenile Chinook Salmon in the Southern Sacramento- San Joaquin River Delta – 2012, and many others.

The inclusion of the ICF International (2012) reference in place of recent primary literature is inappropriate since the ICF material is not a primary reference source but rather a compilation of information from a variety of sources, is an administrative draft that is not available to the public, and has not been subject to public review.

The SED discusses flow regulation on the Stanislaus River but does not discuss the IFIM study that was conducted for use as the technical basis for establishing the instream flow recommendations in support of the 1997 agreement. (Draft SED, at p. 7-30.) Results of the IFIM study showing the relationship between weighted usable area (WUA) and instream flow for various lifestages of Chinook salmon could, and should, have been used as part of the assessment of predicted changes in upstream spawning and rearing habitat as a function of each alternative flow scenario. The response of instream habitat for salmonids is substantially more complex than

reflected by a simple assumption that more flow produces more and higher quality habitat. Habitat suitability for a given lifestage of Chinook salmon and steelhead (and for other fish as well) is an interaction among physical factors such as water depth, water velocity, substrate, and cover (Raleigh, *et al.* 1986). As instream flow increases the suitability of habitat may decrease in response to water depths and water velocities that increase to levels that are no longer suitable. In the absence of analyses of potential changes in habitat quality and availability based on habitat preferences and suitability no meaningful comparison of the effects of variation in seasonal instream flows on upstream habitat can be made. The simplifying assumption in the SED that more flow will result in more upstream habitat is not supported technically and may result in misleading and inappropriate conclusions.

The SED analyses of potential flow-salmonid relationships fails to use analytic tools such as the juvenile salmon passage survival model, lifecycle models for Chinook salmon, the salmon egg mortality model, and juvenile salmon rearing model and other tools for assessing and evaluating the effects of the range of potential management actions on the reproductive success, survival, and abundance of salmonids predicted in response to the range of management strategies. . Examples of analytic tools that potentially could have been used in the assessment include the Delta Passage Model, IOS (Zeug, *et al.* 2012), the CDFG SALSIM model, USBR egg mortality model, USBR SALMOD model, DSM2 and others. NMFS is also in the process of developing a Chinook salmon lifecycle model (initially focused on winter-run) that may provide insight into the assessment. The SED simply assumes, without justification, that more flow during the February-June period each year will, in a positive linear relationship, always produce increased benefits to salmonid populations.

Chapter 7 of the SED presents virtually no biological analysis of the predicted response of various lifestages of Chinook salmon or steelhead to the changes that would occur in the seasonal timing and magnitude of instream flows under each of the alternatives included in the SED. For example, the SED presents no comparative analysis of changes in the quality or quantity of spawning or juvenile rearing habitat in the upstream tributaries under the alternatives (see discussion of IFIM above). Similarly, the SED presents no comparative analysis of changes in egg survival for juvenile Chinook salmon under the alternatives, no analysis of changes in egg survival and hatching as a function of seasonal variation in instream flows and water temperatures under each alternative, and no comparative analysis of changes in juvenile rearing habitat suitability and juvenile abundance that can be used to evaluate the biological response of the target species to the proposed actions. No results of lifecycle population modeling are present in the SED that would have provided prediction of the potential effects of implementing each alternative management strategy on the abundance of adult Chinook salmon and the contribution of the proposed actions on adult escapement to the San Joaquin River basin.

Similarly, the SED provides no analysis or discussion of the level of uncertainty associated achieving the salmonid population goals. In the absence of a stated biological goal (e.g., increase average adult salmon abundance by 50%) there is no technical basis presented in the SED for evaluating the ability of each of the alternatives (no project, 20, 40, or 60% unimpaired flow allocation) as the preferred project based on the ability to achieve the biological goal, given the level of biological uncertainty, with the greatest flexibility and least impacts on other beneficial uses. The technical analysis of alternatives presented in the SED lacks scientific rigor and therefore the selection of a preferred alternative appears to be arbitrary.

There are uncertainties inherent in each of these biological analyses (that should have been discussed and disclosed in the SED) but uncertainty is not a sufficient justification for the complete absence of comparative analyses among alternatives for the key metrics of interest. In the absence of comparative biological analyses for various salmonid lifestages both in upstream habitat and during migration through the lower river and Delta, the SED is incomplete and deficient.

The absence of references to these and other recent scientific investigation of aquatic resources in the Delta suggest a lack of understanding and depth of knowledge of recent findings and new results as technical support and foundation for the assessment. The absence of the application of analytical tools for comparative analysis of the potential response of various salmonid lifestages to the proposed alternative actions further undermines the rigor, credibility, and usefulness of the SED.

b. Disjointed And Fragmented Presentation Of Information

The discussion in Chapter 7 frequently requires the reader to go to other sections of the document or appendices for information required to evaluate the assessment details (see Draft SED, at pp. 7-30, 7-34, 7-38, 7-41, 7-43, 7-59 and elsewhere in Section 7 for examples). The format of the assessment leads to a disjointed and fragmented presentation. The presentation should be largely stand-alone with technical support from other sections and appendices. The key elements of other analyses or technical support needed to fully interpret results of the assessment presented in Chapter 7 should be summarized in the assessment to allow the reader the opportunity to understand the foundation and basis for the assessment results, interpretation, and conclusions.

The discussion of the approach and application of various analytical tools used in comparative analyses of the potential biological response of each lifestage of Chinook salmon and steelhead (this analysis is completely missing from the SED) should discuss and disclose the key assumptions and functional relationships (e.g., flow-habitat in each tributary, temperature-egg mortality relationships, juvenile survival-flow relationships, adult escapement-flow relationships, etc.) used in the biological analyses, with each updated to include the most recent data available and not simply relying on outdated analyses. Similarly, the discussion and interpretation of results should include considerations of factors other than seasonal flows that affect the response of salmonids and their population dynamics, as well as areas of uncertainty in the predicted response (for many of the relationships that would be used to support these analyses, 95% confidence intervals can be estimated on the range of predicted biological response to a given alternative that can then help inform comparative analyses among alternatives).

As currently presented, Chapter 7 does not adequately present the needed technical foundation to evaluate the assessment results and feels like material is scattered in various sections, and appendices, to obscure results and potential problems with the analyses rather than provide a transparent foundation for the assessment.

c. Flow-Survival Relationships

The foundation for analysis of alternatives for salmonids is based on flow-abundance relationships over the past several decades developed by CDFW (adult escapement to the San Joaquin River basin vs. spring flow 2.5 years earlier) and CWT based flow-survival relationships from VAMP studies. As noted above, all of the functional relationships used to support the SED biological analyses need to be updated to reflect the most current data and interpretations

available. Chapter 7 of the assessment does not present either of these key and fundamental relationships, but rather directs the reader to the 200+ page appendix C for this foundational material. These key relationships are used to support the fundamental assumption of the assessment that more spring flow in the San Joaquin River and its tributaries improves the survival and abundance of Chinook salmon and steelhead. There is no discussion, however, that these two relationships were developed only for fall-run Chinook salmon and that no data are presented or available to date on the flow-survival relationship or flow-abundance relationship for steelhead (and yet the same fundamental relationship is used in the analysis for steelhead with no technical support or disclosure). These two relationships are also used to conclude that increased spring flows on the tributaries will result in increased salmonid abundance and survival with no discussion or disclosure that these relationships were developed only for the mainstem San Joaquin River and are not specific to any of the tributaries. There are data from CWT studies on survival flow relationships for the tributaries but these data were not analyzed or included in the assessment. As noted above, this more recent data shows that salmon survival through the south Delta channels has been reduced to less than 5% and in 2011 (a high flow year of about 10,000 cfs) was actually less than 1%. These reductions of salmon survival are likely due to increase predation by invasive species that cannot be corrected with higher flows. As the IPR of the VAMP studies noted: "'the very low recent survival rates seem unlikely to be high enough to support a viable salmon population, even with favorable conditions for ocean survival and upstream migration and spawning success for adults' (Hankin et al. 2010)."

Chapter 7, should present a discussion, for example, of the data on adult fall-run Chinook salmon escapement and spring flows 2.5 years earlier. This is a fundamental element of the foundation used as the basis for the SED. First, all the data used in this relationship should be updated to include adult Chinook salmon escapement estimates through 2011.

Second, results of the CDFW's prior analysis of these data focused on average flow at Vernalis during April through May and therefore provide no technical basis for the seasonal period selected for use in the proposed implementation alternatives that are based on flows over the period from February through June. As currently presented, there is no analysis in SED, Chapter 7, that establishes the rational for specific flow levels in February-March or June as part of the evaluation of the effects of various alternatives on salmonid population dynamics. Similarly, the SED presents no comparative analysis of alternatives regarding the effects of the proposed instream flows on spawning, egg incubation, hatching success, fry rearing and survival, etc., during the February-March time period nor any biological rational for the role of instream flows in the lower river and Delta for salmonids throughout June since the vast majority of juvenile migration is completed (and typically seasonal water temperatures are highly stressful) by June. The absence of rigorous analyses of the life history and functions of salmonids for use in assessing the relative biological benefits of the various alternatives (e.g., what is the biological value to juvenile Chinook salmon of providing higher flows in June to their population dynamics and survival when compared to the effect of this action on reducing reservoir storage and coldwater pool for over-summering steelhead and for meeting the 56 F temperature criteria for Chinook salmon egg incubation in October) is a major deficit in the SED analyses.

Third, the flow-escapement relationship developed originally by CDFW represents adult returns to the entire San Joaquin River basin and cannot be used to support findings related to the flow-abundance relationship for any specific tributary as was suggested in the SED.

Fourth, the flow-abundance relationship is driven to a large extent by adult escapement that occurred one or more decades ago (e.g., 1983, 1958, 1969, 1998, 1982, and 1967) in response to very high (flood flow) conditions in which river flows during April and May averaged over 15,000 cfs. Had the flow-abundance relationship been limited to a range of managed flows that are consistent with the flow range under the proposed alternatives the predicted changes in comparative abundance of adults among alternatives would be substantially less than that predicted by using flood flows in the analysis. It is also important to acknowledge that adult fall-run Chinook salmon escapement in 2006 was very low despite have an average April-May flow at Vernalis of 20,000 cfs which, based on the assumed flow-escapement relationship would have been predicted to result in adult escapement of approximately 30,000 salmon, rather than the low escapement actually observed. Chapter 7 provides no discussion or analyses of these and other factors important to the interpretation of results of comparisons among alternative actions.

The assessment discusses the more recent studies, and then apparently disregards those results without explanation. This is inappropriate because there appears to be a fundamental change in the flow-survival relationships (and likely the flow-abundance relationship for fall-run Chinook salmon on the mainstem San Joaquin River) in recent years. Results of VAMP and pre-VAMP studies showed a marked declining trend in juvenile fall-run Chinook salmon survival over the period from the late 1990s through mid-2000s. In 2006 survival estimates between Durham Ferry and Chipps Island declined to approximately 5%. Survival has remained at these low levels through 2011. The decline in survival has been independent of San Joaquin spring flows and SWP/CVP exports. In fact, in 2011 San Joaquin River flows were high and yet survival was low. These recent results are counter to the foundation assumptions used in developing the assessment and the strategy of developing alternative flow scenarios that result in increased flows (e.g., 60% unimpaired spring flow alternative) in the February-June period.

It has been hypothesized that predation on juvenile salmon during downstream migration in the lower San Joaquin River and Delta by species such as largemouth bass and striped bass has increased in recent years and substantially altered the flow-survival relationship. The SED assessment does not present or discuss these recent data or the level of uncertainty that the proposed range of alternative actions would achieve the goal of increased salmonid survival.

Results of the 2011 studies lead to a number of key questions regarding the effectiveness of increased spring flow for increasing juvenile salmonid survival that are not transparent in the Chapter 7 assessment.

The absence of technical support for many of the SED findings undercuts the weight that can be given to the analysis and interpretation of results presented in Chapter 7.

d. Flow Modeling

The model analysis of changes in flows is based on the median monthly flow derived for each model scenario. (Draft SED, at p. 7-58.) The use of the median flow in these analyses is not appropriate and fails to properly analyze potential adverse impacts that are most stressful in dry and critically dry hydrologic conditions. The median values may be biased by high flow periods that are not captured in a more detailed comparative analysis of conditions among alternatives. In previous environmental documents the use of median values has been rejected by state and federal agencies. (For example, in the 2010 draft BDCP Effects Analysis State and Federal resource agencies commented that the use of average flows for a month across years or average flows over a

period of months within a year were not acceptable for use in assessing fishery related impacts or potential benefits and requested that comparative analyses be performed to eliminate the use of averages and median flows in the analysis.) The conventional approach toward flow assessment has been a month by month comparison each year over an 82 year period of hydrologic record for use as a technical basis for assessing the potential for adverse impacts. (For example, see the Stockton Delta Water Supply Project 2005 EIR fishery analysis; Stockton 2005.) A similar detailed assessment is also the standard approach to conducting water temperature effects analysis rather than relying on averages or median values. (For example, water temperature modeling used as part of effects analyses for salmonids is typically conducted at an hourly or six-hour time-step to reflect seasonal and diel variation in water temperatures that affect fish growth and survival.)

The comparative analysis of differences among alternatives needs to reflect variation in hydrologic conditions (water year conditions) which are not disclosed in the current approach to the assessment.

In addition, the assessment focuses primarily on the February-June period but needs to also analyze changes in environmental conditions within each area year-round to reflect the habitat requirements and life history of each of the target species. This is particularly important for steelhead that require one or more years of juvenile rearing in the rivers where summer temperatures and flow conditions are important.

The application of additional biological models such as the USBR egg mortality model and the USBR SALMOD models can be applied to improving the quantitative assessment of effects of changes in water temperature on salmonids.

As a result of the issues related to the thresholds and criteria used in the assessment and the reliance on median monthly conditions in the analyses, all of the findings presented in Chapter 7 comparing significance of various alternative release strategies lack the support of substantial evidence, and should be re-analyzed.

e. Steelhead

Results of fishery monitoring on the San Joaquin River tributaries (snorkel surveys, rotary screw traps and weirs) and mainstem (Mossdale trawl) provide information on the resident *O. mykiss* (steelhead) population within the basin as well as information on migratory steelhead. Results of these surveys indicate that the steelhead population inhabiting the San Joaquin River system is very small and may be largely supported by the production of the resident trout population. (See presentation by NMFS to SWRCB regarding steelhead status in the San Joaquin River available at http://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/bay_delta_plan/water_quality_control_planning/docs/060611wrkshp/nmfs.pdf.) No quantitative estimates of the abundance of adult steelhead returning to the basin to spawn are available or whether the steelhead population is self-supporting or dependent on adult strays from other river systems. Appendix C states that steelhead are on a continuing decline (Draft SED, App. C, at p. 3-28), but evidence suggests they were never abundant in the San Joaquin, but were instead the occasional offspring of an abundant resident population that migrated within freshwater, but seldom to sea. Recent otolith microchemistry analysis has revealed that a high percentage of smolts had resident mothers. (Zimmerman, *et al.* 2009.) Thus, a natural flow regime in the San Joaquin does not support a steelhead "population."

Historically, steelhead migrated into the higher elevation reaches of the San Joaquin River system (similar upstream habitat as historic spring-run Chinook salmon) where summer water temperatures remained cool and supported juvenile rearing over the summer months. (Moyle 2002, NMFS 2009.) Steelhead juveniles rear in freshwater for one or more years before migrating to coastal marine waters. (Moyle 2002, NMFS 2009.) With the construction of rim dams within the San Joaquin River basin steelhead have been restricted to lower elevation habitat and rely on coldwater from the dams to provide suitable flow and temperature conditions throughout the spring, summer, and fall months. Exposure of juvenile steelhead to elevated summer temperatures and the associated limited physical habitat available for summer rearing are thought to be limiting factors affecting carrying capacity of tributary rivers for steelhead rearing. (NMFS 2009.) As a result of the importance of maintaining suitable summer water temperatures to support juvenile steelhead rearing in the upstream tributaries, the SED must include a rigorous and well documented analysis of the effects of each alternative scenario on individual reservoir storage (by month over all 82 years included in the simulation modeling) coupled with fine-grained (1 hour or 6 hour time step) water temperature modeling of habitat conditions as a function of seasonal meteorological conditions and distance downstream of each dam. Results of these temperature analyses, especially during the summer of drier years when reservoir storage is reduced by both hydrologic conditions and the proposed seasonal instream flow releases between February and June under each proposed alternative management scenario included in the draft SED. The current steelhead population in the basin is very small and adverse changes in summer flow and water temperature associated with the proposed action has the risk of contributing to high juvenile mortality or potentially extirpation of steelhead from the basin.

Appendix C makes the explicit assumption that flows for Chinook will be good for steelhead. (Draft SED, App. C, at p. 3-13.) This is inaccurate. The natural flow regime in the San Joaquin basin was dominated by spring runoff, which probably supported spring-run Chinook to a greater degree than fall-run Chinook. Examples from several other river systems demonstrate that the transition point in a river system from supporting fall-run to spring-run Chinook is also the transition point between predominantly anadromous and resident life histories of rainbow trout. Flow regimes that tend to support spring-run Chinook also tend to support resident rainbow, which historic evidence indicates was the case in the San Joaquin Basin.

2. Regulatory Setting

The regulatory setting section, SED at Section 7.3, is missing several important elements including CVPIA-AFRP, (Draft SED, at p. 7-48), the interim Biological Opinions for USFWS and NMFS (*Id.* at p. 7-48), the current update of the USFWS Native Delta Fish Recovery Plan, (*Id.* at p. 7-49), recognition of the development of a Central Valley salmonid recovery plan by NMFS (*Id.* at p. 7-49), the CDFG ITP for SWP export operations (*Id.* at p. 7-50), and development of BDCP, (*Id.* at p. 7-5). There is also no real discussion of Essential Fish Habitat management under NMFS. The discussion of the status of longfin smelt at p. 7-20 should include a discussion of the recent USFWS determination. The SED also incorrectly characterizes the OCAP consultation as the BiOps are not expected to be in effect until the BDCP becomes operational, as there are court established deadlines for the completion of new biological opinions prior to the operation of new conveyance facilities. (Draft SED, at p. 7-48.)

3. Alternatives

There is no evaluation of alternatives for how to get the most good from use of the limited water available. Carryover storage in reservoirs will obviously be affected in many years and there is no consideration of how that should affect choice of amounts and duration of flow prescriptions. The tradeoffs to fish of spreading the use of water across 5 months rather than focusing on specific functions are not discussed. Use of a salmon lifecycle model and/or other analytical tools is needed to assess the relative contribution of various elements of the proposed management strategies and the associated predictions of biological benefits to the population dynamics of the target species. For example, rather than providing higher sustained flows over extended periods during the February-March period for fry migration the application of short-duration pulse flow migration cues may be a more effective management strategy. Results of these comparative analyses would be useful in identifying substantial differences in management strategies that impacts how water operations could support productive salmon runs.

4. Environmental Setting

a. Striped Bass

The assessment on page 7-24 of the draft SED notes that striped bass are a pelagic species included in the POD. The discussion fails to note that both delta and longfin smelt are also POD species. The SED discusses striped bass predation mortality on juvenile Chinook salmon within Clifton Court Forebay but does not discuss the larger issue of predation mortality in the San Joaquin River and its tributaries and within the Delta on the survival of juvenile Chinook salmon and steelhead. (Draft SED, at p. 7-25.) Results of acoustic tagging studies conducted in the past several years have shown that predation is a major factor affecting juvenile salmonid survival. (E.g., Buchanan, *et al.*, 2013.) Predation mortality on a regional scale may or may not be related to river flows. For example, it can be hypothesized that an increase in stream flows will result in faster downstream migration by juvenile Chinook salmon and therefore will reduce the duration of exposure and risk of predation mortality (increased juvenile survival). Data are available from VAMP studies and the USBR Six-year steelhead study, as well as other experimental studies of juvenile salmon migration and survival in the lower rivers and Delta that could have been analyzed in the draft SED to inform this analysis. There is also a growing body of recent scientific information from acoustic tagging studies in the rivers and Delta that demonstrate the high levels of mortality occurring on juvenile salmon as they migrate downstream that appears to be largely independent of river flow. The absence of discussion of predation on juvenile salmonid survival and how predation could contribute to the observed decline in salmon survival to approximately 5% in the lower San Joaquin River that appears to be largely independent of river flow (e.g., see results of 2006 and 2011 VAMP survival studies)[17] is a major omission from the assessment and may significantly bias the interpretation of the potential effects of flow on survival and abundance of Chinook salmon.

[17] Buchanan, R., Presentation to Delta Science Conference, October 2013 [Lowest observed survival for San Joaquin River acoustic telemetry to date occurred in spring of 2011 when river inflows were greater than 10,000 cfs].

b. Delta Smelt

The draft SED states that delta smelt prefer areas where fresh and brackish water mix in the salinity range of 2–7ppt. (Draft SED, at p. 7-10.) The SED should also state that delta smelt are known to occur year round in the Cache Slough region, which is fresh water. (Merz, *et al.* 2011; Baxter, *et al.* 2010; Sommer, *et al.* 2011).

The SED states that delta smelt larvae are transported downstream to the low salinity habitat. (Draft SED, at p. 7-19.) This was the thinking prior to discovery of a year-round subunit of delta smelt in the Cache Slough region. It is now known that downstream transport is not an obligate life history trait. (Baxter, *et al.* 2010; Merz, *et al.* 2011.)

The draft SED states that changes in delta smelt habitat quality in the San Francisco estuary can be indexed by changes in X2 and that over the range of historical experience the quantity or suitability of estuarine habitat increases when outflows are high (USBR 2008). (Draft SED, at p. 7-43.) Prior to 1987 this may have been true, but not for delta smelt, which have never been shown to have a statistically significant relationship to X2. (Jassby, *et al.* 1995; Kimmerer 2002; Kimmerer, *et al.* 2009.) Also, post-1987 the relationships between X2 and many species abundances have declined or have broken down (e.g., the longfin smelt relationship). (Kimmerer 2002; Kimmerer, *et al.* 2009.)

The SED states that turbidity in the southern Delta is low, which may reduce habitat for delta smelt and other species (Feyrer 2004; Feyrer and Healey 2003; Feyrer, *et al.* 2007; Monsen, *et al.* 2007; Nobriga, *et al.* 2008), and therefore flow patterns that cause delta smelt to move into the southern Delta are likely to negatively affect the population. (Draft SED, at p. 7-45.) The link between turbidity and delta smelt presence is well established. The south Delta is acknowledged to be too clear for delta smelt except during rainfall runoff events, when the pumps are already controlled by the USFWS biological opinion on delta smelt.

The SED states that changes in Delta inflows from the LSJR have the potential to alter LSZ salinity gradients and the location of X2, which can influence temperature, turbidity, and other habitat characteristics (Moyle, *et al.* 2010). (Draft SED, at p. 7-46.) In fact, LSJR flows exert little influence on X2 location and have virtually no effect on water temperatures downstream of the Delta. (Wagner, *et al.* 2011.)

The SED states that the export facilities are known to entrain most species of fish inhabiting the Delta (Brown, *et al.* 1996) and are of particular concern in dry years, when the distributions of delta smelt and longfin smelt shift upstream, closer to the diversions (Stevens, *et al.* 1985; Sommer, *et al.* 1997). (Draft SED, at p. 7-43.) It must be added that there is little evidence that entrainment has a population-level effect on either delta smelt or longfin smelt. Entrainment is no longer considered a major threat to longfin under the existing BiOp. (USFWS (2012).)

c. Longfin Smelt

Page 7-10 of the draft SED indicates that longfin smelt can be found in both the seawater and freshwater areas. While this is true, they are found in far lesser numbers in freshwater areas except during spawning. (Moulton 1974; Chibgu, *et al.* 1998; Chigbu 2000; CDFG 2009; Rosenfield 2010; Rosenfield and Baxter 2007.) They are generally limited to the LSZ and westward. (Gray, *et al.* in prep.) Spawning takes place in freshwater. (Wang 1986; Moyle 2002.)

The SED states that longfin smelt eggs typically hatch in February and disperse downstream. (Draft SED, at p. 7-20.) The principal nursery for larvae is the Suisun and San Pablo Bays. (*Ibid*.) However, a large number of larvae are also caught in the Napa River. (Hobbs, *et al.* 2006; Gray, *et al.* in prep.) It should be further noted that the existing surveys do not cover the entire range of Bay-Delta longfin smelt, and therefore the extent longfin spawn in freshwater tributaries in the Bay is largely unknown.

d. White Sturgeon

The SED states that white sturgeon inhabit riverine, estuarine, and marine habitats at various life stages during their long lives (BDCP 2010) and that the greatest portion of the population occurs in the brackish portion of the estuary, moving in response to salinity changes. (Draft SED, at p. 7-14.) This statement is from Kolhorst, *et al.* (1991), which is based on data from the 1970s-1980s. Wang (2007) concluded that the majority of the white sturgeon larval population is believed to be in the upper Sacramento River, although more larvae are found in Suisun Bay and Montezuma Slough in wet years. The SED should reflect the updated understanding offered by Wang (2007).

e. Splittail

The SED describes Sacramento splittail as a large minnow endemic to the Bay-Delta and confined to the lower reaches of the Sacramento River and SJR, the Delta, Suisun and Napa Marshes, and tributaries of northern San Pablo Bay (Wang 1986; Moyle, *et al.* 2004). (Draft SED, at p. 7-20.) Splittail are a fairly long lived species with high reproductive potential. Reproductive success is greatest in those years when high river flows associated with flood events result in seasonal inundation of floodplains where adult splittail successfully spawn and eggs incubate. (Moyle, *et al.* 2004, Moyle 2002.) After hatching the larval splittail remain associated with inundated floodplain vegetation for a period of time before dispersing downstream and the floodplain inundation recedes. (Moyle, *et al.* 2004, Moyle 2002.) The SED Chapter 7 presents no analysis of the changes in water surface elevations that would occur at various locations within the tributaries or mainstem river associated with each of the proposed alternatives nor any assessment of the potential change in seasonal floodplain habitat inundation that may occur under the alternatives that would affect spawning habitat for splittail. The SED alternatives could have the potential to increase the seasonal inundation of floodplain habitat by higher winter releases or may result in a reduction in floodplain inundation as a result of reductions in reservoir carry over storage. Much of the San Joaquin River system is incised and has been channelized which may preclude floodplain inundation under the alternatives and therefore provide no biological benefit to splittail spawning. In the absence of such biologically based comparative analyses there is no technical basis presented in Chapter 7 to assess the potential for beneficial or adverse impacts of the alternatives on splittail. This is an example of the types of analyses that are missing throughout Chapter 7 of the SED.

f. Rainbow Trout

The SED describes rainbow trout as landlocked steelhead. (Draft SED, at p. 7-23.) While they are genetically identical to steelhead, rainbow trout are not always landlocked. Depending on stream conditions, steelhead trout may volitionally choose to not migrate to the ocean. As discussed above, the San Joaquin River tributaries support populations of resident trout. Resident trout inhabit the rivers throughout the year. As discussed above for steelhead, late spring,

summer, and fall flows and water temperatures are important in determining habitat quality and availability for resident trout. Detailed hydrologic simulations of monthly reservoir storage and coldwater pool volumes are needed for all 82 years of the modeling coupled with detailed (hourly or 6 hour time step) water temperature model results for a range of seasonal meteorological conditions and distances downstream of each dam for use as a technical basis for assessing the potential effects of each alternative on resident rainbow trout. These detailed analyses are not presented in Chapter 7 of the draft SED.

g. Indicator Species, Fall Run Chinook Salmon And Steelhead

The SED states that indicator species were selected for the environmental analysis because they meet one of the following criteria: (1) they are native species whose populations in California are declining and/or have received a special-status designation by federal or state resource agencies, or (2) they are recreationally important game fish species. (Draft SED, at p. 7—53.) Use of indicator or surrogate species in environmental analyses must be done with caution. Care must be exercised to assure that the surrogate species actually has the same or largely similar life history characteristics and habitat requirements as the target species. (Andelman and Fagan 2000; Dale, *et al.* 2004; Murphy, *et al.* 2011.)

The discussion of trends in salmon escapement presented on page 7-29 and Figure 7-1 in the draft SED are poorly documented. In discussing Figure 7-1 the assessment concluded that the highest returns occur after years of high spring flows, yet Figure 7-1 does not include any data on river flows. This same issue occurs on page 7-33 in reference to Figure 7-2. Similarly, the analysis of escapement on page 7-29 discusses adult returns in the 1970s, 1980, and 1990s but provides no discussion of adult returns between 1999 and 2012 despite the data being readily available in GRANTAB. The assessment also discusses results of juvenile monitoring in 1996-2005 but fails to discuss any more recent monitoring results. This also applies to the discussion on steelhead monitoring in 2006-2007 on page 7-29, but does not provide any reference of results of more recent monitoring despite steelhead being identified in the assessment as a key indicator species. Similarly, on page 7-32, the draft SED presents estimates of predation from PFMS in a 1999 report, but fails to discuss more recent efforts by AFRP and others to assess mortality on juvenile salmon from predation.

The SED states that LSJR flow alterations can potentially create an environment that is physiologically stressful to most organisms that utilize the Bay-Delta and X2, including Chinook salmon and Central Valley steelhead. (Draft SED, at p. 7-46.) In fact, neither salmon nor steelhead make use of the LSZ for either spawning or rearing.

The assessment also incorrectly identifies Sacramento pikeminnow as a nonnative predator, but the Sacramento pikeminnow is actually a native species. (Draft SED, at p. 7-32.)

h. Environmental Stressors

(i) Tuolumne River Gravel Augmentation

The discussion of the Tuolumne River starting on page 7-35 of the draft SED could be expanded to include more recent information on gravel augmentation, e.g., in Table 7-6, as well as activities associated with investigations on predation and interactions with gravel pits as well as other studies done in support of FERC hydroelectric relicensing and other programs.

(ii) Merced River Habitat Conditions

The discussion of habitat conditions on the Merced River at, page 7-39 of the draft SED is primarily based on information reported by Stillwater in 2002. There have been a number of activities since 2002 (see Stillwater 2002 for the Merced River corridor restoration plan) to start to improve habitat conditions that are not included in the assessment discussion. Similarly, the discussion of the hatchery on page 7-39 does not include any discussion of the current hatchery review process and development of a hatchery genetics management plan (HGMP); the hatchery management plans are being developed by CDFW for Central Valley salmonid hatcheries as part of a broader west coast review of hatchery management by state and federal resource agencies. The draft SED discusses diseases in the hatchery and wild populations based on studies conducted in 2000 and 2002, but does not mention the current disease investigations and assessments that have been conducted as part of the VAMP survival studies.

(iii) The Discussion Of Delta Inflows And Hydrodynamics Is Incomplete And Inaccurate

The discussion of Delta hydrodynamics on page 7-43 does not present any of the recent analyses of OMR and salvage, the USBR six-year steelhead survival studies, the 2012 Stipulation Study, results of VAMP, and a number of other relevant sources of information.

The Delta inflows and hydrodynamics discussion on page 7-43 focuses exclusively on project operations and entrainment. In addition, the discussion in Chapter 7 improperly attributes hydrodynamics in the Delta to CVP/SWP export operations with little or no discussion of the effects of other in Delta diversions, gate and barrier operations, and no mention of the impact of tides on hydrodynamics. (Draft SED, at p. 7-44.) This is an incomplete and inaccurate description of inflows and hydrodynamics.

(iv) Diversions And Entrainment

It is only an hypothesis that pumping may confuse outmigrating salmonids, but the draft SED presents it as if it is established fact. . (Draft SED, at p. 7-44.) There are no studies that have established this hypothesis. In fact, studies to date have shown that survival through Old and Middle River is not necessarily worse than survival on the mainstem of the San Joaquin River. (Buchanan, *et al.* 2013.) Results of juvenile Chinook salmon survival studies conducted in 2011 as part of VAMP using acoustic tags, for example, showed that the survival of juvenile salmon migrating from the lower San Joaquin River into Old River and subsequently to the export facilities was higher than comparative survival for those juvenile salmon that migrated downstream in the mainstem San Joaquin River. (Buchanan, *et al.* 2013.) Further, preliminary results of analysis of acoustic tag data for juvenile steelhead released and monitored as part of the 2012 Stipulation Study show that route selection and survival do not vary substantially in response to SWP and CVP export rates or OMR reverse flows; instead, – tidal currents appear to be a major factor affecting the migration behavior of juvenile salmonids within Delta channels. (Hanson 2012.)

This section improperly characterizes hydrodynamics as being exclusively driven by project operations without any mention of the tides, San Joaquin River flows, etc. , and there is no mention of in-Delta diversions and their adverse impacts on salmon survival in the southern Delta. The SED must be revised to take the most recent evidence into account, and to assess the impacts of all stressors on salmon survival in the southern Delta.

(v) Water Quality

The discussion of turbidity, delta smelt habitat and flow presented in Chapter 7 is based on several errors and omissions. The discussion of delta smelt habitat presented by Feyrer, *et al.* 2007 and Feyrer, *et al.* 2010 cited on page 7-45 has to do with the low salinity zone,- not the south Delta. What flow patterns does the State Board believe bring delta smelt into the south Delta? (Draft SED, at p. 7-45.) Chapter 7 presents no analysis or data on the area within the central and south Delta considered in the SED to be within the zone of the influence of the water projects. Similarly, Chapter 7 presents very little information on the salinity tolerance of various key fish species and lifestages considered in the analysis. In addition, the draft SED neither compares the ranges of salinities (monthly over the 82 years of simulation) that would occur under the various alternatives being analyzed, nor does it assess a certain salinity range that would cause physiological stress to any of the fish species in question. Thus, there is no basis to determine if the salinity ranges in the south Delta are a concern.

See discussion regarding existing environmental conditions for discussion of effects of agricultural discharges in Lower San Joaquin.

(vi) Predation

Predation mortality has been identified as a major source of mortality on juvenile salmonids migrating through the lower San Joaquin River and Delta at specific locations such as the Head of Old River (Bowen, *et al.* 2009, Bowen and Bark 2010) and with Clifton Court Forebay (Gingras and McGee 1997, Clark, *et al.* 2009) and elsewhere (SJRGA 2010). Predation is a significant concern throughout the Delta. See discussion above regarding the role of predation on juvenile Chinook salmon mortality in the lower river and Delta. Recent studies have also demonstrated the significance of predation by fish such as striped bass on mortality of juvenile Chinook salmon further upstream in the tributary rivers as well.

5. The Draft SED Fails To Analyze The Full Range Of Stressors On Sensitive Native Fish Species In The Southern Delta And Lower San Joaquin River

To cite but one example of Chapter 7's failure to analyze the full range of stressors in the southern Delta, there is no discussion of the effects of the introduced Asian clam and nutrients on the food web and the food resources on pelagic species in Chapter 7. In the absence of a discussion and consideration of the importance and role of other stressors on the fish species of interest, an inappropriate conclusion can be drawn from the draft SED that by simply providing greater seasonal flows under one or more of the alternatives, the biological objective of increased salmonid abundance and population viability will be achieved. In reality, flow alone is not going to accomplish the biological goal of salmonid restoration or recovery. As reflected in the 2006 escapement data and 2006 VAMP survival study, providing higher flows does not assure higher juvenile survival or greater adult abundance. (SJRGA 2007.) Other factors such as predation, food availability, and ocean conditions are important in determining salmonid population dynamics that are largely independent of river flow.

6. Impact Analysis

a. There Is No Scientific Evidence Presented In The Draft SED Or Appendices To Support The Assumption That 60%, 40% Or 20% Of Unimpaired Flows Will Support The Biological Functions Necessary To Support Viable Fish Populations

The staff justification cites pieces of information that sound relevant, but they make no attempt to integrate that information into a quantitative forecast of benefits to be gained by implementing their objective. The functional mechanisms that lead to increased salmon production need to be identified and quantified and linked to flow rates, or else there is no basis for selecting any of the flow alternatives. Independent reviewers of the Joint Stipulation similarly found fault with NMFS that functional relationships to quantify how fish were expected to respond to mandated water operations were lacking, and that lack of linkage led to a flawed adaptive management experiment. (Delta Stewardship Council 2012 available at http://deltacouncil.ca.gov/sites/default/files/documents/files/secure/LOOAR_2012/rev_mat/LOOAR_2012_rev_2012_10_01_Joint_Stip_report_FINAL.pdf.) No scientific evidence is presented to substantiate that providing flows at 60%, 40% or 20% of unimpaired flows will support the biological functions necessary to support viable fish populations. There is no evaluation of how alterations to the present system, including channelization, loss of floodplain, loss of tidal wetlands, and other dramatic changes in pre-development natural hydrologic and ecological conditions will alter how native fish respond to the flow regime. Key alterations that may influence salmon response to flow are invasive species (particularly predators) and channelization.

b. The Thresholds Of Significance Lack the Support of Substantial Evidence in the Record

The impact assessment repeatedly applies a threshold of significance indicating that the change in occurrence of an aquatic impact criterion needs to be at least 10% greater than the baseline to represent a significant adverse impact. (E.g. Draft SED, at pp. 7-3 and 7-4.) However there is no discussion or rationale presented in Chapter 7 to support the 10% threshold of significance used in these analyses. In other Central Valley environmental documents, a difference of 5% has been used for purposes of impact analysis based on the variance (noise) expected in simulation model results to distinguish a real predicted change in a given metric from the baseline. (For example, the BDCP Effects Analysis applied a 5% significance threshold reflecting the inherent errors and uncertainties in simulation model results.) By selecting a 10% threshold of significance, the assessment in Chapter 7 may underestimate impacts that would have been detected using the 5% threshold of significance. An increase in salmonid egg or juvenile mortality of 5% can be biologically significant. The assessment needs to provide technical support and transparency regarding how the 10% threshold was established, and it must justify departing from the 5% threshold that is used in other EIR analyses of impacts to sensitive aquatic resources in the Delta. In the absence of a meaningful discussion and technical foundation for this fundamental element of the assessment methodology the threshold criteria appears to be arbitrary.

c. AQUA-1: Changes In Availability Of Warm Water Species Reservoir Habitat Resulting From Changes In Reservoir Levels

The assessment applies a number of questionable and unsupported criteria for assessing potential impacts to various target fish species. For example, the assessment of fluctuations in

water surface elevation in the reservoirs on spawning success of largemouth bass is based on a decrease in surface elevation of 15 feet in a month. (See, e.g. Draft SED, at p. 7-60.) The rationale presented in the assessment is weak and poorly supported by any technical analysis of appropriate criteria for use in assessing the effects of decreased water surface elevation on spawning. Habitat suitability as a function of water depth is well known for largemouth bass spawning. The criteria used in the assessment conclude that there would be no adverse impact on spawning when reservoir elevation decreases by less than 15 feet. Habitat suitability, however, indicates that many largemouth bass spawn in water that is 4 feet in depth or less. (Stuber, *et al.* 1982.) If, in this example, if a bass nest is in 4 feet of water and the reservoir level decreases by 10 feet before the eggs have hatched and the fry have left the nest, the nest would have been completely dewatered and the reproduction lost. But the 15-foot threshold of significance used in the assessment would imply that there was no significant adverse impact to bass. In order to be meaningful, the thresholds of significance need to be sensitive to the species habitat requirements and habitat preferences. There are a number of Central Valley environmental documents that present criteria and rationale for assessing impacts on largemouth bass spawning resulting from reservoir levels decreasing during the spring that can serve as a much better model than that presented in Chapter 7.

d. AQUA-2: Changes In Availability Of Coldwater Species Reservoir Habitat Resulting From Changes In Reservoir Storage

Changes in reservoir elevation can also result in passage barriers to the upstream migration of coldwater species inhabiting the reservoir and block access to spawning habitat which was not addressed or discussed in the assessment. (Draft SED, at p. 7-63.) As in the flow analysis, the evaluation of changes in reservoir elevation should be done for every year in the 82 year simulation period by month to assess habitat changes under various hydrologic and release regimes.

The discussion of changes in coldwater pool habitat at page 7-64 is based on end of September elevation. But a more robust analysis would be based on monthly changes in hypolimnion volume for each reservoir. In addition, changes in hypolimnion volume by month would also be needed to include reservoir coldwater pool volume in the water temperature modeling for downstream conditions.

e. AQUA- 3: Changes In Quantity/Quality Of Spawning, Rearing, And Migration Habitat Resulting From Changes In Flow

The current approach in Chapter 7 is oversimplified and provides a fundamentally misleading and incorrect analysis of alternatives and habitat conditions for the target salmonid species.

The assessment assumes that an increase in flow in a given month represents an improvement in habitat conditions for salmonids. As discussed above, the use of previous flow-survival relationships is questionable as a technical basis to assume, as was done in Chapter 7, that an increase in flow results in an increase in survival or abundance of salmonids. Further, the assessment relies on an evaluation of changes in wetted area as an assessment criterion. (Draft SED, at p. 7-58.) The assessment assumes that an increase in wetted area represents an improvement in habitat conditions for Chinook salmon and steelhead. There is no technical basis to support this assumption. Habitat suitability for various lifestages of Chinook salmon and

steelhead is determined by parameters such as water depth, velocity, substrate, and cover, – not simply wetted area. Depending on the geometry of a given channel an increase in flow in a very wide and flat channel would increase the wetted area to a large extent but the depth and velocity of the wetted channel margin would not be suitable for salmonids (e.g., the wetted area may only be several inches deep) while in a confined channel a change in flow would not result in a change in wetted area but may result in an increase in depth or velocity that no longer provides suitable habitat for a given lifestage of fish. These differences are not be accounted for in the current analysis presented in Chapter 7. As an alternative approach, changes in suitable habitat for salmonids is typically based on changes in weighted usable area (WUA) based on habitat suitability curves as is done in IFIM analyses.

f. AQUA-4: Changes In Exposure Of Fish To Stressful Water Temperatures From Changes In Reservoir Storage And Releases

A water temperature threshold for the incipient lethal temperature for juvenile steelhead rearing of 84 F is used in the assessment. (Draft SED, at p. 7-89.) There is no discussion of the source of information used in developing that incipient lethal threshold criterion. The typical incipient lethal temperature threshold used for juvenile steelhead is 26 C or 78.8 F. (Myrick and Cech undated.) Water temperature, especially during the summer rearing period for juvenile steelhead, is a major limiting factor in many Central Valley rivers, and using a higher temperature threshold, as was done in the assessment in Chapter 7 results in underestimating adverse impacts to a listed species. This analysis needs to be supported by scientific data and significance criteria that provide an objective and transparent technical analysis of potential effects to juvenile steelhead. The analysis also needs to address the temperature tolerance of juvenile fall-run Chinook salmon that may be oversummering in the rivers as discussed on page 7-33 and elsewhere in Chapter 7.

Currently, there is no discussion or analysis presented on summer water temperatures for rearing juvenile fall-run Chinook salmon in the assessment.

The water temperature modeling is important in evaluating potential effects associated with the various flow alternatives. It was not clear from Chapter 7 exactly how the temperature modeling was performed. There was discussion of using a 6-hour time step temperature model but then it appears that a daily average model was actually used in the analysis. How the maximum daily temperatures were derived, a critical step in the biological assessment, was not described. The calibration and validation of the temperature model was not described or presented as a graph and statistical comparison of actual versus predicted temperatures over a range of flow and seasonal conditions. Therefore, there is no information presented that can be used to assess the accuracy of the water temperature model at various locations and seasons. Similarly, there was no discussion regarding the basis for selecting the water temperature model applied in this assessment. Additionally, it was not clear how the water temperature model accounted for seasonal changes in cold water pool volume in each reservoir through each of the years, including carryover storage etc., in developing meaningful predictions of summer and early fall temperatures for use in the assessment. There also needs to be a specific analysis of the ability to meet suitable water temperature conditions in October for fall-run salmon egg incubation (typically less than 56 F) as part of the assessment of changes among alternatives.

This information was not disclosed in the assessment in a way that could be used to evaluate the effects on reproductive success of fall-run that spawn in October. The draft SED

must be revised to include this information to ensure that its analysis of temperature impacts is supported by substantial evidence in the record.

g. AQUA-5: Changes In Exposure To Pollutants Resulting From Changes In Flow (Dilution/Mobilization Effects)

The draft SED's analysis of exposure to pollutants is inadequate and does not support a conclusion that water quality will be significantly changed.

While the SED concludes that the lower flows of LSJR Alternative 2 would result in a significant impact to water quality for juvenile salmonids and other fish species, there is insufficient evidence provided to support this conclusion. In fact, the introductory text to AQUA-5 indicates that increased flows may be as likely to increase as to decrease pollutant concentrations.

> Increased flows would have the potential to *increase mobilization and concentration of pollutants* in surface waters in the tributaries and LSJR, potentially increasing exposure of aquatic organisms to toxic substances... However, increased flows would also provide benefits to indicator species by *diluting existing pollutants* in the water column, and any other pollutants that may be mobilized from the sediment on the bottom of the riverbed and along the river channel.

(Draft SED, at p. 7-101, italics added.) There is no data provided on existing pollutants levels in the water column versus in sediments on which to draw any conclusion regarding whether increased flow would have a positive or negative effect on water quality.

The analysis also claims "[d]ecreased flows could also result in increased temperatures, which generally increase the toxic effects of metals and reduce the survival time of Chinook salmon if lethal levels of metals are present." (Draft SED, at p. 7-101.) No citation is provided to support this statement. While increased temperature may increase toxic effects of metals, the opposite is true for pyrethroids. Increased temperatures decrease the toxicity of pyrethroids (Phillips et al 2004; Anderson et al 2006. [18])) Since no data is presented on actual pollutants present, there is no way to determine whether changes in temperature will have a positive or negative effect on pollutant toxicity.

h. AQUA-6: Changes In Exposure To Suspended Sediment And Turbidity Resulting From Changes In Flow (Mobilization)

Chinook salmon and steelhead evolved under natural conditions in which rainfall and stormwater runoff across a watershed resulted in a coincident increase in instream flows and an increase in river turbidity. (Moyle 2002.) Sediments from the watershed were washed by the runoff into the streams and river, primarily during later winter and spring storms. Results of fishery monitoring continue to show that pulse flows coincident with increased turbidity provide an environmental cue that stimulates downstream migration by juvenile salmon and steelhead.

[18] Anderson BS, Phillips BM, Hunt JW, Worcester K, Adams M, Kapellas N, Tjeerdema RS. 2006. Evidence of pesticide impacts in the Santa Maria River watershed, California, USA. Environ Toxicol Chem 25:1160–1170.

Phillips BM, Anderson BS, Hunt JW, Nicely PA, Kosaka RA, Tjeerdema RS, deVlaming V, Richard N. 2004. In situ water and sediment toxicity in an agricultural watershed. Environ Toxicol Chem 23:435–442.

(NMFS 2009.) Operation of upstream dams and reservoirs, however, change the dynamic interaction between storm flows and turbidity. The reservoirs trap inflows from the watershed and the residence times of water within a reservoir allow fine sediments to drop out of suspension resulting in a reduction in turbidity. As a result, releases of freshwater from a reservoir may be able to mimic the accretion and recession patterns of a storm event but are de-coupled from the natural turbidity signal that is also thought to be important in the biological response of juvenile salmonids to a flow release. There have been a number of studies conducted on Central Valley rivers in which pulse flow events have been provided by reservoir releases during the spring that did not result in a corresponding cue for downstream migration as reflected in results of fishery monitoring. (EBMUD unpublished data.) With increased channelization, levee stabilization, channel bed armoring, and reductions in peak flows by reservoir operations, sediment mobilization from the watershed limited to areas downstream of the dam typically do not provide strong turbidity cue when driven by reservoir releases. Thus, simply providing increased flows through reservoir releases will not assure that the function relationships and mechanisms important to the life history of salmonids will be re-established.

i. AQUA-7: The Analysis Of Changes In Redd Dewatering And Fish Stranding Losses Resulting From Flow Fluctuations Is Inadequate Because It Is Based On Median Monthly Flow

The hydrologic analyses presented in Chapter 7 were based on monthly average conditions and the statistical median monthly flows estimated by the model. (Draft SED, at p. 7-108.) This analysis is largely insensitive to the actual conditions that would result in redd dewatering and juvenile stranding. Rather than using a comparison of median monthly flow that can obscure meaningful changes in flows that occur in specific months under specific hydrologic conditions, a comparison of flows each month over the 82 year period of modeling would be more appropriate for assessing the potential for redd dewatering. Criteria for the magnitude of flow fluctuations that would result in a change in water surface elevation from one month to the next during the egg incubation period is the typical approach used in these types of analyses. Ramping rates and a maximum change in flow (surface elevation) are also typically prescribed at mitigation and avoidance measures. Further, juvenile stranding frequently results from short-duration flow fluctuations such as associated with storms or changes in dam operations that may occur over a period of hours or days. The analyses presented in the SED cannot detect these short-duration type of events (Draft SED, at pp. 1-108 – 1-112.) As discussed above, specific ramping rate criteria are typically used to avoid the risk of juvenile stranding as part of a CEQA analysis.

j. AQUA-8: The Analysis Of Changes In Spawning Habitat Quality (Spawning Gravel) Resulting From Changes In Peak Flows Is Not Supported By Substantial Evidence

Typically information on the grade of a river, channel width, velocities, and characteristics of the substrate are used in hydraulic models to estimate the river flow rate that would mobilize gravel movement and bed load transport. That flow would then be used to estimate whether the managed flows under each alternative would be sufficiently high to result in gravel movement. No analyses of this type were presented in Chapter 7 of the SED for use as a technical basis for assessing effects of flow management on spawning gravels in the upstream reaches of each tributary river. (Draft SED, at pp. 7-112 – 7-113.) Thus, the conclusions regarding effects of the LSJR flow alternatives on spawning habitat quality are not supported by substantial evidence.

k. AQUA-9: The Analysis Of Changes In Food Availability Resulting From Changes In Flow, Nutrient Transport, And Water Quality (Food Web Support) Lacks The Support Of Substantial Evidence

The draft SED provides only a generalized qualitative discussion of potential changes in nutrients and food supplies in response to the various alternatives. (Draft SED, at pp. 7-113 – 7-114.) Data similar to that described above for the IFIM analyses can be used to help provide additional information on potential changes in instream habitat conditions that would affect macroinvertebrate production and food supplies for juvenile salmon and other fish. (Gard 2006.) As noted above, if food production downstream of the dam in a limited reach of the river where water temperatures are suitable is insufficient to provide adequate flood resources, then carrying capacity will be limited and the survival and abundance of fish will not respond to changes in flow alone as predicted. Also, as seasonal water temperatures increase, for example in response to reduced coldwater pool reserves, the metabolic rate of juvenile oversummering steelhead will increase and their growth and survival will decrease if there is not adequate food production in the area of the river they inhabit. The SED provides very little discussion or disclosure of the importance of flood production in supporting juvenile rearing habitat and how variation in seasonal flows under the alternatives can affect these relationships.

Moreover, the SED states that, "[t]he primary processes that alter food web support include magnitude and frequency of bed mobilizing flows and floodplain inundating flows." (Draft SED, at p. 113.) Changes in residence time and nutrient loads and concentrations are also key determinants of productivity and food availability. Neither of these is analyzed in the draft SED. Increased flows generally decrease residence time which can increase or decrease primary production depending on numerous factors. (Lucas et al 2009. [19])

Changes in nutrient loads, forms, and concentrations also impacts food availability and quality in complex ways. (Glibert et al 2011.[20]) However, the draft SED lacks any analysis of how any of the alternatives might change nutrient loads, forms, or concentrations and how those changes might impact food availability.

The introductory comments to this section are misleading. The SED states, "[i]n general, increased spring flows were assumed to create and improve aquatic and riparian habitat, increase aquatic production, and nutrient input from terrestrial sources." (Draft SED, at p. 7-114.) This section should acknowledge what is described in the individual alternative analyses that increased flows only provide these functions if they are allowed to spill out of riprap lined channels and reconnect with the adjoining land, or if they are of sufficient magnitude to mobilize bed sediments.

Until these deficiencies are remedied, the analysis of AQUA-9 lacks the support of substantial evidence.

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[19] Lucas, L.V., J.K. Thompson, and L.R. Brown. 2009. Why are diverse relationships observed between phytoplankton biomass and transport time? Limnol. Oceanogr., 54(1): 381–390.

[20] Glibert, P.M., D. Fullerton, J.M. Burkholder, J.C. Cornwell, and T.M. Kana. 2011. Ecological stoichiometry, biogeochemical cycling, invasive species, and aquatic food webs: San Francisco Estuary and comparative systems. Reviews in Fisheries Science, 19(4):1-60.

l. AQUA-10: The Analysis Of Changes In Predation Risk Resulting From Changes In Flow And Water Temperature Lacks The Support Of Substantial Evidence

It has been hypothesized that increased flow during the late winter and spring migration period for juvenile salmonids contributes to a reduction in the risk of predation mortality and increased juvenile survival. (Stillwater 2003, NMFS 2009.) The potential mechanisms underlying this hypothesis, however, have not been tested. Studies on the migration timing of juvenile salmonids have shown evidence of increased migration coincident with increased instream flow and increased turbidity associated with storm events. (Stillwater 2003, NMFS 2009.) A reduction in predation mortality may therefore not be the direct result of increased flow but rather the associated effects on increased turbidity that makes detection of a juvenile salmon by predators more difficult and/or a reduction in water temperatures that reduces the metabolic rate and prey consumption rates of the predators as well as reducing potential thermal stress on the prey and thereby increasing their ability to avoid predators. It can also be hypothesized that increased flow results in increased water depths and velocities that reduce habitat suitability for predatory fish and thereby reduce predator densities and the associated risk of predation mortality.

No studies or data have been developed to support the hypothesis regarding the effects of increased flow on predator habitat and densities in the San Joaquin River basin or Delta. Predatory fish such as striped bass are able to inhabit a wide range of riverine and tidal areas and there is no evidence that increased flows within the range that would be managed on the San Joaquin River system would reduce striped bass densities or the densities of other predatory fish such as largemouth bass that use physical structures as a refuge from increased flows and velocities. Studies are currently being conducted to further evaluate the potential mechanisms that affect the risk of predation. (Cavallo, *et al.* 2012.)

Predation mortality has been identified as a major factor affecting the survival of juvenile salmonids in Central Valley rivers and the Delta. (Cavallo, *et al.* 2012, SJRGA 2010, Buchanan, *et al.* 2013.) However, Chapter 7 is devoid of any analysis that could show a relationship between river flow and predation rates. (Draft SED, at pp. 7-114 – 7-117.) In fact, using either coded wire tags or acoustic tag technologies it is extremely difficult to determine when and where predation mortality has occurred (e.g., if an acoustically tagged juvenile salmonid is preyed on the tag continues to send out a signal while in the stomach and digestive track of the predator, it is very difficult to determine that a predation event has occurred). There is currently no data or analysis that would support predictions of an incremental change in predation mortality as a function of flow within the range of alternatives considered in the draft SED. The draft SED's discussion seems to be founded on the unproven assumption that simply providing more flow will result in a reduction in predation mortality for migrating juvenile salmonids.

In fact, the most relevant studies on predation undermine the SED's assumption that higher flow will translate into lower predation. The results of the 2006 VAMP survival study found that juvenile salmon survival in the lower San Joaquin River and Delta was low (2-9% based on Chipps Island recoveries) presumably as a result of high predation rates, despite having high flows at Vernalis during the spring migration period (average Vernalis flow in May 2006 exceeded 26,000 cfs). (SJRGA 2007.) There is no technical analysis or basis presented to support a finding that one or more of the flow alternatives considered in the SED would result in a predictable reduction in predation mortality for juvenile salmonids migrating within the lower San Joaquin River and

Delta. In the absence of a credible technical analysis no conclusion can be drawn regarding the potential relationship between flow and predation in Chapter 7 of the SED.

m. AQUA-11: The Analysis Of Changes In Disease Risk Resulting From Changes In Flow, Water Temperature, And Water Quality Lacks The Support Of Substantial Evidence

The draft SED provides no information or analysis of the potential effects of the alternatives on the risk of disease on the health and survival of salmon, steelhead, and other fish. (Draft SED, at pp. 7-117 – 7-121.) Although the risk assessment would need to be largely qualitative, information on changes in seasonal water temperatures from the detailed temperature analysis discussed above would be an important element in this analysis. As discussed above, detailed comparative analyses of changes in seasonal water temperatures, by month over the 82 year period, by location are not presented in Chapter 7. Without this detailed analysis, the SED's conclusions about disease risk lack the required support of substantial evidence in the record.

n. AQUA-12: The Analysis Of Changes In Fish Transport Resulting From Changes In Flow Is Based On Unsupported Hypotheses

As discussed above, it can be hypothesized that changes in seasonal flows during the juvenile salmonid migration period could potentially result in changes in migration rates and route selection that can influence the risk of predation, entrainment, and other sources of mortality. But it is unknown whether juvenile salmon migrate through the lower river and Delta faster (shorter period of time) when river flows are greater. There is a body of data collected as part of VAMP, (including pre-VAMP), the 2012 Stipulation Study, the USBR Six-year study, and other investigations that can be used to directly test and evaluate this hypothesis as part the SED analysis. (Hanson 2012.) These types of analyses, however, were not done or presented in Chapter 7 of the SED. Thus, the analysis of changes in fish transport lacks the support of substantial evidence.

o. AQUA-13: The Analysis Of Changes In Southern Delta And Estuarine Habitat Resulting From Changes In SJR Inflows And Export Effects Should Be Supplemented With Delta Passage Modeling Results

The influence of San Joaquin River flows on hydrodynamics and habitat conditions diminished substantially with distance downstream into the tidally dominated Delta channels. (DWR DMS2 unpublished data.) Results of salinity simulation model analyses and hydrodynamic modeling (e.g., DSM2 estimates of water velocities and direction) can be used to develop comparisons of key metrics as indicators of habitat change at various locations within the Delta as a function of the proposed alternative flow scenarios. Application of routing models such as the Delta Passage Model ("DPM") have the ability to model comparative migration by juvenile salmon through the Delta in response to changes in hydrodynamics associated with river flows, expert's, etc. (Cavallo, *et al.* 2011.) These types of comparative analyses could be done to help inform decisions regarding the potential effects of various alternative instream flow schedules and operations. However, it appears that no such studies have been performed or used as part of the technical and analytic framework for assessing fishery effects of alternatives considered in Chapter 7 of the draft SED. (Draft SED, at pp. 7-123 – 7-125.)

7. The Discussion Of Mitigation By Way Of Adaptive Management Lacks The Support Of Substantial Evidence

Chapter 7 frequently describes mitigation for adverse impacts on flows during the February-June period by relying on adaptive management assuming that if the total volume of water released was the same and therefore impacts could be mitigated by re-allocation of releases among months. (Draft SED, at pp. 7-67, 7-76, 7-111.) There is no discussion in Chapter 7, however, of how this would actually occur. There is no discussion of how hydrologic uncertainty over the period would be addressed and assumed that perfect knowledge of hydrology for the entire February-June period is known. If this is in fact a mitigation strategy Chapter 7 needs to have a more robust and technically sound discussion of how this would be applied on each of the contributing tributaries. There also needs to be a discussion of other regulatory issues such as meeting flood control requirements, FERC requirements, other agreements and commitments, coordination among reservoirs and allocation of contributions to meeting flow conditions, etc. as part of the discussion of adaptive management. The current discussion of adaptive management presented in Chapter 7 is overly simplistic and inadequate to assess whether or not this is a feasible method to mitigate and avoid adverse impacts in flow allocation among months.

G. Specific Comments Regarding Chapter 8— Terrestrial Biological Resources

Page 8-2, Section 8.1, Table 8-1, BIO-1, LSJR Alternative 1: Impacts of LSJR Alternative 1 and SDWQ Alternative 1 (the No Project Alternative) are not presented in this table. The reviewer is instead referred to Chapter 15 for an analysis of the No Project Alternative. This is inconvenient, and the rationale for separating out the analysis of the No Project Alternative into a separate chapter is not provided. This makes it more difficult for the reviewer to make side-by-side comparisons of the alternatives in this table.

Page 8-13, Section 8.2.2: The text at the bottom of the second paragraph introduces the discussion of vegetation, wildlife, and special-status species that are specific to the area of potential effects for the SDWQ alternatives that follows. This however seems to contradict the statement made on page 8-1 (last two sentences on the page) that state that: "*The SDWQ alternatives are not expected to result in significant adverse modifications to the existing terrestrial habitat or result in impacts on plant and animal species. Therefore, the SDWQ alternatives are not analyzed in detail in this chapter.*"

Page 8-23, Section 8.4.2, last bullet on the page: "…the lowest monthly flows on the Stanislaus would be eliminated under SLFR Alternatives 2, 3 and 4.": Additional explanation of why the lowest monthly flows would be eliminated is needed. This is also true on the next page for the bullets concerning the Merced and Tuolumne, and the LSJR.

Page 8-24, Section 8.4.2: The first full paragraph of text indicates that the effect of LSJR Alternatives 3 and 4 on the terrestrial system below Vernalis would be largely immeasurable. More explanation is needed here. Does immeasurable mean indistinguishable from existing conditions? Does it mean no effect?

Page 8-25, Section 8.4.2, the text that refers to Tables 8-6a-c: "*For the purpose of relative comparison, the tables summarize the percent of time the reservoirs would fluctuate greater than 10 feet*." This statement would be clearer if illustrated with an example.

Page 8-25, Section 8.4.2, second paragraph: While direct and indirect impacts are defined, the analysis that follows does not typically distinguish between direct and indirect impacts. Further distinctions between impacts that are direct and indirect could be added.

Page 8-28, Section 8.4.3, BIO-1, middle of third paragraph: "*This periodic inundation could create conditions suitable for dispersal and establishment of riparian plants through sediment deposition, water transport of plant seeds and fragments to new locations, increased water availability, and reduced competition from upland plant species (e.g., nonnative grasses) that are intolerant of prolonged submergence*." This statement should be modified to acknowledge that the periodic inundation may also increase competition from some invasive nonnative plants that are relatively tolerant of prolonged submergence, including Himalaya blackberry and giant reed.

General comment for the impact analysis: Subheadings should be added to guide the reviewer through the text. For example, under the description of LSJR Alternative 2 on pages 8-29-31, headings for the Stanislaus River, Tuolumne River, Merced River, Reservoirs and Salinity text should be added to distinguish one area of focus from another.

General comment: Beneficial effects of the alternatives receive inconsistent treatment in this chapter. Beneficial effects are described in some instances (at the bottom of page 8-33 where the benefits of greater water availability to support riparian growth are mentioned) while little mention of beneficial effects are described elsewhere.

Page 8-37, Section 8.4.3, BIO-4, LSJR Alternative 2, first paragraph: The analysis concludes that there would be a significant impact on special-status animal species resulting from the loss of riparian vegetation on the Stanislaus River. If true, this statement should be supported by a full description of the impacts on each affected special-status species.

Page 8-39, Section 8.4.3, BIO-4, LSJR Alternatives 3 and 4: The conclusion in the first paragraph that the impacts would be similar to those identified for LSJR Alternative 2 merits some explanation.

H. Specific Comments Regarding Chapter 9 – Groundwater Resources

1. The Impact Analysis For Groundwater Resources Is Legally Inadequate Because It Fails To Use Existing Models Of Groundwater Basins In The Plan Area To Estimate The Impacts Of LSJR Alternatives On Groundwater

"The purpose of an environmental impact report [and, by extension, a SED] is to provide public agencies and the public in general with detailed information about the effect which a proposed project is likely to have on the environment; to list ways in which the significant effects of such a project might be minimized; and to indicate alternatives to such a project." (Pub. Resources Code, § 21061.) When assessing impacts, "an agency must use its best efforts to find out and disclose all that it reasonably can." (Cal. Code Regs., tit. 14, § 15144.)

The analysis of impacts on groundwater resources is limited to identifying whether or not groundwater pumping may increase by more than five percent. (Draft SED, at p. 9-2, Table 9-1; 9-21.) There are groundwater models available for the Turlock Basin, the Modesto Basin and the Eastern San Joaquin Basin, as well as regional groundwater models for the Central Valley. These existing models should have been used to quantify the impacts on groundwater resources.

Instead, the SED purports to use conservative assumptions, and uses the results from the WSE and assumed baseline groundwater pumping rates. (Draft SED, at pp. 9-21 – 9-23.) Ultimately, the SED performs a qualitative analysis of the potentially significant effects of groundwater pumping.

The State Board should use the existing groundwater models, and make a reasonable good-faith effort to disclose the impacts on groundwater basins in the plan area instead of basing its analysis on purportedly conservative assumptions.

2. The Impact Analysis Fails To Evaluate Reasonably Foreseeable Indirect Impacts From Increased Reliance On Groundwater

Impacts on groundwater resources could have the effect of lowering groundwater levels basin-wide, which could result in impacts such as reduced accretions to rivers (for gaining rivers, e.g., Tuolumne River), increased seepage from rivers, subsidence, as well as the air emissions from increased groundwater pumping lifts and increased energy use. In addition, as reliance on groundwater increases, this may impact the salinity and total dissolved solids in the groundwater applied to crops, which can cause increased salinity in irrigation discharges to the LSJR and its tributaries. These reasonably foreseeable indirect impacts should be analyzed with available groundwater models, as noted above.

3. The Impact Analysis Fails To Evaluate The Impacts On Groundwater In A Range Of Water Year Types For The San Joaquin Valley

The SED fails to evaluate the impacts of the various LSJR alternatives on a number of resources, including groundwater, under the standard San Joaquin Valley Water Year Hydrologic Classifications (wet, above normal, below normal, dry and critical). This is crucial because the same percentage increase in reliance on groundwater in a critical year may be significant, whereas the same percentage increase in a wet or above normal year may not. Thus, the Impact Analysis should be performed using existing models of groundwater basins for the standard range of water year types.

4. The Conclusion That The State Board Lacks The Funding Needed To Exercise Its Legal Authority To Regulate Groundwater Extractions Is Not Supported By Substantial Evidence

The SED states that the State Board has the legal authority to mitigate otherwise significant impacts on groundwater resources resulting from LSJR Alternatives 3-4, as well as the Preferred LSJR Alternative. (Draft SED, at pp. 9-27 – 9-27; 20-21.) But the SED concludes that neither approach is economically feasible due to unspecified budgetary constraints. There is no substantial evidence in the record to support this assertion. Thus, the SED is vulnerable to legal challenge under CEQA. (*County of San Diego v. Grossmont-Cuyamaca Community College Dist.* (2006) 141 Cal.App.4th 86, 108 [where the record contained no estimate of the lead agency's cost to mitigate traffic impacts, conclusion that mitigation was economically infeasible lacked the required support of substantial evidence].)

The SED should either supplement these conclusions with the required evidence, or the State Board should commit to implementing all feasible mitigation within its legal authority.

I. Specific Comments Regarding Chapter 10 – Recreational Resources And Visual Quality

1. The Analysis Of Reservoir Water Levels Is Based On Flawed Or Unrealistic Assumptions, That Undermine The Impact Analysis For Recreational Resources That Are Sensitive To Water Levels In Reservoirs

In Appendix F.1, the SED discloses that the "rule curves" for modeling and establishing downstream flow targets for the LSJR flow objectives were formulated using an unrealistic assumption that diversion dams on the three eastside tributaries are operated based on storage levels at the end of January of each water year. (Draft SED, App. F.1 at pp. F.1-20.)

Diversion dams are currently operated by determining the reservoir storage and snowpack prior to the beginning of the growing season, not at the end of January. However, the modeling used to estimate the impacts of the LSJR assumes that the dams will be operated to deliver water based on storage levels at the end of January of each year. (*Ibid*.) This methodology results in unrealistic modeling that undermines the analysis of impacts on a host of resources, including recreational resources that depend on water levels in the reservoirs on the three eastside tributaries.

2. The Impact Analysis Discloses That The LSJR Alternative Selected To Support And Maintain The Natural Production Of Viable Native Migratory Fish Populations Lacks Any Evidentiary Basis

The SED lacks any substantial evidence that the salmonid population viability factors (e.g., abundance, spatial extent or distribution, genetic and life history diversity, migratory pathways, and productivity) can be achieved by providing flows that approximate a percentage of unimpaired flow.

In Chapter 10, the draft SED frankly acknowledges that "increased flows may improve conditions for fish. (Draft SED, at p. 10-26, emphasis added.) But "[i]t is unknown whether any increase in fish populations would be large enough to measurably enhance sport fishing opportunities, but some beneficial impact is anticipated." (Draft SED, at p. 10-26.) For LSJR Alternative 3, the SED states "increased flows [to 40% of unimpaired flow] *may* enhance fishing opportunities . . ." (Draft SED, at p. 10-28, emphasis added.) But it concludes that LSJR Alternative will not affect water-dependent recreational opportunities, including sport fishing, at all. (*Ibid*.)

These statements highlight the fact that the fundamental objective of the LSJR flow objective alternatives lacks the support of substantial evidence.

J. Specific Comments Regarding Chapter 11 – Agricultural Resources

1. The Description Of The Environmental Setting Lacks Adequate Discussion Of Water Rights Or Factors Contributing To Salinity Loadings In The Southern Delta

The draft SED's description of the environmental setting in the Southern Delta with respect to agricultural resources contains several flaws. First, the draft SED states that "[w]ater users in the SDWA claim riparian or appropriative rights that allow for direct diversion of surface water

from Delta waterways onto farmland." (Draft SED, at p. 11-12.) However, the draft SED does not provide any further discussion of the nature or scope of the claimed water rights within the SDWA or whether water users within the SDWA are diverting water under valid water rights. The draft SED seems to assume that these claimed rights actually "allow for direction diversion of surface water" however that assumption is unsubstantiated, and, as the discussion above concerning the draft amendments indicates, is unlawful. The draft SED should be revised to make it clear that the nature and scope of valid water rights in the Southern Delta has not been determined and that it is possible that some of the agricultural diversions in the Southern Delta are illegal.

The second flaw in the description of the Southern Delta's environmental setting is the draft SED's failure to acknowledge the various factors that affect salinity in the southern Delta. The draft SED states that "salinity in the southern Delta is strongly influenced by the concentrations at Vernalis." (Draft SED, at p. 11-12.) This bare assertion, without a discussion of the other factors that influence salinity in the southern Delta, creates an imbalanced and inaccurate description of salinity in the southern Delta. As acknowledged elsewhere in the draft SED, there are numerous factors that influence salinity in the Southern Delta, including:

> low flows; salts imported to the SJR Basin in irrigation water; municipal discharges; subsurface accretions from groundwater; tidal actions; diversions of water by the CVP, SWP, and local water users; channel capacity; and discharges from land-derived salts, primarily from agricultural drainage. Salinity in the southern Delta is also affected by evapo--concentration of salts due to local agricultural operations, and to a lesser extent, by local municipal wastewater treatment plant discharges. Poor flow or circulation patterns in the southern Delta waterways also cause localized increases in salinity concentrations.

(Draft SED, at p. 1-7.) The draft SED's description of water quality in the southern Delta (p. 11-12) should be expanded to identify these additional factors that affect salinity in the southern Delta.

2. Regulatory Setting

The draft SED states that the "[r]elevant state programs, policies, plans, or regulations related to agricultural resources are described in [section 11.3]." (Draft SED, at p. 11-13.) However, there are state programs and policies in addition to those listed in section 11.3 that relate to agricultural resources in the plan area. For example, the Central Valley Regional Water Board's Irrigated Lands Regulatory Program (ILRP) regulates discharges from irrigated lands within its jurisdiction, including from irrigated lands within the plan area. Another example, the Grasslands Bypass Project, is discussed in detail above. The draft SED should be revised to include a description of all relevant state programs, policies, plans, or regulations.

3. Impact Analysis

a. The Impact Analysis Makes Improper Assumptions That Lead To A Flawed Impact Analysis

There are several flaws in the draft SED's impact analysis for agricultural resources. First, the impact analysis assumes that under the SDWQ Alternatives, "salinity conditions in the southern Delta would not be degraded" because the "program of implementation for the numeric salinity objectives contained in SDWQ Alternatives 2 and 3 includes continued U.S. Bureau of

Reclamation (USBR) compliance with the Vernalis salinity requirement currently established in the 2006 Bay-Delta Plan and implemented through D-1641." (Draft SED, at p. 11-18.) This provision and the provisions requiring Reclamation and DWR to install, operate and maintain barriers, conduct monitoring and conduct studies are flawed for the reasons discussed above, which include but are not limited to the requirement that water right conditions necessary to implement objectives must be considered and determined in a subsequent adjudicative water right proceeding and that it is improper for the State Water Board to pre-determine water right conditions in this legislative water quality planning process

The second flaw with the impact analysis is that the "potential agricultural acreage impact (AG-1 and AG-2 for the SDWQ Alternatives) is estimated by assuming year-round irrigation salinity concentrations of 1.0 dS/m and 1.4 dS/m for SDWQ Alternatives 2 and 3, respectively." (Draft SED, at p. 11-18.) The assumption of steady-state salinity concentrations is not supported by substantial evidence in the record. The data show that salinity concentrations in the southern Delta fluctuate significantly throughout the year. (*See e.g.* Draft SED, App. F.2, at pp. F.2-69-72 [tables showing historical monthly salinity levels], F.2-77 [tables showing historical daily salinity levels].) Therefore, the draft SED's assumption that salinity concentrations would be either 1.0 EC or 1.4 EC year-round is not supported by substantial evidence and likely results in an over-estimate of the SDWQ Alternatives' impacts on agricultural resources. It would be more appropriate for the draft SED to assume salinity levels that reflect the historical variation in salinity levels throughout the year.

b. <u>The Impact Analysis Shows That A Salinity Objective Of 1.4 EC Would Have "Less Than Significant" Impacts On Agricultural Resources</u>

Even using very conservative assumptions, the draft SED's impact analysis shows that a salinity objective of 1.4 EC would have "less than significant" impacts on agricultural resources. (*See* Draft SED, at pp. 11-30, 11-33.) Assuming the "minimum amount of precipitation" and a year-round salinity level of 1.4 EC, a salinity objective of 1.4 EC is estimated to result in a 5% yield reduction in Dry Bean and a 3% reduction in Almonds. (Draft SED, at p. 11-30.) This impact analysis likely over-estimates the effects on agriculture, because it assumes minimum precipitation and it also assumes that irrigation water has a salinity level of 1.4 EC year-round. Both of those assumptions are conservative and the steady-state assumption for salinity levels does not reflect the lower concentrations of salinity that would occur throughout the irrigation season. (*See e.g.* Draft SED, App. F.2, at pp. F.2-69-72 [tables showing historical monthly salinity levels], F.2-77 [tables showing historical daily salinity levels].) The draft SED should explain why this alternative is not preferred – why it would not provide "reasonable" protection of agricultural beneficial uses of water in the southern Delta.

K. <u>Specific Comments Regarding Chapter 12 – Cultural Resources</u>

The analysis of reservoir water levels is based on flawed or unrealistic assumptions that undermines the impact analysis for cultural resources that are sensitive to water levels in reservoirs. In Appendix F.1, the SED discloses that the "rule curves" for modeling and establishing downstream flow targets for the LSJR flow objectives were formulated using an unrealistic assumption that diversion dams on the three eastside tributaries are operated based on storage levels at the end of January of each water year. (Draft SED, App. F.1 at p. F.1-20.)

Irrigation diversions are currently determined based on the reservoir storage and snowpack prior to the beginning of the growing season, not at the end of January. However, the modeling used to estimate the impacts of the LSJR assumes that irrigation diversion amounts will be based on storage levels at the end of January of each year. (*Ibid*.) This methodology results in unrealistic modeling that undermines the analysis of impacts on a host of resources, including cultural resources that depend on water levels in the reservoirs on the three eastside tributaries.

L. Specific Comments Regarding Chapter 13 – Service Providers

1. The SED Uses An Inappropriate Threshold of Significance For Evaluating Impacts To Drinking Water Supplies

The SED concludes that impacts to water quality for municipal drinking water purposes are less than significant based on a finding that the upper limit of the Secondary MCL for EC would not be exceeded. (Draft SED, at p. 13-2.) Use of the upper limit of the secondary MCL (1.6 EC) as the threshold of significance is inappropriate. At a minimum the threshold should be set to the WQCP's own water quality standard for protection of municipal and industrial uses of 1.0 EC. Alternatively, the threshold of significance should be set to the *recommended* secondary MCL of 0.900 EC.

2. The SED Lacks Substantial Evidence To Support Its Conclusions That Implementation Of The SDWQ Or LSJR Alternatives Would Have No Significant Impact On The SWP Or CVP

The SED concludes that none of the SDWQ or LSJR alternatives would substantially degrade water quality for municipal drinking water purposes. (Draft SED, at pp. 13-31 13-32.) The conclusion is based on a narrow focus on diversions in the Delta for direct use as drinking water, and it limits its discussion of the severity of impacts to compliance with the upper limit of the secondary drinking water MCLs. (Draft SED, at p. 13-32.) The SED finds no significant impact based on a determination that salinity in the southern Delta would be maintained under all alternatives within the historic range of salinity of 0.2 EC – 1.2 EC. However, these conclusions lacks the support of substantial evidence because no modeling was performed to determine these alternatives' potential impacts on water quality at the Banks or Jones Pumping Plants. .

In addition, the analysis is based on too narrow of a focus. Many water service providers experience impacts at salinities below the secondary MCL. Salinity in the drinking water supplies can cause corrosion, unpleasant taste and odor, economic impacts to utilities and their customers, and constraints on water recycling and groundwater management programs. Bromide, one component of salinity, can produce harmful disinfection byproducts in drinking water such as bromate and trihalomethanes (THMs) which are known human carcinogen. SWP and CVP water is already seasonally high in bromide, and bromate and THMs can easily form at levels of health concern, even with well-managed treatment. Drinking water suppliers that treat SWP and CVP water already must take steps to ensure bromate and THM levels do not exceed the MCLs.

Water service providers may experience increased costs to minimize or avoid those impacts by blending lower quality water with high quality water or incorporating additional treatment facilities or processes. However, these options may not be available or technically or economically feasible for all service providers. As the quality of a water source changes, the ability to blend and treat water changes; considerations absent from the proposed update and draft SED.

For example, water from the SWP is used by the Metropolitan Water District of Southern California ("MWD") to blend with the more saline water from the Colorado River Aqueduct. Thus, even if the levels of salinity in water in the southern Delta remains within the limits established for secondary MCLs, any increase in salinity that may affect the quality of SWP exports may have a significant adverse impact on the quality of water MWD supplies to its member agencies.

The SED should include modeling of the water quality impacts of all the alternatives at the Jones and Banks pumping plants, including modeling under different water year types, and revise the impacts analysis in light of the modeling results.

3. Regulatory Setting, California Drinking Water Standards Are Mischaracterized

The draft SED describes the Secondary MCL for specific conductance under the California Drinking Water Standards as something that can be exceeded. (Draft SED, at p. 13-23.) While there may be limited consequences from the Department of Public Health, exceeding a secondary MCL must be reported to consumers in annual water quality reports and can degrade public confidence in their utilities' performance. Most utilities establish their own objectives below the MCLs. In addition, throughout this section, the SED describes salinity as a constituent not harmful to human health. This characterization fails to acknowledge the effect of salinity on disinfection byproduct formation such as bromate and trihalomethanes (THMs) which are known carcinogens and regulated under California and federal drinking water standards.

4. The Environmental Setting And Analysis Of Impacts On Service Providers Improperly Omits Any Analysis Of The Contribution Of In-Delta Agricultural Discharges On Salinity In The Southern Delta

The SED accurately states that salinity in the southern Delta is a function of many factors, including the amount and salinity concentrations of SJR flow entering the southern Delta at Vernalis, daily tidal action, CVP and SWP operations, agricultural return flows, municipal wastewater discharges, and other influences. (Draft SED, at p. 13-7.) The SED discloses that the influence of in-Delta agricultural discharges and groundwater accretions is more pronounced than WWTP discharges in the southern Delta. (Draft SED, at p. 13-9.) However, the environmental setting focuses its discussion of contributions to salinity concentrations in the southern Delta on WWTP discharges, and omits any discussion or characterization of the contribution of agricultural return flows, which the SED identifies as a larger factor than WWTP discharges. (Draft SED, at p. 13-7 ["Winter salinity is mostly influenced by agricultural runoff . . ."; "Generally, when temporary barriers are installed, tidal exchange is reduced, and salinity in the southern Delta during these lower flow periods can increase as a result of other sources (e.g., discharge of agricultural drainage, discharge of WWTPs"].)

Indeed, while the contributions of WWTP and agricultural discharges in the southern Delta are acknowledged, the SED inaccurately, and inconsistently states that WWTP discharges and agricultural return flows generally reduce salinity because salinity is inversely proportional to flow in the southern Delta. (Draft SED, at p. 13-8.) While higher freshwater flows from upstream rivers and operations of the SWP and CVP projects will reduce salinity in the southern Delta, there is no evidence that increased discharges from WWTPs and southern Delta farmlands somehow

decreases salinity. To the contrary, the SED states that salinity in the southern Delta downstream from Vernalis generally increases. (Draft SED, at p. 13-8.)

Absent any attempt at quantifying or characterizing the agricultural discharges in the southern Delta, the Environmental Setting and impact analysis on service providers is fatally flawed. To remedy this deficiency, the State Board should require agricultural dischargers in the southern Delta to file reports of waste discharge disclose the results of the reports or modeling in the SED.

As it stands, instead of requiring dischargers of salts into the southern Delta to reduce their salinity inputs and fund their fair share of special studies and monitoring and reporting requirements, the State Board relies heavily on DWR and USBR for continuing to install temporary barriers, and for formulating, funding, and implementing costly studies and monitoring and reporting requirements. (Draft SED, App. K,.) In addition, Appendix H states that depending on the results of these additional special studies, "DWR may be required to install low lift pumping stations at the temporary barriers as a method of compliance." (Draft SED, App. H at pp. H-44, H-94.) Among other deficiencies discussed above, this is inconsistent with the mandate in the Water Code that requires the State Board to establish salinity objectives in a manner that can reasonably be achieved "through the coordinated control of *all* factors which affect water quality in the area." (Water Code, § 13241, subd. (c), italics added.)

The State Board should quantify all salinity inputs in the southern Delta, and the program of implementation should apportion responsibility for special studies and other measures, such as use of temporary barriers, fairly among the sources of salinity, not just the SWP and CVP.

5. The SED's List Of Water Suppliers Is Inaccurate And Should Be Revised To Include All Water Suppliers That Rely On Water That May Be Impacted By The LSJR Flow And Southern Delta Salinity Objectives

The SED only lists CVP (operated by the U.S. Bureau of Reclamation), SWP (operated by the Department of Water Resources), and Contra Costa Water District as "water suppliers." (Draft SED at pp. 3-18, 3-19.) There are many more water suppliers that will be affected by the implementation of the Preferred LSJR and SDWQ Alternatives. (Draft SED, at pp.13-5, 13-6, Table 13-2 [irrigation districts and their contracting water districts].) The SED, the Water Quality Control Plan and program of implementation, and any subsequent quasi-legislative or quasi-adjudicatory actions taken to implement the Phase 1 objectives, should study impacts to all water suppliers, and should incorporate fair-share limits on diversions to achieve the LSJR flow objective, and should impose all appropriate regulatory limits on WWTP and agricultural discharges.

6. The SED Fails To Analyze The Potential Impacts On Service Providers Under A Range Of Water Year Types

As noted above, the SED does not analyze the impacts on service providers under a range of water year categories. Thus, there is no way to know if the Preferred LSJR and SDWQ Alternatives or other alternatives will have more severe impacts on water supply in normal, below normal, or critical dry water years. Indeed, the SED discloses that "[t]here have been periodic exceedances [of the existing southern Delta salinity objective] in recent dry years at one or more of the southern Delta monitoring stations . . . ." (Draft SED, at p. 13-8.) Thus, it is clear that the impacts of discharges into the southern Delta have, and will continue to cause exceedances of the

existing and preferred alternative salinity objective in dry and critically dry years, and the SED's analysis and program of implementation should reflect that fact, instead of resorting to annual averages and generalizations about the historic range of salinity in the southern Delta.

7. The WSE Model Relies On An Unrealistic Assumption That Undermines The Impact Analysis For Water Suppliers

In Appendix F.1, the SED discloses that the "rule curves" for modeling and establishing downstream flow targets for the LSJR flow objectives were formulated using an unrealistic assumption that diversion dams on the three eastside tributaries are operated based on storage levels at the end of January of each water year. (Draft SED, App. F.1 at pp. F.1-20.)

Diversion dams are currently operated by determining the reservoir storage and snowpack prior to the beginning of the growing season, not at the end of January. However, the modeling used to estimate the impacts of the LSJR assumes that the dams will be operated to deliver water based on storage levels at the end of January of each year. (*Ibid*.) This methodology results in unrealistic modeling that undermines the analysis of impacts on water suppliers.

M. Specific Comments Regarding Chapter 19 – Antidegradation Analysis

The draft SED defers the "Antidegradation Analysis" and states that the State Water Board will consider "all relevant information and determine if the Lower San Joaquin River (LSJR) alternatives or southern Delta Water Quality (SDWQ) alternatives would unreasonably affect the water quality or adversely affect the designated beneficial uses of water from the estuary in the final SED." (Draft SED, at p. 19-1.) The Public Water Agencies acknowledges that the antidegradation analysis is being deferred to a later time. They expect to comment on that analysis once it is available for public review.

N. Specific Comments Regarding Chapter 20 – Preferred LSJR Alternative And SDWQ Alternative

The comments provided immediately below supplement or summarize other comments on the draft alternatives and draft SED, presented in this letter. Those comments are incorporated herein by this reference.

1. The Draft SED Fails To Explain Why The State Water Board Would Adopt A LSJR Flow Alternative That Has Significant Effects On Other Beneficial Uses Of Water

One of the basic purposes of CEQA is to "[d]isclose to the public the reasons why a governmental agency approved the project in the manner the agency chose if significant effects are involved." (14 C.C.R. § 15002, subd. (a)(4).) The draft SED states that the Preferred LSJR Alternative "35 percent unimpaired flow requirement would strike a balance between providing water for protection of fish and other competing uses of water, including agriculture and hydropower generation." (Draft SED, at pp. ES-2, ES-3.) However, the draft SED estimates that the Preferred LSJR Alternative would result in a 9% decrease in water diversions in the plan area and a 14% and 10% decrease in water diversion on the Tuolumne and Merced Rivers, respectively." (Draft SED, at p. 20-8.) The draft SED fails to assess whether it is "reasonable" to cause significant impacts to agricultural beneficial uses of water in an effort to protect fish and

wildlife beneficial uses. The draft SED also fails to disclose the reasons why the State Water Board would adopt amendments to water quality control plan that have significant effects on beneficial uses of water. Therefore, the draft SED fails to fulfill one of the basic purposes of CEQA, which is to disclose to the public the reasons why the agency may approve a project with significant effects on the environment.

The draft SED also fails to explain why the 35% of unimpaired flow was selected as the preferred alternative, even though 30% of unimpaired flow is estimated to result in "less than significant" impacts on aquatic resources. (*See* Draft SED, at pp. 7-3 – 7-8.) For example, there is no analysis in the draft SED regarding the tradeoffs between the 30% and 35% unimpaired flow options, in terms of fish and wildlife versus water supply diversions. Without this information, the State Water Board does not have sufficient information to determine what constitutes a "reasonable" level of water quality protection, in light of the competing beneficial uses of water.

2. The Preferred LSJR Alternative Of 35% Of "Unimpaired Flow" Is Not Supported By Substantial Evidence In The Administrative Record

One of the identified "objectives" or "goals" of the draft amendments to the LSJR flow objectives is to provide flow conditions in the LSJR and three eastside tributaries sufficient to support and maintain the natural production of native fish populations, including "flows that mimic the natural hydrographic conditions" to which native fish species are adapted. (Draft SED, at p. 3-2.) To meet this objective, the Preferred LSJR Alternative would require 35 percent "unimpaired flow" February-June on each of the three eastside tributaries and on the SJR at Vernalis. (Draft SED, at p. 20-3.) However, "unimpaired flows" do not mimic the natural hydrographic conditions to which native fish species adapted because the Bay-Delta ecosystem has been highly altered from the predevelopment ecosystem to which native fish species adapted. As described in the draft SED, "unimpaired flow" is merely a calculation of the "river flow at a specified location that would occur if all runoff from the watershed remained in the river, without storage or diversion." (Draft SED, at p. 5-7.) An "unimpaired flow" regime will not mimic "natural" hydrographic conditions because the flows will be occurring in a highly altered system.

There does not appear to be any explanation, scientific analysis, or biological rationale for why 35% of the unimpaired hydrograph is the preferred implementation approach. (Draft SED, at pp. 20-1 – 20-29.) Further, the SED does not present any analysis of the biological benefits to Chinook salmon or steelhead population dynamics that would be achieved by implementing the preferred alternative (35% allocation) when compared quantitatively to other alternatives. Similarly, the SED provides no detailed comparative analysis of potential adverse impacts that would be avoided by implementation of the preferred alternative to salmonids and other beneficial uses when assessed in relationship to other alternatives (e.g., 20%, 40%, 60 %, the no project alternative, etc.).

The following are examples of the many unanswered questions raised by the SED's failure to analyze the preferred alternative. Why was 35% of the unimpaired hydrograph selected as the preferred alternative? In what way does 35% of the unimpaired hydrograph achieve the salmon viability factors? Does 35% of the unimpaired hydrograph improve salmon survival downstream of Vernalis? Does 35% of the unimpaired hydrograph improve the conditions in the upper tributaries (e.g., gravel transport, temperature, turbidity, spawning habitat, etc.) Why does 35% of the unimpaired hydrograph best meet the goals and objectives of the project? Was 35% selected only because this was somewhere in the middle between 20% and 60%? Does the selection of the

35% of the unimpaired hydrograph reduce potentially significant environmental effects; if so, which ones and to what extent are the significant effects minimized? In many cases the breakpoint between significant and insignificant impact fell between the 20% and 40% of unimpaired alternatives. Since the SED did not evaluate the 35% unimpaired flow alternative there is no way to determine its potential environmental impact.

There is not substantial evidence in the administrative record to support the conclusion that an "unimpaired flow" regime will support the physical and ecological processes necessary to support native fish populations. The draft SED fails to evaluate "unimpaired flow" in the context of a highly modified ecological system and instead assumes that the "unimpaired flow" approach is necessary to support native fish populations. That assumption is not supported by substantial evidence and fails to account for the complex and inter-related physical and biological characteristics of the Bay-Delta ecosystem. The confounding relationships between flows and other environmental factors make the ecological consequences of an "unimpaired flow" regime highly uncertain. The "natural hydrographic conditions" to which native fish species are adapted included a complex and dynamic habitat that has been significantly altered by human actions. An "unimpaired flow" regime will not restore those dynamic habitat functions and it will not mimic "natural" hydrographic conditions.

O. Specific Comments Regarding Appendix H Of The Substitute Environmental Document

Public Resources Code section 21159 requires the SED to include, at a minimum, all of the following:

> (1) An analysis of the reasonably foreseeable environmental impacts of the methods of compliance.
>
> (2) An analysis of reasonably foreseeable feasible mitigation measures.
>
> (3) An analysis of reasonably foreseeable alternative means of compliance with the rule or regulation.

Draft Appendix H sets forth the evaluation of methods of compliance. However, it erroneously includes as a "method of compliance" the construction and operation of low lift pumps in conjunction with the continued installation of temporary barriers in the southern Delta to address impaired salinity, and it omits any analysis of potential mitigation for impacts of developing new surface water resources in the southern Delta.

First, Draft Appendix H indicates that depending on the outcome of the additional special studies to be conducted by Reclamation and DWR, the State Water Board may require DWR to construct and operate low lift pumping stations. (Draft SED, App. H, at pp. H-44, H-94.) As stated, the cost to implement the temporary barriers is $6 million/year. Depending on the number and type of low lift pumping stations, the initial cost to construct those ranges from $5.5 million to $551 million, and annual costs to operate would cost between $1.4 million and $89.9 million. (*Id*. at pp. H-94 – H-95, Tables H-20 – H-23.)

Since the best available scientific data demonstrates that SWP operations have no adverse impact, and some beneficial impact on salinity in the southern Delta, there is no factual or legal basis to require DWR to construct or operate temporary barriers or low lift pumping stations to protect agricultural beneficial uses in the southern Delta due to elevated levels of salinity. Thus, the draft SED and Appendix H should remove this as a potential "method of compliance" with the new southern Delta salinity objective.

Second, Draft Appendix H discloses two potential surface water supply projects, the Davis-Woodland Water Supply Project ("DWWSP") and the Delta Water Supply Project ("DWSP"). (Draft SED, App. H, at pp. H-45 – H-46.) However, the environmental analysis of these projects is deficient, even at a programmatic level. The analysis omits any analysis of potential impacts of new diversions in the southern Delta on aquatic wildlife, including state and federally listed threatened and endangered species. (*Id*. at p. H-50.) In addition, there are no potentially feasible mitigation measures identified for any of those projects potentially significant adverse environmental impacts. (*Id*. at pp. H-100 – H-115, Table H-24.) Draft Appendix H should be revised to include an assessment of the potential impacts of new surface water supply projects in the southern Delta, and should identify potentially feasible mitigation measures to address any potentially significant impacts.

Attachment 3

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Attachment 4

(Relevant Legal Standards and Rules)

1. Beneficial Use & Highest Use of Water

The California Constitution declares:

> [T]hat because of the conditions prevailing in this State the general welfare requires that the water resources of the State be put to beneficial use to the fullest extent of which they are capable, and that the waste or unreasonable use or unreasonable method of use of water be prevented, and that the conservation of such waters is to be exercised with a view to the reasonable and beneficial use thereof in the interest of the people and for the public welfare. The right to water or to the use or flow of water in or from any natural stream or water course in this State is and shall be limited to such water as shall be reasonably required for the beneficial use to be served, and such right does not and shall not extend to the waste or unreasonable use or unreasonable method of use or unreasonable method of diversion of water.

(Sec. 2, Art. X, Cal. Constitution; *see* Water Code § 100 [same].) It is the declared policy of this state "that the use of water for domestic purposes is the highest use of water and that the next highest use is for irrigation." (Water Code, § 106.)

2. Water Quality

Our state legislature has found and declared "that activities and factors which may affect the quality of the waters of the state shall be regulated to attain the highest water quality which is *reasonable, considering all demands being made and to be made on those waters* and the total values involved, beneficial and detrimental, economic and social, tangible and intangible." (Water Code, § 13000, italics added.)

Pursuant to Water Code section 13170, the State Water Board "may adopt water quality control plans in accordance with the provisions of Sections 13240 to 13244, inclusive, insofar as they are applicable . . . ." A water quality control plan "consists of a designation or establishment for the waters within a specified area of all of the following: (1) Beneficial uses to be protected[;] (2) Water quality objectives[;] (3) A program of implementation needed for achieving water quality objectives." (Water Code, § 13050, subd. (j).) The "beneficial uses" of water that may be protected against quality degradation include, but are not limited to, "domestic, municipal, agricultural and industrial supply; power generation; recreation; aesthetic enjoyment; navigation; and preservation and enhancement of fish, wildlife, and other aquatic resources or preserves." (Water Code, § 13050, subd. (f).) "Water quality objectives" are "the limits or levels of water quality constituents or characteristics which are established for the reasonable protection of beneficial uses of water or the prevention of nuisance within a specific area." (Water Code, § 13050, subd. (h).) The "program of implementation" for achieving water quality objectives must include, but is not limited to, the following: "(a) A description of the nature of actions which are necessary to achieve the objectives, including recommendations for appropriate action by any entity, public or private[;] (b) A time schedule for the actions to be taken[;] (c) A description of surveillance to be undertaken to determine compliance with objectives." (Water Code, § 13242.)

A water quality control plan must conform to the policy that the activities and factors which may affect water quality "shall be regulated to attain the highest water quality which is *reasonable, considering all demands being made and to be made on those waters* and the total values involved, beneficial and detrimental, economic and social, tangible and intangible." (Water Code, § 13000, italics added; § 13240; § 13170.) The State Water Board "shall establish such water quality objectives in water quality control plans as in its judgment will ensure the *reasonable* protection of beneficial uses and the prevention of nuisance . . . ." (Water Code, § 13241, italics added.) Factors to be considered by the State Water Board in establishing water quality objectives shall include, but not necessarily be limited to, all of the following:

(a) Past, present, and probable future beneficial uses of water.
(b) Environmental characteristics of the hydrographic unit under consideration, including the quality of water available thereto.
(c) Water quality conditions that could reasonably be achieved through the coordinated control of all factors which affect water quality in the area.
(d) Economic considerations.
(e) The need for developing housing within the region.
(f) The need to develop and use recycled water.

(Water Code, § 13241.)

In addition, the CWA requires the State to submit any revised or new beneficial uses (referred to as designated uses under the CWA) or water quality objectives (referred to as water quality criteria under the CWA) to the Administrator of the Environmental Protection Agency. The CWA provides:

> Whenever the State revises or adopts a new standard, such revised or new standard shall be submitted to the Administrator. Such revised or new water quality standard shall consist of the designated uses of the navigable waters involved and the water quality criteria for such waters based upon such uses. Such standards shall be such as to protect the public health or welfare, enhance the quality of water and serve the purposes of this chapter. *Such standards shall be established taking into consideration their use and value for public water supplies, propagation of fish and wildlife, recreational purposes, and agricultural, industrial, and other purposes, and also taking into consideration their use and value for navigation.*

(33 U.S.C. § 1313, subd. (c)(2)(A), italics added.)

"In performing its regulatory function of ensuring water quality by establishing water quality objectives, the Board acts in a legislative capacity. The Water Quality Control Plan itself is thus a quasi-legislative document." (*U.S. v. SWRCB* (1986) ["Racanelli Decision"] 182 Cal.App.3d 82, 112.) "The established procedures for quasi-legislative acts are few." (*Id.* at p. 114.) Before adopting any water quality control plan, the State Water Board must first provide notice of a public hearing and hold a public hearing regarding the proposed water quality control plan. (Water Code, § 13244.) In conducting "rulemaking proceedings" such as any hearings designed for the adoption or amendment of a water quality control plan, the State Water Board must "comply with all applicable requirements established by the Legislature (Government Code Section 11340, et seq.)." (23 C.C.R. §§ 649.1, 649, subd. (a).) The Government Code requires that a state agency permit "both oral and written statements, arguments, or contentions" at the public

hearing for the rulemaking proceeding and the state agency "shall consider all relevant matter presented to it before adopting, amending, or repealing any regulation." (Gov. Code § 11346.8, subd. (a).)

Also, prior to adopting a water quality control plan, the State Water Board must submit the scientific portions of the WQCP, along with a statement of the scientific findings, conclusions, and assumptions on which the scientific portions of the WQCP are based and the supporting scientific data, studies, and other appropriate materials, to an external scientific peer review entity for its evaluation. (Health & Safety Code, § 57004, subd. (d)(1).)

3. Substitute Environmental Document

The State Water Board's regulations require that a SED prepared in lieu of an EIR include, at a minimum, the following information:

> (1) A brief description of the proposed project;
>
> (2) An identification of any significant or potentially significant adverse environmental impacts of the proposed project;
>
> (3) An analysis of reasonable alternatives to the project and mitigation measures to avoid or reduce any significant or potentially significant adverse environmental impacts; and
>
> (4) An environmental analysis of the reasonably foreseeable methods of compliance. The environmental analysis shall include, at a minimum, all of the following:
>
> (A) An identification of the reasonably foreseeable methods of compliance with the project;
>
> (B) An analysis of any reasonably foreseeable significant adverse environmental impacts associated with those methods of compliance;
>
> (C) An analysis of reasonably foreseeable alternative methods of compliance that would have less significant adverse environmental impacts; and
>
> (D) An analysis of reasonably foreseeable mitigation measures that would minimize any unavoidable significant adverse environmental impacts of the reasonably foreseeable methods of compliance.

(Cal. Code Regs., tit. 23, § 3777; subd. (b).) As to each "significant" impact identified under subdivisions (b)(2) and (b)(4)(B) of section 3777, a SED must contain findings as described in CEQA Guidelines section 15091,[21] and if applicable, a statement described in CEQA Guidelines section 15093.[22] (Cal. Code Regs., tit. 23, § 3777, subd. (d), § 3779.5, subd. (c).)

[21] Section 15091 of the CEQA Guidelines requires an agency to make one or more of the following findings for each of the significant effects of the proposed project:

Under CEQA, a "significant effect on the environment" means a "substantial, or potentially substantial, adverse change in the environment." (Pub. Res. Code, § 21068.)[23] Under the CEQA Guidelines, "effects" of the project include:

> (1) Direct or primary effects which are caused by the project and occur at the same time and place.
>
> (2) Indirect or secondary effects which are caused by the project and are later in time or farther removed in distance, but are still reasonably foreseeable. Indirect or secondary effects may include growth-inducing effects and other effects related to induced changes in the pattern of land use, population density, or growth rate, and related effects on air and water and other natural systems, including ecosystems.

(14 C.C.R. § 15358, subd. (a).)

4. Water Rights

A right to appropriate water is recognized as a private property right and "once rights to use water are acquired, they become vested property rights." (*Racanelli Decision*, *supra*, 182

> (1) Changes or alterations have been required in, or incorporated into, the project which avoid or substantially lessen the significant environmental effect as identified in the final EIR.
> (2) Such changes or alterations are within the responsibility and jurisdiction of another public agency and not the agency making the finding. Such changes have been adopted by such other agency or can and should be adopted by such other agency.
> (3) Specific economic, legal, social, technological, or other considerations, including provision of employment opportunities for highly trained workers, make infeasible the mitigation measures or project alternatives identified in the final EIR.

[22] Section 15093 of the CEQA Guidelines states:

> When the lead agency approves a project which will result in the occurrence of significant effects which are identified in the final EIR but are not avoided or substantially lessened, the agency shall state in writing the specific reasons to support its action based on the final EIR and/or other information in the record. The statement of overriding considerations shall be supported by substantial evidence in the record.

[23] Section 15382 of the CEQA Guidelines provides a more detailed definition of "significant effect on the environment," as follows:

> a substantial, or potentially substantial, adverse change in any of the physical conditions within the area affected by the project including land, air, water, minerals, flora, fauna, ambient noise, and objects of historic or aesthetic significance. An economic or social change by itself shall not be considered a significant effect on the environment. A social or economic change related to a physical change may be considered in determining whether the physical change is significant.

Cal.App.3d at p. 101.) The Constitution prohibits a state from depriving any person of property "without due process of law." (Sec. 1, Amendment XIV, U.S. Constitution.) Thus, appropriative water rights "cannot be infringed by others or taken by governmental action without due process and just compensation." (*Racanelli Decision*, *supra*, 182 Cal.App.3d at p. 101.) Therefore, the procedural protections provided by law with respect to appropriative water rights are necessary to ensure that due process is provided by the State.

The State Water Board regulations state that the following permit term shall be included in every water right permit issued by the Board:

> Water Quality Objectives. The quantity of water diverted under this permit and under any license issued pursuant thereto is subject to modification by the State Water Resources Board if, *after* notice to the permittee and an opportunity for hearing, *the board finds* that such modification is necessary to meet water quality objectives in water quality control plans . . . No action will be taken pursuant to this paragraph unless *the board finds* that (1) adequate waste discharge requirements have been prescribed and are in effect with respect to all waste discharges which have any substantial effect upon water quality in the area involved, and (2) the water quality objectives cannot be achieved solely through the control of waste discharges.

(23 C.C.R. § 780, subd. (b)(1), italics added.) The regulations also state that:

> (a) In exercising its discretionary authority respecting applications to appropriate water, including prescribing or modifying permit terms and conditions, the board may require releases of water diverted and stored *whenever such releases are determined by the board to be in the public interest* or are needed to protect public trust uses of water, *if such requirement is reasonable under Article X, Section 2 of the California Constitution*.
>
> [. . .]
>
> (c) Before requiring releases of water pursuant to subsection (a) of this section over the objection of the applicant or permittee, the board will hold a hearing and make findings with respect thereto. The hearing will be limited to a consideration of (1) the basis of any recommendation of the Department of Fish and Game pursuant to Water Code Section 1243; (2) *whether such releases are necessary to maintain or enhance beneficial uses or to meet water quality objectives in the relevant water quality control plan*; (3) the probable effect of releases upon the applicant's proposed project; (4) evidence to assist in the preparation of dry and critical year relief provisions related to releases; and (5) any other issues which may be relevant to the appropriateness of a release requirement.

(23 C.C.R. § 784, subd. (a), (c), italics added.)

"[I]n undertaking to allocate water rights, the Board performs an adjudicatory function." (*Racanelli Decision*, *supra*, 182 Cal.App.3d at p. 113.) An "adjudicative proceeding" means an "evidentiary hearing for determination of facts pursuant to which the State Board or a Regional

Board formulates and issues a decision." (23 C.C.R. § 648, subd. (a); Gov. Code § 11405.20.) All "adjudicative proceedings" before the State Water Board are governed by 23 C.C.R. 648 et seq., chapter 4.5 of the Administrative Procedure Act[24] (Gov. Code § 11400 et seq.), sections 801-805 of the Evidence Code, and section 11513 of the Government Code. (23 C.C.R. § 648, subd. (b).) Those regulations and statutory provisions provide procedural protections for the party or parties to whom the adjudicative proceeding is directed.

The State Water Board regulations state that "[t]he party or parties to an adjudicative proceeding before the Board shall include the person or persons to whom the agency action is directed" and in a water right proceeding, the party or parties shall include the water right application or petitioner . . .." (23 C.C.R. § 648.1(a), (b).) "Parties" must be "given a reasonable opportunity on request to refute officially noticed technical or scientific matters . . .." (23 C.C.R. § 648.2.) In addition, "[a]ny witnesses providing written testimony shall appear at the hearing and affirm that the written testimony is true and correct." (23 C.C.R. § 648.4(d).)

Chapter 4.5 of the Administrative Procedure Act ("APA") provides the administrative adjudication provisions of the APA. (Gov. Code, § 11400.) Chapter 4.5 of the APA "supplements the governing procedure by which an agency conducts an adjudicative proceeding." (Gov. Code, § 11415.10, subd. (b).) The APA defines an agency "decision" for the purposes of an administrative adjudication as "an agency action of specific application that determines a legal right, duty, privilege, immunity, or other legal interest of a particular person."[25] (Gov. Code, § 11405.50.) Article 6 of Chapter 4.5 of the APA provides the "administrative adjudication bill of rights." Under that Article, the procedure by which an agency conducts an adjudicative proceeding is subject to all of the following requirements:

> (1) The agency shall give the person to which the agency action is directed notice[26] and an opportunity to be heard, including *the opportunity to present and rebut evidence*.
>
> (2) The agency shall make available to the person to which the agency action is directed a copy of the governing procedure, including a statement whether Chapter 5 (commencing with Section 11500) is applicable to the proceeding.
>
> (3) The hearing shall be open to public observation as provided in Section 11425.20.
>
> (4) The adjudicative function shall be separated from the investigative, prosecutorial, and advocacy functions within the agency as provided in Section 11425.30.
>
> (5) The presiding officer is subject to disqualification for bias, prejudice, or interest as provided in Section 11425.40.
>
> (6) The decision shall be in writing, be based on the record, and include *a statement of the factual and legal basis of the decision* as provided in Section 11425.50.

(Gov. Code, § 11425.10, subd. (a), italics added.)

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[24] Certain portions of chapter 4.5 of the Administrative Procedure Act are not applicable to "adjudicative proceedings." (See 23 C.C.R. § 648(c) [listing inapplicable articles and sections].)

[25] The term "person" includes "an individual, partnership, corporation, governmental subdivision or unit of a governmental subdivision, or public or private organization or entity of any character." (Gov. Code, § 11405.70.)

[26] See Government Code section 11440.20 for notice requirements.

Government Code section 11513 provides the following additional procedural rights for the party or parties to an adjudicative proceeding, including:

> (a) Oral evidence shall be taken only on oath or affirmation.
> (b) Each party shall have these rights: to call and examine witnesses, to introduce exhibits; to cross-examine opposing witnesses on any matter relevant to the issues even though that matter was not covered in the direct examination; to impeach any witness regardless of which party first called him or her to testify; and to rebut the evidence against him or her. If respondent does not testify in his or her own behalf he or she may be called and examined as if under cross-examination.
> (c) The hearing need not be conducted according to technical rules relating to evidence and witnesses, except as [otherwise] provided [in Section 11513].

(Gov. Code, § 11513.)

Evidence Code sections 801 through 805 govern witness testimony in an adjudicative proceeding. Evidence Code section 801 provides:

> If a witness is testifying as an expert, his testimony in the form of an opinion is limited to such an opinion as is:
> (a) Related to a subject that is sufficiently beyond common experience that the opinion of an expert would assist the trier of fact; and
> (b) Based on matter (including his special knowledge, skill, experience, training, and education) perceived by or personally known to the witness or made known to him at or before the hearing, whether or not admissible, that is of a type that reasonably may be relied upon by an expert in forming an opinion upon the subject to which his testimony relates, unless an expert is precluded by law from using such matter as a basis for his opinion.

(Evid. Code § 801.) Evidence Code section 804, subd. (a) provides that "[i]f a witness testifying as an expert testifies that his opinion is based in whole or in part upon the opinion or statement of another person, such other person may be called and examined by any adverse party as if under cross-examination concerning the opinion or statement." (Evid. Code § 804, subd. (a).)

Attachment 5
(Discharges By Grasslands Bypass Project)

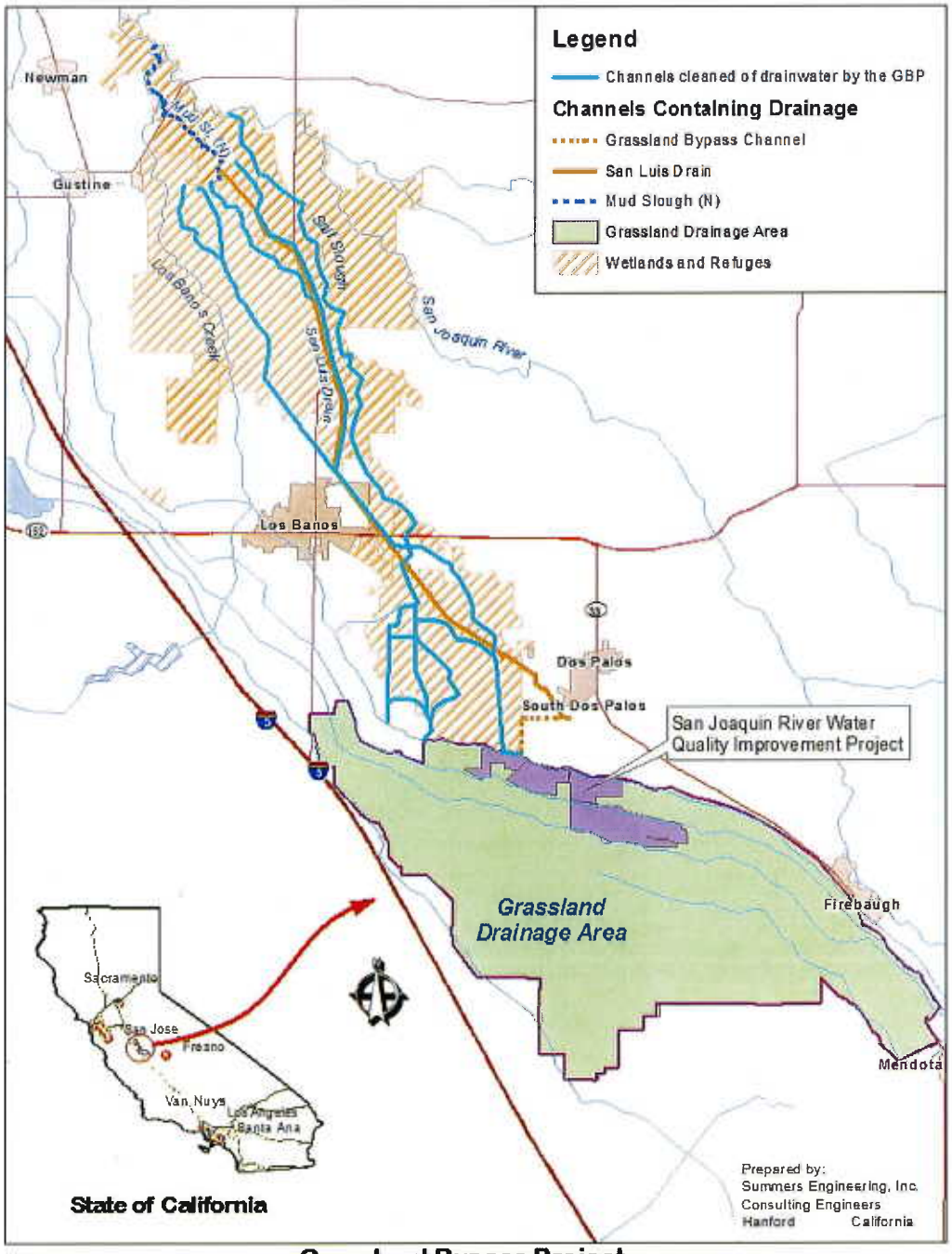
Table 1
Discharge Comparison from Grassland Drainage Area
Values October thru September

	WY 95	WY 96	WY 97	WY 98	WY 99	WY 00	WY 01	WY 02	WY 03
Volume (AF)	57,574	52,978	39,856	49,289	32,317	31,342	28,235	28,358	27,345
Se (lbs)	11,875	10,034	7,096	9,118	5,124	4,603	4,377	3,939	4,032
Salt (tons)	237,530	197,526	172,602	213,533	149,081	139,303	142,415	128,411	126,500
B (1,000 lbs)	868	723	753	983	630	619	423	544	554
Se (ppm)	0.076	0.070	0.066	0.068	0.058	0.054	0.057	0.051	0.054
Salt (µmhos/cm)	4,102	3,707	4,306	4,308	4,587	4,420	5,016	4,503	4,600
Boron (ppm)	5.5	5.0	7.0	7.3	7.2	7.3	5.5	7.1	7.5

	WY 04	WY 05	WY 06	WY 07	WY 08	WY 09	WY 10	WY 11	WY 12	Reduction from WY 95 to WY 12
Volume (AF)	27,640	29,957	25,995	18,531	15,665	13,166	14,529	18,513	10,486	82%
Se (lbs)	3,860	4,305	3,563	2,554	1,736	1,264	1,577	2,047	750	94%
Salt (tons)	121,138	138,908	119,646	79,094	66,254	55,556	67,661	87,537	38,400	84%
B (1,000 lbs)	530	585	539	278	269	233	315	419	234	73%
Se (ppm)	0.051	0.053	0.050	0.051	0.041	0.035	0.040	0.041	0.026	
Salt (µmhos/cm)	4,358	4,611	4,577	4,244	4,206	4,196	4,631	4,702	3,642	
Boron (ppm)	7.1	7.2	7.6	5.5	6.3	6.5	8.0	8.3	8.2	

Note: WY 97, 98, & 05 include discharges through Grasslands
Note: GAF quality data used where RWQCB data was missing or pending.

Figure 1



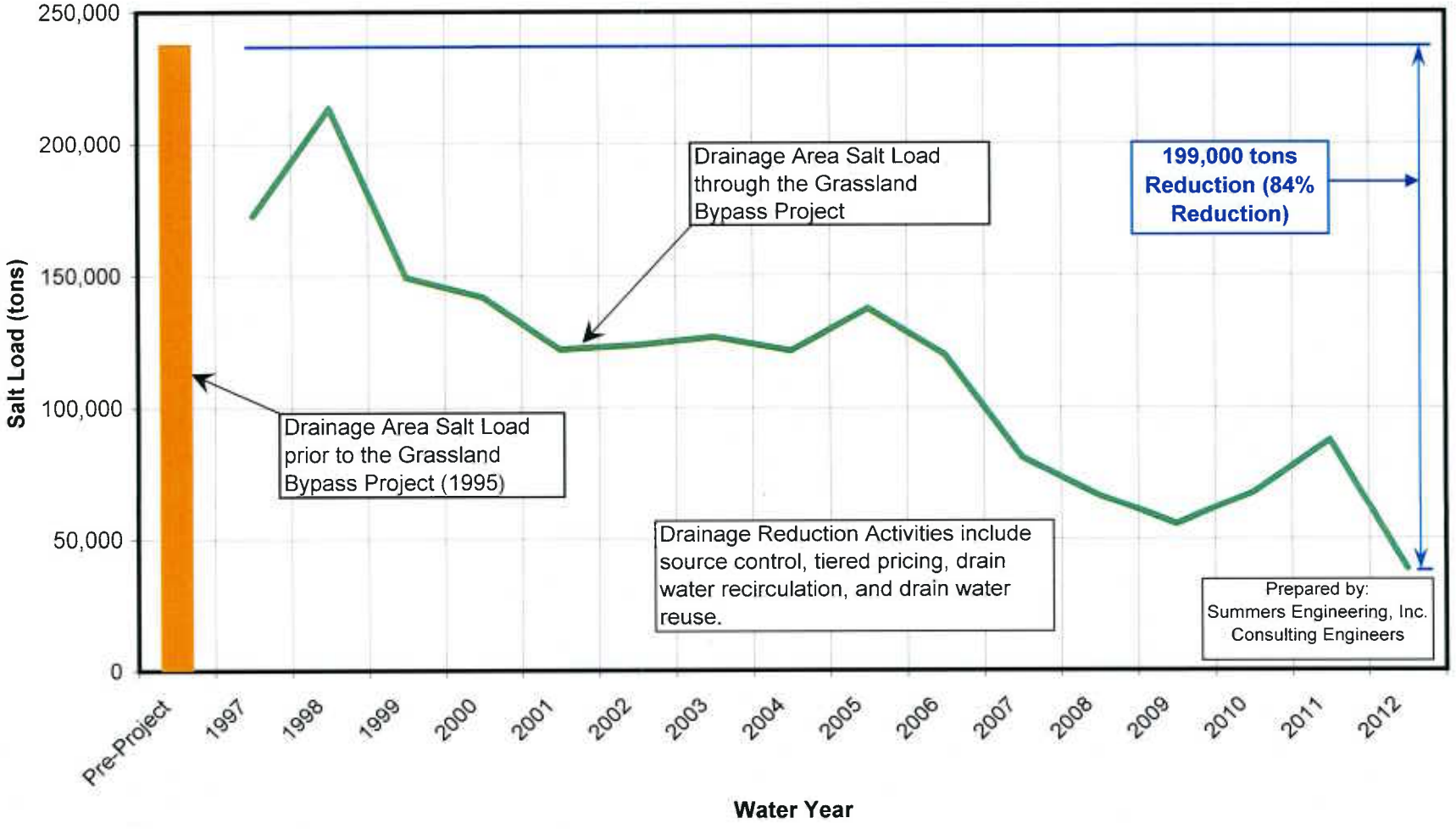
Grassland Bypass Project
Location Map

NW/SJDMA/Sta.Cru/Mis./2013/GDAN01

Figure 2

Grassland Drainage Area

Drainage Area Salt Load



G:\data\SPRDSHTS\GRASLAND\DRNGRPHS, Salt Graph

ATTACHMENT B

Technical Memorandum
Water Quality Control Plan, Phase 1, SED
Groundwater

The groundwater chapter of the Draft SED was reviewed for the State Water Contractors (SWC) by Terry Erlewine. Mr. Erlewine has performed water resource planning and analysis for many years. He has conducted many surface and groundwater resources studies, including water uses, operations studies, groundwater modeling, and groundwater conjunctive use programs. Mr. Erlewine was formerly a Senior Engineer with the California Department of Water Resources (DWR). In his 13-year tenure with DWR, he was involved in all aspects of surface water and groundwater projects.

It is Mr. Erlewine's and the SWC opinion that there is weak evidence to support the Draft SED's conclusions. The groundwater analysis should have utilized existing models to analyze the likely cumulative effect of the Water Board's proposed changes to the WQCP and the implementation of the Sustainable Groundwater Management Act ("SGMA"). Mr. Erlewine's specific comments are as follows:

- Draft SED at p.9-3. The Draft SED states: "This analysis assumes that an average annual reduction in the groundwater balance for a subbasin by increased groundwater pumping and reduced recharge from surface water equivalent to 1 inch or more of water across the subbasin could be potentially significant"

  ***Comment**: There is no support provided for this level of significance. It is also somewhat misleading, as a 1 inch reduction in net recharge would result in several times greater impacts on groundwater levels. (See Draft SED at p. 9-46.) Moreover, effects on groundwater levels are cumulative, so an annual impact of 1-inch reduction in net recharge could lower groundwater levels by several feet over a period of years.*

- Draft SED at p. 9-3. The Draft SED states: "However, since the groundwater projections that will be afforded by SGMA cannot be determined at this time with precision, this chapter evaluated the potential impacts on groundwater levels from LSJR alternatives without including SGMA as an ameliorating factors…"

  ***Comment**: While it may not be possible to precisely determine the exact management actions that agencies will take to comply with SGMA, it is possible to identify a potential range of actions. SGMA requires proactive measures to address undesirable conditions such as "chronic lowering of groundwater levels." Agencies will be required to take actions to avoid those kinds of impacts, which have not been analyzed in the SED. General actions that would be required to meet SGMA would include increasing recharge, which could be severely limited due to the constraints on impairment of flow being proposed in the Draft SED or reductions in consumptive use. These actions could be analyzed with available modeling analysis and the economic impacts of these measures to deal with SGMA could be analyzed with the economic analysis methodology presented in Chapter 20.*

The SED goes on to make the statement that "estimates of impacts are likely more conservative (i.e., worse) than would occur in the groundwater basins over time." (Ibid.) Because the SED incorrectly estimates reductions in groundwater recharge/discharge using a semi-quantitative framework, the statement that estimates of impacts are more conservative is incorrect. The semi-quantitative analysis presented in this chapter is inaccurate and does not identify significant environmental impacts to both groundwater and surface water flows. To properly analyze groundwater impacts of the proposed revisions in the Water Quality Control Plan ("WQCP"), a groundwater model or a similar quantitative analysis framework should be used. There are existing groundwater models that are capable of making the required analysis, e.g., the Department of Water Resources' California Central Valley Groundwater-Surface Water Simulation Model (C2VSIM) and the U.S. Geological Survey's Central Valley Hydrologic Model. Either of these existing models could have been used to analyze the groundwater impacts of increased groundwater pumping (as assumed by the Draft SED analysis) or of water management practices that would comply with SGMA.

Instead of using the available modeling tools, the SED uses a semi-quantitative analysis which is deficient and ignores groundwater-surface water interactions. The SED semi-quantitative analysis identifies the net change in average annual groundwater balance and identified impacts of greater than 1-inch as significant. The basis for designating 1-inch as a level of significance is not disclosed. The SED should also have identified the effects of the assumed increase in groundwater use in terms of factors that decision-makers could readily understand, like declines in water levels.

Since the groundwater basin accumulates changes in the groundwater balance over time, the SED should have identified long-term cumulative declines in groundwater levels.

The SED analysis fails to identify the effects of increased groundwater pumping and water levels; the changes that would occur to surface water flows are not identified. The increased groundwater use that would result from the reductions in surface diversion capability would cause lower groundwater levels that would cause large reductions in groundwater accretions to local streams and would likely result in seepage losses from those streams. As a result of the increased groundwater use, local stream systems would change from mostly gaining streams to mostly losing streams, with reductions in flow downstream. Those reductions in flow were not identified due to the defective SED analysis.

- Page 9-14. The Draft SED states: "For example, based on modeling results performed for San Joaquin County to simulate a 5-year period (1989-1993), the Tuolumne River and upper WSJR were gaining rivers, while the Stanislaus River and LSJR (from the Merced River to Vernalis) were losing rivers (NSJCCBA 2004)."

  ***Comment**: This discussion is not consistent with other modeling of the area (e.g., USGS. 2009. Groundwater Availability of the Central Valley Aquifer, California. Professional Paper 1766. Groundwater Resources Program. Edited by C.C. Fount, p. 48). The discrepancy between the USGS modeling results and the Draft SED analysis may be due to the NSJCCBA model being interpreted outside of its primary analysis area in locations where results are likely not well calibrated. As noted previously, the SED could have*

actually applied an existing groundwater model which would have provided results specific to the proposed management actions.

- Page 9-14. The Draft SED states: "In either the losing or gaining scenario, groundwater-surface water interactions are unlikely to have a large impact on total river flow. A recent modeling study of a region east of the SJR extending north of the Stanislaus River to south of the Merced River indicated that groundwater-surface water interactions have a relatively small effect on river flow, generally changing flow by plus or minus 2 cubic feet per second (cfs) per mile (USFS 2015)."

  ***Comment**: The discussion here is based on prior analyses of groundwater that do NOT include the proposed additional pumping that would occur from the surface management actions specified in the SED along with lack of compliance with SGMA requirements. The increase in groundwater pumping that would occur due to the reduced surface diversions indicated in the SED would reduce groundwater levels beyond the assumptions used in the cited modeling reports. Use of available groundwater models would have identified the extent to which surface water flows would be changed by pumping.*

- Page 9-15. The Draft SED states: "However, it is difficult to determine the sustainable yield of a subbasin because of the large degree of uncertainty associated with all components of the water budget. This includes the difficulty of determining whether a certain level of groundwater pumping will reduce accretions to surface water bodies by an amount that will be detrimental to surface water resources."

  ***Comment**: Although there is some level of uncertainty associated with elements of the water balance, a water balance approach was used by the SED to identify impacts. With use of available groundwater models, an initial estimate of sustainable pumping would have been possible and it could have been refined to maintain accretions to surface water bodies at identified levels. The Draft SED analysis chose to not do this analysis, and instead relied on a semi-quantitative analysis which has the same defects in terms of uncertainty in water balance. Stated differently, the Draft SED states that the data is too uncertain to support the appropriate modeling analysis, but then nevertheless uses that same data for its semi-quantitative analysis.*

  Additionally, the statement concerning reduced accretions directly contradicts prior statements (which are probably incorrect) on Draft SED p. 9-14 that "groundwater-surface water interactions have a relatively small effect on river flow."

- Page 9-44 – Geographical Treatment of Aquifer

  ***Comment**: The discussion of the basis for not assessing the effects of the LSJR alternatives on different aquifers could have been avoided if the SED had actually used the available groundwater models of the analysis area.*

- Page 9-45 – Assessment of Irrigation District Groundwater Pumping

  ***Comment**: There is no reason to believe that groundwater pumping would be limited to historical or current levels of installed groundwater pumping capacity. In the absence of*

new restrictions on wells, additional groundwater pumping capacity would likely be installed, which is what has happened in recent years.

- Page 9-46 – "Normalizing the change in groundwater balance by the subbasin area translates the effect into height and directly shows how average groundwater level could be impacts under the LSJR alternatives."

  ***Comment**: This is not an accurate statement of the effect of changes in groundwater balance. As described in the next paragraph, the effects of the change in groundwater balance in an unconfined aquifer (which is the most common occurrence in the Lower San Joaquin Valley) must be adjusted for the specific yield, which multiplies the actual water level effect by a factor of 10 to 14. Additionally, the groundwater level changes are cumulative, meaning that continued changes in groundwater balance of 1 inch per year could cause several feet of decline. The actual impact on groundwater levels is the most meaningful indication of groundwater impacts and should have been estimated directly using one of the existing available groundwater models. The other effects that are not addressed by the SED, which would be identified through use of existing available groundwater models, are the effects on accretions to or seepage from local streams.*

- Page 9.4.3 – Impacts and Mitigation Measures

  ***Comment**: As identified previously, the SED does not identify the cumulative impacts on groundwater levels and groundwater-surface water flow interaction. These effects could have been analyzed through application of the changes in net recharge identified by the WSE to one of the existing groundwater models. The approach to impacts is very indirect, does not disclose the actual effects on groundwater levels for decision makers, and does not disclose the effects on groundwater-surface water interactions that could have a significant adverse effect on streamflows.*

December 15, 2016

Submitted via email: commentletters@waterboards.ca.gov

Ms. Jeanine Townsend
Clerk to the Board
State Water Resources Control Board
P.O. Box 100
Sacramento, CA 95812-2000

Subject: Comment Letter – Bay-Delta Phase II Working Draft Science Report

The State Water Contractors ("SWC") appreciate this opportunity to provide input regarding the Working Draft Scientific Basis Report for New and Revised Flow Requirements on the Sacramento River and Tributaries, Eastside Tributaries to the Delta, Delta Outflow, and Interior Delta Operations ("Phase II Report"). The SWC submit these comments on their behalf and on behalf of the SWC's 27 member agencies.[1]

The comments contained in our technical memorandum, attached, are limited to technical review of the Phase II Report, as requested in the State Water Resources Control Board's ("Water Board's") notice dated October 19, 2016. To the extent that the Water Board would like to discuss alternative actions that are achievable and likely to provide species benefits outside of a technical review of the Phase II Report, the SWC would be pleased to participate in such discussions. The SWC and its members are involved in many collaborative scientific efforts, scientific studies (including field work), and habitat restoration projects. The SWC have been, and will continue to take proactive steps to improve the Delta ecosystem, and would be willing to partner with the Water Board to find achievable and resilient solutions.

It is unfortunate that the Phase II Report does not provide a scientific basis for realistic solutions. Overall, the SWC are extremely disappointed by the analysis contained in the Phase II Report. The document appears to have been written in 2010, providing only a few selected references to the more recently published literature. To the extent new analyses are included in the Phase II Report, those references are most often to analyses that are preliminary, unpublished, and not peer reviewed.

[1] Alameda County Flood Control & Water Conservation District, Zone 7, Alameda County Water District, Antelope Valley-East Kern Water Agency, Casitas Municipal Water District, Castaic Lake Water Agency, Central Coast Water Authority, City of Yuba City, Coachella Valley Water District, County of Kings, Crestline-Lake Arrowhead Water Agency, Desert Water Agency, Dudley Ridge Water District, Empire, West Side Irrigation District, Kern County Water Agency, Littlerock Creek Irrigation District, Metropolitan Water District of Southern California, Mojave Water Agency, Napa County Flood Control and Water Conservation District, Oak Flat Water District, Palmdale Water District, San Bernardino Valley Municipal Water District. San Gabriel Valley Municipal Water District, San Gorgonio Pass Water Agency, San Luis Obispo County Flood Control and Water Conservation District, Santa Clara Valley Water District, Solano County Water Agency, and Tulare Lake Basin Water Storage District.

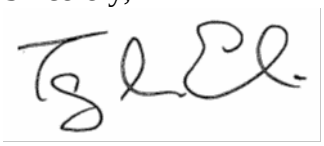
The Phase II Report does not contain a discussion of the best available science and fails to provide uncertainties associated with the science cited. This type of information is critical to provide Water Board members with a tool to make decisions in the future. As currently drafted, this report does not provide an unbiased discussion of the scientific literature.

The Water Board was provided with valuable guidance from at least two independent expert panels that provided reports describing the best available science, but their guidance was largely ignored in the Phase II Report. After the Water Board's Water Quality Control Plan workshops in 2012, the Water Board asked the Independent Science Program to provide assistance in reviewing the significant technical information it received during the workshops. In response, the Independent Science Program organized and hosted at least two independent expert review panels: the Delta Outflow and Related Stressors ("Outflow Panel"), and the Interior Delta Flows and related Stressors ("Interior Flows Panel").[2] The Phase II Report ignores much of the recommendations and guidance provided by these independent expert panels, particularly with respect to disclosure of uncertainty and standard statistical practices.

The independent peer review panels were significantly more qualified in their expectations regarding what could be achieved with new flow in the current Delta. The attached Technical Memorandum provides specific examples of revisions to the Phase II Report to reflect the direction provided by the independent review panels, as well as identifies many relevant studies that were not acknowledged in the Phase II Report.

As the October 19, 2016, notice from the Water Board was limited to technical review of the Phase II Report, the SWC have not provided comments regarding our more fundamental concerns with the flow proposal, even though our concerns are significant regarding implementation, viability, and the legality of the current proposal. The SWC understand that this first review of the Phase II Report is just the initial step in the process. We look forward to continuing the dialog with the Water Board with the shared goal of developing an effective and viable proposal.

Sincerely,



Terry L. Erlewine
General Manager

Enclosure

[2] There have been other expert panels providing input regarding best scientific practices, and those reports provide similar guidance.

TECHNICAL MEMORANDUM
STATE WATER CONTRACTORS' REVIEW OF PHASE II REPORT

This memorandum is in response to the State Water Resources Control Board's ("Water Board") request for written comments on the Working Draft Scientific Basis Report on the Phase II ("Phase II Report") update of the 2006 Water Quality Control Plan for the San Francisco Bay/ Sacramento – San Joaquin Delta Estuary ("WQCP").[1] The SWC have identified a number of major flaws with the Phase II Report that will require substantial revisions. The Phase II Report should be substantially revised and recirculated for public comment before peer review, and before being used as a basis for management.

I. The Phase II Report's technical rationale does not support its proposal.

A. Unimpaired flow is not a proxy for pre-development or "natural" flow.

Best available science shows that unimpaired flow is not an appropriate measure of natural flow on the valley floor or in the Delta. We recommend that the revised draft of the Phase II Report cite recent supporting scientific work, including work by Howes et al. (2015) on the evapotranspiration from natural vegetation that was present in the Delta and Central Valley and work by Fox et al. (2015) that quantifies the expected mix of vegetation in the Delta and Central Valley under natural or pre-development conditions. Further, we recommend that the revised draft Report cite work by Huang (2016) that utilized the above-cited work to compare annual and seasonal unimpaired and natural Delta outflow estimates. Huang found, similar to Fox et al. (2015), that unimpaired outflow estimates are a poor proxy for natural outflow estimates, significantly overestimating natural flows. Huang's comparison of average annual and unimpaired and natural Delta outflow is shown in Figure SWC-1 by 40-30-30 water year type. Similarly, his comparison of average monthly unimpaired and natural Delta outflow is shown in Figure SWC-2.

Given that the best available science shows unimpaired flow to be an inappropriate measure of natural flow on the valley floor or in the Delta, proposed flow standards should be justified based on flow function and not on purported benefits associated with emulation of natural conditions. Thus, use of unimpaired flow criteria (as an accounting tool) should not be:

- Justified as a means to improve habitat conditions through restoration of natural flow conditions, functions, etc.
- Used as a justification for the need to increase required flows on the valley floor and/or in the Delta.
- Used as a baseline from which to measure annual or seasonal trends in flows on the valley floor or in the Delta.

[1] The Technical Memorandum contains comments addressing global concerns about the Phase II Report. Exhibit A to the Report includes specific comments with page references.

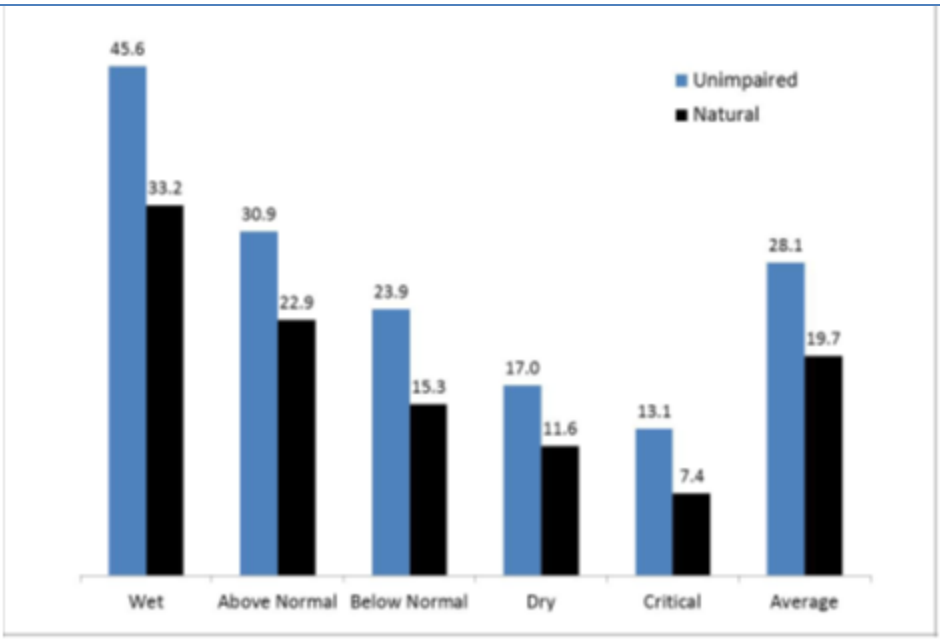


Figure SWC 1. Average Annual Unimpaired and Natural Net Delta Outflow (MAF)

This chart compares annual average "unimpaired" and "natural" Delta outflow estimates (in units of million acre-feet) for the 93-year hydrologic period spanning water years 1922 through 2014. Comparisons are shown by 40-30-30 water year type as well as the full period average. This chart clearly shows that unimpaired flow estimates are significantly higher than natural flow estimates under all hydrologic conditions. Under average conditions, the annual unimpaired flow estimate is 43 percent higher than the natural flow estimate. (ref: Huang (2016))

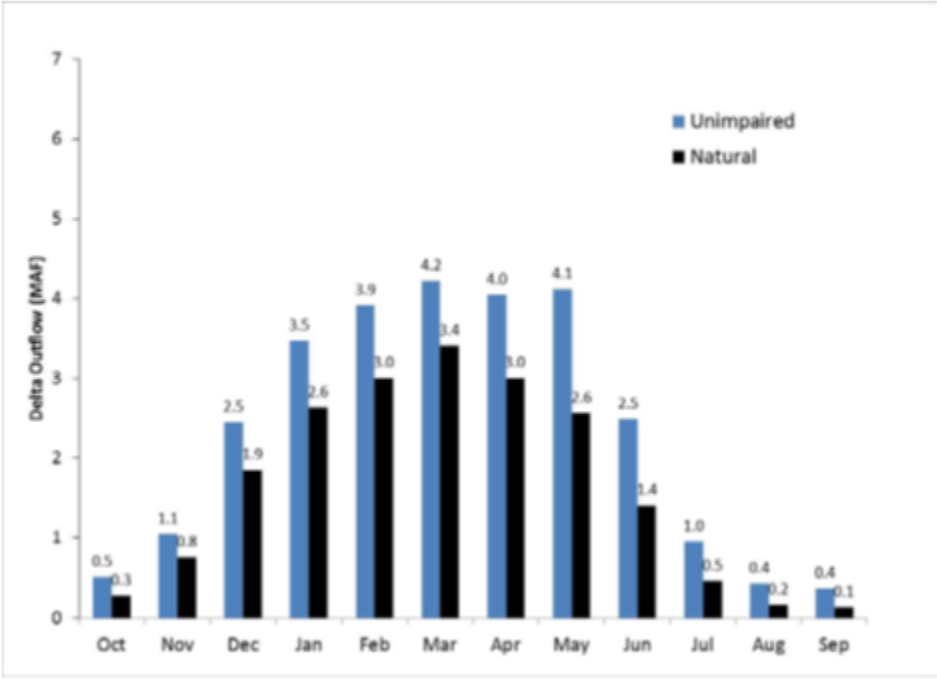


Figure SWC-2. Comparison of Monthly Natural and Unimpaired Net Delta Outflow Estimates by 40-30-30 Water Year Type: Water Years 1922-2014 Averages

B. The Phase II Report is not proposing "natural flow."

The regulatory flow proposal is based on DWR's unimpaired flow calculation as a means to define a pool of water for adaptive management for the intended purpose of "sculpting" flows. (See e.g., Phase II Report pp. 1-9 and 1-10.) The Phase II Report does not identify the types of actions it would take to "sculpt" flows, and therefore it is unclear what the Water Board means by this term. The SWC recommend that the Phase II Report be revised to provide examples of the types of flow being proposed, as well as the conceptual model that the Water Board would be evaluating as part of its adaptive management plan.

The Phase II Report cites literature supporting the idea that a percent of the natural hydrograph be preserved as a method for restoring the Delta ecosystem. However, the Water Board is really proposing a plan where it would "sculpt" flows, not necessarily in proportion to unimpaired flows. Therefore, the cited literature does not support the intended action. It should be further noted, as the water contractors and others explained during the 2012 Water Board workshops, the literature relevant to using unimpaired flows as a restoration tool cautions that the outcome, particularly in highly altered systems, is highly uncertain. See SWP-CVP Water Contractors (2012) pp. 6-2 to 6-5, citing Poff et al. (1997), Poff and Zimmerman (2010), Pierson et al (2002), and Bunn and Arthington (2002)[2] ["The advice from aquatic ecologists on environmental flows might be regarded at this point in time as largely untested hypotheses about the flows that aquatic organisms need and how rivers function in relation to flow regime."].)

The Phase II Report should have disclosed the uncertainty associated with this literature.

C. The Phase II Report is not proposing a "functional flow."

During the recent workshop, there was a definitional discussion about what is a "functional flow." The SWC have been discussing the need for functional flows for many years, so knowing that there is a misunderstanding regarding the use of this term is informative. Based on the literature, the SWC define a functional flow as supporting a specific ecological function that is relevant to one or more native fish species. It requires an investigation of the conditions under which native fish evolved, how those conditions have changed, and what can be done to restore those conditions within the context of today's highly altered system. Historically, the water and landscape were much more interconnected where high flows would spill out onto the landscape creating spawning and rearing habitat, and feeding the rivers as it slowly drained back into the main channels carrying nutrients, detritus, and lower trophic organisms produced in these nutrient rich, often shallow and slow moving waters, among other important functions. Merely putting more water down rip-rap lined levees does not recreate these historical conditions. The best opportunities for restoring functional flows may be in areas where some remnant of the predevelopment environment still exists, like floodplains, or in the restoration of these land-water connections elsewhere. To further explain this point, we recommend that the Water Board review the SFEI 2016. (Attached for your convenience, Exhibit B.) In our highly altered system, the concept of unimpaired flow is not the same as functional flow or natural flow, as it

[2] The Phase II Report also cites Rozengurt et al. 1987, which appears to be an unpublished technical report from the Water Board hearings in 1987. From this submittal, it is not possible to determine the technical basis for the author's conclusion. With all of the research that has been completed in the last nearly 30 years, it is surprising that the Phase II Report would rely on an unsubstantiated document.

would merely provide for transport functions (i.e., increasing the depth and velocity of water in leveed and rip rapped channels) without providing for many other important functions.

D. The concept of flow as mitigation for past harm is unsupported.

At the December 7, 2016, workshop, it was suggested that since land and water are disconnected in our highly altered system, perhaps more water than pre-development annual outflow is required to compensate for past damage. This may be the case to restore specific functions, like recreating cold water pool below rim dams to compensate for blocking salmon passage to higher elevation spawning grounds. However, this concept only serves to reinforce why a blanket application of a percent of the unimpaired hydrograph flows in this highly altered system is inappropriate. For example, additional flow could dilute pesticides, assuming that is a beneficial use of water, or it may merely flush the problem further downstream. The additional flow may not enhance lower food web productivity. In fact, we may need to create areas with lower flows to restore some of the productivity that was lost when we eliminated the Delta's dendritic, dead-end channels for flood control and navigation. As part of our submittals during the 2012 Water Board workshops, the state and federal water contractors provided a detailed discussion and literature review on the subject of flow and flow function in regard to what could be achieved in this system with additional flow. Please State Water Contractors and Central Valley Project Contractors' (2012) (Submittal to SWRCB: Ecosystem Changes to the Bay-Delta Estuary: A Technical Assessment of Available Scientific Information, available at: http://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/docs/cmnt081712/daniel_nelson.pdf.)

II. The historical flow trends analysis is skewed by the selected baseline.

The SWC would like to further clarify that the appropriate time period for defining the flow patterns under which native species evolved is predevelopment. It should not be assumed that the native fish were doing well until recently, as is suggested in the Phase II Report. (Phase II Report, p. 1-3 ["…many of the native fish and wildlife species maintained healthy populations until the past several decades when water development intensified.") The native fishes had already experienced enormous ecological change as early as the beginning of the last century. When evaluating changes in flow patterns, the Phase II Report uses a baseline of the 1940s, 1950s, or 1960s, which were highly artificial time periods when the reservoirs were in place but demand was not fully developed. During these time periods, the reservoirs were releasing significant flow at times when there would not have been as much water under "natural" or pre-development conditions. Comparing a time period with unnaturally high outflow to more recent time periods is not a biologically meaningful comparison.

The state and federal water contractors provided information regarding flow trends in their 2012 submittal to the Water Board during the Analytical Tools Workshop. Since that time, the referenced work has been peer reviewed and published (Hutton et al. (2015).) The Phase II Report presents the older unpublished work and ignores the more recent published literature. For example, the Phase II Report at p. 2-65 (Figure 2.4-9) cites the unpublished Fleenor et al. (2010) report to the Water Board and concludes:

> …the position of X2 has been skewed eastward in the recent past, as compared to pre-development conditions and earlier impaired periods, and that variability of salinity in the western Delta and Suisun Bay has been significantly reduced.

The Phase II Report (Figure 2.4-9) shows daily X2 over several time periods, with the associated text suggesting a trend. However, as shown in Hutton et al. (2015) at p. 9, Table 3, whether there is a trend in the location of X2[3] depends on the selected baseline years as well as the month. From 1968-2012, there is no statistically significant trend in the location of X2 for the months January through August. Conversely, the results for the longer record, 1922-2012, show a statistically significant increasing trend (more salinity) in the location of X2 in the months January through June; no trend in July; and a decreasing trend in X2 (less salinity) in the months August and September.

During the Fall X2 months of September-November, the trend analysis also varies depending on the baseline years chosen. On p. 2-67, Figure 2.4-10, the Phase II Report uses a baseline of 1967 and suggests an increasing trend (more salinity) over time. Hutton et al. 2015 also observed this trend using a 1967 or 1968 baseline. However, Hutton et al. (2015) shows multiple comparisons using different baselines, and the results using the longer time period of 1922-2012 show mixed results (September= decreasing trend, October= no trend, November = increasing trend). (See, Figure 2, below, Hutton et al. 2015, p. 8.)

[3] The Phase II Report recommends that the "… Dayflow X2 equation should be updated using more salinity and flow data which is now available to reduce uncertainty in the relationship between Delta outflow and daily average X2…" Given their potential role in future Bay-Delta outflow and salinity standards, the SWC agree that empirical X2 equations should be updated to reflect best available flow and salinity data. The SWC recommend that alternative approaches in addition to Jassby et al. (1995), i.e. the Dayflow X2 equation, be summarized in the Phase II Report and evaluated for future use by the Water Board, including: Monismith et al. (2002), MacWilliams et al. (2015), Hutton et al. (2015), and Rath et al. (2016).

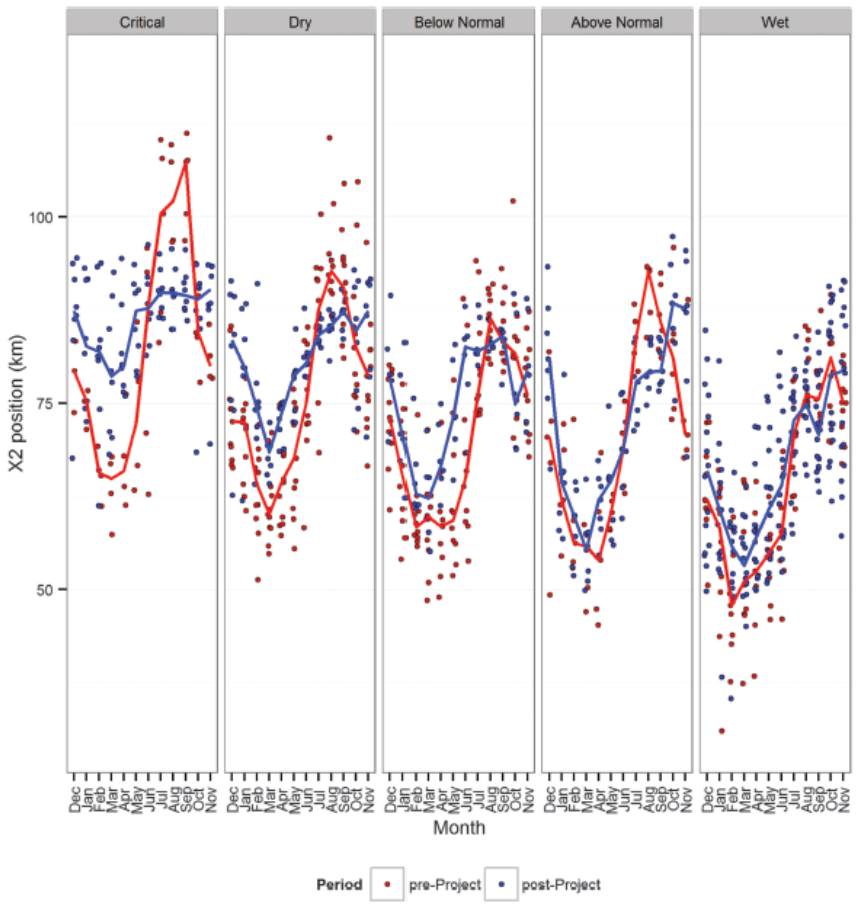


Fig. 3. (Color) Average monthly X2 position is shown by water year class on the Sacramento River branch under preproject (water years 1922–1967) and postproject (water years 1968–2012) conditions, with lines connecting the seasonal medians; symbols show individual year values (red = preproject and blue = postproject), with lines connecting the seasonal medians; in all but wet years, the postproject X2 position tends to be further downstream (i.e., lower) in summer months and further upstream (i.e., higher) in other months; the X2 position in October and November is generally more closely associated with the previous water year; thus, the x-axis spans the months December through November

The changes in X2 location post-project should be expected, reflecting use of the project reservoirs to manage salinity and buffer against dry years. Upstream water storage construction and increased in-basin and out-of-basin water use has affected X2 in different ways, depending on season and water year class. For example, X2 position exhibits less intra-annual variability in the post-project period than it did in the pre-project period (water years 1922-1967). (Hutton et al. (2015).) Post-project X2 position is typically further upstream (i.e., higher) in wet months (February through May) of dry and critically dry years and further downstream (i.e., lower) in the dry months of August and September. This reduction in dry year variability is a straightforward result of reservoirs being operated to store water in wet periods and to release water during dry periods, thus damping the variation in Delta salinity. At the other hydrologic extreme, in wet years, flows are sufficiently high that reservoir operations have less effect on the Delta salinity gradient, resulting in great similarity between pre-project and post-project X2 position.

The SWC recommend that figures, such as Phase II report, Figure 2.4-4, p. 2-63, and other scientific presentations purported to show long term trends, yet based on truncated time series, be removed or updated to reflect the full available nine-decade record. The SWC further recommend that statements that attribute flow and salinity trends to key drivers be removed

unless attribution is supported by quantitative analysis. (See e.g., Phase II report, p. 2-62 ["Since 2000, there has been reduction in spring outflow and a reduction in the variability of Delta outflow throughout the year (Figure 2.4-7) due to the combined effects of exports and variable hydrology."].) There are many actors and drivers in the system, and the causes of changes in outflow[4] are not always obvious.

III. The Phase II Report should follow the recommendations of its independent expert review panels, particularly in the areas of best statistical practices and disclosure of uncertainty.

After the Water Board's WQCP workshops in 2012, the Water Board requested that the Delta Science Program provide assistance in reviewing and assessing the written materials and oral presentations it received in order to identify the best available science to inform the Water Board's decision related to the Water Quality Control Plan Update, Phase II. In response, the Delta Science Program organized and hosted at least two independent expert review panels who produced reports in response to the Water Board's request: the Delta Outflow and Related Stressors ("Outflow Panel Report"), and the Interior Delta Flows and related Stressors ("Interior Flows Panel Report").[5] The Phase II report does not follow the recommendations and guidance provided by these independent expert panels, particularly with respect to disclosure of uncertainty and standard statistical practices. The independent expert panels also provided specific guidance regarding the types of analyses that should be given greater consideration, and that guidance has been ignored as well.

A. The Phase II Report should follow the expert panels' recommendations regarding disclosure of uncertainty.

The Outflow Panel Report (Reed et al. 2014, p. 36) advised that, "It is critical that quantitative analyses communicate uncertainty in recommended flow criteria to decision makers." The Outflow Panel Report (Reed et al. 2014, p. 29) stated further that:

> As with the use of all indices of abundance, the link between changes in the index and changes in the population-level abundances are not claimed to be exact. We emphasize the importance of communicating uncertainty in functional relationships when using them to evaluate the efficacy of various flows.

And, at Reed et al. (2014), p. 25, "…they should also include estimates of uncertainty derived using the same (standardized) statistical methods."

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[4] The Scientific Basis Report describes the existing approach for estimating Delta outflow through the Net Delta Outflow Index (NDOI) calculation. The Report also discusses the USGS monitoring station network and how measurements compare with the NDOI calculation. The SWC recommend that the Report summarize relevant aspects of Sandhu et al. (2016), Fleenor et al. (2016), and Monismith (2016). We agree with Sandhu et al. (2016) that,"*A water balance approach similar to the Net Delta Outflow Index (NDOI) remains the most suitable tool to define net Delta outflow for regulatory purposes, but should be updated to incorporate improvements to consumptive use estimates and correct a few known water accounting errors."* However, the SWC also acknowledge that, given its scientific complexity and regulatory importance, alternative approaches should be explored to increase our scientific understanding of Delta outflow on various timescales.

[5] There have been other expert panels providing input regarding best scientific practices, and those reports provide similar guidance.

1. For example, the Phase II Report should have disclosed scientific uncertainty in its Longfin Smelt analysis.

Contrary to the Delta Science Program review panel's recommendations, the Phase II Report does not communicate the uncertainty associated with the X2-abundance relationships. Instead, the Phase II Report uses the Longfin Smelt X2-abundance relationship to predict how much water would be required to achieve the United States Fish and Wildlife Service's recovery goal, without any mention of uncertainty. (Phase II Report, p. 3-46. ["The analysis indicates that flows in excess of 100,000 cfs are needed since the *Corbula* invasion to meet the USFWS recovery goal of 6,400. In comparison, before the *Corbula* invasion, flows of 50,000 and 30,000 cfs would have been sufficient to meet the goal in January-March and March-May, respectively."]) By being silent on the issues of uncertainty, the Phase II Report leaves the false impression that if we provide the volume of flow, recovery targets will be achieved.

As one method of communicating uncertainty, the Outflow Panel Report recommended that the X2-abundance relationships be viewed on a linear scale, stating at Reed et al. (2014), pp. 24-25 that:

> …X2-abundance relationship should also be shown using linear scales (i.e., these can be in addition to logarithmic and other transformed scales). The more appropriate transformations and best practices used for statistical analyses must still be used; linear plots are an addition to these analyses. This is important for more clearly showing the magnitude of the expected species response as X2 shifts.

The Outflow Panel Report included a figure showing the Longfin Smelt X2-abundance relationship on a linear scale as an illustration of the expected magnitude of the species response. See Figure 3, below, Reed et al. (2014), p. 30. From its Figure 3, it can be observed that after 1987, the Longfin Smelt X2-abundance relationship indicates that abundance is significantly less responsive to changes in X2.

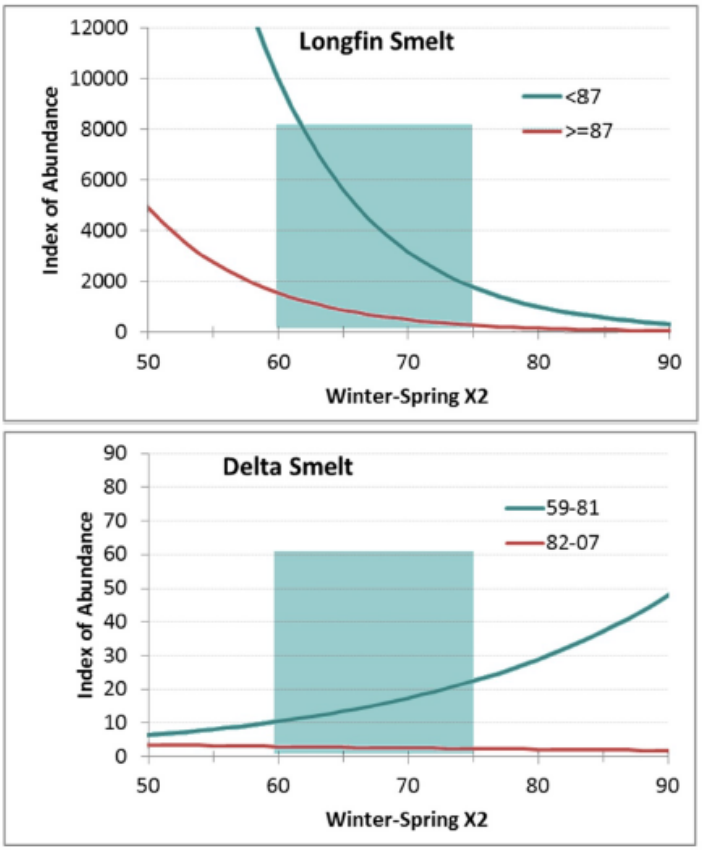

Figure 3. Relationships between Longfin (upper panel) and Delta Smelt (lower panel) abundance indices (mid water trawl and tow net series respectively) and average X2 over the winter-spring period during two different periods of time (before 1987 and after 1986 for Longfin Smelt; 1959-1981 and 1982-2007 for Delta Smelt). These relationships are based on parameters from Table 2 of Kimmerer et al. (2009) transformed from $\log_{10}$ to linear space. The blue boxes represent the X2 range required to achieve low salinity conditions in Suisun Bay.

Again, the Phase II Report does not follow the Outflow Panel's recommendation and only considers the relationship on a log-scale. (See Phase II report, p. 3-47.)

Based on its understanding of uncertainty, partially informed by its Figure 3, the Outflow Panel Report (Reed et al. (2014), p. 29 (emphasis add.)) concluded:

> In the Panel's judgment, based on X2-abundance relationships the evidence that the relatively modest changes in fall[6] Delta outflows that are being proposed are going to result in substantial increases in abundance of key pelagic species is highly uncertain. Substantive increases in Longfin Smelt abundance index may be realized under the proposed 75% winter-spring unimpaired flow standard. **Even in that case, population changes may be very difficult to detect given the variance of the regression, potentially high observation error in the sampling programs, and the infrequent implementation of high flows, even under the unimpaired flow strategy**.

[6] This paragraph relates to Longfin Smelt, so it appears that this reference to fall is a typo. Although, as the paragraph immediately above the referenced section is in regard to fall X2 for Delta Smelt, it could be a reiteration of the Outflow Panel's view on the certainty associated with Delta Smelt Fall X2.

Once again failing to follow the expert panel's recommendation, and without any explanation or qualification, the Phase II Report's conclusion is to the contrary, predicting increases in Longfin Smelt abundance. (Phase II Report, p. 3-49 ["Delta outflows predicted to increase longfin smelt population…."].)

2. For example, the Phase II Report should have disclosed uncertainty regarding the indirect effects of the SWP-CVP on out-migrating San Joaquin River Chinook salmon.

The Phase II Report's discussion of the potential relationship between San Joaquin River flow, SWP-CVP exports, and San Joaquin River Chinook salmon survival is based almost entirely on the 2009 National Marine Fisheries Service Biological Opinion ("NMFS BiOp") thereby ignoring all of the current literature. (Phase II Report, pp. 3-43 to 3-44.) The best available science does not support the Phase II Report's conclusion that, "Juvenile salmonids migrate out of the San Joaquin basin during February through June (SWRCB 2012) and may need protection from export-- related mortality at any time during this period in order to preserve life history diversity." In fact, it is unclear how or if any change in current project operations would further benefit salmonid survival.

The Phase II Report should rely on the description of the current state of the science, and recommended management actions contained in the Draft Collaborative Adaptive Management Team (CAMT) Salmon Scoping Team Synthesis Analysis (Draft Salmon Synthesis Report).[7] The Draft Salmon Synthesis Report is a collaborative effort between state and federal fishery agencies, environmental interests, and the state and federal water contractors. The limitation of the report is that it focuses exclusively on the potential effects of the SWP and CVP, and therefore would not necessarily provide the Water Board with information regarding what actions could improve species abundance. The SWC nevertheless believe that the Draft Salmon Synthesis Report provides a useful description of the best available science and should inform future revisions to the Phase II Report.

The SWC understand that the final Salmon Synthesis Report will not be released until later this month. [8] However, the draft findings that were presented to the CAMT management team are informative, indicating areas of scientific disagreement and gaps in available information that should be discussed in the Phase II Report. The initial findings of the Draft Salmon Synthesis Report include, for example, that there is, "**Inconclusive evidence of a relationship between exports and through-Delta survival**." (See Draft Salmon Synthesis Report, Presentation to CAMT, at slide 17, emphasis add.) The Delta Science Program concluded similarly during its review of the implementation of the 2009 NMFS BiOp stating, "**The study found that fish entrainment into the inner Delta was not related to pumping operations…..**" (Anderson et al. (2012), p. 31.)

The Draft Salmon Synthesis Report explains the reasons for this uncertainty, which include:

[7] The SWC appreciate the Phase II Report's reference to the Salmon Synthesis Report and we understand that the final report was not available to Water Board staff.

[8] The SWC have attached the CAMT Power Point presentation that summarizes the Salmon Synthesis Report. (See Exhibit C.) We will forward the complete report when it is available to the CAMT members.

- All observations are in the presence of management operations (I:E, E:I, OMR restrictions) which makes it difficult to assess their effectiveness.
- There has been low variability and limited replication in conditions during tagging studies.
    - Most observations of smolts have been at low levels of inflows and exports.
- Low overall survival makes it difficult to detect changes in survival.

(See Draft Salmon Synthesis Report, Presentation to CAMT, slide 31.) The findings of the Draft Salmon Synthesis Report further include a finding that:

- Export effects vary with distance from the facilities**.**
- Largest export effect was estimated in Old River near the SWP and CVP intakes.
- Almost no effect at junctions off Sacramento River such as Georgianna Slough.
- Small effect at junctions leading off San Joaquin River, except HOR.

(See Draft Salmon Synthesis Report Presentation, slide 34, emphasis add.) This finding is important as it highlights the importance of being spatially explicit when characterizing the effects of the state and federal water projects on hydrodynamics.

Of course, the Phase II Report has the obligation to identify changes in hydrodynamics that are biologically relevant to the species. There is a high degree of uncertainty regarding such relationships. For example, the fundamental assumption underlying the Phase II report is that an increase in river flows is predicted to result in increased abundance or survival of a targeted fish species. The fact that results of juvenile Chinook salmon survival studies conducted in the lower San Joaquin River in 2006 and 2011, both higher flow years during the spring juvenile salmon migration period, did not result in markedly higher survival rates when compared to years with substantially lower spring flows, underscores the high level of uncertainty in these biological relationships that is not discussed in the report.

Management actions up to now, like those contained in the 2009 NMFS BiOp, have largely focused on tidally averaged flows. In its review of the implementation of the 2009 NMFS BiOp, the Delta Science Program (Anderson et al. (2012), p. 21) explained that tidally averaged flows aren't biologically meaningful:

> The general project operations have been managed in terms of mean flows in OMR and in the San Joaquin River. This has been the fundamental approach for operations of the system for years but has resulted in inadequate protection for fishes. In part, this is because attempts to understand the movement and survival of fish through the Delta to date have not considered effects of tides, which are the dominant control on flow velocities and mean direction of flow.
>
> Delta survival of steelhead, and especially Chinook, was extremely low based on tagging studies. Characterizations of survival in terms of river km or mean flows are inadequate because the rapid travel time and complex routing of fish through different reaches cannot be explained by these mean measures. The IRP suggests the travel, routing and survival of fish through the system needs to account for migrant behavior and the behaviors of predators in response to the strong tidal influences in the Delta.

Interior Flow Panel Report (Monismith et al. (2014), p. 53) made a similar observation stating:

> Metrics useful for managing water diversions (e.g. water exports, Old and Middle River flow) must be used with caution because they represent highly aggregated measures of the velocities fish detect and respond to in the near field.

The 2009 NMFS BiOp is an example of this tidally averaged flow management approach, where net flows were estimated using the particle tracking model. This approach assumes net flow in a tidal environment is an important factor influencing juvenile salmonids. On this topic, during review of studies in 2012, the Delta Science Program (Anderson et al. (2012), p. 15) concluded:

> The Spring 2012 plan for water operations focused on characterizing smolt movement with mean project operations, OMR flows, pump exports and I/E ratio. The plan appeared to be based upon the assumption that fish movements and survival would be correlated with measures of mean flow. However, studies cited in the Tech Memo demonstrated weak correlations between smolt movement and particle tracking model studies and between project operations, OMR flows and smolt movement and survival. Studies available in the literature and many published in the region have demonstrated that fish movement across a wide range of taxa exhibit behavioral response to tidal oscillations.

The Draft Salmon Synthesis Report includes information related to biologically relevant flows, for example changes in velocity. As also explained, however, there is scientific uncertainty regarding, "The magnitude of change in flow or velocity needed to influence salmonid behavior or survival that is biologically relevant." (See Draft Salmon Synthesis Report Presentation, slide 44.)

The findings in the Draft Salmon Synthesis Report are based on the published literature, which is available to the Water Board, and a more complete discussion of the available scientific information would have highlighted areas where acknowledgement of uncertainty is appropriate.

B. The Phase II Report should follow the recommendations of its independent expert review panels regarding application of best statistical practices to inform decisions regarding reliability of technical information.

The Interior Flows Panel (Monismith et al. (2014), p. 2) stated:

> The Panel was concerned that little experimentally validated quantitative guidance on flow management was available to the Board. We provide a set of criteria for identifying the most useful science on which to base updated flow standards. In particular, we suggest the Board look favorably on synthesis papers that have the following characteristics:
>
> 1. Hypotheses establish *a priori*, not developed after the fact;
>
> 2. Parameter estimates (i.e., effects estimates) with uncertainty bounds are reported rather than simply significant P values; and

3. Models that are not overfit; the ratio of independent observations to the number of fitted parameters is at least 10.

The Phase II Report does not follow this guidance. For example, the Outflow Panel provided a specific example of failure to follow number 2, disclosure of uncertainty bounds. The example is the TBI/NRDC Longfin Smelt analysis that is also Figure 11 of the Water Board's 2010 Flow Policy Report. The Outflow Panel observed (Reed et al. (2014), pp. 35-36) that:

> On the negative side, we feel the strength of the relationship has been oversold because there is no consideration of uncertainty in model predictions. This deficiency is not unique to the TBI/NRDC analysis within the flow criteria report. Here, we repeat the TBI/NRDC analysis in a Bayesian framework, as an example, to highlight the importance of communicating uncertainty to policy makers.

The results of the Outflow Panel Report's Bayesian framework showed (Reed et al. (2014), p. 36) that:

> Examination of the data points in the TBI/NRDC analysis shows considerable overlap in flows for years when populations decline (y=0) and grow (y=1), and only four of the 20 years with positive population growth had flows larger than those of years with population declines (Fig. 5). Not surprisingly then, the uncertainty envelope for this relationship is relatively wide, and is also asymmetric (dashed lines in Fig. 5).

And, (Reed et al. (2014), p. 36) further:

> That is, outflow requirements to achieve population growth in 50% of years could be 40% lower or 70% higher than the reported mean…These wide ranges illustrate a much different and more uncertain outcome then impression based solely on the expected value, and the expected value is all that is provided in the flow criteria report (SWRCB 2010).

The Phase II Report repeated the same error that the Outflow Panel observed in the 2010 Flow Policy Report. The Phase II Report does not discuss the wide range of uncertainty in the results. (Phase II Report, 3-46, pp.3-48, and 3-49.) The Phase II Report did not mention nor address the critical comments regarding this analysis provided by the Outflow Panel. The Phase II Report also failed to discuss Nobriga and Rosenfield (2016), whose results also suggest that outflow cannot be used to rebuild the Longfin Smelt population over time.[9]

C. The Phase II Report should follow the recommendations of its independent expert review panels regarding use of correlation analysis to inform management actions.

Contrary to the direction of the Outflow Panel, the Phase II Report takes the standard set of species abundance-X2 relationships, and uses those correlations to predict increased species abundance at various levels of potential future outflow.[10] By being silent as to uncertainty, the

[9] Nobriga and Rosenfield 2016 will be discussed in more detail in the Longfin Smelt section.

[10] The Phase II Report's stated purpose is to provide flows to support native species, but it then references abundance-X2 relationships for species that are non-native (e.g., striped bass, American Shad). The Water Board

Phase II Report gives the false impression that its analysis is highly predictive and reliable. Rather than fully acknowledging the importance of understanding the biological mechanism underlying a correlative analysis when formulating management actions, the Phase II Report basically concludes that the correlations are so strong that management action is justified. What the Phase II Report fails to acknowledge is that the nature of the appropriate management action is informed by understanding the underlying biological mechanism. Stated differently, we don't know what the appropriate management action is until the mechanism is understood. This limitation of the use of correlative analysis should have been more fully disclosed in the Phase II Report.

The Outflow Panel (Reed et al. (2014), p.65) provided advice regarding correlation analysis as a basis for regulatory action, as follows:

> Even when all of these conditions are met, [11] the abundance relationships with outflow (X2) are correlations, sometimes quite strong and robust, but they are still correlations. In the case of using outflow in the Delta ecosystem, as in many other ecosystems, correlations can be misunderstood and over-interpreted because they are specific to a set of conditions and they do not provide information on causality.

And:

> …correlations can appear to be simple and direct but often reflect many steps in a complicated set of processes and mechanisms. An example is the conceptual model relating outflow to the population dynamics of Longfin Smelt (Figures 3-5, Rosenfield 2010); outflow appears in many places in the conceptual model and these are many pathways that relate outflow to environmental conditions and biological processes that ultimately combine to affect population abundance and distribution.

And:

> Without a very long data record for field observations sufficient to tease out effects of multiple factors (which is impractical) and a strong basis of experiments and process-level studies (not just monitoring of abundance indices), correlation-based indicators have inherent uncertainty that can result in projections with various levels of inaccuracy or even unexpected results.

The Phase II report should more completely acknowledge the limitations of correlative analysis, and discuss the more recent scientific information focusing on mechanism.

For example, for Longfin Smelt, there have been analyses and field studies that do provide insight into potential mechanisms. And, these studies do not necessarily support the prevailing hypothesis that Longfin Smelt spawn upstream in the freshwater areas of the Delta, with greater upstream spawning success in wet years.

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should reconsider whether it should be enhancing predator species, like striped bass, when they are predator fishes that threaten native Chinook salmon smolts.

[11] The Outflow Panel Report includes recommendations related to "conditions" for a scientifically sound adaptive management program for flow based management actions. See Outflow Panel Report at pp. 63-64.

Lenny Grimaldo and others have completed several years of larval sampling in the tidal marshes around Suisun Bay and San Pablo Bay. Grimaldo et al. (presentation and in review) found that even in the recent drier years, the tidal marshes around San Pablo Bay, Suisun Bay and Napa River are replete with newly hatched Longfin Smelt. This finding is significant for several reasons. First, this observed indication of spawning in brackish/low salinity regions is counter to the prevailing view that Longfin Smelt spawn in upstream freshwater locations. Second, this spawning and larval rearing is occurring in tidal marshes, rather than open water. And third, significant spawning and larval rearing is occurring at these downstream locations, suggesting a counter-hypothesis that more Longfin Smelt spawn downstream of the Delta in normal and wetter years and then move upstream into the Delta by fall.

Their field work is supported by the surveys as there is no statistical relationship between winter-spring outflow and larval abundance in the Delta. The relationship to spring outflow is with the following fall, suggesting that Longfin Smelt move upstream after spawning in wet years. See Figure SWC-3, below, Grimaldo et al. presentation at UCD Smelt Symposium.

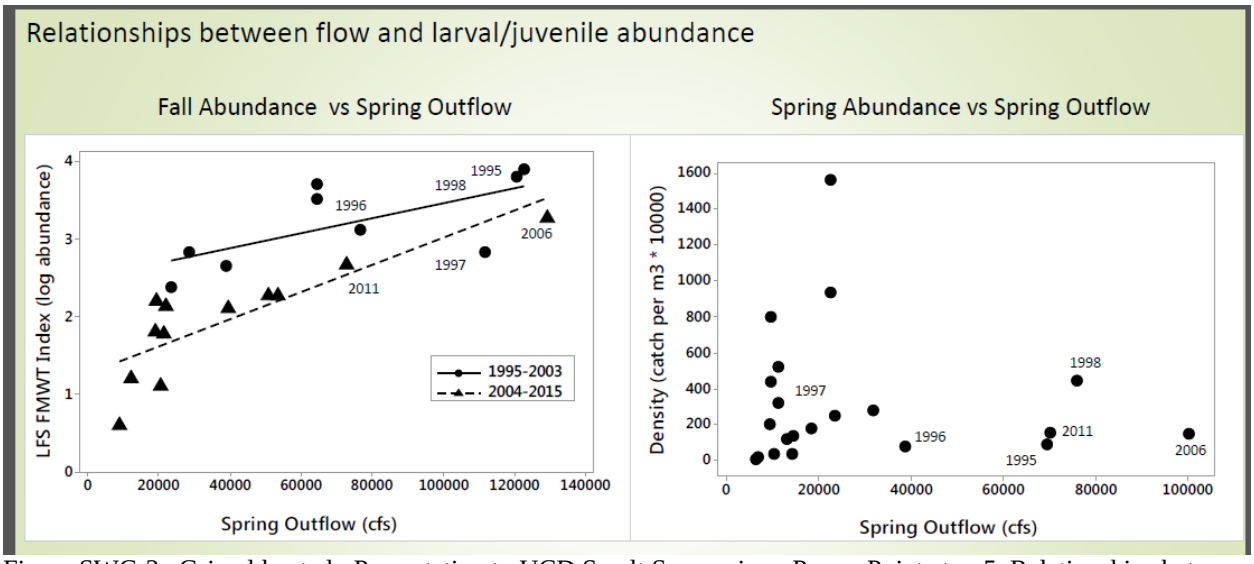

Figure SWC-3. Grimaldo et al., Presentation to UCD Smelt Symposium, Power Point at p. 5, Relationships between flow and larval/juvenile abundance.

The finding by Grimaldo et al. is consistent with the life cycle modeling results by Maunder et al. (2015). The life cycle modeling results confirmed that winter-spring flow is important to Longfin Smelt but the operative flow was not necessarily Delta outflow, as Napa River flow, used as a surrogate for local inflow, performed equally well.

The recent field studies and modeling efforts suggest that the most effective management action may be restoration of tidal marshes surrounding the Bays, and potentially even agreements with downstream water users to increase flows in Bay tributaries.

However, even if the underlying biological mechanism is related to Delta outflow, it does not necessarily follow that reservoir releases can create the conditions that are beneficial to Longfin Smelt. Flow resulting from wet hydrology has different properties than flow resulting from reservoir releases. Dr. Cliff Dahm made this point in a presentation to the Delta Science Council on October 5, 2016, with a figure showing how concentrations of things like nutrients increase

with wet hydrology, being the result of run-off from land. See Figure SWC-4, below. Reservoir releases do not create flows with nutrient and turbidity and other properties that benefit fish.

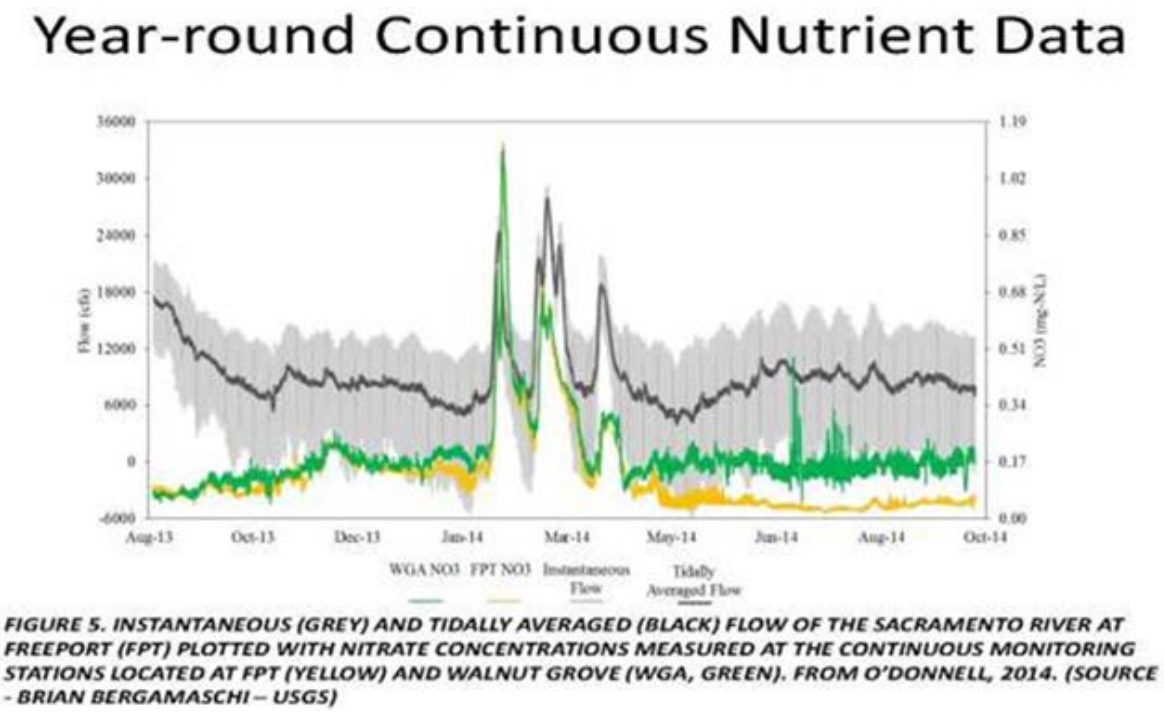

FIGURE 5. INSTANTANEOUS (GREY) AND TIDALLY AVERAGED (BLACK) FLOW OF THE SACRAMENTO RIVER AT FREEPORT (FPT) PLOTTED WITH NITRATE CONCENTRATIONS MEASURED AT THE CONTINUOUS MONITORING STATIONS LOCATED AT FPT (YELLOW) AND WALNUT GROVE (WGA, GREEN). FROM O'DONNELL, 2014. (SOURCE - BRIAN BERGAMASCHI – USGS)

Exhibit SWC-4. Slide presentation to Delta Science Council (October 5, 2016) by Dr. Cliff Dahm.

Longfin Smelt is just one example of the importance of understanding the underlying mechanism. This is true for each species with an abundance-X2 correlation. As further example, Kimmerer (2002) hypothesized that the mechanism underlying American shad's and splittail's abundance-X2 relationship is floodplain inundation. In this case, more outflow will not necessarily increase floodplain inundation and shad and splittail abundance. In addition, by knowing that floodplain inundation is what is needed for the fish, engineering fixes can facilitate floodplain inundation at lower river flows, and that saved water could then be reused for other beneficial uses further downstream. It may also be true that the Bay Shrimp, Starry Flounder and Pacific Herring relationships are really driven by gravitational circulation in the seaward reaches of the estuary, since these species hatch in or near the ocean and presumably use net landward bottom currents to move into and up the estuary (Kimmerer (2002).

Regardless of the ultimate outcome of these studies and others, the Phase II Report should have more fully acknowledged the uncertainty associated with relying solely on correlative analysis as a basis for management actions.

IV. The Phase II Report fails to incorporate the valuable technical information received during the 2012 WQCP workshops, as well as more recent technical information.

The science contained in the Phase II Report appears to focus on published literature that existed around the time of the 2010 Flow Criteria Report, largely ignoring the large quantity of relevant, peer reviewed and published scientific literature that has become available since that time.

Interestingly, to the extent newer analyses are referenced, the selected analyses are largely unpublished and preliminary and therefore should be considered with caution until those analyses have been properly reviewed.

The SWC are providing examples of highly relevant literature that should have been included in the Phase II Report, below. While the SWC have tried to provide a comprehensive list, we may have unintentionally missed some important work. Since ICF International, who appears to be currently under contract to the Water Board, is also involved in the preparation of the California WaterFix planning documents, the SWC know that ICF has in-house staff that are very knowledgeable and aware of the current literature and ongoing science investigations. Generally, the studies we reference, below, are also referenced in the existing California WaterFix Planning documents, and/or have ICF field staff currently participating in the studies. The SWC recommend that ICF also be asked to provide a list of relevant literature and scientific information that should have been included in the Phase II Report.

A. The Phase II Report failed to discuss the more recent literature regarding fall outflows for Delta Smelt.

The Phase II Report cites Feyrer et al. (2007), the 2008 Fish and Wildlife Biological Opinion, and Nobriga et al. (2008) to support fall outflow for Delta Smelt. (Phase II Report, p. 3-6, 3-63, 3-68.)

Nobriga et al. (2008) is not relevant to the issue of fall flows as it was an analysis related to summer habitat.

The 2008 Biological Opinion relied on Feyrer et al. (2007) in addition to some unpublished work also provided by Feyrer et al. The unpublished work eventually became Feyrer et al. (2011), which took a different approach than Feyrer et al. (2007) and the earlier unpublished work referenced in the 2008 Biological Opinion. The Feyrer et al. (2007) paper has received critical comments. (See e.g, Deriso (2008), unpub., NAS (2010).) Among other criticisms, Feyrer et al. used a linear additive model that produces the result that zero adults in one year could still yield some young in the following year, a result that is biologically implausible. The limitations of the Feyrer et al. (2007) analysis should be discussed, at least in terms of full disclosure of uncertainty.

At present, the fishery agencies rely most heavily on Feyrer et al. (2011) to justify the Fall X2 RPA action. The Phase II Report should have referenced and discussed Feyrer et al. (2011), as well as the subsequent review of that paper contained in Manly et al. (2014). The Phase II Report should have also discussed Kimmerer et al. (2009) and (2013). Of particular interest is the conclusion in Kimmerer et al. (2013) at p.13[12] that:

> The lack of consistent parallels between the availability of salinity-based habitat and abundance could have had several causes. First, our use of salinity as the only variable that defines habitat is clearly inadequate…Given the difficulty in determining the controls on the delta smelt population, it is not surprising that such a simple descriptor of habitat is inadequate for this species.

[12] See also p. 3, Table 1, Sept-Dec. period analyzed.

The only other referenced analysis in the Phase II Report is from the 2015 IEP MAST Report. The referenced analysis is preliminary and has not been peer reviewed. Even the MAST Report cautions against the reliance on the referenced analysis stating, "Furthermore, results are preliminary and included for illustrative purposes only; peer-reviewed publications of these analyses need to be completed before they can be used to draw any conclusions." (MAST Report, p. 152.)[13] This disclaimer from the MAST report is not disclosed in the Phase II Report.

The Phase II Report should have provided a more comprehensive description of the referenced figure from the MAST Report. For example, as explained at p. 160, Table 8, of the MAST Report, Figure "81(b)" on p. 159, reproduced in the Phase II Report on p. 3-70 (Figure 3.8-4.), is not the best model. The MAST Report's best models did not find that fall flows or X2 had important explanatory power. The SWC did their own calculation converting the Mast Report's AIC scores into evidence ratios. That conversion shows evidence that the MAST Report's best model was 16 times greater than the model reproduced in the Phase II Report, which was actually the third best MAST Report model. The Mast Report's best model did not find that fall flows or fall X2 were important drivers of species abundance. (See Mast Report at p. 160, Table 8.)

The Phase II Report should also have discussed the currently available life cycle models and multivariate analyses. The Delta Outflow Panel highlighted the value of life cycle models in the context of the MAST Report analysis referenced above. The Outflow Panel stated (Reed et al. (2014, p. 35):

> Many of the uncertainty, but restrictive, assumptions that would need to be stated explicitly in a properly documented full life-cycle model are often implicit, but never evaluated, in simpler analyses. A good example here would be the negative relationship between the trend in 20 mm tow-net series for Delta Smelt and fall X2 (IEP MAST 2013, as presented by Mueller-Solger at the workshop on day 2). If that relationship alone is used to support increased flows, then decision makers are implicitly assuming that increasing the abundance of larval Delta Smelt will lead to a similar increase in the population of adults. This may not be the case if flow has substantial effects on growth and survival in later life stages or if the effects of environmental factors unrelated to X2 are important in determining the ultimate survival to the adult life stage. Life-cycle modeling offers a framework for making explicit the calculations from changes in larvae to populations-level responses.

The currently available life cycle or multivariate models have not identified fall flows as being an important driver of species abundance. (Thomson et al. (2010), MacNally et al. (2010), Rose (2013), Maunder and Deriso, (2011).[14]) The results of these models should have been described in the report. If other model results are available, for example from the Newman model developed by the United States Fish and Wildlife Service, these results should be discussed as well.

[13] This disclaimer also applies to the MAST analysis on Phase II Report p. 3-70 regarding spring outflow for Delta Smelt.

[14] Maunder and Deriso are currently re-running their model using an updated version of the NCEAS data used in Thomson et al. 2010 and MacNally et al. 2010. The preliminary results suggest that fall outflow/X2 has poor explanatory power.

B. The Phase II Report discussed preliminary and unpublished analyses related to summer flows for Delta Smelt.

The referenced analysis, CDFW (2016), is unpublished and has not been peer reviewed. The CAMT is currently reviewing the CDFW analysis and planning future studies.

The figures reproduced in the Phase II Report at p. 3-67 illustrate some of the limitations of the analysis that should have been discussed. For example, does the variance explained (R^2) get worse as the summer progresses? Are these results indicating a benefit of summer flows or are they the result of flows, or some other condition correlated with flows, from some earlier time period? Does the correlation breakdown if different time periods are investigated (it does)? Does the correlation breakdown if different surveys are used to assess survival, for example using ratios between the Spring Kodiak Trawl and 20 millimeter survey instead of Summer Tow Net (it does)? And, why does the observed relationship breakdown when the data is analyzed differently?

C. The Phase II Report failed to discuss the more recent literature related to winter-spring flows for Longfin Smelt.

The Phase II report references Nobriga and Rosenfield (2016) in support of the finding that, "The population abundance of juvenile longfin smelt in fall is positively correlated to Delta outflow during the previous winter and spring reproduction period." (Phase II Report at p. 3-46.) However, the Phase II report should have also discussed the Nobriga and Rosenfield finding on pp. 55-56 that:

> We found no indication that freshwater flow moderated the survival of Longfin Smelt between age 0 and age 2, but we did detect evidence that survival during this life stage transition is density dependent,

And,

> …freshwater flow variation has been linked to productivity early in the life cycle- an effect that is subsequently tempered by density-dependent survival during the juvenile life stage.

The implication is that new flow is unlikely to build the Longfin Smelt population overtime because of density dependence. This finding certainly questions the reasonableness of a management action that would use additional flows to increase Longfin Smelt abundance.

In regard to potential biological mechanisms underlying the observed relationship, see discussion regarding correlation analysis, above. The correlation discussion is relevant as to whether X2 (Delta outflow) is the flow that is biologically relevant to Longfin Smelt.

The Phase II Report does cite Kimmerer et al. (2009) for the conclusion that, "...the observed X2-abundance relationships are inconsistent with a mechanism that involves extent of low-salinity habitat." This finding, however, should have been more than a passing reference as it also raises questions regarding whether increased Delta outflow in the winter-spring could increase Longfin Smelt abundance. If the underlying biological mechanism isn't low-salinity habitat, and it isn't larval transport (since as shown above many Longfin Smelt are born and rear

downstream in the bay), there is significant uncertainty as to whether additional outflow, particularly outflow created from reservoir releases rather than from wet hydrology, could be reasonably expected to improve Longfin Smelt abundance.

The Phase II Report should have provided a more complete discussion of the existing literature.

D. The Phase II Report failed to discuss the more recent literature related to flows for Chinook salmon.

The Phase II Report should have provided a more balanced discussion of the published literature regarding the relationship between flow and fish survival, particularly on the San Joaquin River.[15] The 2009 NMFS BiOp relies heavily on studies of coded wire tagged smolts performed from the late 1960's to the late 1970's, and analysis of adult returns 2.5 years after a set of flow conditions were observed (Kjelson et al (1981); Kjelson et al. (1982). The Phase 2 Report follows the same approach.

The Phase II Report should have discussed the more recent literature.[16] For example, releases of coded wire tagged salmon in the San Joaquin River and Old River as part of the Vernalis Adaptive Management Plan (VAMP) and earlier coded wire tag releases (1985-2004) were analyzed by Newman (2008). This analysis showed a positive but non-significant effect of flow on survival of fall-run smolts in both the San Joaquin River main stem and Old River route. Similarly, Zeug and Cavallo (2013) failed to find a flow effect on the recovery of coded wire tagged salmon released in the San Joaquin and recovered in the ocean. Releases of acoustically tagged salmon in the San Joaquin River have yielded survival estimates much lower than those estimated from CWT releases (SJRG (2011); Buchannan et al (2013); SJRG (2013). The effect of flow on survival of these releases has not been directly integrated into statistical models. However, qualitative information suggests that through-Delta survival during 2011 (a high discharge year) was similar to survival during lower discharge years (2010 and 2012). This finding suggests that San Joaquin River salmon survival is not responding to higher flows.

E. The Phase II Report failed to discuss the more recent science related to Old and Middle River flows

The Phase II report relies exclusively on the 2008 FWS BiOp and the 2009 NMFS BiOp to characterize the direct effects of the state and federal water projects. (See e.g., Phase II Report, p. 3-41.)

Old and Middle River Flow (OMR) is not a flow metric that is particularly meaningful to the fish. OMR is merely a method of estimating take by the SWP-CVP. The Phase II Report cites no evidence supporting the use of OMR as a habitat variable. The discussion provided in section II(A)(2), above, regarding the inadequacy of using tidally averaged flows, like OMR, as a management action is relevant to this discussion as well. As the Draft Salmon Synthesis Report Presentation explains, "[OMR] Effects on indirect mortality are hypothesized; data are limited." Draft Salmon Synthesis Report, Presentation to CAMT, slide 38 [OMR Flow Management].)

[15] In regard to studies on the Sacramento River, there is some indication of a flow-survival relationship. (See Perry et al. 2010.) However, the type of magnitude of flow that could support increased survival is unclear. Whether flows originating from reservoirs would have a beneficial effect is unknown.

[16] The SWC have provided a list of relevant literature published since the 2009 NMFS BiOp. See Exhibit D, Attached.

Direct and indirect "take" at the SWP and CVP, as defined by the state and federal Endangered Species Acts, is already being managed by three different fishery agencies, state and federal. The best available science does not suggest that further restrictions on SWP-CVP operations would provide significant species benefits.

1. The Phase II Report failed to discuss recent science related to direct take of Delta Smelt and Longfin Smelt.

There is no evidence cited to suggest that already low salvage needs to be lower to protect the fish and wildlife beneficial uses. For example, as the United Fish and Wildlife Service explained in its recent Longfin Smelt listing assessment (FWS 2016, pp. 30-31):

> …the best available science suggests that the vast majority of Longfin Smelt do not spawn or rear in areas of the Delta (CDFW, no pagination), where they or their progeny are in danger of entrainment…current regulations put in place to protect Delta Smelt have reduced entrainment.

The 2012 Longfin Smelt federal listing decision stated similarly, "**Entrainment is no longer considered a major threat to longfin smelt in the Bay-Delta because of current regulations.**" (77 Fed. Reg. 63, 19774.)

In regard to Delta Smelt, the OMR technical discussion in the Phase II Report is outdated, solely referencing the analyses contained in the 2008 BiOp. For example, since the BiOp, it has become apparent that turbidity is an important environmental indicator of a Delta Smelt salvage event. The FWS and the water agencies are in agreement on this point. In recent years, the FWS, DFW, DWR and Reclamation have been closely monitoring Delta Smelt distribution and turbidity from December through June; and when necessary, taking real-time management actions in an effort to avoid entrainment events.

At a minimum, the Phase II Report should have discussed existing management actions being taken to avoid Delta Smelt entrainment, and acknowledged that entrainment is currently not a concern for Longfin Smelt.

2. The Phase II Report fails to discuss recent science related to direct take of salmonids.

There is little evidence to suggest that further limiting SWP-CVP export pumping would provide important species benefits.

Current direct take of Chinook salmon at the SWP-CVP is very low, representing only a fraction of allowed take under the current incidental-take permits issued by NMFS. As explained by the Delta Science Program, even if the total population is over estimated in calculating the incidental take limits, current take by the water projects is likely not a concern. Each year, the Delta Science Program reviews different aspects of the implementation of the biological opinions. As part of this review, the expert panel reviewed the juvenile production estimate (JPE) in 2014. The JPE is the basis for each year's allowed incidental take by the water projects. At the conclusion of their review, the Delta Science Program (Anderson et al. (2014) at p. 17) concluded:

> …the JPE for the 2014 drought year could have been overestimated by up to a factor of three. However, even at this level of actual take (338 WRCS) would be only 4% of the Annual Take Limit. Thus, even if the JPE were significantly overestimated in WY 2014, the run was not likely endangered by export operations.

The Phase II Report should have discussed the current very low levels of take.

F. The Phase II Report fails to provide a sufficiently detailed and updated description of "other stressors."

Chapter 4 of the Phase II Report provides a general description of aquatic ecosystem stressors and the effects of the stressors on aquatic wildlife. The stressor descriptions are brief and provide little detail regarding the effect of the stressors on aquatic species, the management programs to address the stressors, and the interactions between stressors and flow management. Chapter 4 also includes very little discussion of how the information on ecosystem stressors interacts with the flow recommendations in the report. The Delta Independent Science Board (Delta ISB) is reviewing the Phase II Report, at the request of the Water Board. The Delta ISB discussed their comments on the Phase II Report at their meetings held on November 18 and December 8, 2016. One of the main comments that the Delta ISB identified is that the Phase II Report suffers from a lack of quantitative treatment of any effects from non-flow stressors, and provides little information regarding methods for reducing effects of non-flow stressors. The Delta ISB recommends that the Phase II Report include a fuller description of non-flow stressors, the agencies that are responsible to regulate the stressors and our scientific understanding of the stressors, to provide better balance to the fuller descriptions of flow stressors in the report. The SWC agrees with these comments and urges the Water Board to substantially revise Chapter 4 of the Phase II Report to address the Delta ISB comments.

The Delta Science Program is completing its State of Bay-Delta Science 2016 this month, with the expected publication of the third and last group of SBDS papers. The SBDS (2016) papers address several ecosystem stressors, including Delta habitat changes, predation, Delta food web changes, climate change, nutrients and contaminant effects. The papers provide an up-to-date synthesis of science on these topics, with focus on scientific findings of the last ten years. The SWC urges the Water Board to thoroughly consider the SBDS (2016) as it revises the Phase II Report to include a more comprehensive discussion of non-flow stressors.

The section on physical habitat loss and alteration describes changes to the landscape (e.g. loss of tidal marsh, riparian, floodplain habitat) but does not mention that historical flows, the natural flows that Delta species evolved with, would spill into these areas, creating rearing and spawning habitat, and providing an influx of food as the waters drained back into the channels. These are functions that will not be restored by simply increasing flows down the existing channels. This section also lacks a discussion of the complex relationship between flows and phytoplankton growth and that primary productivity is amongst the lowest of all estuaries studied. The Phase II Report should be revised to consider the important interrelationships between flows and the landscape, including timing and placement of flows, and residence time, to enhance the food web.

The water quality section includes general descriptions of Bay-Delta water quality conditions and the regulatory programs in place or in development; however, the chapter lacks information

regarding the expected water quality improvements and timeline for those improvements, and the importance of addressing the water quality stressors to improve the Bay-Delta ecosystem. The chapter describes several specific contaminants and their general effects with an example or two, but fails to convey that most water samples collected in the Delta contain multiple contaminants and that mixture effects can be additive or synergistic. Recent monitoring studies have detected multiple contaminants occurring simultaneously in water samples collected in the Delta (Orlanda et al. (2013), Orlando et al. (2014)). For example, in 2012 and 2013, 27 pesticides and/or degradates were detected in Sacramento River samples, and the average number of pesticides per sample was six. Similarly, in the San Joaquin River samples, 26 pesticides and/or degradates were detected and the average number detected per sample was nine. The water quality section also includes very limited discussion of the evidence of contaminant effects in the Bay-Delta. The SBDS (2016) paper addressing contaminants, which is expected to be published at the end of December 2016, will be important information for the Water Board to consider as it revises the Phase II Report.

The water quality section includes several statements that the stressors interact with flows, but not much detail on how they interact. For example, the document states that flows dilute contaminants, but does not mention that concentrations of many contaminants are greatest during large flows due to transport from land applications. On page 4-5, the document states, "Reduced freshwater inflow from the Sacramento---San Joaquin River system may also reduce the estuary's capacity to dilute, transform, or flush contaminants (Nichols (1986))." The Phase II Report should also note that some contaminant degradates are more toxic than their parent compound, and that diluting and flushing contaminants may only move the problem downstream.

The water quality section does not include discussion of changes in loads and types of nutrients and the impacts of those changes, other than a brief description of ammonia/ammonium. The SBDS (2016) paper addressing nutrients, which is expected to be published at the end of December 2016, will be important information for the Water Board to consider as it revises the Phase II Report. Page 4-7 states the Microcystis aeruginosa blooms tend to occur with elevated nutrient concentrations, among other things, but does not mention the evidence that these blooms are growing on ammonium. For example, a recent study by Lee et al. (2015), found that Microcystis aeruginosa in Delta field experiments and lab experiments had much higher uptake rates for ammonium as compared to other forms of nitrogen.

The section on nonnative species includes limited discussion on changes in the food web, but fails to convey how significantly the food web has changed, and makes no mention of all the evidence of food limitation in many of the at risk fish species. The section on nonnative species also describes the different ways nonnative species can impact native species including competition and predation, but fails to mention the negative correlation between nonnative and native species.

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Exhibit A, Specific Comments

Page	Comment
1-9	The PWAs have previously commented extensively on the fact that unimpaired flows are not the same as natural flows (see, e.g., the PWA's submittal to the SWRCB on ecosystem changes to the Bay-Delta estuary, section 6). Continued recommendation to use unimpaired flows as the yardstick by which percentages of flow for ecosystem services are applied will overestimate both summer and fall flows. These seasons have seen higher flows than are natural via reservoir releases. The majority of literature citations used in the Draft Scientific Basis report do not mention unimpaired flows or an equivalent metric (see, e.g., Rozengurt et al. 1987, Poff et al. 1997, Pringle et al. 2000, Freeman et al. 2001, Bunn and Arthington 2002, Poff and Zimmerman 2010, Petts 2009, Montagna et al. 2013, Kiernan et al. 2012, all cited on p. 3-2).
2-54	The Phase II report states that, "The Sacramento River is a major source of the fresh water in the Old River Channel which is ***pulled upstream through*** Georgiana Slough and the Delta Cross Channel Gates". [Emphasis added] These waters flows by gravity into these channels. It is not "pulled" there by exports. See Cavallo et al. (2015) for an analysis of exports influence flow and fish proportions at these junctions.
2-56	The Phase II Report states that, "Export operations combined with changes in channel geometry, gates and barriers have greatly altered ***the natural direction of flow*** in the Delta…." [Emphasis added]. In some channels of the central and south Delta, a calculated tidally averaged flow will yield a negative value, however, this does not mean the direction of flow has changed. As explained in Monismith et al. (2014) flow direction in most Delta channels does not change as a result of exports. Fish cannot perceive "net" flows and therefore have minimal significance to them- except for fish that are passively drifting (a seemingly uncommon strategy among Delta fishes).
2-56	The Phase II Report states that, "…high export pumping rates has caused reverse flows in the Southern Delta…" Reverse flows implies a meaning that is contrary to the reality of Delta hydrodynamics. The use of a term like "reverse flows" without a detailed explanation and definition is something more typical of news report than a scientific document about Delta flow conditions.
2-57	The Phase II Report indicates agricultural barriers are installed beginning April 15th. This is incorrect, agricultural barriers are typically installed in mid-May or later.
2-57	The Phase II report states that the HORB is installed, in part, to keep salmon smolts away from predators in the interior Delta. Acoustic tagging studies indicate predation problems are at least as bad in the mainstem San Joaquin River downstream of HOR and at points of the interior Delta accessible by other junctions also downstream of HORB.
2-58	The Phase II Report indicates exports can greatly reduce Delta outflow and alter Delta hydrodynamics. This description is vague or even misleading. Exports can only reduce outflows up the maximum allowable export level- a fraction of typical total Delta inflow (particularly in spring).
2-58	The Phase II Report states: "The most prominent example of changes in flows direction in the Delta occurs in the Old River and Middle River Channels of the San Joaquin River." [emphasis added] This excerpt and the sentences which follow it misrepresent Delta hydrodynamics. Again, no evidence has been provided of changes in flow direction. Tidally averaged "net" flow and OMR is not a measure of flow direction. As indicated previously and expanded upon in the Appendix to this technical memo, net negative flows do not correspond with changes in flow direction. This is important because fish perceive and are potentially impacted by changes in flow direction, but do not perceive and are unlikely to be influenced by "net" flows alone (Monismith et al. 2014).
2-60	The Phase II Report states, "Large tidal exchanges below the confluence of the Sacramento and the San Joaquin Rivers make it difficult to measure flow through the larger channels".

Page	Comment
	This statement is true, and it highlights the inappropriateness of relying upon tidally averaged flows. Large tidal flows are what fish and other organisms are actually experiencing- tidally averaged flows are an abstraction that fish are incapable of perceiving (see Monismith et al. 2014).
3-1	The report is based on flow information in the absence of consideration of other competing factors such as other water uses or the need for cold water to support salmonids in the tributaries. Reservoir storage and coldwater pool management have been identified as critical factors effecting salmonid spawning, egg incubation, hatching, and juvenile rearing. Depletion of coldwater results in seasonal exposure to elevated water temperatures that can result in high levels of salmonid stress and mortality. Isolating flow alone in the analysis has the potential to result in depletion of coldwater and significant reductions in habitat quality and availability, reduced salmonid production, survival, growth, and population abundance and diversity. The analysis must integrate instream flows with reservoir storage and coldwater pool management to produce meaningful and beneficial management strategies.
3-1	The report identifies the importance of stressor reduction and habitat restoration in addition to instream flows as "essential for protecting fish and wildlife resources" but provides no linkage for implementing the suite of management actions needed to meet biological goals. Implementing flow alone is not expected to achieve the stated goals and could lead to unintended adverse impacts to other beneficial water uses. For example, SWRCB D-1485 prescribed a flow regime for striped bass based on an analysis of juvenile abundance and spring Delta outflows similar to those reported in Chapter 3 for other species. Despite providing the spring Delta outflows striped bass abundance did not increase as predicted. Similarly, high flows during the spring of 2006 and 2011 occurred in the San Joaquin River but survival of juvenile fall-run Chinook salmon did not increase as predicted. These examples illustrate the high degree of uncertainty in predicting flow-abundance relationships which is not reflected in Chapter 3. Chapter 3 page 3-1 states that the report "identifies flows that are predicted to either produce population growth of specific native indicator aquatic species populations more than half of the time or maintain populations near abundance goals previously identified in the Delta Flow Criteria Report". This foundation for the recommendations ignores the interaction among environmental factors such as availability of suitable coldwater and other stressors such as predation as well as the high degree of uncertainty that species will respond to flow alone as predicted by the report.
3-2	The Phase II report states, "Flow is not simply the volume of water, but also the direction, timing, duration, rate of change and frequency of specific flow conditions." This is true, but directly contradicts the simplified presentation of "net" flows in the prior chapter. Estuary flows are complex, and boiling them down to a simple metric leads like "net" flows leads to misunderstandings about how much river inflows or exports can change habitat and hydrodynamics in the tidal Delta.
3-2	The report cites Rozengurt et al. 1987 as the basis for a finding that upstream diversions that exceed 30 to 40-50% of unimpaired flows result in degraded habitat and fish populations that are not able to recover. Relying on a single reference that is almost 30 years old is not a sufficient scientific basis for establishing thresholds reported in this finding.
3-2	Much of the discussion in Section 3.2 on flows and the ecosystem are presented as if the statements are established facts directly related to the Bay-Delta system. The discussion would be more appropriately characterized and presented as a conceptual model and series of hypotheses related to potential management actions that require testing and validation and are currently subject to unknown levels of uncertainty regarding the actual response of various species and lifestages to these and other environmental conditions.
3-4	The Phase II report indicates natural flow regime can offset the negative effects of hatchery on naturally produced populations. This is wild speculation with no logical foundation or basis in the scientific literature.

Page	Comment
3-4	The discussion of how the rim dams and altered flow regimes have caused a loss of geomorphic processes related to the movement of water and sediment is missing more recent research into sediment transport in the Bay-Delta. Without question, the rim dams have trapped sediment. It is widely acknowledged that a step change in sediment transport occurred sometime after 1983 as the sediment pulse from hydraulic mining cleared the Bay-Delta (Wright and Schoellhamer 2004; Schoellhamer 2011). Other anthropogenic activities have also affected the sediment load in the Bay-Delta, such as riverbank protection and altered land uses (Wright and Schoellhamer 2004). In the Suisun Bay region, land surface erosion and wind resuspension are the major determinants of turbidity (Ruhl and Schoellhamer 2004; Brown et al. 2013). Turbidity in the Bay-Delta is largely uncoupled from flow (Wright and Schoellhamer 2004; Hestir et al. 2013). Sediment inputs from small tributaries have become more important than the larger river systems (McKee et al. 2013). No matter that turbidity decreases predation and cues migration if flow changes cannot increase it.
Table 3.4-5	The table presents a count of watersheds supposedly impacted by water related-stress. The source of the data is the NMFS recovery plan (2014). NMFS (2014) is not an appropriate source of information for such an analysis as it does not provide any data analysis- just a listing of stressors.
3-7	The Phase II Report states: "…most relationship continue to remain strong since first described and better understanding of the likely mechanisms is rapidly developing." This claim is inaccurate, no evidence has been provided which supports mechanisms. Studies such as Bever et al. (2016) suggest that different Delta outflows do not appreciably affect hydrodynamics and other physical factors thought to be important to Delta fishes.
3-7	The report states that modeling results show the low salinity zone has been skewed eastward in the recent past and variability in salinity in the western Delta has been reduced. The report does not discuss how reservoir releases and managed Delta outflow has been used to provide reduced salinity in the Delta during some seasons and years when compared to unimpaired conditions to support other beneficial uses such as municipal drinking water and agricultural irrigation supplies. The SWRCB is required to balance all of these beneficial uses rather than focus solely on estuarine habitat for aquatic species. The report should provide a discussion of how information developed through the flow analysis will be integrated with other analyses of balanced and competing uses.
3-7	The report cites Jassby et al. 1995 as the single reference for a finding that "statistically significant inverse relationships have been demonstrated between the landward extent of X2 and the abundance of a diverse array of estuarine species". Many of these earlier relationships have changed over the past 20 years as a result of interactions with other factors such as the introduction and rapid population expansion of non-native Asian clams, expansion of predator populations, and proliferation of non-native submerged vegetation. The implication of the report statements is that if the Delta outflows were increased to levels that occurred in the past the abundance of many of the estuarine species would also increase. This is overly simplistic and fails to account for a number of factors that have changed that have major implications for how estuarine species are likely to respond to changes in flow or X2 location alone.
3-8	The report discusses the importance of turbidity in Grizzly and Honker bays as a habitat feature for delta smelt and salmon. The report correctly discusses the importance of wind-driven re-suspension of sediments rather than outflow on turbidity in the western region of the estuary. The report does not, however, discuss the effects of proliferation of submerged aquatic vegetation (SAV) on turbidity conditions throughout the Delta and whether increased flows or wind would result in turbidity conditions as in the past. This is example of over-simplification of the estuarine dynamics that contribute to high uncertainty in the biological and abiotic response to environmental conditions.
3-8	Reference to Bever et al. (2016) is inaccurate. Bever et al. (2016) did not find that Delta Smelt are found most frequently in the shoals of Grizzly and Honker bays; they found that Delta

Page	Comment
	Smelt are found more frequently in areas where specified salinity and turbidity metrics were met, along with low seasonally-averaged velocity. These conditions were met in 2011 but not 2010, as reflected by the higher FMWT catches in Grizzly and Honker bays in 2011. These were the only two years considered in the Bever et al. (2016) analysis.
3-8	Reference to MacWilliams et al. (2016) is inaccurate. MacWilliams et al. (2016) did find that there has been a decline in the percentage of time the LSZ has occupied >75 km-2. However, this does not tell the complete story of the findings of MacWilliams et al. (2016). They also found that there has not been a significant trend in fall average Delta outflow from 1980 through 2014, and that there may be only a very weakly significant trend in increasing X2 from 1980 to 2014 between September and November. Therefore, the trend of decreasing average LSZ area is not solely attributable to either increases in X2 or to decreases in outflow. Also, MacWilliams et al. (2016) examined only the LSZ, defined as between 0.5 and 6 psu, ignoring upstream freshwater areas where Delta Smelt are known to congregate. Hence, the value of the findings of MacWilliams et al. (2016) in a population context is unknown. The associated maps of seasonal salinity gradients and Delta Smelt CPUE (Feb-Jun) in MacWilliams et al. (2016) show just what one would expect – downstream movement of Delta Smelt during high outflow years and upstream movement during lower outflow years.
3-8	After inaccurately describing MacWilliams et al. (2016), the Draft Scientific Basis report ties itself to the Feyrer et al. (2007) hypothesis that decreases in the extent of the LSZ is of crucial concern, because it limits the foraging area of Delta Smelt and is therefore a bottleneck. In previous comments, both in this document and on the Flow Criteria report, the PWAs have demonstrated that the notion of maintaining fall X2 downstream of the confluence is not strongly supported. Even though the National Academy of Science characterized the fall X2 requirement in the USFWS BiOp effects analysis (2008) as "conceptually sound," they also characterized the weak statistical relationship between the location of X2 and the size of smelt populations as "difficult to justify." An independent peer review of the USFWS effects analysis (2008) questioned the utility of the fall X2 habitat analysis, noting that a few data points may have had high influence on the outcome. The independent reviewers even questioned whether the fall X2 stock-recruit model was inappropriate for the data used (Rose et al. 2008 at 7). The Flow Criteria report did not include a requirement for fall outflow.
3-9	The report states that "reverse flows in the southern Delta are associated with increased entrainment of some fish (Grimaldo et al. 2009) and disruption of migration cues for migratory fish". Although the report states this as a demonstrated fact there is no scientific reference or analysis of the potential effect of reverse flows on disruption of migration cues for migratory fish. Although presented as fact this statement is an unsupported hypothesis and has not been demonstrated.
3-9	The report states that "long-term water diversions also have contributed to reductions in the phytoplankton and zooplankton populations in the Delta itself as well as alterations in nutrient cycling within the Delta ecosystem (NMFS 2009)". The NMFS 2009 Biological Opinion did not develop independent analyses to support this finding. Although the BiOp may have made these statements the primary reference sources supporting scientific analyses of these relationships is needed. This is an example of many citations in the report that are presented as fact without actual scientific references or support.
3-11	The report states that updated analyses of flow and abundance for selected species were developed based on data from the CDFW fall midwater trawl and Bay otter trawl surveys. The report provides no discussion or justification of the selection of these two data sources for the analyses. For example, why was the Bay Study otter trawl data used but apparently not the Bay Study midwater trawl data which covers the same geographic area and time period as the otter trawl surveys? The report should include an appendix documenting the methods used to develop abundance indices from each survey, how missing surveys were addressed, how changes in sampling stations were addressed, etc. The appendix should also provide tabular

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	documentation of all of the data used in these flow-abundance relationships given their importance in the updated analyses and findings.
3-11	The report states that abundance indices used in the updated flow-abundance relationships were developed by SWRCB staff but omitted zero values for the abundance indices citing Kimmerer 2002 as the rationale. Many more recent analyses of species abundance include zero values in the analysis. The methods and assumptions used in the SWRCB flow-abundance analyses should be subject to independent scientific peer review by qualified statisticians and biologists before they are accepted for use in this analysis. At a minimum, the flow-abundance relationships should be recalculated and presented based on indices that include zero catch values as well as new methods or estimating abundance such as those recently developed by Newman and others. Credibility of the updated flow-abundance relationships is critical to the review and confidence that can be placed on the results and their interpretation. As currently presented, results of the analyses presented in the report do not meet the basic criteria of independent scientific peer review.
3-12	The Phase II Report makes the case that increased river inflow will improve through-Delta survival of juvenile salmonids. No evidence is offered to support the claim. The Appendix to this technical memo explains the weak mechanistic basis for river flows to have a hydrodynamic benefit to juvenile salmonids in the tidal Delta.
3-12	The report states that "a combined species evaluation has been prepared for all four runs of Chinook salmon and Central Valley steelhead". The report states that steelhead and salmon share similar life history strategies that factors that benefit salmon will also benefit steelhead. The use of data from salmon as a surrogate for steelhead, however, has been criticized in several forums including the NMFS 2009 BiOp. No data are presented in the report to support the assumption that salmon are a suitable surrogate for salmon in the Delta. In fact, results of acoustic tag survival studies conducted in the lower San Joaquin River support the opposite conclusion that salmon are not a surrogate for juvenile steelhead. Comparative survival estimates for acoustic tagged fish in 2011 and 2012 estimated juvenile steelhead survival as 0.32 and 0.54 respectively while juvenile fall-run Chinook salmon survival at the same times was 0.02 and 0.03 respectively; over an order of magnitude different in both years. The large disparity in these results supports a conclusion that juvenile Chinook salmon should not be used as a surrogate for juvenile steelhead without validation. Findings in the report representing combined salmon and steelhead should not be relied on in the analysis.
3-12	The report presents a finding that "flows greater than 20,000 cfs at Rio Vista between February and June are expected to improve juvenile salmon survival during outmigration". The report presents no results of analyses or even a reference to the scientific literature as support for this fundamental conclusion. What data were used to support the finding that survival increases at Rio Vista flows greater than 20,000 cfs? What is the basis for a 20,000 cfs threshold? Is this the average flow between February and June or the minimum flow? This is an example of one of the many key findings presented in the report without scientific support. At a very minimum the report should discuss the data used in support of each finding and present results of graphic and statistical analyses supporting each of the specific findings and conclusions.
3-12	The report states a conclusion that "juvenile salmon emigrating from both the Sacramento and San Joaquin Rivers through the Delta have better survival if smolts remain in the main stem river channels and do not migrate through the interior Delta". This is another example of an unsupported conclusion in the report. No data or even references to the scientific literature are provided to support this finding. In fact, results of recent acoustic tag survival and migration studies in the lower San Joaquin River and Delta refute the broad finding in the report noting that juvenile salmon survival was not different between those fish migrating in the mainstem and those that migrated into interior Delta channels. In fact, for some of the studies survival to Chipps Island was greater for those salmon that migrated into the interior Delta and were

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	salvaged at the CVP and trucked to a release site in the western Delta. Unsupported and in some cases incorrect findings and conclusions presented in the report undermine the credibility and value of the report and support the need for independent scientific peer review of the report before findings are used in developing management actions for further balancing and analysis.
Figures 3.4 through 14	These figures present course and unreliable data and should be deleted in favor of peer-reviewed data provided by Zeug and Cavallo (2014).
3-16	The report states "juvenile Chinook salmon movements are controlled by tides in the Delta. Juveniles move into shallow water habitat on the rising limb of the tide and return to main channels when the tide recedes (Ley and Northcote 1981; Healey 1991)". The report is misleading in implying information regarding the importance of tides on juvenile rearing habitat or movements in the Delta. No studies are available that document the tidal movement of juvenile salmon in the Delta. The report cites no Delta-specific literature. Both the cited references for Levy (note the typo in the report citation) and Northcote and Healy were based on juvenile salmon rearing in British Columbia and not the Bay-Delta estuary. This is an example of overstating the basis of knowledge used in support of the report findings and discussion.
3-17	The document cites MacFarlane and Norton (2002) to support the claim that through-Delta migration takes 40 days. This study is based upon inferences from the size of captured fish- not from fish tagging. Numerous fish tagging studies now available indicate a much faster transit rate.
3-20	Many of the figures presented in Section 3.4 are based on adult salmon escapement from a 2012 version of GrandTab. GrandTab data are available through 2015 (2016 CDFW reporting) and could be used to update all of these figures. The drought started in 2012 and is not reflected in the current figures in this section. Rather than relying on escapement for Chinook salmon abundance trends a better metric would be total adult ocean abundance (escapement and harvest) since escapement alone is affected by changes commercial and recreational harvest.
3-26	The document indicates there are six Central Valley hatcheries raising fall run Chinook salmon including (in the footnote) Trinity and Klamath River Hatcheries. This is an error. Five CV hatchery produced fall Chinook- Trinity and Klamath are not CV hatcheries.
3-27	Figure 3.4-10 presents information on the cumulative smolt outmigration of juvenile fall-run Chinook salmon from the San Joaquin River drainage based on CDFW sampling at Mossdale. Since this report focusses on the Sacramento River system primarily, the relevance or use of juvenile fall-run migration data from the San Joaquin River in the analysis is not clear. Why does the report not use juvenile salmon monitoring data from the Sacramento River system such as rotary screw trapping at Red Bluff and Knights Landing, trawling at Sacramento, and trawling at Chipps Island? Why are data on run timing not presented for each of the races of Chinook salmon of relevance rather than only for fall-run?
3-32	Table 3.4-5 presents results of a SWRCB staff analysis of the percentage of watersheds affected by flow-related stressors. The report does not, however, present information describing the basic criteria that were used to assess habitat conditions and stressors, the assumptions and methods used in the analysis, separate the analysis based on salmonid runs or watersheds, or discuss the application of the results of this analysis to the recommendations or conclusions presented in the report. The report discussion should be revised to provide sufficient information to assess the results of the analyses being presented. Results of all of the analyses presented in the report should be subject to independent peer review prior to being used as a basis for management recommendations.

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3-32	The report presents in Table 3.4-6 information on the effects of pulse flow operations on adult straying rates from the Mokelumne River. The use and relevance of this information in the flow analyses presented in the report is not apparent. The report discussion should be expanded to describe how these results are being factored into the report findings and recommendations
3-33	See comment above regarding analyses presented in Table 3.4-5
3-33	The discussion of reestablishment of cottonwoods and other native trees along the Sacramento River ignores the fact that the Sacramento River and many of its tributary systems are managed for flood control. CDFW (2012) itself recognizes this, stating (at p. 27): "More uniform flows year-round and stream bank armoring have resulted in diminished natural channel formation, altered food web processes, and slower regeneration of riparian vegetation." The Board must balance the extent to which flow strategies can be used to reestablish native trees along the river with the flood control and other beneficial needs of downstream beneficial uses.
3-35	The report states "studies indicate that higher flows during these periods are protective of outmigrating juveniles increasing both the abundance and survival of emigrants out of the Delta". The report provides not citations to the scientific literature to support this fundamental finding. No analyses are presented that show the relationship between river flow or Delta outflow and either abundance or survival of juvenile salmon from various watersheds. Further, the report draws simplified and general findings without providing the scientific support or details of the analyses. For example, results of recent acoustic tag survival studies on the lower San Joaquin River showed that estimated survival to Chipps Island was 2% in 2011 a high flow year and 3% in 2012 a low flow year. These results directly contradict the statement in the report. Similarly, survival estimated in 2006, a high flow year, was not greater on the lower San Joaquin River than estimated for low flow years. Further, the production of juvenile salmonids (abundance) is determined in large part by abundance of spawning adults and flow and temperature conditions during the summer and fall spawning and egg incubation period which is separate from the flows in late winter and spring on juvenile migration and survival.
3-35	The report again states that survival is greater for those juvenile salmon that migrate downstream in the main stem rivers and lower for those that migrate into the interior Delta. See comment on page 3-12 above.
3-35	The report cites Kjelson and Brandes 1989 on a positive relationship between salmon smolt survival between Sacramento and Suisun Bay and mean daily flow at Rio Vista during May or June with increasing survival as flows increased from 7,000 to 25,000 cfs. The report, however, does not present data from these early coded wire tag studies on the relationship between Rio Vista flow and salmon smolt survival. Results of more recent survival studies should be presented in the report to support flow-survival relationships for mark-recapture and acoustic tag studies on both the Sacramento and San Joaquin Rivers. A large body of survival information has been collected over the past 20 years that is not well represented in the report.
3-35	The report cites Brandes and McLain 2001 as reporting "a positive relationship between abundance of unmarked outmigrating Chinook salmon and April-June flow at Rio Vista". Figure 3.4-12 (page 3-36) also present information on Chinook salmon catch and Rio Vista April-June average flows. The upper panel presents results for the period 1978 to 1997. The lower panel presents results for two time periods including 1976-1997 and 1998-2015. Data from the upper panel (a) was reported to be replicated in lower panel (b) for comparison and yet the two plots appear to be different. The data sets used in generating these figures should be re-checked. In addition, the discussion should be expanded to include: are the differences in catch a function of differences in actual population abundance or simply a seasonal change in migration timing as a function of flow or other conditions, and how would flow in April-June effect abundance for fall-run salmon that were spawned in October-December and reared

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	in the upper watershed until migrating downstream in the spring.
3-35	The Phase II report cites Brandes and MClain (2001) for evidence of a positive relationship between abundance and catch-per-unit-effort. In fact, there is no evidence to suggest CPUE was tracking increased abundance- higher flows and turbidity are often associated with more efficiency capture due to turbidity.
3-37	The report concludes that flows greater than 20,000 cfs between February and June are expected to increase the abundance of juvenile fall-run and winter-run Chinook salmon at Chipps Island. Data are available from several sources including acoustic tag survival studies, spawning surveys, lifecycle modeling, Knights Landing and Sacramento surveys and others that should be integrated and synthesized to further evaluate this key finding and flow threshold effect. The limited data analysis presented in the report is sufficient to develop a testable hypothesis for a flow-survival and flow-abundance relationship but requires further validation prior to use as a basis for management actions.
3-37	The report again relies on information from juvenile salmon for use as a surrogate for steelhead with no validation (see comment page 3-12 above). The report states that similarities in life histories among these species are justification for the assumption. The juvenile life history of fall-run Chinook salmon that migrate downstream as fry and young-of-the-year smolts (typically 40-100 mm in length after only a few months of rearing in the river) is substantially different than for steelhead that spend 1 to 2 years rearing in the river and migrate downstream at 150 mm or larger.
3-37	The document cites Schaffter 1980 as cited by Low et al. 2006 regarding entrainment at junctions, but fails to cite more recent acoustic telemetry based analyses including Cavallo et al. (2015) which provided a comprehensive analysis of such data.
3-38	Relationships between the mean proportion of flow diverted into the interior Delta in January (Figure 3.4-13) and December (Figure 3.4-14) and juvenile winter-run Chinook salmon losses at Delta export facilities are based solely on only two years in both plots with virtually no relationship for all other years included in the analysis. These analyses should be updated to include results of monitoring between 2006 and 2016. Management of the DCC gates has changed in recent years and results of these earlier estimates may not be applicable to current conditions.
3-39	The report briefly discusses the results of non-physical barrier testing conducted at Georgiana Slough. The report attributes these studies to USGS and cites papers by Perry et al. 2014. DWR was the agency that directed the studies and there are additional detailed reports and analyses that are not cited or used in the report description. The discussion of flow alternatives for guiding juvenile salmonids and improving migration and survival should be expanded.
3-39	The report states that tagging and modeling studies have shown improvements in juvenile Chinook salmon survival in the lower San Joaquin River with the Head of Old River Barrier (HORB) installed during the spring. The report should be updated to include information from more recent acoustic tag survival and migration studies for both juvenile Chinook salmon and steelhead as a function of the Old River channel junction. The report should be revised to include more recent study results.
3-39	The report states that juvenile salmon may be more likely to migrate toward the export facilities during periods when exports are increased compared to when exports are reduced. The report cites Vogel 2004 as the basis for the statement. Data available on juvenile salmon migration and survival prior to 2004 that could be used by Vogel would have been limited to coded wire tags. These tags do not provide information on migration route. In the absence of additional information presented in the report there is no basis to assess the analyses of a relationship between south Delta route selection and SWP and CVP export rates. Rather than relying on CWT data these analyses should be based on recent results of acoustic tag migration and survival studies using both salmon and steelhead. The analyses presented in the

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	report should be revised and updated.
3-40	Table 3.4-7 reports to present a synthesis of information on seasonal timing and magnitude of flows intended to increase juvenile salmonid survival and abundance. The analyses presented in the report, however, are generally inadequate to actually assess these flow conditions. For example, no data or references to scientific literature are presented in the report to support a relationship between either abundance or survival of juvenile salmonids and positive flows in the San Joaquin River at Jersey Point, flow-survival relationships at Georgiana Slough, relationships between OMR reverse flows and either salmonid abundance or survival, or the San Joaquin River inflow to export ratio and either salmonid survival or abundance. Many of the relationships included on Table 3.4-7 have been hypothesized but have not been explicitly tested or validated. Information summarized in the report is inadequate for use as scientific support for these seasonal flow recommendations.
3-41	The report discusses the use of PTM model results to assess the risk of entrainment and salvage of juvenile salmonids. Past PTM model results have been criticized in their application to assessing migration behavior of actively swimming juvenile salmon and steelhead. The PTM approach used in the past as part of the NMFS 2009 BiOp has been revised and more refined hydrodynamic simulation modelling approaches are being developed and applied. Presenting results of the earlier PTM approach in the report may be confusing and potentially misleading and inaccurate.
3-42	The Phase II Report cites the1995 Working Paper and USFWS 1995 to support the influence of "net" negative flows on juvenile salmonids. These studies are outdated and have been supplanted by superior statistical analysis and particularly by acoustic telemetry studies. Newman (2008) provides the definitive analysis of export-survival for SJR origin juvenile salmon.
3-42	Results of analyses of salmon salvage at the SWP and CVP as a function of OMR reverse flows presented in Figures 3.4-15 and 3.4-16 from the 2009 NMFS BiOp have been extensively criticized. Monthly losses used in these plots were not normalized for abundance of juvenile salmon in the population and therefore the reported relationships were confounded. These graphs are confusing and should not be included in the report. Revised graphs are available.
3-43	Figure 3.4-17 reports temperature corrected survival indices from CWT juvenile Chinook salmon released at Jersey Point and recaptured at Chipps Island. The report presents no discussion of the basic methods used in these studies, how survival was corrected for temperature, or why only results from 1989-1991 are reported when a large number of additional CWT releases have been made at Jersey Point. Further, given the tidal nature of the Delta in the vicinity of Jersey Point and Chipps Island no mechanism has been hypothesized for the reported relationship presented in the report. Additional refined data from more recent acoustic tag studies as well as survival studies conducted as part of VAMP should be used to further assess this hypothesized relationship. In addition, results of hydrodynamic simulation modelling should be reviewed to determine the physical relationship between Delta inflow, flow at Jersey Point, the effects of inflow on water velocity and flow direction at Jersey Point, and how flows may affect migration behavior and survival in this reach of the estuary.
3-43	The report states that "studies also indicate that San Joaquin River basin Chinook salmon <u>production</u> increases when the ratio of spring flows at Vernalis to exports increases" (emphasis added). Salmon production is a function of the number of spawners (number of eggs) and hatching success producing juvenile salmon fry and smolts. For fall-run Chinook production occurs between October and February or March. No mechanism is hypothesized in the report for how the Vernalis inflow to export ratio in the spring could affect juvenile salmon production. The discussion in the report should be expanded and clarified.
3-43	The report states that "it should be noted that the flow at Vernalis is the more significant of the two factors". The report, however, does not present any discussion or analysis of the relative

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	contribution of flows and exports to the ratio or how these during the spring relate to either salmon production. The effect of the spring ratio of flow and exports on salmon or steelhead survival is largely uncertain.
3-44	The report states that average daily outflows of 41,900 and 29,200 cfs in January-March and April-May were associated with positive longfin smelt population growth in half of the years. No literature citation is presented to support these flow thresholds in the report. Was the basis for these thresholds documented and peer reviewed? In addition, the report fails to acknowledge that detailed statistical modeling conducted as part of a state-space longfin smelt population dynamic model (Maunder et al. 2014) tested these two flow thresholds and found that they did not significantly improve predictions of smelt abundance.
3-45	Figure 3.5-1 presents a declining trend in longfin smelt abundance as reflected in the fall midwater trawl surveys. The report predicts that longfin smelt abundance will increase with increased late winter and early spring Delta outflow increases. The graph, however, shows a generally declining trend. Abundance in 2011 following high flows in the winter and spring increased somewhat but was the increase as great as would be predicted by the earlier relationships? The change in the intercept of the flow-abundance relationships presented in Figure 3.5-2 (page 3-47) has a dramatic effect on the predicted abundance of longfin smelt that could be achieved under managed flow regimes. The report should discuss uncertainty in the flow-abundance relationships and the ability of the longfin smelt population to achieve historic high levels of abundance under current conditions independently of Delta outflows.
3-48	Figure 3.5-3 shows estimated relationships between Delta outflow and the probability of longfin smelt population growth. It should be noted from the figures that positive population growth has been observed over a wide range of Delta outflow conditions including those above and below the flow thresholds included in the report. Further, the report should include a discussion regarding the potential mechanisms through which Delta outflow may effect longfin smelt geographic distribution, survival, and abundance. The report should also include a discussion of the other factors effecting longfin smelt including predation and limitations on zooplankton food availability as well as non-flow methods, such as shallow water habitat restoration that could contribute to increase food production to benefit longfin smelt.
3-50	Figure 3.5-4 presents data on longfin smelt salvage and OMR reverse flows. As discussed for salmon it is not clear from the presentation in the report whether or not estimates of total salvage have been adjusted to account for variation in population abundance. The graph should be updated to reflect salvage data between 2008 and 2016 under the OMR operating criteria. Results from earlier years included in the presentation may not be relevant to more recent conditions.
3-51	Figure 3.5-5 presents information on longfin smelt salvage and OMR reverse flows through 2007. The data and graphs should be updated to also include more recent results from 2008 to 2016 to show current patterns and trends.
3-52	Figure 3.5-6 presents information on longfin smelt salvage and X2 location through 2007. The data and graphs should be updated to also include more recent results from 2008 to 2016 to show current patterns and trends.
3-53	Table 3.5-1 presents a summary of seasonal flows thought to be protective of longfin smelt. As noted above, further analysis and conflicting results exist regarding the Delta outflow thresholds and relationships for longfin smelt. The technical basis for developing flow relationships for longfin smelt requires further analyses.

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3-53	The report includes a conclusion that average Delta outflows over 37,000 cfs between March and July appear to be needed to consistently produce strong white sturgeon year class recruitment. The report should include a scientific reference in support of this finding. Given the high fecundity and long lifespan of sturgeon how frequently are high flows needed to support the population from a lifecycle perspective? The report also includes an unsupported assumption that white sturgeon are a suitable surrogate for green sturgeon that should be discussed.
3-56	The report notes that CDFW analyses of white sturgeon indicate a stock-recruitment relationship that that reduced recreational harvest results in a reduction in Delta outflow requirements. Given their listed status green sturgeon cannot be harvested legally and therefore flow needs for green sturgeon may be lower than those estimated for white sturgeon. Further, a non-flow management action that curtailed white sturgeon harvest in the estuary could be used to improve recruitment and population abundance. The report should include a discussion or these and other factors contributing to sturgeon population dynamics
Section 3.6.2.1	The discussion of reestablishment of cottonwoods and other native trees along the Sacramento River ignores the fact that the Sacramento River and many of its tributary systems are managed for flood control. CDFW (2012) itself recognizes this, stating (at p. 27): "More uniform flows year-round and stream bank armoring have resulted in diminished natural channel formation, altered food web processes, and slower regeneration of riparian vegetation." The Board must balance the extent to which flow strategies can be used to reestablish native trees along the river with the flood control and other beneficial needs of downstream beneficial uses.
3-58	The report notes that Delta outflows of 38,000 to 47,000 cfs are needed between February and May to improve Splittail abundance. The overview summary should include a citation to the source of information supporting this conclusion. The mechanisms thought to affect Splittail reproduction in high flow years is seasonal inundation of floodplain habitat. Channel margin habitat restoration to include areas of shallow water lower velocity inundation for a sufficient period of time to allow spawning, egg incubation, and hatching represent non-flow actions that would benefit Splittail and reduce flow requirements. Further, since the expected function mechanism is floodplain habitat inundation flows should target upstream riverine areas and would not necessarily represent Delta outflow.
3-64	Figure 3.8-1 presents information on the trend in delta smelt abundance based on the fall midwater trawl surveys. It is not clear from the presentation if the smelt abundance index has been standardized to a core group of sampling stations or if the sampling has varied for the period used in this trend analysis. The report should also be expanded to discuss the delta smelt inhabiting the Cache Slough complex and the hypotheses regarding habitat suitability in the northern Delta. The report should also acknowledge restoration actions designed to improve delta smelt habitat and implementation of the delta smelt resiliency strategy as current and near future actions to increase smelt abundance.
3-65	The discussion of various investigations into factors affecting delta smelt should be expanded to also include information on the current delta smelt lifecycle model being developed by Newman. Further, detailed analyses of delta smelt data are currently underway as part of the CAMT delta smelt scoping team activities and will be available to further inform the technical foundation for delta smelt management.
3-67	The report should acknowledge the comments on the recent analysis of summer and fall flows for delta smelt. The flows in many months are autocorrelated and difficult to interpret potential cause-effect relationships which contribute to management uncertainty.
3-68	There were a number of criticisms of analyses and interpretations of data regarding the importance of fall flows and X2 location for delta smelt. Many of these were part of the USFWS litigation. The report does not acknowledge or address many of the alternative analyses or the level of uncertainty associated with summer and fall flow needs for delta

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	smelt.
3-69	Table 3.8-1 simply presents a summary of the flows and X2 locations outlined in the 2008 USFWS BiOp. These should be regarded and untested hypotheses rather than a strong scientific basis for future management actions. Further analysis is underway on many of these topics and needs to be factored into the synthesis of information available on delta smelt population dynamics and their habitat needs including zooplankton food resources, low salinity habitat, shallow water and other biotic and abiotic factors. The application of the delta smelt lifecycle model is also expected to provide useful insights into the relative contribution of various management actions on different lifestages of delta smelt.
3-71	Figure 3.8-5 presents information on the cumulative percentage of adult delta smelt salvaged at the SWP and CVP. Data used in the graph extend through 2006. Data should be updated to also include an analysis of the most recent 10 years of salvage operations. Changes have occurred in use of turbidity and other factors in managing smelt salvage. The report states that "flows and turbidity of 20,000 to 25,000 cfs and 10 to 12 Nephelometric Turbidity Units (NTU) initiate upstream migration (Figure 3.8-5)". Figure 3.8-5, however, presents no information in support of either flows or turbidity stimulating upstream migration.
3-73	Figure 3.8-7 shows delta smelt salvage and OMR reverse flow from the 2008 USFWS BiOp. The delta smelt salvage data has been criticized as not accounting for population abundance as a confounding factor in the analysis. There is no discussion of the methods used or purpose of using OMR reverse flows weighted by salvage. Current operations take into account the geographic distribution of pre-spawning adult delta smelt as well as turbidity conditions in the Delta. The report should be revised to include a discussion or current operations and their effectiveness in reducing and avoiding delta smelt salvage.
3-73	As with other sections of the report the overview findings for starry flounder would benefit from citation to the source of information used as the basis to conclude that a Delta outflow of 21,000 cfs between March and June is needed to improve starry flounder abundance.
3-75	The report states that more Delta outflow results in higher age-one starry flounder abundance the following year based on Bay Study surveys. It is unclear and not discussed in the report whether higher flows result in greater abundance of juvenile starry flounder or simply that high flows and lower salinity result in a greater number of juveniles entering San Francisco Bay where they are then sampled in the Bay Study surveys.
3-76	Throughout the report flow analyses are based on historical median Delta outflow over a period of time and the abundance target for a given species based on the 2010 Flow Criteria Report. The technical basis for the Flow Criteria Report abundance targets should be critically reviewed by an independent peer review process in combination with review of the current report and analyses. Simply basing a flow objective on a historic median flow condition such as that done for starry flounder assumes, with no support, that changes in flows are the controlling factor for species abundance despite a number of other non-flow changes that have occurred in the estuary over that period of time (e.g., expansion of non-native predator populations, reductions in prey availability, physical habitat alterations, etc.) will not impact the population response to a prescribed change in Delta outflow.
3-77	Citations for the basis of a 19,000 to 26,000 cfs Delta outflow in March-May for bay shrimp is needed in the overview.
3-78	Figure 3.10-1 shows no trend in abundance for bay shrimp in the Bay Study surveys over the period from 1980 through 2013. Given the lack of trend in abundance over time the rational of a need to change or manage Delta outflow in a way different from that over the past 30 years is not clear and requires explanation.
3-81	The range in flows included in the analysis from 19,000 to 26,000 cfs, representing a change of 7,000 cfs over a three month period reflects the magnitude in variability among methods and assumptions used in this report. Variation in the range of almost 40% reflects a high degree of uncertainty in the approach and interpretation of results, especially for a species that

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	has shown no trend of declining abundance over the past 30 years. The report should discuss these factors as part of the context for interpreting results as a basis for management.
3-83	The report states that mysid abundance has declined in recent years most likely in response to competition for food with the Asian clam and other grazers. If the decline in mysid abundance is the result of these biotic factors no basis is presented in the report that increased flows would result in increased abundance. The report also states that after 1987 abundance showed a positive relationship with X2 with lower flows related to higher mysid abundance. Given the logic outlined for other species in the report there appears to be no basis or rational for recommending higher Delta outflows than have occurred recently and potentially lower flows could be beneficial.
3-84	No data or supporting analysis is presented in the report for the flows ranging from 11,400 to 29,200 cfs recommended by CDFW. The wide range of 17,800 cfs in the recommendations reflects the high degree of uncertainty in these recommendations. There does not appear to be any technical basis presented in the report to support a recommendation for modified Delta outflows.
3-84	Given the increasing trend in abundance and size of largemouth bass inhabiting the Delta, and their role as a major predator on native fish, it is not clear why Section 3.12 does not include a discussion of largemouth bass in a way parallel to striped bass.
3-85	Based on evidence documenting predation on native fish by striped bass, and the goals of the flow study to increase native fish abundance, it does not seem consistent to increase Delta outflow for the benefit of striped bass which could contribute to increase predation mortality on other sensitive native species. The report should acknowledge and address these policy conflicts among species and well as among other beneficial water uses in the subsequent integrated analyses.
3-85	The comments outlined above are all applicable and need to be taken into consideration and addressed/resolved as the technical and scientific foundation for the discussion presented in Section 3.13. The conclusions will need to be revised based on response to the individual species analyses.
4-1	Section 4 provides only a very general discussion of other stressors and offers no substance on how these critical stressors can or will be addressed as part of an integrated approach to improving conditions for Bay-Delta fish and other aquatic resources. The report appropriately acknowledges the need to address both hydrology and other stressors to implement an integrated strategy that has the potential to substantially improve conditions within the rivers and estuary for native fish species. Modifying Delta outflow criteria alone is not expected to result in major fishery benefits in the absence of addressing other major stressors. In addition, modifying Delta outflows alone without adequate consideration of interactions with other key factors such as coldwater pool management or salinity control for other beneficial uses is not expected to achieve the broader goals of improving conditions for a variety of native fish species. The discussion in Section 4 provides little substance regarding how other stressors would be addressed or the integration and coordination between Delta outflow and other stressors as part of an overall strategy that balances and meets a wide range of needs. Section 4 requires major revisions in order to provide meaningful input to the process.
5-1	The report states that the conceptual basis for all of the requirements are supported by the best available scientific information on functional flow needs for individual species and the ecosystem as well as statistical analyses. As outlined above, the analyses presented in Chapter 3 are lacking in a number of areas information on the methods used in the data analyses, key assumptions, and technical documentation and have not been subject to independent scientific peer review which should be part of the scientific standard for best available information. Many of the analyses have not been updated to include more recent data and many of the discussions of data and results, including concerns, are incomplete and imbalanced. Further, many of the analyses are only partially completed as a result of the initial approach for

Page	Comment
	including consideration of only instream flows and Delta outflows in the absence of integration with other key elements of developing an integrated management framework that also considers factors such as reservoir storage and coldwater pool management, temperature control, other stressors, other beneficial water uses, etc.
5-2	The report discusses how "science indicates that more natural flows that closely mimic the shape of the unimpaired hydrograph including general seasonality, magnitude, and duration of flows generally provide those functions". The report focus has been on increasing Delta outflow but must also address and analyze impacts associated with adopting an unimpaired hydrograph approach means dealing with periods when Delta outflows may be substantially lower than under current conditions. Low flow conditions such as those that occurred historically during the late summer and during droughts would result in salinity intrusion further upstream into the Delta and have a major impact on water quality and subsequently water supplies for irrigation and municipal use. These low flow periods are also part of the hydrologic dynamics that effected estuarine functions and processes and need to be addressed in the report and subsequent analyses of management alternatives.
5-4	In analyzing an unimpaired flow range from 35 to 75% potential impacts to reservoir storage and coldwater pool management as well as to other beneficial uses require a systematic approach to simulation modeling and application of quantified performance metrics. For example, and standard set of temperature suitability criteria such as those proposed by EPA (2003) using 7DAMDT by lifestage may provide comparison of habitat changes across alternatives. Changes in salinity intrusion into the Delta and changes in water supplies should also be based on standardized metrics of analysis.
5-5	The report states that the Water Board "generally does not plan to consider flows that are lower than drier baseline conditions". Adoption of an unimpaired hydrologic scenario includes both higher and lower flows. Low flow periods historically were important in maintaining ecosystem functions through reduction in invasive vegetation, reduction in resident predatory fish populations, and other functions. One of the concerns expressed is that flow management under current conditions provides higher summer flows and more stable conditions that alter these ecological dynamics. The analysis should include a full range of unimpaired flows and not be artificially constrained by current baseline flow operations.
5-6	The report recommends that year round baseflows be maintained in all Delta tributaries. As noted above, low late summer flows or in some systems seasonally dry channels served an ecological function such as vegetation and predator control. The analysis should reflect a full range of unimpaired flow conditions and not be constrained artificially. For example, it is thought that one of the reasons seasonally inundated floodplain habitat is so productive as a juvenile salmonid rearing habitat is that it is dry most of the year and hence populations of predatory fish are not present.
5-10	The report states that "lack of hydrologic connection between tributaries and the Sacramento River was identified as the most common stressor for both adult and juvenile salmon, The loss of connectivity commonly results of water temperatures that are too elevated . . ". The magnitude of seasonal instream flows is just one of the many factors that affect thermal conditions in a tributary. Given the warm summer air temperatures, the length of many tributaries, lack of riparian shading, in some cases limited to no water storage, and shallow and wide channels exposed to solar heating it is not clear how the SWRCB plan will achieve the goal of maintaining suitable summer temperatures for juvenile salmonid rearing throughout many of the valley tributaries. The analysis of interactions between tributary flows and water temperatures will require the development and application of water temperature simulation models and other analytic tools as part of the evaluation of flow alternatives. The ability of flow management, given all of the other constraints, on meeting the objective of maintaining suitable temperatures and perennially flows while also meeting specific habitat needs for migration, spawning, egg incubation, and upstream juvenile rearing is highly

Page	Comment
	uncertain.
5-11	The report discusses implementation of the unimpaired flow strategy through an adaptive management framework but provides no details on how adaptive management will be implemented. The report should be expanded to provide additional description on how adaptive management of the flow elements of the plan will be performed, decision making, performance monitoring, testable management hypotheses, and other elements of an adaptive management process.
5-12	The report recommends increased Delta outflows from January through June. As noted above, embracing the concepts of unimpaired flows for ecological processes also includes greater hydrologic variability and lower late summer flows than may be currently occurring. The report should address how the full range of flow variability is being integrated into the management strategy and how analyses will be performed to assess potential adverse impacts to other water uses and water quality including both temperature and salinity
5-13	The report is recommending higher Delta outflow during the winter and spring but also higher fall flows for X2 based on the USFWS 2008 BiOp. The report does not adequately establish a scientific basis for adopting a fall flow and X2 element. Given the water costs and level of uncertainty in biological benefits to delta smelt and potential impacts to other species and water uses the fall action should be considered to be an untested hypothesis. Additional analyses are currently underway to further explore the fall action and limited field monitoring has been performed. In the absence of results of further analyses of integrated operations under the range of proposed flows outlined in the report recommending inclusion of a summer or fall flow action is premature.
5-17	The report states that in wetter years modeled and actual flows are frequently greater than the minimums identified through these analyses and therefore higher flows should be regulated to protect from them from future water development. Since any future diversions would need to be permitted by the SWRCB on an individual basis it is not clear why added flow regulation is needed at this time. The report discussion should be expanded and clarified regarding the need and intent of identifying added regulation at this time.
5-19	The report states that D-1641 and the 2006 Bay-Delta Plan do not provide for Delta outflow that meet the flow goals outlined in Table 3.13-2 during dry water years. The analyses that were used to support the flow thresholds discussed in Chapter 3 of the report focused only on the high flow range. Although the report discusses the ecological benefits of wider flow variation the report and analyses presented do not adequately address either the frequency or magnitude of low flow conditions and therefore do not provide a scientific basis to factoring low flows into the proposed management strategy. The native fish inhabiting the Bay-Delta evolved to respond to both high and low flow conditions. The report implicitly assumes that addressing only high flows will meet the biological needs. The analysis and consideration of flow ranges included in the report should be broadened to also address naturally occurring droughts and other low flow conditions.
5-19	The key assumption underlying the report and its recommendations is “the higher the flows up to 100 percent of unimpaired flow (and higher in the summer and fall) and the lower the X2 value, the greater the benefits are for native species and the ecosystem . . “. This fundamental assumption is guiding all of the analyses presented in the report. This, however, differs from the unimpaired flow regime where variability in hydrologic conditions between high and low flow conditions is a key attribute of ecosystem functions. The report approach, analyses, assumptions, and recommendations need independent peer review and a broader consideration of the application of the unimpaired flow strategy than is currently part of the analyses. The analysis of potential benefits associated with changes in flow regimes needs to also address the highly altered state of the Delta, biotic and abiotic factors other than flow that effect ecosystem dynamics, and other stressors that impact fish species. The simple paradigm embodied in the report that more flow alone is the answer is overly simplistic, unrealistic, and

Page	Comment
	subject to high uncertainty. This same concept is discussed on page 5-26 and generally throughout the body of the report.
5-27	The report recommends including the fall X2 outflow operations managed adaptively. See comments on pages 5-11 and 5-13 above
5-31	The report suggests a potential narrative requirement regarding water temperature management in tributaries. See comments page 5-10 above. The discussion in the report should be expanded to describe how a narrative requirement will provide suitable salmonid habitat in these tributaries
5-33	The report provides a general discussion of cold water habitat requirements within various Central Valley watersheds for salmonid migration, spawning, egg incubation, and juvenile rearing. The report acknowledges the importance of water temperature conditions impacting habitat availability and suitability and the adverse impacts of exposure to seasonally elevated temperatures. The report does not, however, provide results of modeling or analysis of how the proposed unimpaired flow regimes will impact reservoir storage, coldwater pool, or downstream temperatures and their effect on habitat suitability for various lifestages of Chinook salmon, steelhead, sturgeon, and other species. Given the difficulties currently encountered with coldwater pool management and maintaining suitable temperatures the report provides no discussion of how greater instream flow releases can or will be managed or the impacts of greater releases on temperature conditions year round, especially in dry years.
5-38	The report includes additional DCC gate closures in October, new limitations on OMR reverse flows, and added constraints on spring and fall exports as a function of San Joaquin River flows. The report does not present results of modeling or analysis of the potential impacts of these recommendations on water quality, or native fish survival or abundance. For example, DCC gate closures in October have been identified as an action to improve adult fall-run Chinook salmon migration into the Mokelumne River and reduce straying, but this action has potential adverse impacts on Delta water quality and other factors that are not identified or addressed in the report. Similarly, Chapter 3 of the report provides no analyses or technical basis for modifications to OMR reverse flows as a method for increasing survival. No data are presented on juvenile salmon or steelhead survival in response to OMR reverse flow magnitude, timing, or duration. Similarly, the report provides no analyses of the relationship between San Juaquin River flow and export ratio during the spring and juvenile salmonid migration or survival. These are additional examples that occur throughout the report of recommended changes to management actions without scientific support, analysis, or disclosure of potential impacts and uncertainty in outcomes. In many instances the report appears to simply adopt actions that were included in the 2008 USFWS or 2009 NMFS BiOps without critical analysis of supporting information or analysis of data collected over the past decade while the BiOps have been in effect.
5-42	The report states that information in Chapter 3 supports an expanded window of limited maximum export rates to protect juvenile salmonids and a lower minimum export rate of 800 cfs. The report, however, presents only limited information on potential relationships between export rates, flow to export ratios, or minimum export rates on juvenile salmon and steelhead survival to Chipps Island. The analyses presented in the report are insufficient and inadequate to support specific modification to south Delta export operations.

Exhibit B

A DELTA TRANSFORMED

ecological functions, spatial metrics, and landscape change

IN THE SACRAMENTO-SAN JOAQUIN DELTA

SAN FRANCISCO ESTUARY INSTITUTE
AQUATIC SCIENCE CENTER
SFEI
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A DELTA TRANSFORMED

ecological functions, spatial metrics, and landscape change

IN THE SACRAMENTO-SAN JOAQUIN DELTA

A Report of the Delta Landscapes Project:
Management Tools for Landscape-Scale Restoration of Ecological Functions

PREPARED FOR THE CALIFORNIA DEPARTMENT OF FISH AND WILDLIFE AND ECOSYSTEM RESTORATION PROGRAM

OCTOBER 2014

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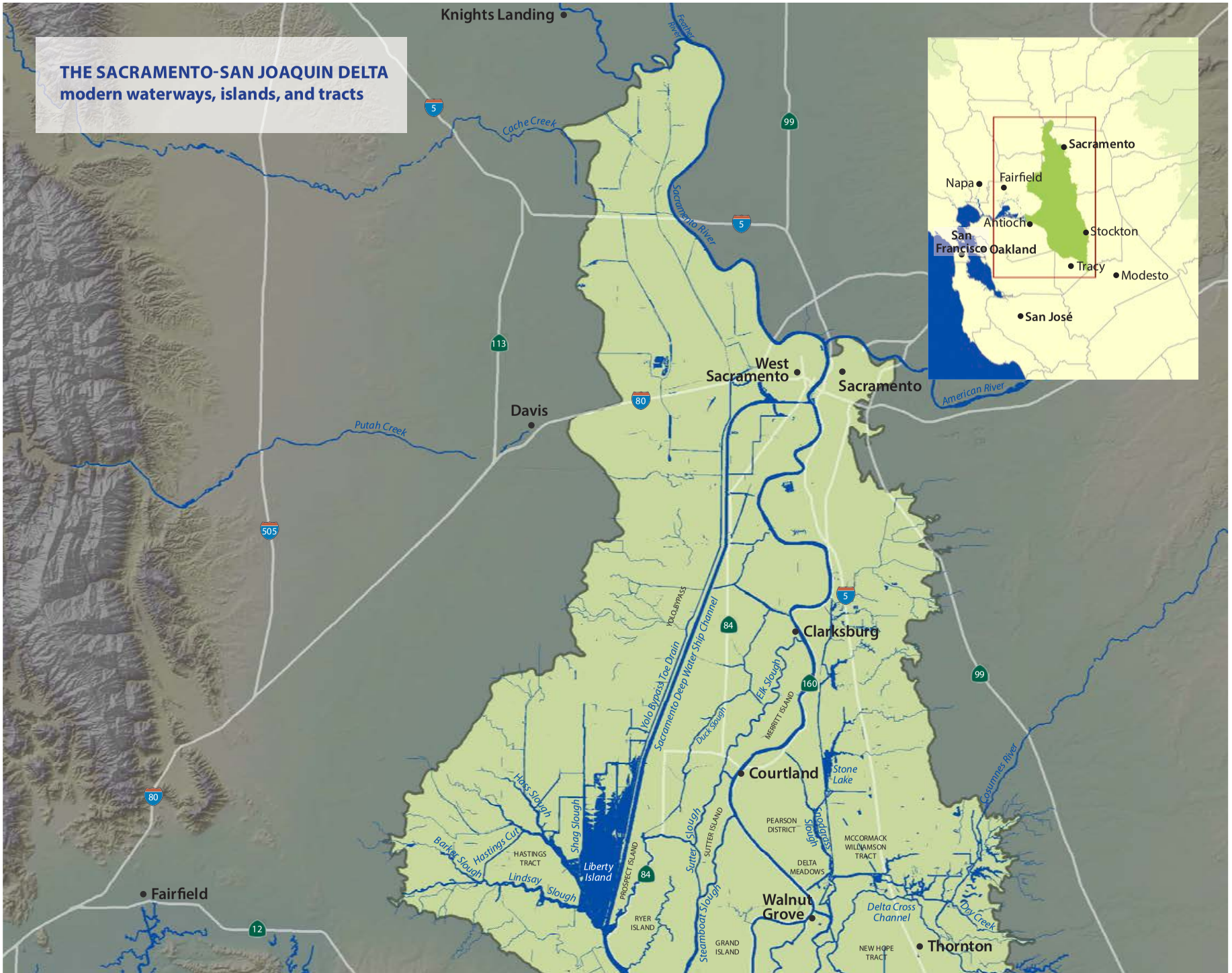
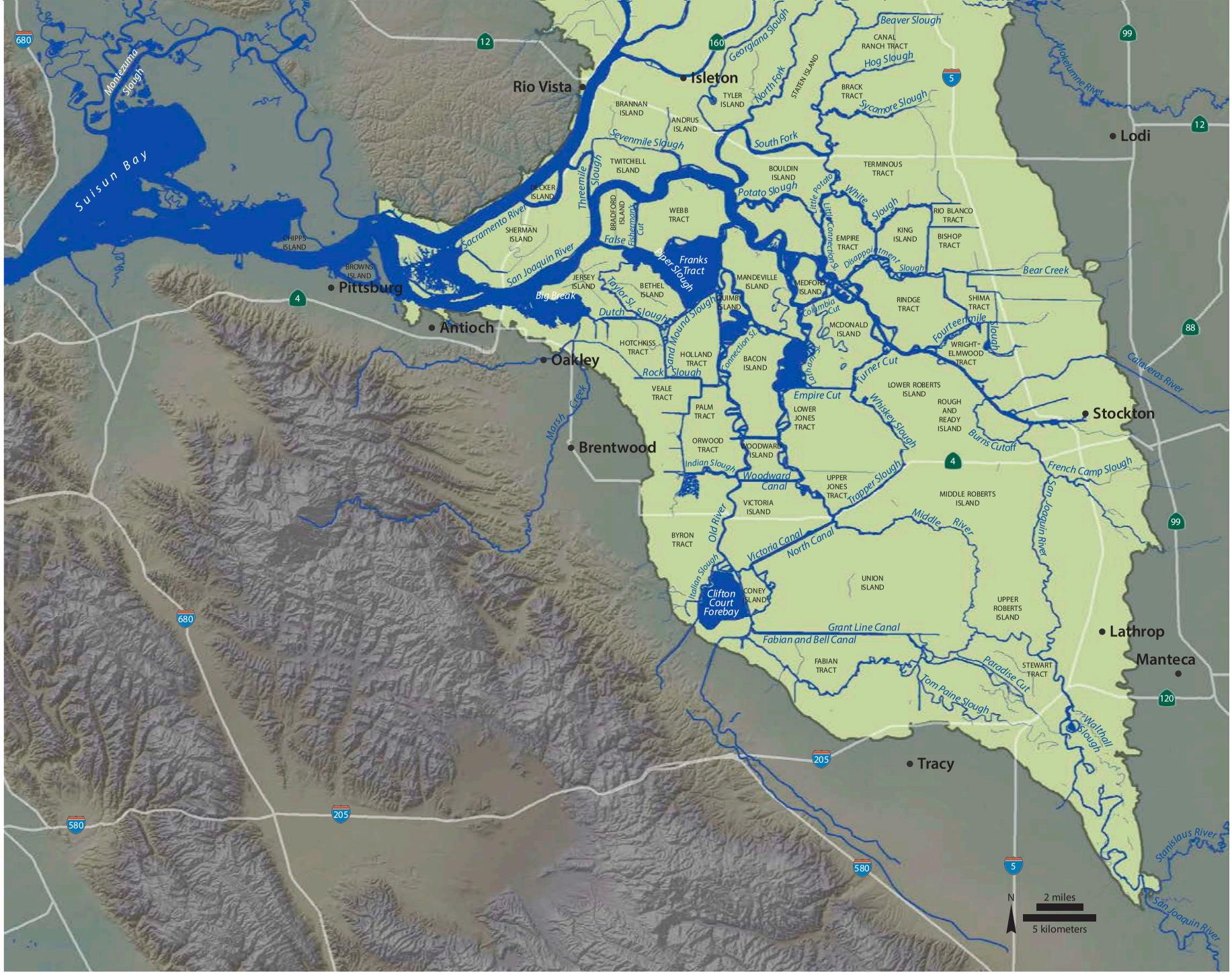
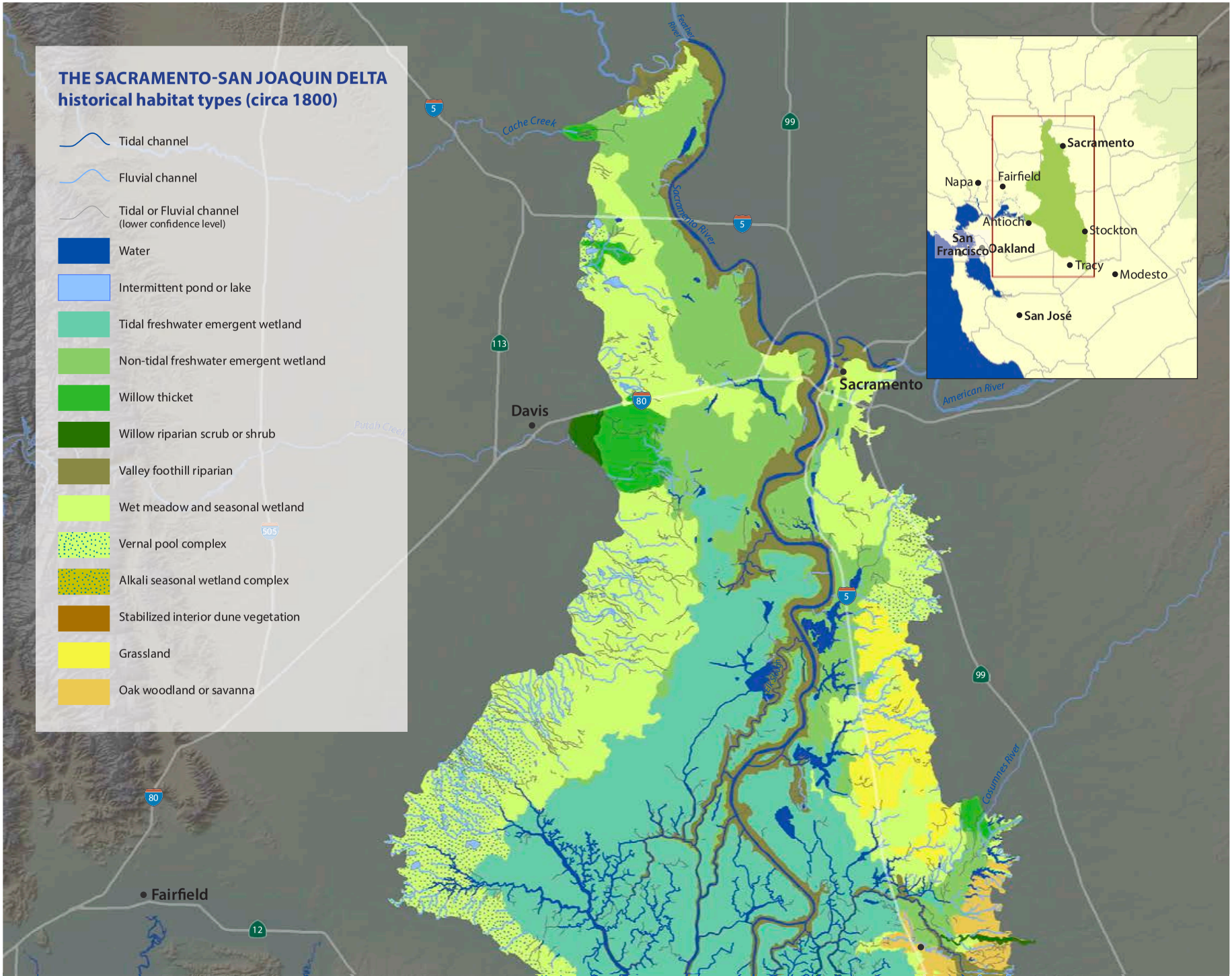
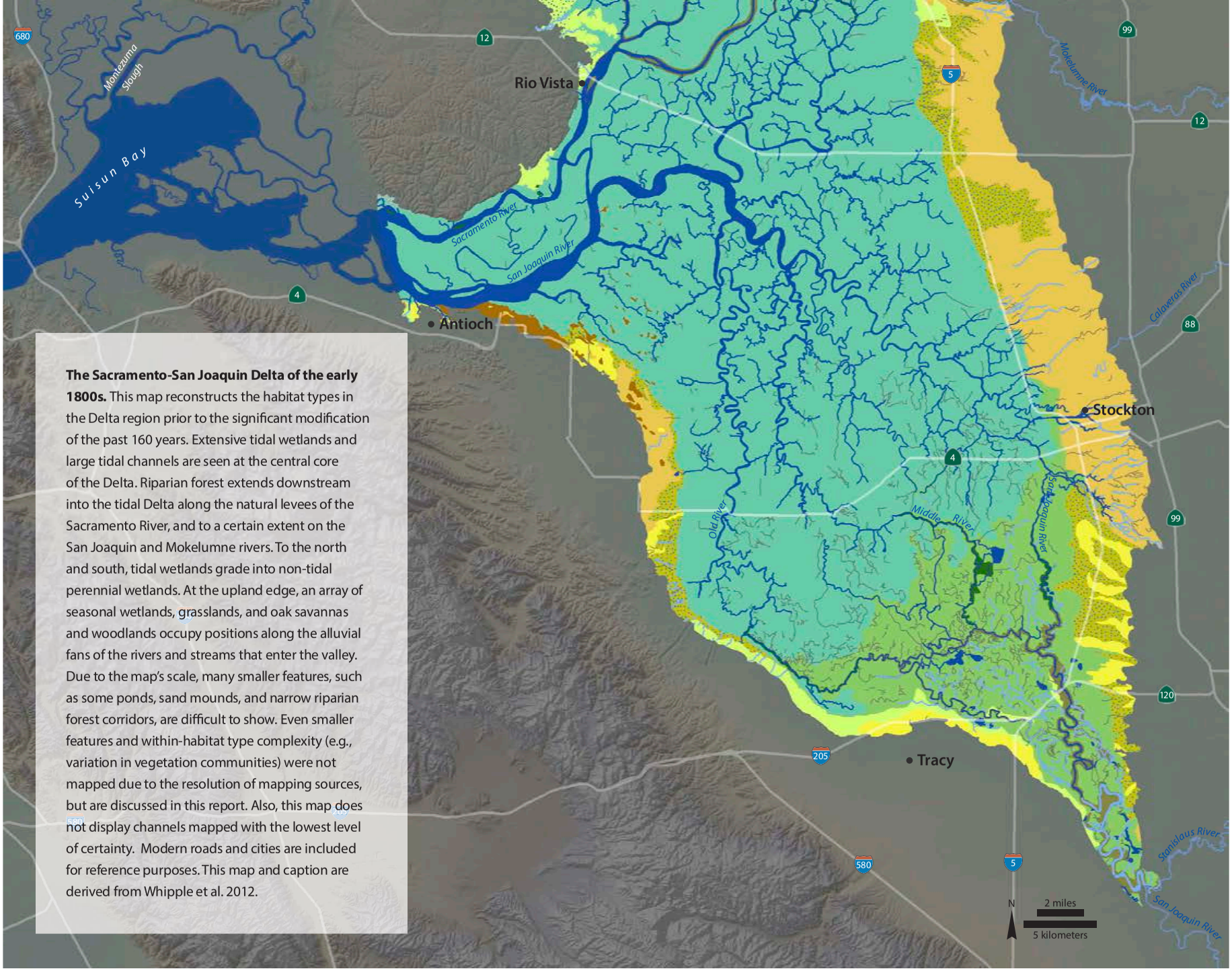
Ecosystem Restoration Program

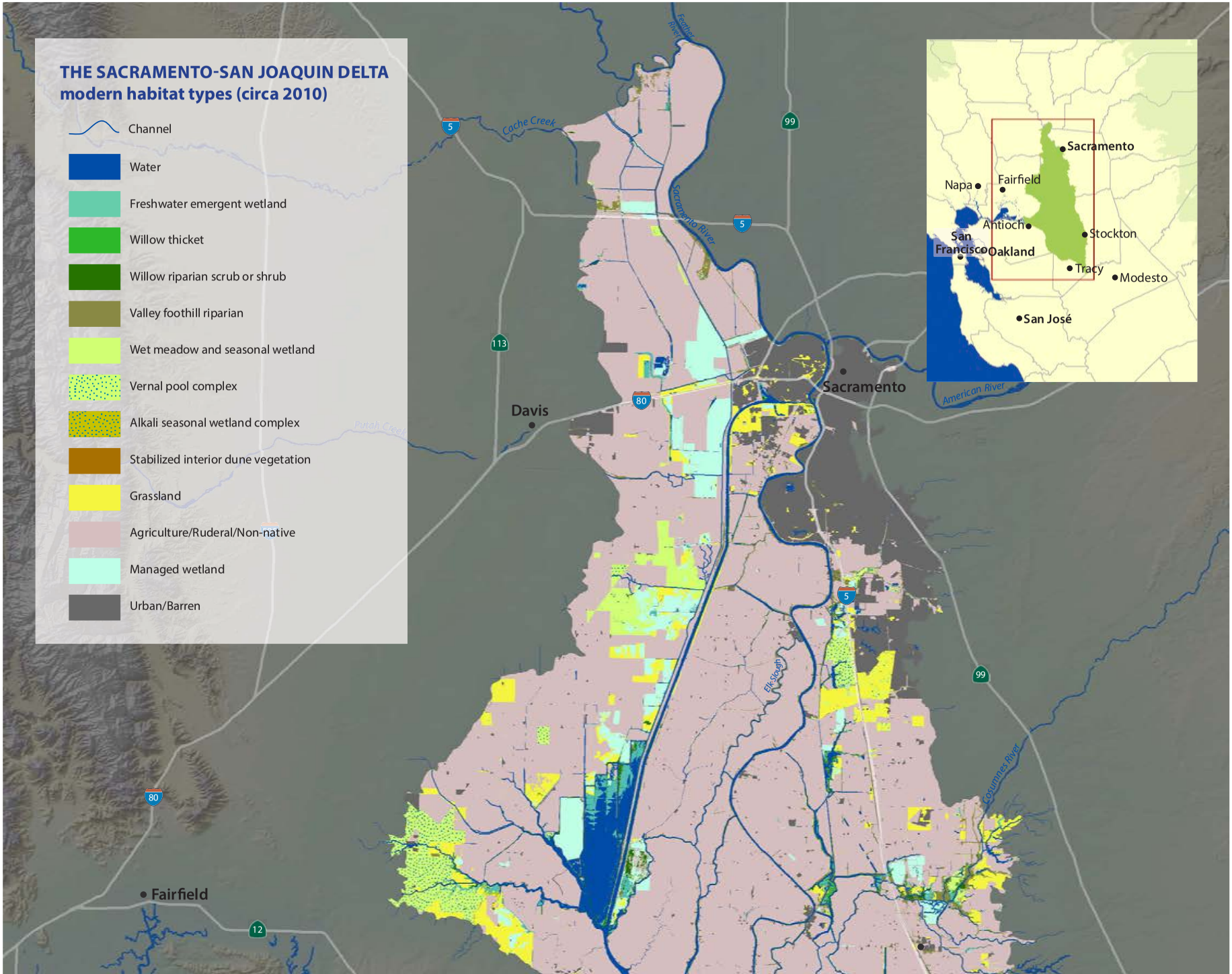

THE SACRAMENTO-SAN JOAQUIN DELTA
modern waterways, islands, and tracts
Knights Landing
Feather River
Cache Creek
Sacramento River
Putah Creek
Davis
West Sacramento
Sacramento
American River
Clarksburg
Yolo Bypass
Yolo Bypass Toe Drain
Sacramento Deep Water Ship Channel
Elk Slough
Duck Slough
MERRITT ISLAND
Courtland
Stone Lake
Cosumnes River
Hass Slough
Shag Slough
Barker Slough
Hastings Cut
HASTINGS TRACT
Liberty Island
Lindsay Slough
PROSPECT ISLAND
Sutter Slough
SUTTER ISLAND
Snodgrass Slough
PEARSON DISTRICT
MCCORMACK WILLIAMSON TRACT
DELTA MEADOWS
Fairfield
Walnut Grove
Delta Cross Channel
Dry Creek
RYER ISLAND
Steamboat Slough
GRAND ISLAND
NEW HOPE TRACT
Thornton
Sacramento
Napa
Fairfield
Antioch
Stockton
San Francisco
Oakland
Tracy
Modesto
San José
5
99
113
80
505
84
160
12

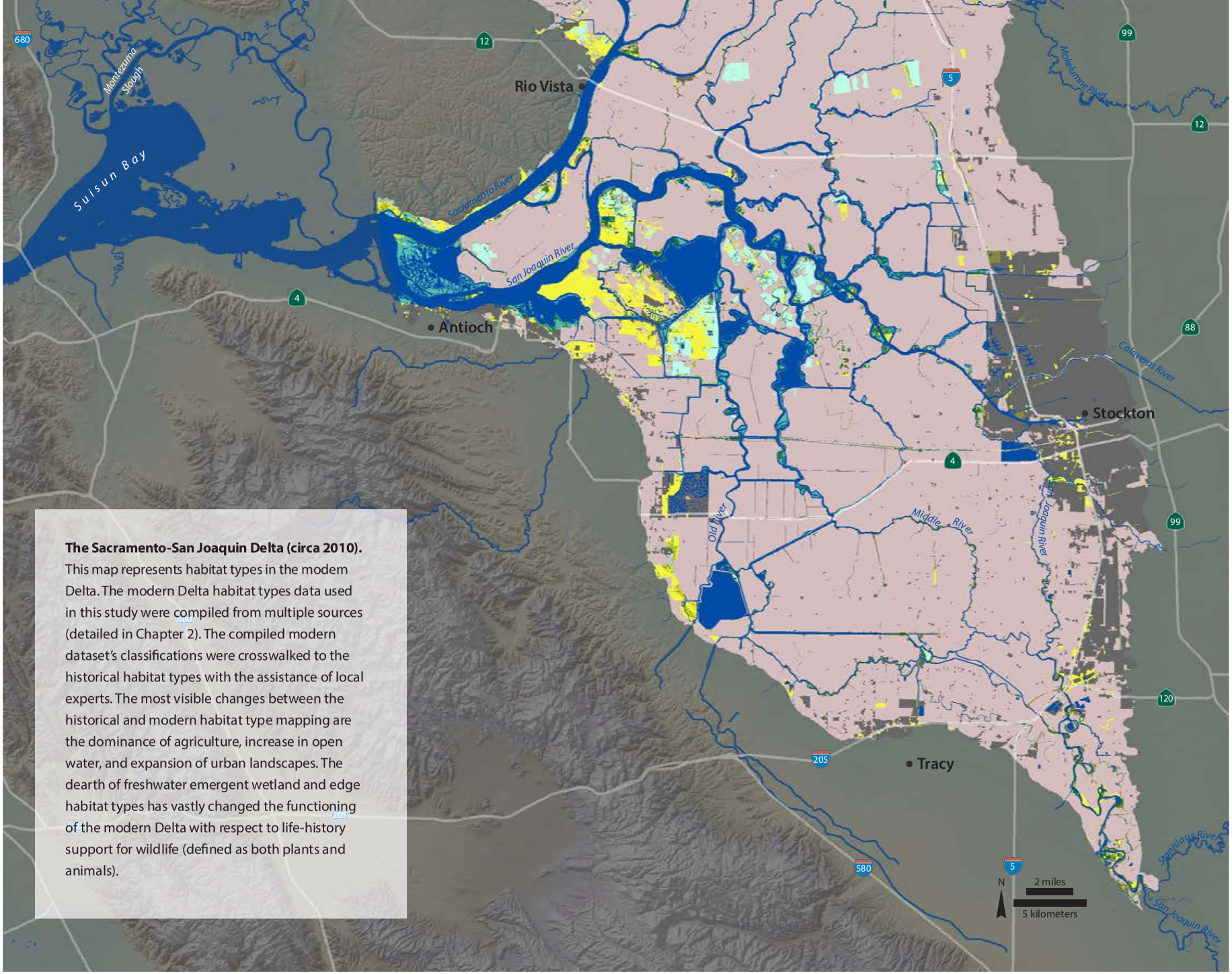

Suisun Bay
Montezuma Slough
Rio Vista
Isleton
Georgiana Slough
Beaver Slough
CANAL RANCH TRACT
Hog Slough
North Fork
TYLER ISLAND
STAEN ISLAND
BRACK TRACT
Sycamore Slough
Mokelumne River
Lodi
BRANNAN ISLAND
ANDRUS ISLAND
Sevenmile Slough
South Fork
TWITCHELL ISLAND
BOULDIN ISLAND
TERMINOUS TRACT
Potato Slough
Little Potato Slough
White Slough
DECKER ISLAND
Threemile Slough
BRADFORD ISLAND
Fisherman's Cut
WEBB TRACT
RIO BLANCO TRACT
KING ISLAND
BISHOP TRACT
EMPIRE TRACT
Little Connection Slough
Disappointment Slough
Bear Creek
CHIPPS ISLAND
SHERMAN ISLAND
Sacramento River
San Joaquin River
False River
Upper Slough
Franks Tract
BROWNS ISLAND
Pittsburg
JERSEY ISLAND
BETHEL ISLAND
Big Break
Taylor Slough
MANDEVILLE ISLAND
MEDFORD ISLAND
QUIMBY ISLAND
Columbia Cut
RINDGE TRACT
SHIMA TRACT
Dutch Slough
Sand Mound Slough
MCDONALD ISLAND
Fourteenmile Slough
Antioch
HOTCHKISS TRACT
HOLLAND TRACT
Connection Slough
BACON ISLAND
WRIGHT-ELMWOOD TRACT
Oakley
Rock Slough
Calaveras River
Turner Cut
LOWER ROBERTS ISLAND
VEALE TRACT
Empire Cut
Whiskey Slough
ROUGH AND READY ISLAND
Stockton
Marsh Creek
PALM TRACT
LOWER JONES TRACT
Burns Cutoff
ORWOOD TRACT
WOODWARD ISLAND
Brentwood
Indian Slough
Woodward Canal
French Camp Slough
UPPER JONES TRACT
Trapper Slough
MIDDLE ROBERTS ISLAND
VICTORIA ISLAND
Old River
Middle River
San Joaquin River
BYRON TRACT
Victoria Canal
North Canal
Italian Slough
UNION ISLAND
CONEY ISLAND
Clifton Court Forebay
UPPER ROBERTS ISLAND
Grant Line Canal
Fabian and Bell Canal
Lathrop
Manteca
FABIAN TRACT
STEWART TRACT
Paradise Cut
Tom Paine Slough
Walthall Slough
Tracy
Stanislaus River
San Joaquin River
680
12
160
99
5
4
88
120
205
580
N
2 miles
5 kilometers


THE SACRAMENTO-SAN JOAQUIN DELTA
historical habitat types (circa 1800)
Tidal channel
Fluvial channel
Tidal or Fluvial channel
(lower confidence level)
Water
Intermittent pond or lake
Tidal freshwater emergent wetland
Non-tidal freshwater emergent wetland
Willow thicket
Willow riparian scrub or shrub
Valley foothill riparian
Wet meadow and seasonal wetland
Vernal pool complex
Alkali seasonal wetland complex
Stabilized interior dune vegetation
Grassland
Oak woodland or savanna
Cache Creek
Sacramento River
Davis
Sacramento
American River
Putah Creek
Fairfield
Napa
Antioch
Stockton
San Francisco
Oakland
Tracy
Modesto
San José
Calaveras River



The Sacramento-San Joaquin Delta of the early 1800s. This map reconstructs the habitat types in the Delta region prior to the significant modification of the past 160 years. Extensive tidal wetlands and large tidal channels are seen at the central core of the Delta. Riparian forest extends downstream into the tidal Delta along the natural levees of the Sacramento River, and to a certain extent on the San Joaquin and Mokelumne rivers. To the north and south, tidal wetlands grade into non-tidal perennial wetlands. At the upland edge, an array of seasonal wetlands, grasslands, and oak savannas and woodlands occupy positions along the alluvial fans of the rivers and streams that enter the valley. Due to the map's scale, many smaller features, such as some ponds, sand mounds, and narrow riparian forest corridors, are difficult to show. Even smaller features and within-habitat type complexity (e.g., variation in vegetation communities) were not mapped due to the resolution of mapping sources, but are discussed in this report. Also, this map does not display channels mapped with the lowest level of certainty. Modern roads and cities are included for reference purposes. This map and caption are derived from Whipple et al. 2012.


THE SACRAMENTO-SAN JOAQUIN DELTA
modern habitat types (circa 2010)
Channel
Water
Freshwater emergent wetland
Willow thicket
Willow riparian scrub or shrub
Valley foothill riparian
Wet meadow and seasonal wetland
Vernal pool complex
Alkali seasonal wetland complex
Stabilized interior dune vegetation
Grassland
Agriculture/Ruderal/Non-native
Managed wetland
Urban/Barren
Cache Creek
Sacramento River
Feather River
Davis
Sacramento
American River
Elk Slough
Mokelumne River
Fairfield
Napa
Antioch
Stockton
San Francisco
Oakland
Tracy
Modesto
San José
5
80
99
113
12



The Sacramento-San Joaquin Delta (circa 2010). This map represents habitat types in the modern Delta. The modern Delta habitat types data used in this study were compiled from multiple sources (detailed in Chapter 2). The compiled modern dataset's classifications were crosswalked to the historical habitat types with the assistance of local experts. The most visible changes between the historical and modern habitat type mapping are the dominance of agriculture, increase in open water, and expansion of urban landscapes. The dearth of freshwater emergent wetland and edge habitat types has vastly changed the functioning of the modern Delta with respect to life-history support for wildlife (defined as both plants and animals).

SUGGESTED CITATION

San Francisco Estuary Institute-Aquatic Science Center (SFEI-ASC). 2014. A Delta Transformed: Ecological Functions, Spatial Metrics, and Landscape Change in the Sacramento-San Joaquin Delta. Prepared for the California Department of Fish and Wildlife and Ecosystem Restoration Program. A Report of SFEI-ASC's Resilient Landscapes Program, Publication #729, San Francisco Estuary Institute-Aquatic Science Center, Richmond, CA.

REPORT AVAILABILITY

Report is available on SFEI's website at www.sfei.org/projects/delta-landscapes-project.

COVER CREDITS

Front cover, left to right, top to bottom: maps of historical and modern marsh in the Sacramento-San Joaquin Delta (developed for this report); Liberty Island (photo by Barbara Beggs, USFWS).

Back cover, left to right: NAIP 2005; detail from map of historical habitats of the Sacramento-San Joaquin Delta (Whipple et al. 2012); detail from map of historical inundation in the Sacramento-San Joaquin Delta (Whipple et al. 2012); Snow and Ross' geese (photo by Steve Emmons, USFWS); portion of map by WH Hall, ca. 1880, Grand Island and Suisun Bay to foothills and 1st Standard North (Hall ca. 1880, courtesy of California State Archives).

CONTENTS

Acknowledgments

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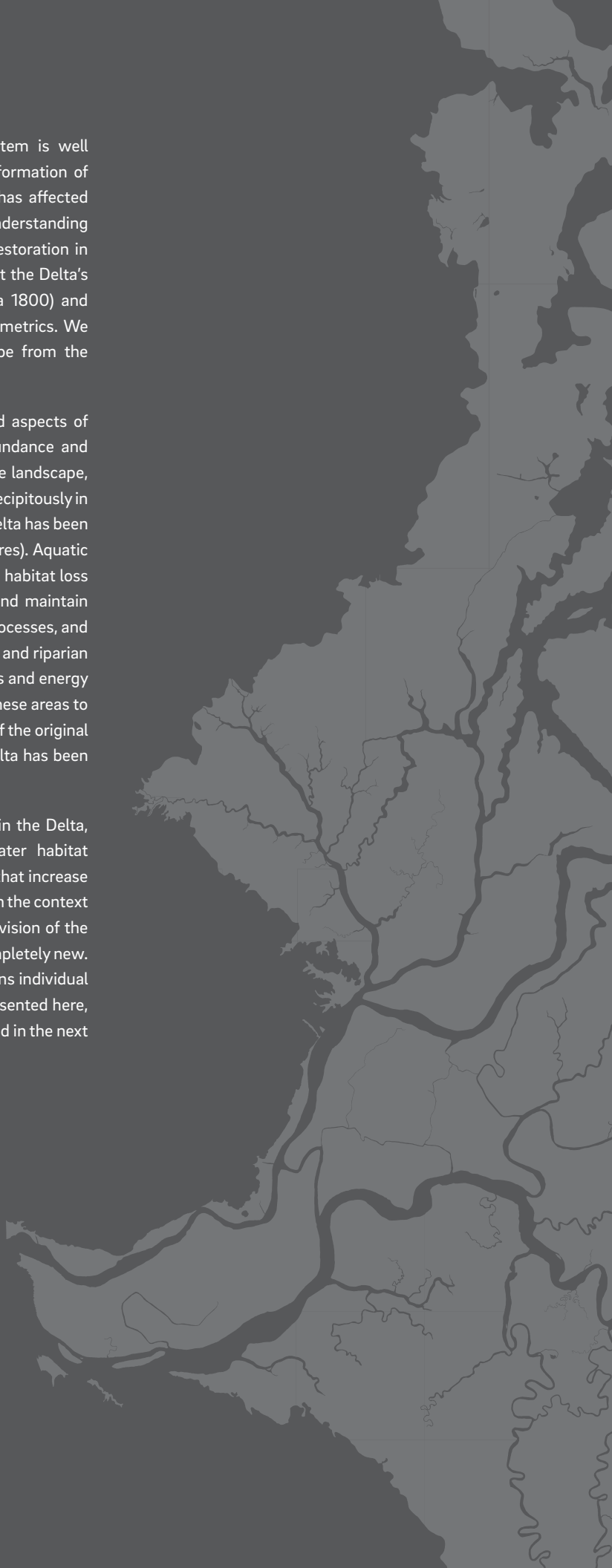
Executive Summary

While the decline of the Sacramento-San Joaquin Delta ecosystem is well recognized, relatively little is known about how the physical transformation of the Delta landscape—which took place more than a century ago—has affected its ability to support native plants and animals. The need for this understanding is urgent, as plans are being developed for substantial ecological restoration in the Delta. To fill this gap, we synthesized scientific knowledge about the Delta's native species with recent mapping of the pre-development (circa 1800) and contemporary Delta habitats to define ecologically relevant spatial metrics. We then analyzed the historical transformation of the Delta landscape from the perspective of these measures.

Based on scientific literature and input from experts, we identified aspects of the pre-development Delta landscape that contributed to the abundance and resilience of native wildlife populations. Habitats that dominated the landscape, such floodplains, marshes, and wide riparian forests, have declined precipitously in extent. For example, 98% of the freshwater emergent marsh in the Delta has been lost (from approximately 190,000 hectares to just over 4,000 hectares). Aquatic habitats have also undergone wholesale conversion. Underlying this habitat loss and degradation is the loss of the physical processes that create and maintain these habitats, conferring resilience upon the landscape, biological processes, and wildlife populations. The disconnection of floodwaters from marshes and riparian areas has not only altered habitats but also the exchange of materials and energy that affects the food web, water quality, and the future potential of these areas to be restored and provide habitat value. Thus, despite retaining some of the original system's template, with its sinuous channels and tidal flows, the Delta has been fundamentally transformed.

To improve the health and resilience of native wildlife populations in the Delta, another transformation will be required—one that restores greater habitat extent, connectivity, and diversity, as well as the physical processes that increase resilience and drive ecosystem function. This restoration must occur in the context of invasive species and changes in freshwater flow, necessitating a vision of the future that incorporates knowledge of the past and present but is completely new. This will require a landscape-scale framework for restoration that joins individual project "pieces" into a functional landscape "puzzle." The metrics presented here, as well as the landscape restoration conceptual models to be produced in the next phase of this project, can be useful tools to meet this challenge.



Recent state policy sets ambitious goals for ecosystem restoration in the Sacramento-San Joaquin Delta. *The Delta Plan and California Water Code, as well as other regional documents, identify the need to go beyond small-scale habitat restoration to create larger functional landscapes of interconnected habitats.*[1-6] *Yet there is little quantitative guidance available to help design the complex spatial systems that are likely to achieve these goals. This report provides the first analysis of landscape ecology metrics in the pre-disturbance and contemporary Delta to help define, design, and evaluate functional, resilient landscapes for the future.*

[1] *California Water Code, Section 85302 (e)(1). "The Delta Plan shall include measures that…restore large areas of interconnected habitats within the Delta and its watershed by 2100."*

[2] *Teal et al. 2009. "Restoration strategies must be designed from a systems perspective that the Delta is considered as an interconnected watershed-river-marsh-estuary-ocean landscape."*

[3] *The Delta Plan 2013. "Management plans and decisions need to be informed by a landscape perspective that recognizes interrelationships among patterns of land and water use, patch size, location and connectivity, and species success."*

[4] *California Department of Water Resources 2013, Bay Delta Conservation Plan (BDCP; Public Draft). "The BDCP will contribute to the restoration of Sacramento-San Joaquin River Delta (Delta) ecosystems largely by addressing ecological functions and processes on a broad landscape scale."*

[5] *Wiens et al. 2012. "Historical ecology can provide a tool for using the past to understand the foundations of the present landscape and to assess its future potential for restoration by considering landscape patterns, processes, and functions and the conditions to which species are adapted."*

[6] *Delta Independent Science Board 2013. "We suggest that successful restoration projects in the Delta will [recognize that]... spatial context is part of the design. Individual restoration projects, regardless of their size, are not isolated from the surrounding aquatic and terrestrial landscape, or from restoration or management actions undertaken elsewhere."*

1. Introduction

Delta Landscapes approach

Before modern development, almost half of California's coastal wetlands were found in the Sacramento-San Joaquin Delta. The Delta supported the state's most important salmon runs, the Pacific Flyway, and endemic species ranging from the delta smelt to the Delta tule pea. In the region's Mediterranean climate, the Delta's year round freshwater marshes were an oasis of productivity during the long dry season. Until reclamation, the Delta stored vast amounts of carbon in its peat soils. Today the Delta functions very differently, having undergone a massive and continuing transformation. Despite the dramatic changes, however, many native species are still found in the Delta, albeit in greatly reduced numbers. Some are threatened by extinction, and others may be soon.[1] The Delta no longer functions as a delta, spreading river and bay water and sediment across wetlands, floodplains, and riparian forests. Recovery of some of these lost ecological functions is considered crucial to ecosystem restoration in the Delta.[2]

Because of biological declines and regulatory challenges, Delta planning efforts often emphasize a few target species in habitat restoration and management. The Delta Landscapes project attempts to provide a "big picture" ecosystem perspective on how we reestablish ecosystem functionality for multiple suites of taxa. Our approach is to evaluate the landscape patterns and processes that supported native species in the historical Delta, measure how they have changed, and assess the potential for reestablishing smaller, modified, but ecologically functional deltaic landscapes in the future. The project contributes a missing dimension to Delta planning by providing a landscape-scale perspective on restoration opportunities that is founded in a sound understanding of how the Delta historically supported native species. This approach gives us the best chance at creating the new, reconciled landscapes of the future that integrate natural and cultural processes, maximizing resilience to climate change, invasive species, and other challenges.[3]

In order to imagine and plan for a functioning Delta ecosystem in the future, we must first understand how a healthy ecosystem looks.[4] Currently, we have no first-hand knowledge of how Delta landscapes functioned because there are no large areas typical of the historical Delta left. Such understanding is essential to evaluating the settings in which native wildlife (defined as plants and animals) evolved and designing future habitats that preferentially benefit these species. To develop this perspective, we analyzed early 1800s habitat mapping and other information from the Delta Historical Ecology Investigation,[5] completed in 2012, through a lens of key ecological functions that supported Delta wildlife. With a team of local and national experts in ecological and physical processes, we developed quantifiable metrics that represent different suites of functions

provided by different Delta settings. In order to evaluate change over time, the selected landscape metrics were also applied to the current Delta.

This first output of the Delta Landscapes project identifies important landscape-scale ecological functions that supported native species, and analyzes how they have changed. In subsequent project reports, these landscape metrics will be integrated with analyses of physical changes and existing constraints to explore the potential for future operational landscape units (OLUs) that would strategically link multiple projects over time into functional landscapes.[6]

Given the multiple uses of the Delta, diverse ecosystem stressors, and future challenges such as sea level rise and flooding, the future Delta will be a novel ecosystem,[7] likely to look very different from either the historical or the contemporary system. Today's Delta experiences multiple layers of impact, including freshwater flow diversions and alterations, contaminants, reduction in sediment supply, and non-native invasive species.[8] But while habitat mosaics cannot necessarily be reestablished in the same places or at the same scale at which they existed historically, they need to be designed to provide many of the same target functions at suitable scales. The challenge is to recognize of the potential resilience of disturbed physical and ecological systems, working in concert with underlying topographic and hydrological attributes to recover desired ecological functions.[9] By understanding how the landscape works and has changed, we can recognize the opportunities to strategically reconnect landscape components in ways that support ecosystem resilience to both present and future stressors.

Report structure

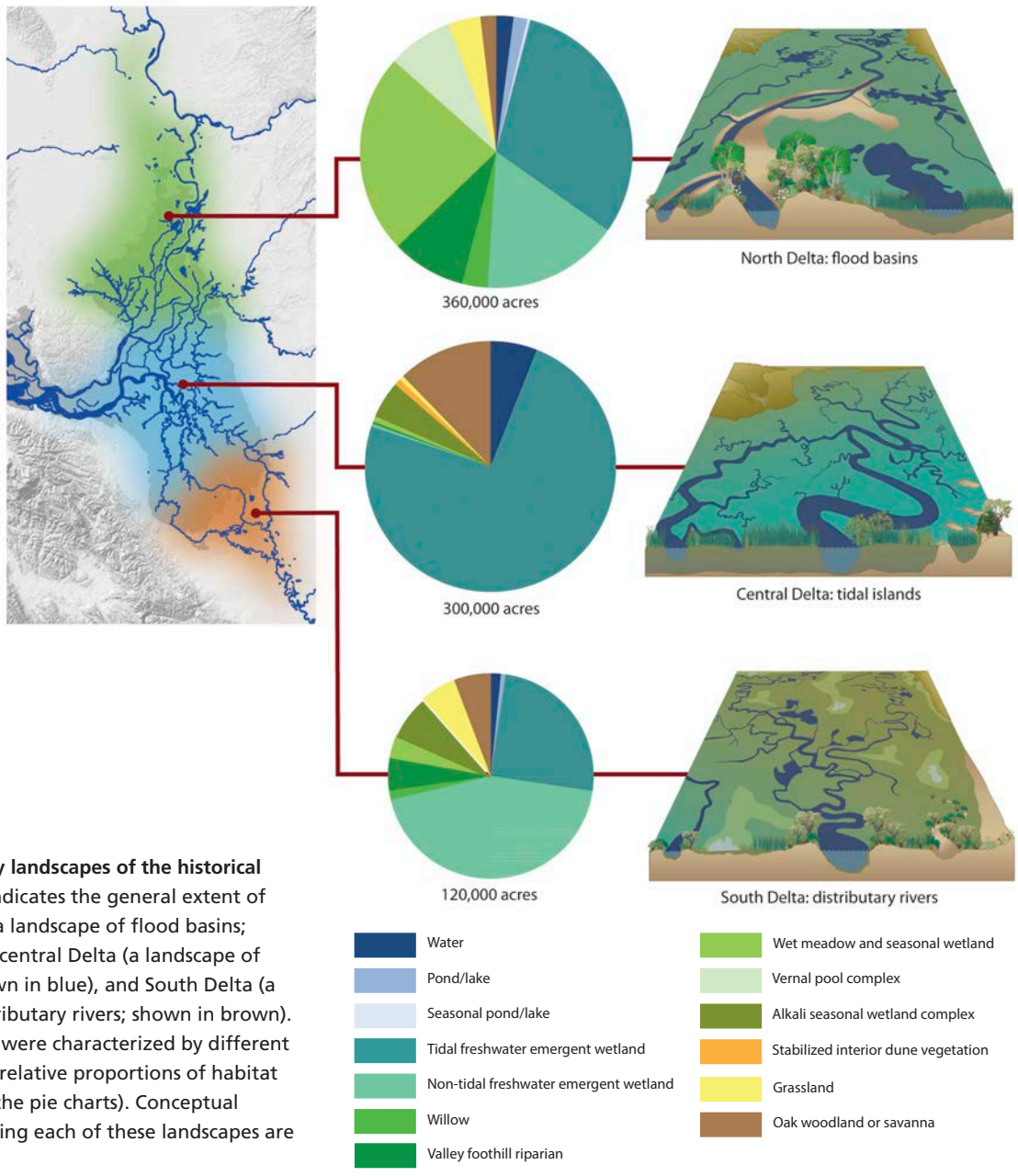
Following this Introduction, Chapter 2 presents a brief overview of the project framework and methods used (a longer, more detailed methods discussion is found in Appendix A). Chapter 3 discusses overall physical change in the Delta as it relates to ecological function. The next five chapters (Chapters 4-8) analyze different dimensions of life-history support for wildlife (animal and plants) in the Delta, focusing on particular habitat-associated guilds: fish, marsh wildlife, waterbirds, riparian wildlife, and marsh-terrestrial transition zone wildlife. Finally, Chapter 9 summarizes key findings and frames next steps in the Delta Landscapes project. The landscape analyses are presented as two-page spreads describing the selected ecological function, the spatial metrics used to evaluate that function, and analysis of that component of the landscape, past and present. Each of these chapters begins with several pages of preparatory background on the chapter topic.

The Delta landscape (below). Left to right: Nurse Slough, Sandhill Cranes at Stone Lake National Wildlife Refuge, giant garter snake, Sacramento River.

Photo Credits: Steve Martarano, USFWS; Justine Belson, USFWS; Brian Hansen, USFWS; Steve Martarano, USFWS

A short primer on the historical Delta landscape (summarized from Whipple et al. 2012)

The Sacramento-San Joaquin Delta historically served multiple physical and ecological functions. It was a perennial freshwater source in a Mediterranean climate, collecting, draining, and mixing water from the interior of the state (40% of the state's freshwater flows) to the ocean (see map on pages iv-v). It likewise served as an extended fluvial-tidal interface, with tidal influence extending past Sacramento. Saltwater influence was historically limited to the brackish Suisun marshes, and diminished towards Sherman Island, though the boundary was variable depending on the water year. Unlike coastal plain river deltas, the Sacramento-San Joaquin Delta is an inverted estuary that narrows at its outlet before opening to the San Francisco Bay.[10] It functioned as a sediment sink, slowing and settling coarser materials eroded from the granitic Sierras, while passing sands and silts downstream to replenish the salt marshes and beaches downstream. It was also the lungs of the region, sequestering carbon and releasing oxygen. The Delta was a highly productive system that provided abundant and diverse food resources to support robust food webs, including



The three primary landscapes of the historical Delta. The map indicates the general extent of the north Delta (a landscape of flood basins; shown in green), central Delta (a landscape of tidal islands; shown in blue), and South Delta (a landscape of distributary rivers; shown in brown). These landscapes were characterized by different assemblages and relative proportions of habitat types (as seen in the pie charts). Conceptual diagrams illustrating each of these landscapes are shown to right.

indigenous tribes. Many native wildlife species were able to exploit the complex and resource-rich landscape of the Delta, some thriving in astonishing numbers.

The historical reconstruction of the Delta reveals the large-scale patterns and heterogeneity that existed before major anthropogenic influences.[11] The central, northern, and southern parts of the Delta were diverse in their geomorphic and hydrologic settings, and in the ecological functions they provided. The central Delta consisted predominately of islands of tidal freshwater emergent wetland (marsh), which supported a matrix of tule, willows, and other species. These wetlands—topographically almost flat—were wetted by twice daily tides, and inundated monthly (if not more frequently) by spring tides. During high river stages in the wet season, entire islands were often submerged with several feet of water. The large tidal sloughs had low banks and, like capillaries, bisected into numerous, progressively smaller branching tidal channels which wove through the wetlands, bringing the tides onto and off of the wetland plain, promoting an exchange of nutrients and organic materials. Channel density in the central Delta was greater than in the less tidally dominated northern and southern parts of the Delta (but lower than the brackish and saline marshes of the estuary downstream). The edges or transition zones around the central Delta were composed of alkali seasonal wetlands, grassland, oak savannas, and oak woodlands. On the western edge of the central Delta, sand mounds (remnant Pleistocene dunes) rose above the marsh, providing gently sloping dry land in an otherwise wet landscape that served as a high tide refuge for terrestrial species.

The ecological functions provided by the north Delta were driven primarily by the great Sacramento River, which created large natural levees and flood basins. These flood basins, running parallel to the river, accommodated large-magnitude floods, which occurred regularly, with inundation often persisting for several months. They consisted of broad zones of non-tidal marsh that had very few channels and transitioned to tidal wetland towards the central Delta. Dense stands of tules over three meters (m) (~10 ft) tall grew in these basins. Large lakes occupied the lowest points in these flood basins.

The north Delta's natural levees, created pre-Holocene by the large sediment supply of the Sacramento River, were broad, sloping features that graded into the marsh. These supra-tidal levees supported dense, diverse, multi-layered riparian forests often up to a mile in width. They ran parallel to the Sacramento River and other large tidal sloughs that conveyed enough sediment to build them over time during high flow events. The levees provided migration corridors for birds and mammals, and allochthonous input (organic debris) and shade to the river systems for aquatic species. Some areas within tidal elevations were seasonally isolated from the tides due to the presence of these levees and complex fluvial and tidal interactions. The edge of the north Delta was lined by seasonal wetlands and willow thickets, or "sinks," at the distal end of tributaries as they entered the flood basins.

The south Delta, like the north, was shaped by a large river system. Here, the three main distributary branches of the San Joaquin River created a complex network of smaller distributary channels, oxbow lakes, tidal sloughs, and natural levees of varying heights which graded across the long fluvial-tidal transition zone. In contrast with the single main channel of the Sacramento and the parallel flood basins, the San Joaquin River had less power and sediment supply to build high natural levees, and thus had many channels branching from the mainstem and coursing through the marsh islands; these channels vacillated between being fluvially or tidally dominated, depending on the time of the year. Small lakes and ponds were scattered in the south Delta, and the marsh was intersected with willow thickets, seasonal wetlands, and grasslands, making it a very diverse place for wildlife. The edge of the south Delta was dominated by alkali seasonal wetland complex, grassland, and oak woodland. The eastern edge of the Delta was shaped by the alluvial fans of the Mokelumne and Calaveras rivers that spread into the marsh.

The Delta was not a static place. Though the positions of large tidal channels, natural levees, and lakes were relatively stable, the Delta would have looked very different depending on the year and season. Areas of marsh that were flooded with several feet of water by late winter could be dry at the surface by late fall. The Delta was a place of significant spatial and temporal complexity at multiple scales.

2. Project Framework and Methods

This chapter provides a brief summary of the project framework and tools developed to assess ecological functions in the historical and modern Delta. A more detailed discussion of the underlying mechanics of these tools (metrics) can be found in Appendix A.

The Landscape Interpretation Team

The challenging task of exploring landscape-scale Delta ecological functions, identifying and quantifying landscape metrics, and eventually generating restoration tools and principles necessitates the collective best professional judgment of a team of experts. For this reason, an interdisciplinary group of high-level scientists was assembled as part of the initial project conception to provide regular input and guidance. This group is referred to as the "Landscape Interpretation Team" (LIT) and was drawn from relevant fields of expertise (including geology,

Landscape Interpretation Team members who have advised this project since its start.

LIT member	Affiliation
Stephanie Carlson	University of California, Berkeley
James Cloern	U.S. Geological Survey
Brian Collins	University of Washington
Chris Enright	Delta Science Program
Joseph Fleskes	U.S. Geological Survey
Geoffrey Geupel	Point Blue Conservation Science
Todd Keeler-Wolf	California Department of Fish and Wildlife
William Lidicker	University of California, Berkeley (Professor Emeritus)
Steve Lindley	National Oceanic and Atmospheric Administration/National Marine Fisheries Service
Jeff Mount	University of California, Davis
Peter Moyle	University of California, Davis
Eric Sanderson	Wildlife Conservation Society
Anke Mueller-Solger	U.S. Geological Survey
Hildie Spautz	California Department of Fish and Wildlife
Dave Zezulak	California Department of Fish and Wildlife

Other advisors: Brian Atwater (University of Washington), Daniel Burmester (CDFW), Jay Lund (UC Davis), John Wiens (Point Blue Conservation Science).

geomorphology, hydrodynamics, animal ecology, plant ecology, landscape ecology, and water resource management). Nineteen individuals have served on the LIT since the Delta Landscapes Project's initiation in 2012 (see table on previous page). LIT members have been consulted individually throughout the project and have met in plenary on five occasions. To date, the LIT has worked closely with SFEI-ASC staff to (1) identify ecological functions provided by the historical Delta's landscapes, (2) identify and prioritize landscape metrics that allow us to assess the extent and distribution of these key ecological functions (both historically and today) and (3) review/interpret initial results.

Identifying key ecological functions provided by historical Delta landscapes

Functions summary

Using the guidelines described below, SFEI-ASC staff first developed a draft list of ecological functions likely provided by the historical Delta. Next, via an iterative process, the draft list was reviewed, prioritized, and edited by the LIT. The result—a final list of key ecological functions for the project to assess—is provided below and in the diagram on page 8. In this section, we also discuss our use of the term "ecological function," how we arrived at the ecological functions list, and each individual function.

POPULATION-LEVEL FUNCTIONS

Functions related to life-history support for wildlife

1) Provides habitat and connectivity for fish
2) Provides habitat and connectivity for marsh wildlife
3) Provides habitat and connectivity for waterbirds
4) Provides habitat and connectivity for riparian wildlife
5) Provides habitat and connectivity for marsh-terrestrial transition zone wildlife

Functions related to wildlife adaptation potential

6) Maintains adaptation potential within wildlife populations

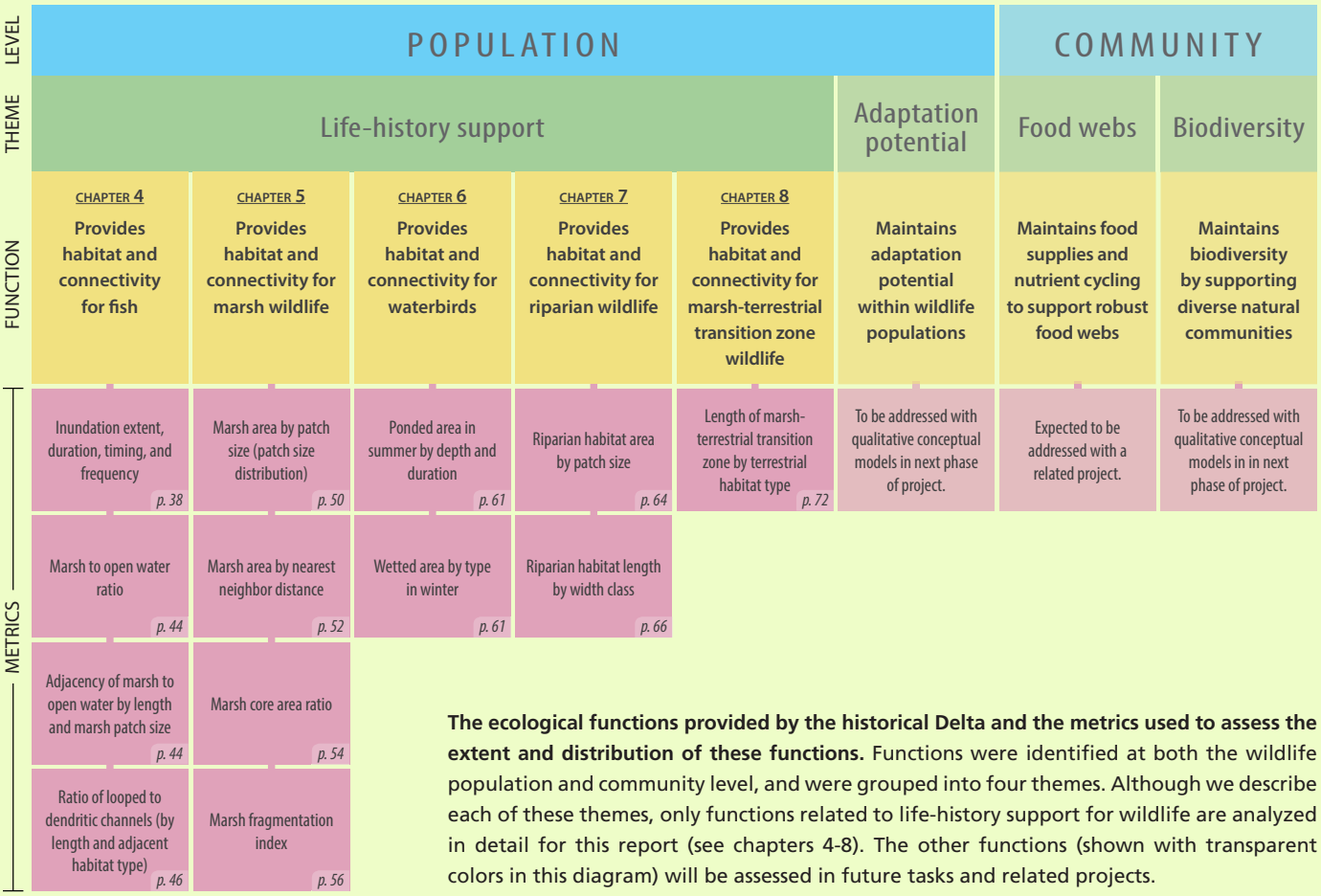
COMMUNITY-LEVEL FUNCTIONS

Functions related to food webs

7) Maintains abundant food supplies and nutrient cycling to support robust food webs

Functions related to biodiversity

8) Maintains biodiversity by supporting diverse natural communities



The ecological functions provided by the historical Delta and the metrics used to assess the extent and distribution of these functions. Functions were identified at both the wildlife population and community level, and were grouped into four themes. Although we describe each of these themes, only functions related to life-history support for wildlife are analyzed in detail for this report (see chapters 4-8). The other functions (shown with transparent colors in this diagram) will be assessed in future tasks and related projects.

What are ecological functions?

Much has been written on the meaning of the word "function" as it is used in the discipline of ecology.[1] In this report we use "functions" to mean "processes or manifestations of processes."[2] Smith et al. (1995) expand upon this basic definition and write that "wetland functions" are "the normal or characteristic activities or actions that occur in wetland ecosystems, or simply, the things that wetlands do. Wetland functions result directly from the characteristics of a wetland ecosystem and the surrounding landscape and their interaction."[3] By choosing to focus specifically on "ecological" functions, we adopt the general framework of the above definitions, but alter their focus. We define "ecological" as the relationship of organisms to one another and to their surroundings. For the purposes of this project, then, "ecological functions" are defined as the processes or manifestations of processes that support organisms. When we identify key ecological functions we are, in effect, attempting to answer the question: "how did the historical Delta environment support life?"

How did we choose which ecological functions to assess?

Environmental processes that support organisms occur at multiple scales, from global to microscopic, and almost any individual function can be broken down into component sub-functions.[4] The function '*provides suitable nesting habitat for Least Bell's Vireo*,' for example, is contingent on the function '*supports riparian vegetation communities with dense shrub cover*,' which, in turn is based on functions like '*promotes successful Salix* spp. *reproduction*' and '*maintains groundwater levels.*' If every process that supported Delta species were called out as a separate ecological function, the number of possible ecological functions would be effectively infinite. We were therefore required to identify and group ecological processes that supported Delta organisms into a manageable number of meaningful functions. To accomplish this, we established the following guidelines:

- **Focus on landscape-scale ecological functions.** We focused on capturing the degree to which specific ecological functions were provided by the overall landscape, and where in the landscape those functions were provided.
- **Focus on functions at both the population level and community level**. We desired to capture functions at both the population and community levels. For example, although food availability is a critical component of the ecological functions relating to population-level life-history support, we also sought to address Delta-wide productivity at the community level. Constraints on primary production and the relative importance of different production sources to the food web are major sources of uncertainty for Delta management today.
- **Focus on key ecological functions.** To keep this task manageable, we were required to focus on a limited number of key ecological functions—those that would have likely and collectively supported healthy wildlife communities in the Delta.
- **Focus on ecological functions for native wildlife.** Our focus on wildlife (which we define here as native plants and animals) is guided by the Delta's regional regulatory framework. The draft Bay Delta Conservation Plan (BDCP), for example, is designed in part to provide for the conservation and management of 56 covered plant and animal species. We focus much of our attention on vertebrates, since they tend to be better researched, are near the top of food webs, and are generally of greater interest to humans.
- **Consider life-history support functions for wildlife groups rather than for individual species.** For functions related to life-history support, we felt it necessary and useful to focus on specific ecological groupings. Ultimately, the ecological groupings we delineated for analyses were fish, marsh wildlife, waterbirds, riparian wildlife, and marsh-terrestrial transition zone wildlife. These groupings are largely based on habitat associations, which we felt was a sensible way to group species given the habitat-based GIS data we use for our analyses.
- **The extent and distribution of functions should be assessable through landscape metrics and supported by the available data**. We prioritized ecological functions for which appropriate landscape metrics and datasets were available to assess the function's extent and distribution (ideally both historically and today).
- **Focus on functions relevant to regional restoration efforts**. We prioritized ecological functions aimed to increase performance of the entire ecosystem, and used the framework of increased resilience and biodiversity to support the Delta's threatened and endangered species as specified by BDCP.

Function descriptions

Through a careful consideration of the historical habitat type map and discussions with the LIT, we identified eight key ecological functions of the historical Delta to focus on for this project (see the box on page 7 and the diagram on page 8). Functions can broadly be divided into four groups: those related to (1) wildlife life-history support, (2) wildlife adaptation potential, (3) food, or (4) biodiversity.

FUNCTIONS RELATED TO WILDLIFE LIFE-HISTORY SUPPORT The majority of this report focuses on wildlife life-history support functions. We define "life-history support" as the processes and characteristics of the Delta that supported the life histories of specific native taxa. Life-history support for wildlife encompasses many smaller species-specific functions, far more than could be detailed in this report. We therefore chose to focus on major wildlife groups: resident and migratory fish, marsh wildlife, waterbirds, riparian wildlife, and marsh-terrestrial transition zone wildlife. We assume that if the landscape provided broad life-history support for these groups then a majority of the related sub-functions were also being provided. Each of the functions related to wildlife support is described in the table below.

FUNCTIONS RELATED TO WILDLIFE ADAPTATION POTENTIAL For this report, "wildlife adaptation potential" is defined as the potential ability of native plant and animal populations to adapt to changing conditions. Wildlife adaptation potential encompasses adjusting to new or increased

The five functions related to wildlife life-history support. Each function relates to a specific wildlife group and is defined here with example sub-functions.

Function	Wildlife group	Description
Provides habitat and connectivity for fish	Native resident and migratory fish	Defined as the processes and the characteristics of the Delta that support the life histories of native resident and anadromous fish. Example sub-functions include '*provides sufficient floodplain inundation to support splittail spawning and rearing*' and '*provides adequate prey to support delta smelt.*'
Provides habitat and connectivity for marsh wildlife	Native marsh wildlife	Defined as the processes and the characteristics of the Delta that support the life histories of obligate and transitory marsh wildlife. Example sub-functions would include '*Black Rail refuge from predation*' (which would have been provided by dense vegetation) or '*tule seed germination*' (which would have been supported by inundation).
Provides habitat and connectivity for waterbirds	Native waterbirds	Defined as the processes and the characteristics of the Delta that support the life histories of waterbirds (which are defined as "birds that are ecologically dependent upon wetlands"[5]). Example sub-functions would include '*provides areas suitable for Sandhill Crane roosting*,' '*provides food for wintering waterfowl*,' and '*provides nesting habitat for breeding ducks.*'
Provides habitat and connectivity for riparian wildlife	Native riparian wildlife	Defined as the processes and the characteristics of the Delta that support the life histories of riparian wildlife, including riparian residents and transients, particularly Neotropical songbirds. Example sub-functions would include '*provides nesting structures for riparian birds*,' '*facilitates movement of terrestrial mammals*,' '*provides food to avian fall migrants*,' '*supports establishment of large valley oaks*,' and '*provides cover to anadromous fish in the form of large woody debris.*'
Provides habitat and connectivity for marsh-terrestrial transition zone wildlife	Native terrestrial-transition zone wildlife	Defined as the processes and the characteristics of the Delta that support the life histories of wildlife that utilize the transition zone between marshes and terrestrial habitats or these terrestrial habitats themselves. Example sub-functions would include '*provides tule elk with access to fresh water during the summer*,' '*provides refuge to Black Rails during spring tides*,' '*provides breeding pond habitat for California tiger salamanders.*'

disturbances and stressors, utilizing newly available resources, and moving as the locations of suitable conditions shift. Wildlife adaptation potential is particularly important in the face of climate change, sea-level rise, and changing water management in the Delta. Species distributions, habitat associations, and life-history strategies are likely to change over time in ways that are difficult to predict. Promoting wildlife adaptation potential at the landscape scale can help to manage for an uncertain future. The large population sizes with high genetic and phenotypic diversity that help drive adaptation potential require extensive, heterogeneous habitats. The ability of species to move along physical gradients (in elevation, salinity, and other parameters) as conditions change requires habitat connectivity. Metrics to characterize wildlife adaptation potential were not developed for this report, because this complex concept could not be adequately quantified with the resolution of data available. However, the drivers behind adaptation potential, namely habitat extent, connectivity, heterogeneity, and diversity, are integrated throughout this report (for example, the importance of alternative life-history support strategies for salmon is discussed in Chapter 4) and will inform future work on this project.

FUNCTIONS RELATED TO FOOD WEBS The amount of food within a system, and the ability of nutrients to be cycled and exchanged throughout that system, are critical to determining the degree to which that system can support wildlife. Constraints on primary production and the relative importance of different production sources to the food web are a major ecological uncertainty in the Delta system. We consider the size and location of high productivity habitats such as tidal marshes and shallow-water areas with high residency time to be important features for maintaining this function, and these are discussed in the related "life-history support" chapters. Estimating primary productivity in different parts of the Delta system was determined to be beyond the scope of this project, given the careful analysis of uncertainties that would be required. However metrics developed for this project may be appropriate to support such calculations in the future.

FUNCTIONS RELATED TO BIODIVERSITY For this project, we define biodiversity as the diversity of plants and animals supported by the Delta. Since biodiversity is the aggregate result of all the life-history support functions provided by the Delta, we do not devote a discrete chapter to biodiversity in this report. However, to understand changes in biodiversity at a landscape scale we make the following assumptions: 1) greater extent and diversity of habitat types will support greater diversity of species, 2) areas of key importance to endemic and rare native species are disproportionately important to overall biodiversity, and 3) preserving processes under which endemic species evolved may favor native over invasive species.

Identifying landscape metrics to assess ecological functions

What are landscape metrics?

Landscape metrics are commonly described as quantitative indices that describe spatial patterns of landscapes based on data from maps, remotely sensed images, and GIS layers.[6] McGarigal (2002) notes that "real landscapes contain complex spatial patterns in the distribution of resources that vary over time" and that "landscape metrics are focused on the characterization of the geometric and spatial patterns."[7] Landscape metrics are traditionally algorithms that quantify specific spatial characteristics of categorical data such as patches, classes of patches, or entire landscape mosaics. We broaden the term to use landscape metrics to quantify particular aspects of the physical landscape, including channel length, width and area, and habitat adjacencies in addition to analysis of patch dynamics. We use these landscape metrics to assess

the extent and distribution of ecological functions. As such, the aspect of the landscape that the metric measures must somehow relate to the provision of the relevant ecological function.

Choosing landscape metrics

We used a series of rules to choose metrics that could be correlated to ecological functions and were feasible given the available data.

- **Landscape metrics are derived from the available data.** The selection of metrics was guided by the available data on the historical and present day Delta. The primary data sources for the historical Delta include a categorical map of historical habitat types and a linear network of historical channels and streams. Metrics were limited to those that could be derived from these and related contemporary data sources and were appropriate given the data's spatial extent and resolution.
- **Landscape metrics should be functional.** McGarigal (2002) uses the terms "functional" and "structural" to distinguish between metrics that measure landscape patterns with and without explicit reference to a particular ecological process.[8] Specifically, he defines functional metrics as "those that explicitly measure landscape pattern in a manner that is functionally relevant to the organism or process under consideration."[9] Since we are using landscape metrics to assess the extent and distribution of specific ecological functions, we selected only functional metrics. We conducted reviews of the available literature to parameterize our metrics for specific species/guilds of wildlife and to define how exactly the metrics relate to the functions they are meant to quantify. That said, some metrics intended to describe the physical landscape of the historical Delta are purely structural.

Metrics to assess the function 'Provides habitat and connectivity for fish'

1) Inundation extent, duration, timing, and frequency
2) Marsh to open water ratio
3) Adjacency of marsh to open water by length and marsh patch size
4) Ratio of looped to dendritic channels (by length and adjacent habitat type)

Metrics to assess the function 'Provides habitat and connectivity for marsh wildlife'

1) Marsh area by patch size (patch size distribution)
2) Marsh area by nearest neighbor distance
3) Marsh core area ratio
4) Marsh fragmentation index

Metrics to assess the function 'Provides habitat and connectivity for waterbirds'

1) Ponded area in summer by depth and duration
2) Wetted area by type in winter

Metrics to assess the function 'Provides habitat and connectivity for riparian wildlife'

1) Riparian habitat area by patch size
2) Riparian habitat length by width class

Metrics to assess the function 'Provides habitat and connectivity for marsh-terrestrial transition zone wildlife'

1) Length of marsh-terrestrial transition zone by terrestrial habitat type

Using the guidelines described above, SFEI-ASC staff first developed a draft list of landscape metrics that could be used to assess the extent and distribution of the ecological functions described above in both the historical and contemporary Delta. Next, via an iterative process, the draft list was reviewed, prioritized, and edited by the LIT and specialized expert groups. In addition to our meetings with the LIT, we also met separately with groups of regional experts to help review, vet, and parameterize the metrics chosen to assess specific functions. The result—a final list of landscape metrics for the project to analyze—is provided in the diagram on page 8 and in the box on page 12. For detailed descriptions of each metric and the methods used to execute them, please see Appendix A.

Calculating landscape metrics

Metrics were developed using spatial datasets of habitat types and channels/water bodies, both for the historical Delta (ca. 1800) and the modern Delta (ca. 2010). We used these layers to assess the chosen metrics for the entire Delta, both for the modern and historical periods. For more information on these datasets, please see the table and images on pages 14-15.

To best correlate our landscape metrics with ecological functions, we parameterized them based on relevant ecological thresholds and data identified in the available scientific literature (see table below). For certain metrics, categories or thresholds were identified to help make the results more easily interpretable in terms of ecological function. Examples of this include patch size, "large" patch size, and definition of "core" vs. "edge" habitat for marsh habitat. Although parameters are based on values from the literature, landscape metrics are inevitably simplifications of the complex relationships between habitat fragmentation and wildlife support, and do not necessarily account for important variables such as population demographics and habitat quality. Detailed information on sources and assumptions used to develop the metrics can be found in Appendix A.

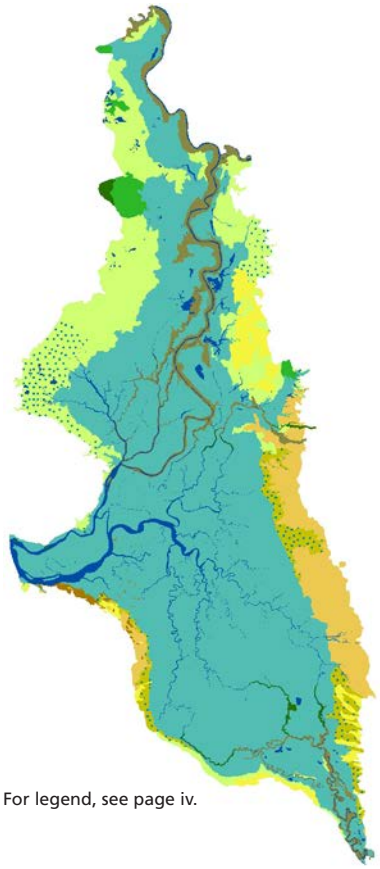
Examples of sources and assumptions used to parameterize metrics (below). For each metric we present the parameter and the rationale used to justify it.

Metric	Parameter	Rationale
Marsh area by patch	When defining marsh patches, discrete marsh polygons were considered part of the same patch if they were located within 60 m of one another	This distance is derived from the rule set for defining intertidal resident rail (e.g. Black Rails) patches developed by Collins and Grossinger (2004), which is based on the best available data on rail habitat affinities and dispersal distances.[10] We assume that the rule set developed for intertidal rails in the South Bay (including Clapper Rails, which are not found in the Delta) is generally applicable to the Delta and non-tidal marsh. Additionally, this simplistic model of a binary landscape (marsh and non-marsh) assumes that all patches of marsh are equally suitable for rails, that the routes of travel between patches are linear, and that the only barrier to rail movement is distance.[11]
Marsh area by nearest "large" neighbor distance	Nearest "large" neighbor distance was calculated for each marsh patch as the linear distance to the nearest neighboring marsh patch of at least 100 ha.	This size threshold is based on (1) regression models of Spautz and Nur (2002) and Spautz et al. (2005), which show a significant negative correlation between Black Rail presence and distance to the nearest 100 ha marsh[12] and (2) the work of Liu et al. (2012), which found that Clapper Rail densities decrease in patches <100 ha.[13]
Marsh core area ratio	Core area ratio is defined as the percent of a marsh patch's total area that is greater than 50 m from the patch edge.	This distance is based on the work of Spautz and Nur (2002) and Spautz et al. (2005) indicating a significant positive relationship between Black Rail presence and marsh area >50 m from the marsh edge.[14]
Riparian habitat length by width class	We determined the length of riparian habitat in three width classes: <100 m wide, 100 – 500 m wide, and >500 m wide.	The 100 m width threshold is based in part on the work of Gaines (1974), who found that Western Yellow-billed Cuckoos were only present in patches at least 100 m wide.[15] Kilgo et al. (1998) found that riparian forest areas at least 500 m wide were necessary to maintain the "complete avian community" in bottomland hardwood forests in South Carolina.[16] These widths largely agree with the findings of Laymon and Halterman (1989) who (based on occupancy and nest predation rates) define riparian habitat <100 m wide as "unsuitable," habitats 100-600 m wide as "marginal" to "suitable," and habitats at least 600 m wide as "optimal" for cuckoo nesting.[17]

Datasets used to run landscape metrics. Data include habitat type layers, channel polygons, channel polylines, and channel bathymetry rasters. These layers were obtained or developed for both the historical and modern time periods.

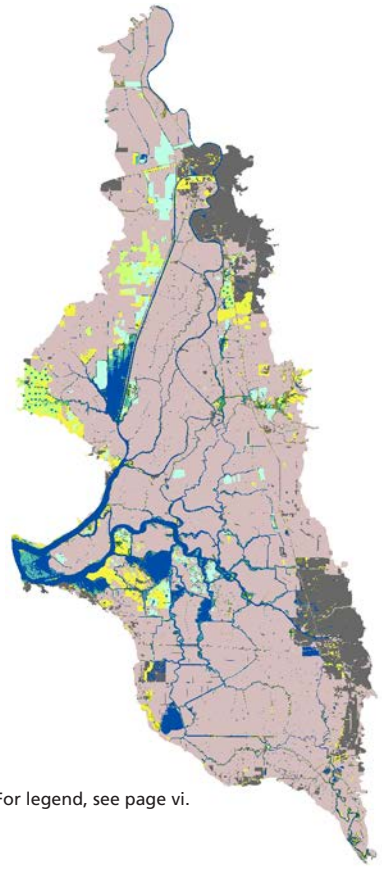
Type of data	Time period	Notes
Habitat type (polygons)	Historical	The historical Delta habitat type data (A, right) used in this study were obtained from SFEI-ASC's *Sacramento-San Joaquin Delta Historical Ecology Investigation*.[18] The dataset classifies the historical Delta into 17 habitat types, the majority of which are based on modern classification systems. Some of these classifications were grouped to facilitate comparison with the modern Delta habitat types layer.
	Modern	The modern Delta habitat type data (B, right) used in this study were compiled from multiple sources, including the CDFW Vegetation Classification and Mapping Program's 2007 Sacramento-San Joaquin River Delta dataset[19] and the 2012 Central Valley Riparian Mapping Project Group Level dataset.[20] Together, these two sources covered greater than 99% of the project's study extent (C, right). The compiled modern dataset's classifications were crosswalked to the historical habitat types (or groups of historical habitat types) with the assistance of local experts.[21]
Channels (polygons & centerlines, bathymetry rasters)	Historical	Historical channel polygons (D, right) were obtained from SFEI-ASC's *Sacramento-San Joaquin Delta Historical Ecology Investigation* historical habitats layer by selecting polygons classified as 'fluvial low order channel,' 'fluvial mainstem channel,' 'tidal low order channel,' or 'tidal mainstem channel.'[22] Historical channel polylines were obtained from the *Delta Historical Ecology Investigation*'s historical creeks layer.[23]
		Historical bathymetry was derived from a variety of historical sources, including mid-19th century surveys of the Sacramento and San Joaquin rivers.[24] The task of developing a historical topographic-bathymetric digital elevation model of the Delta from these data is the focus of a separate project (a collaboration between the San Francisco Estuary Institute and researchers at the UCD Center for Watershed Sciences). This report utilizes interim data from that project.
	Modern	Modern channel polygons (E, right) were derived from the National Hydrography Dataset (NHD)[25] by clipping the dataset to the project study extent and selecting features classified as 'StreamRiver' or 'CanalDitch.' Additional channels that were not included in the NHD but are apparent in contemporary aerial photographs were either incorporated from other datasets (such as CDFW Delta LiDAR hydrography breaklines) or manually digitized by SFEI staff. Modern channel polylines were generated from the polygon dataset (described above) with a custom centerline generation tool.
		Modern bathymetry was extracted from a continuous topographic-bathymetric DEM of the San Francisco Bay-Delta Estuary.[26]

A HISTORICAL HABITAT TYPES



For legend, see page iv.

B MODERN HABITAT TYPES



For legend, see page vi.

C MODERN DATA SOURCES

- CDFG 2007 – VegCAMP Delta Mapping
- CDWR 2012 – VegCAMP CVRMP
- SFEI 2013 – Supplemental Mapping
- WWR 2013 – CSCCA Natural Communities
- BDCP 2013 – Natural Communities

D HISTORICAL CHANNEL LAYERS

- Historical channel polylines
- Historical channel polygons

E MODERN CHANNEL LAYERS

- Modern channel polylines
- Modern channel polygons

N

0 5 10 miles

0 10 20 km

1:115,000

Key project assumptions, limitations, and uncertainties

Inevitably, using available data sources for analyses of an ecosystem as complex as the Delta involves significant assumptions and uncertainties. Here we list the largest assumptions, uncertainties, and limitations associated with the use of our data. For more details, please refer to Appendix A.

General assumptions

Records of what wildlife were present in the historical Delta are sparse and inconsistent. Accounts of how wildlife used the landscape are even more so. Therefore, inferring the ecological functions provided by the historical landscape requires us to make many assumptions, with varying levels of confidence, combining disparate sources to develop a picture of the functioning landscape as a whole. Assumptions made and sources used are referenced in endnotes in the back of the report. Types of information, sources and assumptions used to interpret ecological functions in the historical landscape fell into several broadly defined categories:

- Assumptions based on well-established ecological theory.
- Assumptions based on ecological theory, but that required us to make major assumptions about Delta functioning. For these assumptions, the endnotes provide added detail on our rationale and sources.
- Assumptions based on ecological functions in less disturbed systems (e.g., salmon support in Pacific Northwest wetlands).
- Assumptions based on knowledge of natural history, physiological tolerance, and current habitat associations of Delta species.
- Assumptions based on records of historical occurrence. We did not go back to primary sources to look for incidents of species observations, but where these observations are summarized by other sources we cite them.
- Assumptions based on understanding of first principles of physical processes.
- Landscape metrics are a proxy for ecological function.
- Historical and modern habitat types are directly comparable.

Uncertainties (see Appendix A, pages 95-97 for additional details)

- **Uncertainty associated with the historical spatial data.** For the *Delta Historical Ecology Investigation*, each feature in the historical habitat types and channels layers was assessed for certainty. Overall, certainty of the features' interpretation/location was characterized as fairly high.[27]
- **Uncertainty associated with the modern spatial data.** Some degree of uncertainty is associated with each of the individual datasets compiled to generate our modern habitat types map. Additional uncertainty is associated with the process of crosswalking each of these data sources to the single classification system used in the historical dataset.
- **Uncertainty associated with historical and modern data fidelity.** When making comparisons between the historical and modern landscape, it was important that we compared the same things, at the same scale, using the same measurements. While, for certain analyses, differences in data resolution increased the uncertainty surrounding the precise magnitude of measured changes, we do not believe that these differences impacted the direction of changes or the overall stories told by the analyses.[28]

Limitations

- **The methods do not assess all of the functions that were performed by the historical Delta.**[29] Our high-level list of key ecological functions provided by the historical Delta is meant to broadly capture the functions that would have—likely and collectively—supported healthy wildlife communities in the Delta. Other high-level functions (such as primary productivity) are not addressed, while multitudes of lower-level functions (such as providing roosting habitat for certain bird species) are not specifically or directly identified in the body of this document. The project team decided which ecological functions to address using guidance from the LIT, who reviewed and edited a draft master list of possible ecological functions.
- **The metrics do not assess the landscape quantitatively for fine-scale heterogeneity.** Some historical and modern habitat types are mosaics that encompass smaller features (e.g., small ponds, beaver cuts, large woody debris, and willow-fern patches). We sometimes attempt to generally quantify these but do not discretely map or specifically analyze them.
- **The methods do not assess cultural, recreational, educational, or aesthetic functions of the historical (or contemporary) Delta.**[30] While there is limited information known about indigenous uses of the historical Delta, we recognize that humans had a significant impact on its ecological functioning. This is not a focus of this analysis.
- **Landscape metrics do not represent a direct measurement of the performance of a function.** Landscape metrics to represent ecological function are based on literature on conditions in California and elsewhere, but are not direct measurements of ecological function. As stated above as an assumption, metrics create a proxy for, or a hypothesis about expected ecological outcomes, based on observations elsewhere. The metrics do not include statistical validation/field testing.
- **Metrics do not capture interannual (or in some cases seasonal) variability in hydrology or temperature.** The data used for this analysis create a snapshot in time, from which we have inferred some seasonal and interannual variability. While seasonal variability is captured in timelines of available habitat through a water year for fish and waterbirds, the longer term interannual hydrologic patterns typical of our Mediterranean climate are not quantitatively assessed due to data limitations. Measurements of flow or sediment are not included.
- **The metrics do not acknowledge the limitations of private versus public land in terms of providing ecological function.** The analysis presented here does not distinguish between private or public land in the Delta. For restoration plans to eventually be made from these data, the details and constraints of land holdings must be considered.
- **The metrics do not differentiate between types of agriculture.** We recognize that certain types of wildlife-friendly agriculture are practiced in the Delta currently, and that certain crops and crop patterns provide more ecological benefit than others. At this scale of analysis, our report does not differentiate between types of agriculture, though further research could be done on this topic.
- **The report does not analyze the impact of invasive species or changes to groundwater levels on ecological functions.**
- **The metrics do not weight the modern land surface in terms of severity of subsidence.** During future stages of the Delta Landscapes project which involve integrating the results of the metrics into landscape units, these physical constraints will be considered.

Habitat type	Description
Water	**Tidal mainstem channel:** Rivers, major creeks, or major sloughs forming Delta islands where water is understood to have ebb and flow in the channel at times of low river flow. These delineate the islands of the Delta. **Fluvial mainstem chanel:** Rivers or major creeks with no influence of tides. **Tidal low order channel:** Dendritic tidal channels (i.e., dead-end channels terminating within wetlands) where tides ebb and flow within the channel at times of low river flow. **Fluvial low order channel:** Distributaries, overflow channels, side channels, swales. No influence of tides. These occupy non-tidal floodplain environments or upland alluvial fans. **Freshwater pond or lake:** Permanently flooded depressions, largely devoid of emergent Palustrine vegetation. These occupy the lowest-elevation positions within wetlands. **Freshwater intermittent pond or lake:** Seasonally or temporarily flooded depressions, largely devoid of emergent Palustrine vegetation. These are most frequently found in vernal pool complexes at the Delta margins and also in the non-tidal floodplain environments.
Freshwater emergent wetland	**Tidal freshwater emergent wetland:** Perennially wet, high water table, dominated by emergent vegetation. Woody vegetation (e.g., willows) may be a significant component for some areas, particularly the western-central Delta. Wetted or inundated by spring tides at low river stages (approximating high tide levels). **Non-tidal freshwater emergent wetland:** Temporarily to permanently flooded, permanently saturated, freshwater non-tidal wetlands dominated by emergent vegetation. In the Delta, occupy upstream floodplain positions above tidal influence.
Willow thicket	Perennially wet, dominated by woody vegetation (e.g., willows). Emergent vegetation may be a significant component. Generally located at the "sinks" of major creeks or rivers as they exit alluvial fans into the valley floor.
Willow riparian scrub or shrub	Riparian vegetation dominated by woody scrub or shrubs with few to no tall trees. This habitat type generally occupies long, relatively narrow corridors of lower natural levees along rivers and streams.
Valley foothill riparian	Mature riparian forest usually associated with a dense understory and mixed canopy, including sycamore, oaks, willows, and other trees. Historically occupied the supratidal natural levees of larger rivers that were occasionally flooded.
Wet meadow or seasonal wetland	Temporarily or seasonally flooded, herbaceous communities characterized by poorly-drained, clay-rich soils. These often comprise the upland edge of perennial wetlands.
Vernal pool complex	Area of seasonally flooded depressions, characterized by a relatively impermeable subsurface soil layer and distinctive vernal pool flora. These often comprise the upland edge of perennial wetlands.
Alkali seasonal wetland complex	Temporarily or seasonally flooded, herbaceous or scrub communities characterized by poorly-drained, clay-rich soils with a high residual salt content. These often comprise the upland edge of perennial wetlands.
Stabilized interior dune vegetation	Vegetation dominated by shrub species with some locations also supporting live oaks on the more stabilized dunes with more well-developed soil profiles.
Grassland	Low herbaceous communities occupying well-drained soils and composed of native forbs and annual and perennial grasses and usually devoid of trees. Few to no vernal pools present.
Oak woodland or savanna	Oak dominated communities with sparse to dense cover (10-65% cover) and an herbaceous understory.
Agriculture/ Ruderal/Non-native	Cultivated lands, including croplands and orchards. This habitat type also includes areas dominated by non-native vegetation and ruderal lands.
Managed wetland	Areas that are intentionally flooded and managed during specific seasonal periods, often for recreational uses such as duck clubs.
Urban/Barren	Developed, built-up land often classified as urban, barren or developed. Includes rock riprap bordering channels.

Modern only


Photo by Daniel Burmester

Tidal mainstem channel


Photo by Bill Miller

Valley foothill riparian


Photo by Daniel Burmester

Fluvial mainstem channel


Photo by Daniel Burmester

Valley foothill riparian


Photo by Bill Miller

Fluvial low order channel


Photo by Daniel Burmester

Wet meadow/seasonal wetland


Photo by Bill Miller

Freshwater pond or lake


Photo by Marc Hoshovsky

Vernal pool complex


Photo by Daniel Burmester

Freshwater pond or lake


Photo by Jean Pawek

Stabilized interior dune vegetation


Photo by Bill Miller

Freshwater emergent wetland


Photo by Christopher Thayer

Stabilized interior dun3 vegetation


Photo by Daniel Burmester

Freshwater emergent wetland


Photo by Ingrid Taylar

Oak woodland or savanna


Photo by Bill Miller

Willow thicket


Photo by Jean Pawek

Grassland

Habitat types descriptions and images. The mapping developed and used in this report includes twenty habitat types. With the exception of three types unique to the modern Delta, the classification was first developed for the *Sacramento-San Joaquin Delta Historical Ecology Investigation*.[31] The table **(opposite)** describes each habitat type. Representative images are shown to illustrate what these landscapes may have looked like. Not shown: alkali seasonal wetland complex, agriculture/non-native/ruderal, urban/barren, managed wetlands.

3. Overall Delta Landscape Changes

This chapter describes systemic changes to the Delta ecosystem since the historical period (prior to the analyses of ecological function in the subsequent chapters).

The historical Delta is gone. The defining characteristic of the historical Delta was its extensive wetland landscape, formed over time as floodwaters met the tides. Modern land management has increasingly disconnected floodwaters from the wetlands by widening and deepening channels, diking and draining wetlands for agriculture, and building levees for flood protection. The consequences of this disconnection include a nearly complete loss of Delta wetlands, along with the processes that sustain them, and a dramatic altering of the remaining aquatic habitats. The Delta has become more susceptible to invasive species, and the consequences of those invasions are magnified as a result of habitat loss and alteration. The ecological impacts of these transformations have been dire; the Delta food web has collapsed, wildlife populations have been drastically reduced in size, and the resilience of many remaining populations has been impaired.

The Delta once supported numerous wildlife species, some in great abundance, many of which are now species of concern. Tricolored blackbirds formed the largest breeding colonies of any landbird in North America,[1] Chinook salmon runs were among the largest on the Pacific Coast,[2] despite being at the southern end of the species distribution, and millions of waterfowl wintered in the Central Valley, in concentrations unmatched anywhere in California.[3] Many regionally endemic species inhabited the Delta, including plants (Mason's lilaeopsis, Delta tule pea), insects (Lange's metalmark butterfly, valley elderberry longhorn beetle), fish (delta smelt, longfin smelt, thicktail chub), reptiles and amphibians (giant garter snake, California tiger salamander), and mammals (riparian brush rabbit, riparian woodrat). At least one species endemic to the Delta, the thicktail chub, is now extinct, while several more have been extirpated in the Delta (including the Western Yellow-billed Cuckoo and Sacramento perch). Many more Delta species are at risk of being lost in the future; the draft Bay Delta Conservation Plan (BDCP) lists 56 species as being of immediate management concern.[4]

Six interrelated drivers of change are implicated in the loss of ecological function in the Delta. These drivers interact in a complex physical and biological system, where one driver may tip the scales toward ecosystem collapse, but only because the other drivers have brought the system to that tipping point.[6] The drivers of change are (1) reduction in habitat extent, (2) loss of heterogeneity within habitats, (3) loss of connectivity within and among habitat types, (4) degradation of habitat quality, (5) disconnection of habitats from the physical processes that form, sustain, and confer resilience upon them, and (6) invasion by ecosystem engineers such as Brazilian waterweed and invasive clams, and other predatory fish. Other drivers of change, particularly reductions and alterations in freshwater inflow and contaminants, are also responsible for the loss of ecological function.[5]

The habitats that dominated when the Delta was a functionally intact ecosystem have been reduced to small fractions of their former extent. For example, 15,608 hectares of Valley foothill riparian forest throughout the historical Delta have been reduced to 4,010 hectares: a reduction of 74%. There were at least 3,217 km of small channels (<15 m wide) in the Delta historically (not including an estimated 1,931 km of additional unmapped channels; see Appendix A, page 85), but only 144 km of small channels exist in the modern Delta: a 96-97% loss of channels in this size class. This decrease has most likely reduced the population viability of native wildlife in these habitats by eliminating the large, widely distributed, and connected populations. The reduced extent of high-endemism habitats, such as vernal pools and alkali wetlands, may have significant consequences for biodiversity in the region (see Chapter 8). The effects of habitat loss,

fragmentation, and degradation on marsh and riparian wildlife are discussed in Chapters 5 and 7. As a result of the diking of marshes, dendritic channel networks have been lost, with ecological consequences for native fish (see Chapter 4). The reduction of high-productivity marsh habitat has reduced the food resources available for fish and waterfowl (discussed in Chapter 4 and Chapter 6). In general, the scale-dependent effects of habitat loss on food resources are not well understood. Marsh production, from the marsh plain and the shallow, high-water-residence-time dendritic channels, was undoubtedly consumed and sequestered within the marsh, as well as being consumed by transient and edge wildlife, with some productivity ultimately being exported in one form or another to the broader estuarine and adjacent terrestrial ecosystems.[7]

Historically there was considerable geomorphic and hydrological heterogeneity within Delta habitats, creating diverse options for wildlife. This heterogeneity grew from the complex and variable hydrology, water and air temperature gradients, and differences in geomorphic setting, including topography and soils.[8] These differences manifested as diversity in plant communities and water chemistry, which provided a variety of options for wildlife. The riparian shrub habitats of the south Delta supported different species than the wide riparian gallery forests of the north Delta (see Chapter 7). Likewise, the dense tule marshes of the north Delta, willow-interspersed marshes of the central Delta, and complex marsh mosaics of the south Delta likely supported somewhat different communities of marsh wildlife (see Chapter 5 and Chapter 6). Yet some broadly distributed species with an ability to exploit diverse habitats, like Song Sparrows and Virginia Rails, were likely present across all these types of marsh, as large and diverse populations. Heterogeneity within habitats provided niche opportunities and increased habitat complexity, which is one way to create and maintain the genotypic and phenotypic diversity necessary for adaptation to change. Thus, heterogeneity supported the adaptation potential of wildlife and, in some cases, the development of alternative life-history strategies.[9] Heterogeneity within the Delta allowed different runs of Chinook salmon to exploit different resources at different times of year, supporting the diversity in salmon life-history strategies present today (see Chapter 4).

The modern Delta has lost connectivity within and among habitat types. Once-continuous populations of marsh species are now dispersed metapopulations or small, isolated populations at risk of extirpation. Riparian forests that once were unbroken corridors for terrestrial wildlife movement are now small, isolated, narrow patches often disconnected from the flooding that sustains them. Other habitat types in the Delta are also disconnected from one another, bounded by levees and separated by a matrix of agriculture. Approximately 1,770 km of levees exist in the modern Delta, separating channels and marshes from adjoining habitats. Historical flooding moved sediment, nutrients, and organisms between adjacent habitats, replenishing less productive areas

Damming a Delta slough.

Unknown ca. 1900, MS 229, Dyer Photograph Album, courtesy of Holt-Atherton Special Collections, University of the Pacific Library

on a regular basis and maintaining geomorphic structure. Loss of connectivity in the modern Delta disrupts these water and energy flows, impacting productivity[10] and resilience. Loss of habitat connectivity also reduces the viability of wildlife populations by restricting gene flow and limiting the ability of individuals and species to move conditions change.[11] One exception is that connections between large channels have increased over time as a result of channel cuts and dredging. The over connectivity of the channel network, and abundance of looped channels (combined with altered flow regimes) results in flow paths and chemical signals that are unpredictable for aquatic species.[12]

The quality of remaining habitats within the Delta has been degraded by a loss of complexity and the addition of anthropogenic stressors. The channels that now characterize the Delta are wider, straighter, deeper, and simpler than historical channels, and generally lack the fine-scale structure and micro-topography (e.g., from pools, vegetated banks, channel cut-offs, and backwaters) that once increased habitat value for aquatic wildlife. High nutrient loads and contaminants impair water quality and can reduce wildlife survival and reproductive success.[13] Invasive species have altered food-web dynamics, particularly the Asian clam, which reduces phytoplankton availability.[14] Introduced predatory fish, like bass and sunfish, directly compete with and prey upon native fish.[15] Wetland and upland habitats have also suffered the effects of introduced species such as *Arundo* and Himalayan blackberry, both of which can dramatically alter habitat structure and diversity. Grasslands along the edge of the Delta have been almost entirely converted from perennial grasses and forbs to non-native annual grasses (see Chapter 8).

Habitat types are now disconnected from the processes that created and sustained them. Rivers and sloughs are separated from their floodplains by artificial levees, so flood waters do not deliver the sediment and nutrients to adjacent lands. Most leveed agricultural land has subsided to well below sea level. Similarly, riparian forests are no longer inundated by the floods that maintained the natural levees they grow upon. Upland habitat types now occupy topographic lows. The naturally dynamic and seasonal hydrology of the Delta has been greatly simplified and constrained. Lakes, ponds and basins are now often disconnected from the larger channel network, and no longer fill with floodwaters during the winter and then drain over the summer. Instead, they have become perennial warm-water habitat that favors invasive fish.[16] Though not historically a delta of actively migrating meanders,[17] tidal channels have been deepened, widened, and straightened- their edges hardened- limiting their ability to adjust and respond to environmental changes. The rivers that feed the Delta have been almost uniformly dammed and their channels armored and leveed, simultaneously cutting off peak flows, reducing sediment supply, and altering seasonal hydrology.

These and other interruptions or constrictions of physical processes have contributed to the development of a brittle skeleton of the former Delta, pinned in place by roads and levees, and unable to benefit from the processes that created it. Thus, the changes in physical processes mirror the changes in habitat. Both have been so severely altered and reduced that the dominant features of the historical Delta – extensive marshes nourished with seasonal flooding and supporting vast wildlife populations – are no longer present. The Delta today is a network of deep, engineered channels within a matrix of leveed agriculture, supporting declining native wildlife and increasing invasive species populations.

The following pages describe overall change in habitats and the channel network. These changes are the easiest to quantify, given the available historical and contemporary datasets. Changes in habitat quality, habitat heterogeneity, and physical processes are often described qualitatively, since the datasets necessary for quantification are not available. These overarching analyses provide context for understanding the changes in ecological functions which are assessed in the subsequent chapters.

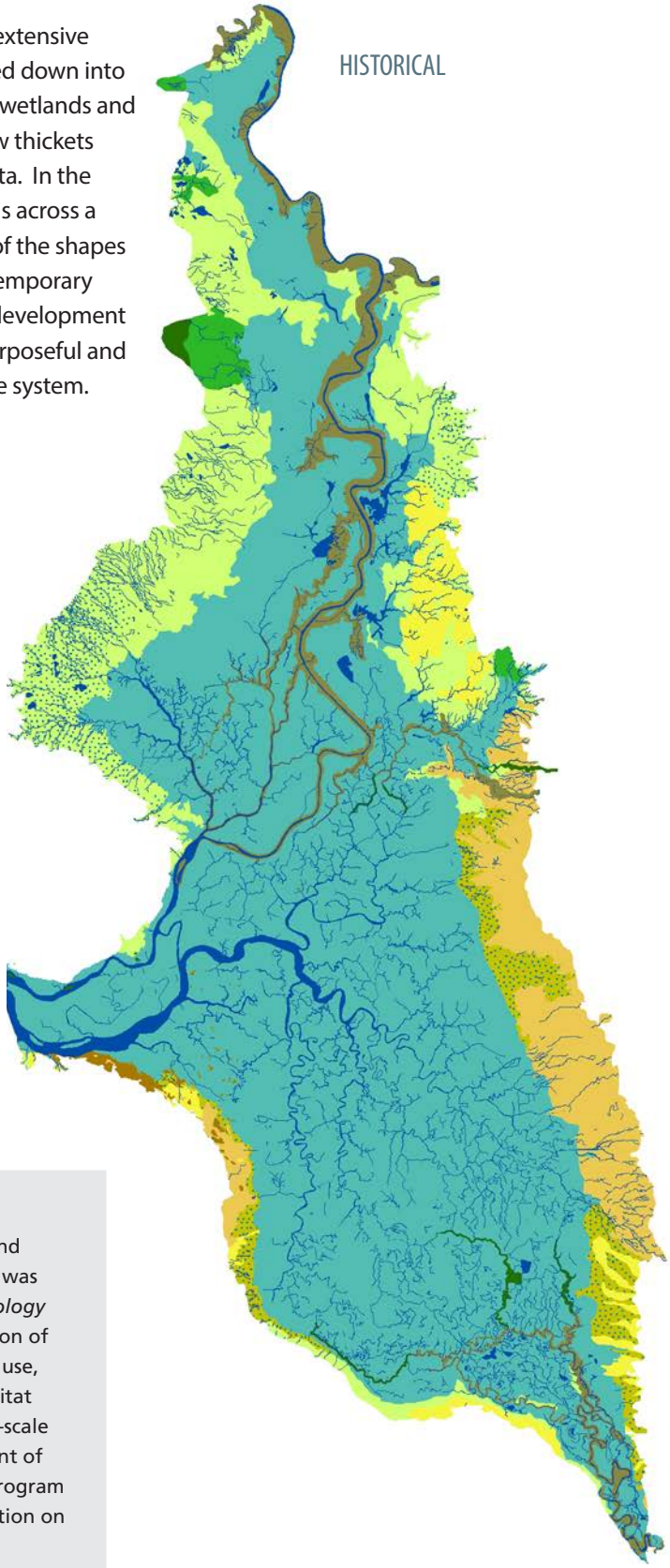
(top) Riprap and oaks on artificial levee, Lindsey Slough. (bottom) Dredges creating meander cuts on the San Joaquin.

Top: Erin Beller, SFEI; Bottom: Covella & Farichild ca. 1910, courtesy of Bank of Stockton Historical Photograph Collection

The extent of habitat type conversion has been extreme

The Delta has been converted from a marsh-dominated landscape to an agriculture-dominated landscape

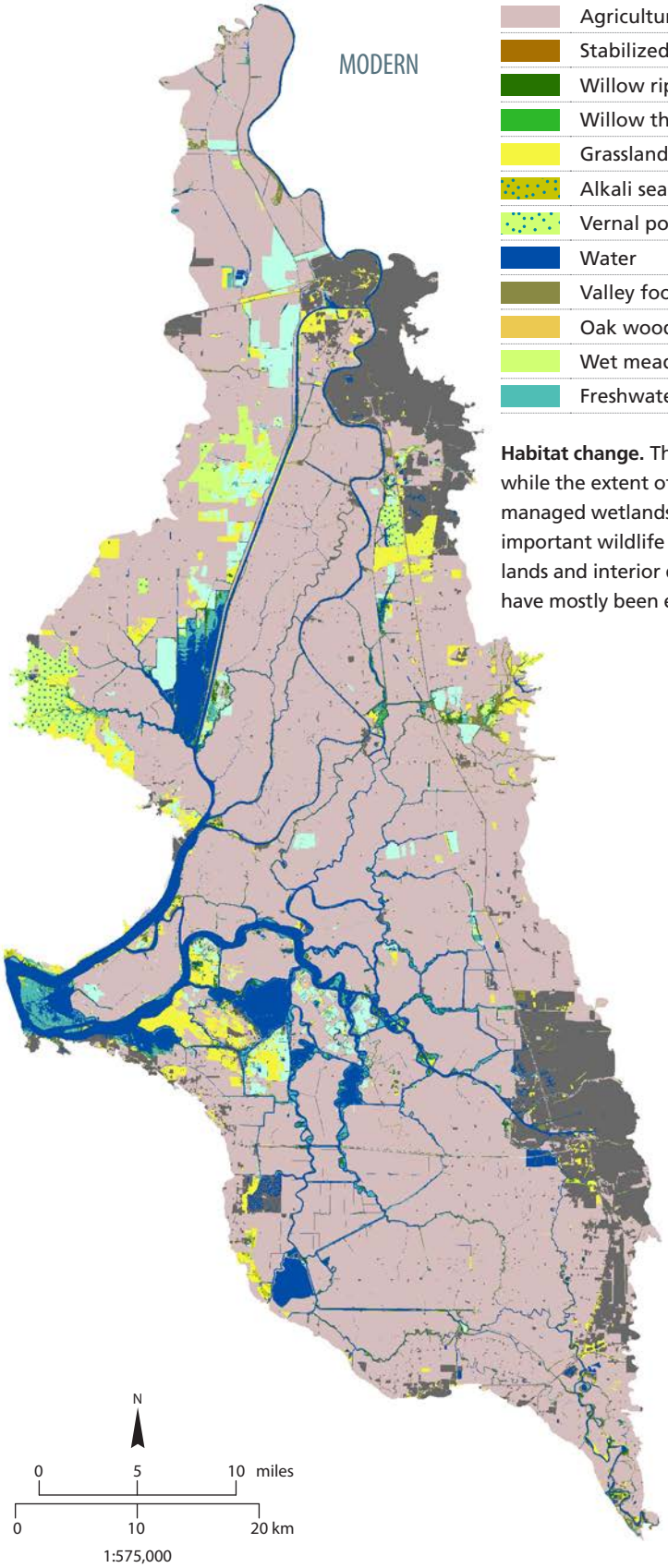
The historical Delta was characterized by a complex and extensive marshland matrix. Broad corridors of riparian forest snaked down into the marsh along major rivers and distributaries. Seasonal wetlands and vernal pools lined the periphery of the north Delta. Willow thickets were interspersed throughout the tules in the central Delta. In the south Delta, tidal wetlands graded into non-tidal wetlands across a long, heterogeneous fluvial-tidal interface. While many of the shapes of these former features can still be identified in the contemporary Delta, habitat type conversion to agricultural and urban development has been extreme. Small remnants and restored (both purposeful and accidental) habitats can be seen scattered throughout the system.



Delta habitat types, past (right) and present (far right). Historical habitat types and channels for the historical Delta ca. 1800 are shown to the right. Modern habitat type mapping ca. 2007 is shown to the far right.

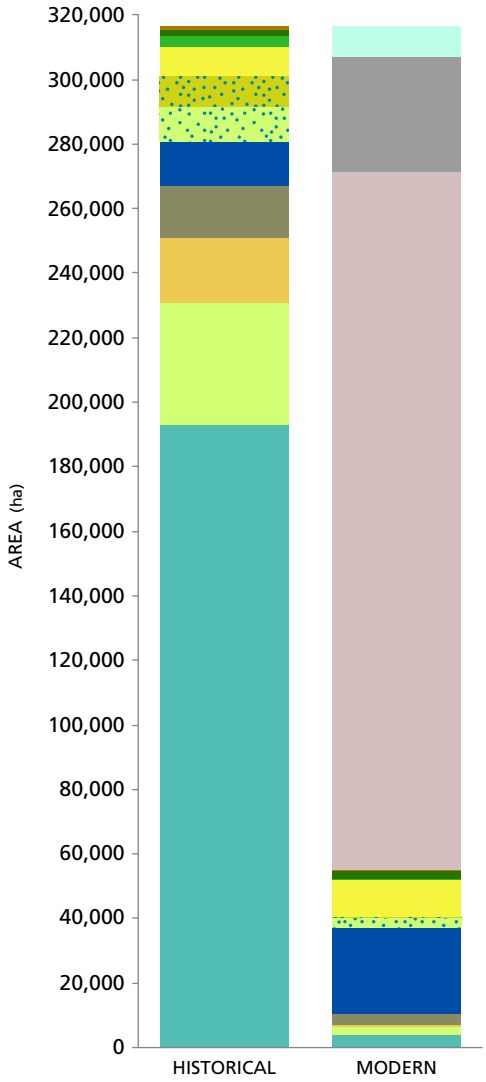
Methods: Habitat type extent

Habitat type acreages were calculated from the historical and modern habitat type maps. The **historical habitat type map** was taken from the *Sacramento-San Joaquin Delta Historical Ecology Investigation.*[18] The **modern habitat type map** is a compilation of several spatial datasets detailing Delta vegetation and land use, with each vegetation type crosswalked to the historical habitat types. The majority of the modern map is derived from fine-scale vegetation mapping produced in 2007 by the CA Department of Fish and Wildlife's Vegetation Classification and Mapping Program (VegCAMP).[19] Please see Appendix A for additional information on developing the historical and modern habitat type layers.



Habitat Type	Area (ha) *Historical*	*Modern*	*% Change*
Managed wetlands	0	9,454	∞
Urban/Barren	0	35,517	∞
Agriculture/Non-native/Ruderal	0	216,085	∞
Stabilized interior dune veg.	1,032	4	-99
Willow riparian scrub/shrub	1,637	2,878	+76
Willow thicket	3,567	132	-96
Grassland	9,108	11,800	+30
Alkali seasonal wetland complex	9,193	238	-97
Vernal pool complex	11,262	3,007	-73
Water	13,772	26,530	+93
Valley foothill riparian	15,608	4,010	-74
Oak woodland/savanna	20,460	0	-100
Wet meadow/Seasonal wetland	37,561	2,445	-93
Freshwater emergent wetland	193,224	4,253	-98

Habitat change. The extent of wetland habitats has decreased in the modern Delta while the extent of open water and grasslands has increased. Agriculture and managed wetlands take up a large portion of the modern Delta and provide some important wildlife support but are not equivalent to historical habitats. Oak woodlands and interior dune scrub have mostly been eliminated.

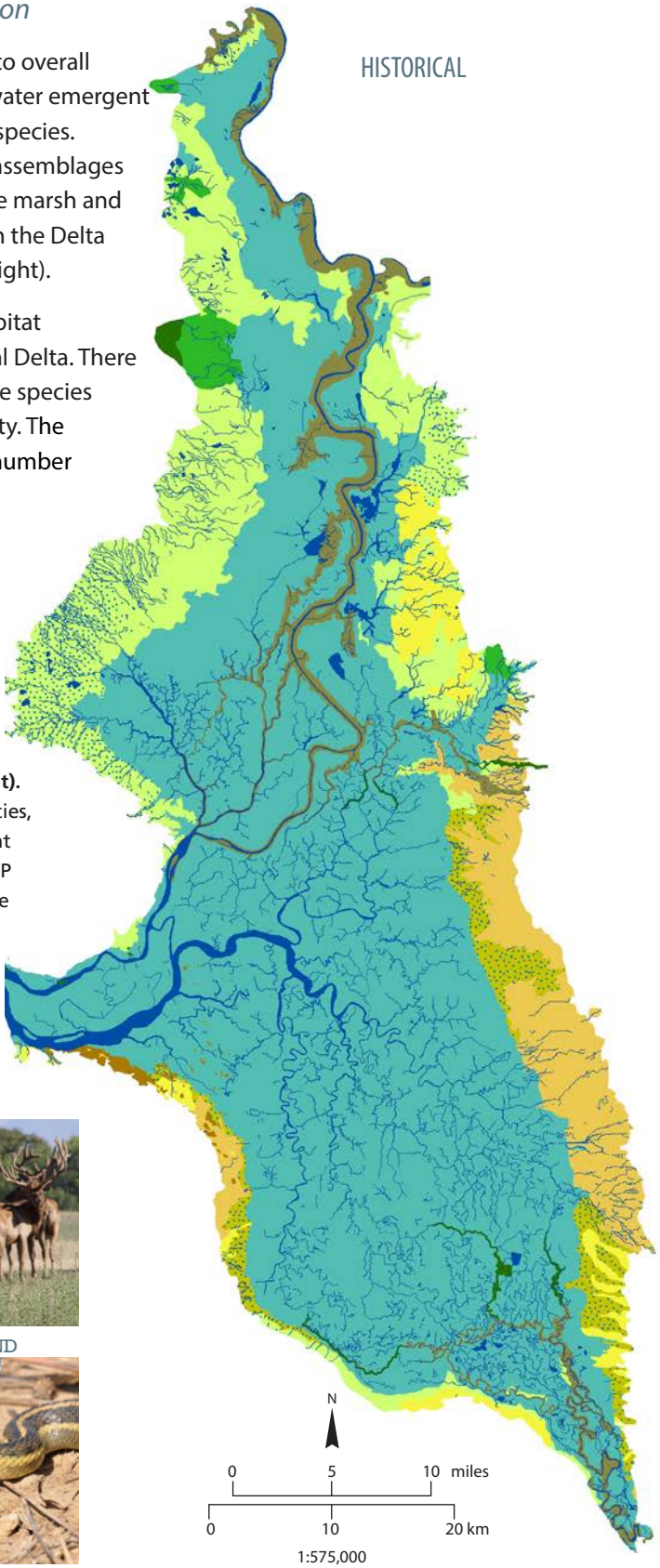


The variety of Delta habitats supported native wildlife diversity

The historical Delta supported a unique assemblage of species, contributing to the overall biodiversity of the region

Habitat diversity within the historical Delta contributed to overall species diversity. Much of the historical Delta was freshwater emergent marsh and aquatic habitat, which supported numerous species. Adjacent habitat types each supported distinct species assemblages and provided additional support to species that used the marsh and aquatic habitats. Many of the protected species found in the Delta today relied on varied habitat types historically (see far right).

Abundant resources from multiple habitat types and habitat adjacencies led to significant biodiversity in the historical Delta. There were also areas of importance to endemic and rare native species that disproportionately contributed to overall biodiversity. The introduction of invasive species has increased the total number of species in some areas, likely at the expense of native species diversity.[20]



Delta habitat types (right) and their affiliated species (far right). Each habitat type in the Delta supported specific suites of species, though several species used multiple habitat types for different phases of their lives. The species listed to the far right are BDCP Covered Species. Historical species-habitat type associations are based on modern species-habitat associations and life-history characteristics.[21]

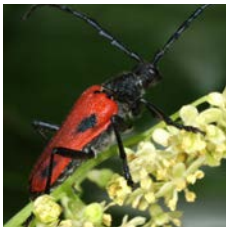
Photo Credits (clockwise from top left): Dan Cox, USFWS; Steve Emmons, USFWS; Lee Eastman, USFWS; Brian Hansen, USFWS; Jon Katz and Joe Silveira, USFWS; Steve Martarano, USFWS


FISH

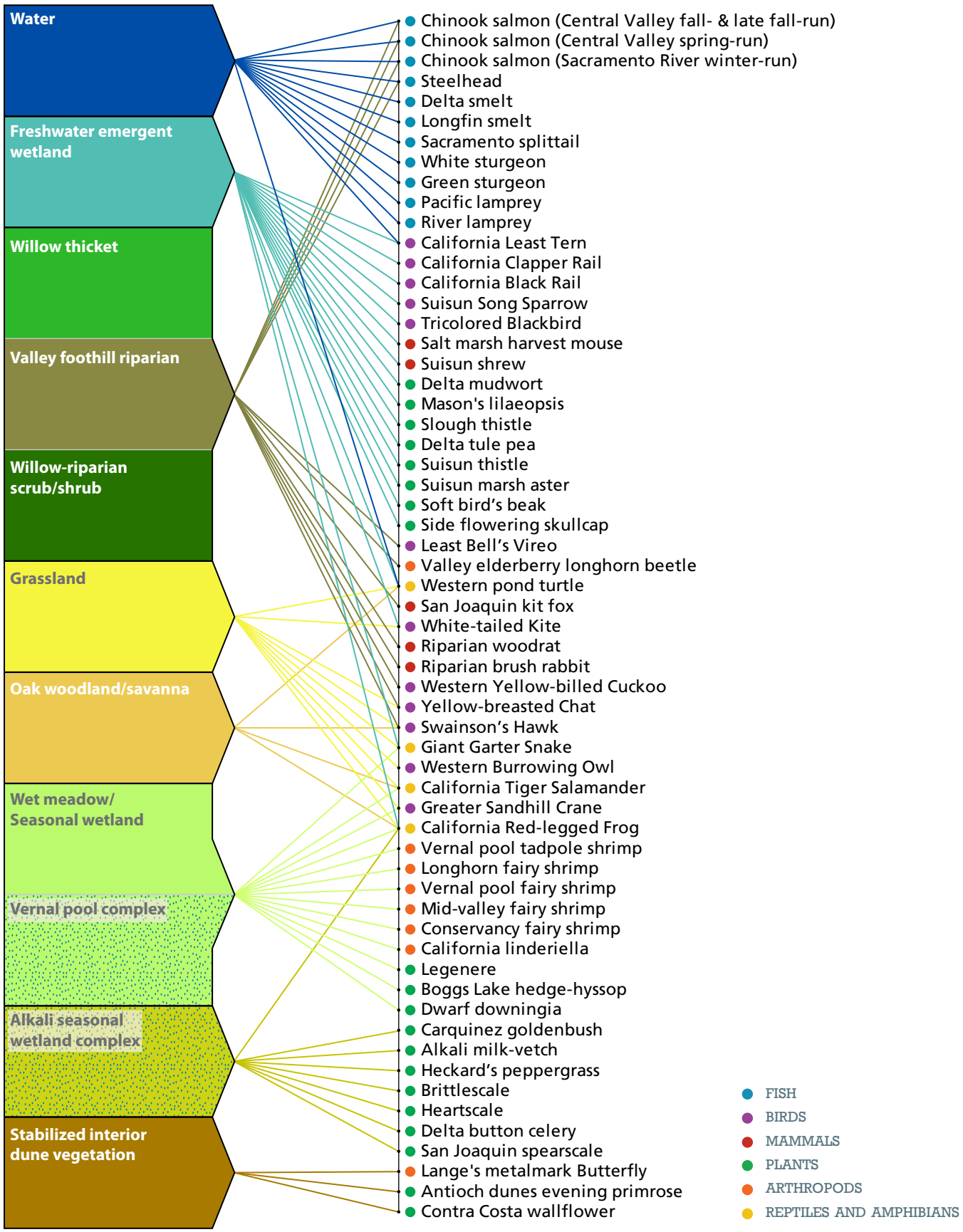

BIRDS


MAMMALS


PLANTS


ARTHROPODS


REPTILES AND AMPHIBIANS


Water
Freshwater emergent wetland
Willow thicket
Valley foothill riparian
Willow-riparian scrub/shrub
Grassland
Oak woodland/savanna
Wet meadow/ Seasonal wetland
Vernal pool complex
Alkali seasonal wetland complex
Stabilized interior dune vegetation
Chinook salmon (Central Valley fall- & late fall-run)
Chinook salmon (Central Valley spring-run)
Chinook salmon (Sacramento River winter-run)
Steelhead
Delta smelt
Longfin smelt
Sacramento splittail
White sturgeon
Green sturgeon
Pacific lamprey
River lamprey
California Least Tern
California Clapper Rail
California Black Rail
Suisun Song Sparrow
Tricolored Blackbird
Salt marsh harvest mouse
Suisun shrew
Delta mudwort
Mason's lilaeopsis
Slough thistle
Delta tule pea
Suisun thistle
Suisun marsh aster
Soft bird's beak
Side flowering skullcap
Least Bell's Vireo
Valley elderberry longhorn beetle
Western pond turtle
San Joaquin kit fox
White-tailed Kite
Riparian woodrat
Riparian brush rabbit
Western Yellow-billed Cuckoo
Yellow-breasted Chat
Swainson's Hawk
Giant Garter Snake
Western Burrowing Owl
California Tiger Salamander
Greater Sandhill Crane
California Red-legged Frog
Vernal pool tadpole shrimp
Longhorn fairy shrimp
Vernal pool fairy shrimp
Mid-valley fairy shrimp
Conservancy fairy shrimp
California linderiella
Legenere
Boggs Lake hedge-hyssop
Dwarf downingia
Carquinez goldenbush
Alkali milk-vetch
Heckard's peppergrass
Brittlescale
Heartscale
Delta button celery
San Joaquin spearscale
Lange's metalmark Butterfly
Antioch dunes evening primrose
Contra Costa wallflower
FISH
BIRDS
MAMMALS
PLANTS
ARTHROPODS
REPTILES AND AMPHIBIANS

The Delta is a highly invaded system

Invasive species have altered the functions and quality of Delta habitats

The Delta has been inexorably altered by the introduction of numerous non-native species. These species have changed not only the community composition of Delta wildlife, with non-native species outnumbering native species in some instances, but have also affected the structure, functions, and processes the Delta can support. The alteration of physical processes and habitats in the Delta has undoubtedly facilitated some of these invasions, and the invasions themselves have further altered and degraded habitats within the Delta. The proliferation of non-native species within the Delta places considerable constraints on the extent to which restoration and other management actions can benefit native species. Non-native species affect the ability of the Delta to support native wildlife through several mechanisms, including habitat alteration, changes in food web structure, competition, and predation (see examples below).

ALTERED HABITAT STRUCTURE

Egeria (shown left) changes flow patterns and turbidity in shallow aquatic habitats. *Arundo* and Himalayan blackberry form dense thickets, impenetrable to some wildlife, in both marsh and riparian habitats.

CHANGED FOOD WEB STRUCTURE

The high filtration rate of the now abundant overbite clam has substantially reduced phytoplankton availability in the Delta. The invasion of the Delta by this clam is correlated with a stepwise decline in fish abundance (Pelagic Organism Decline).

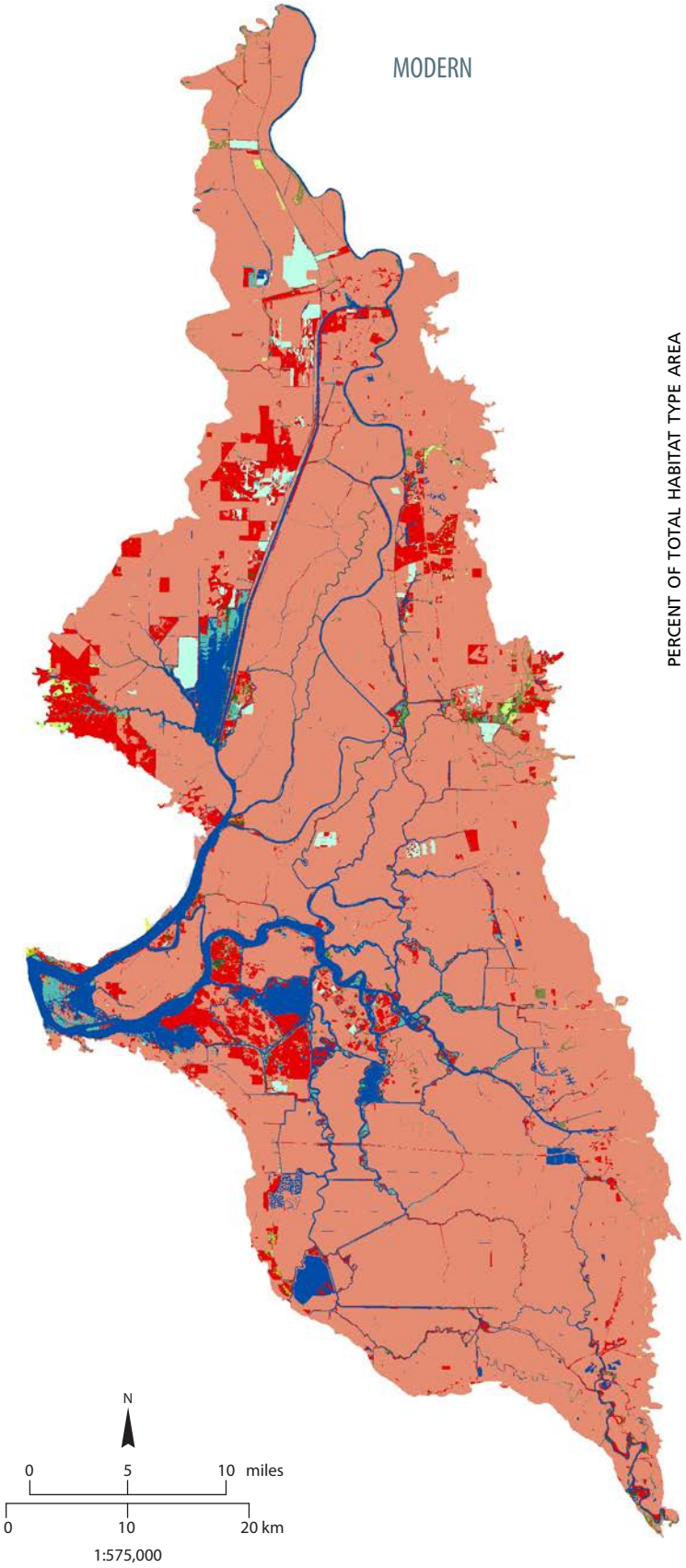
INCREASED PRESSURE ON NATIVE SPECIES

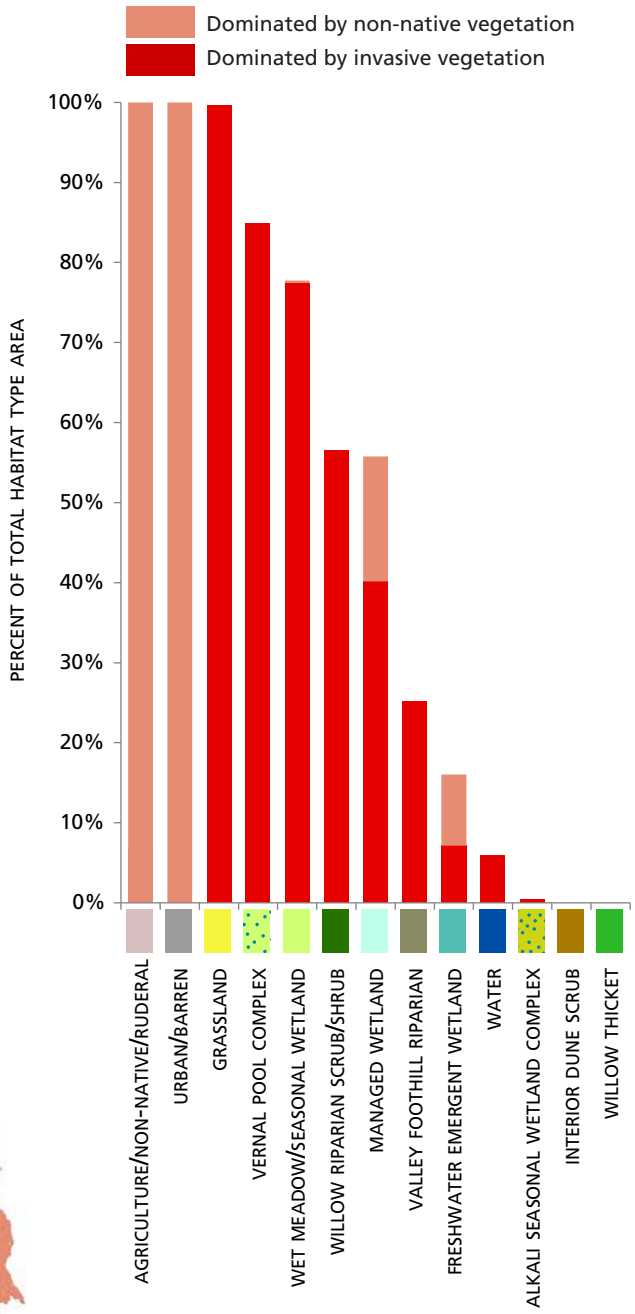
Non-native fish introduced to the Delta for sport, including striped bass (shown left) and bluegill, compete with native species for limited resources. Non-native predators, including feral pets and nuisance species such as house mice and introduced rats, increase predation pressure on native wildlife.

Photo Credits: California Department of Boating and Waterways; Delta Stewardship Council; Dave Giordano, Cal Fish

Methods: Areas dominated by non-native and invasive plants

Individual polygons were marked as dominated by non-native/invasive vegetation if their specific alliance/association-level vegetation mapping unit featured a non-native (as defined by CalFlora)[22] or invasive species (as defined by the California Invasive Plant Council).[23] Where these fine scale classifications were not available, the non-native/invasive designation was determined based on group-level mapping units and best professional judgement. Areas with a habitat type of Agriculture/Non-native/Ruderal or Urban/Barren were classified by default as non-native. See pages 106-109 of Appendix A for a list of the mapping units classified as dominated by non-native/invasive vegetation. Invasive submerged aquatic vegetation is included in the mapping, but may be underrepresented depending on the year and season.



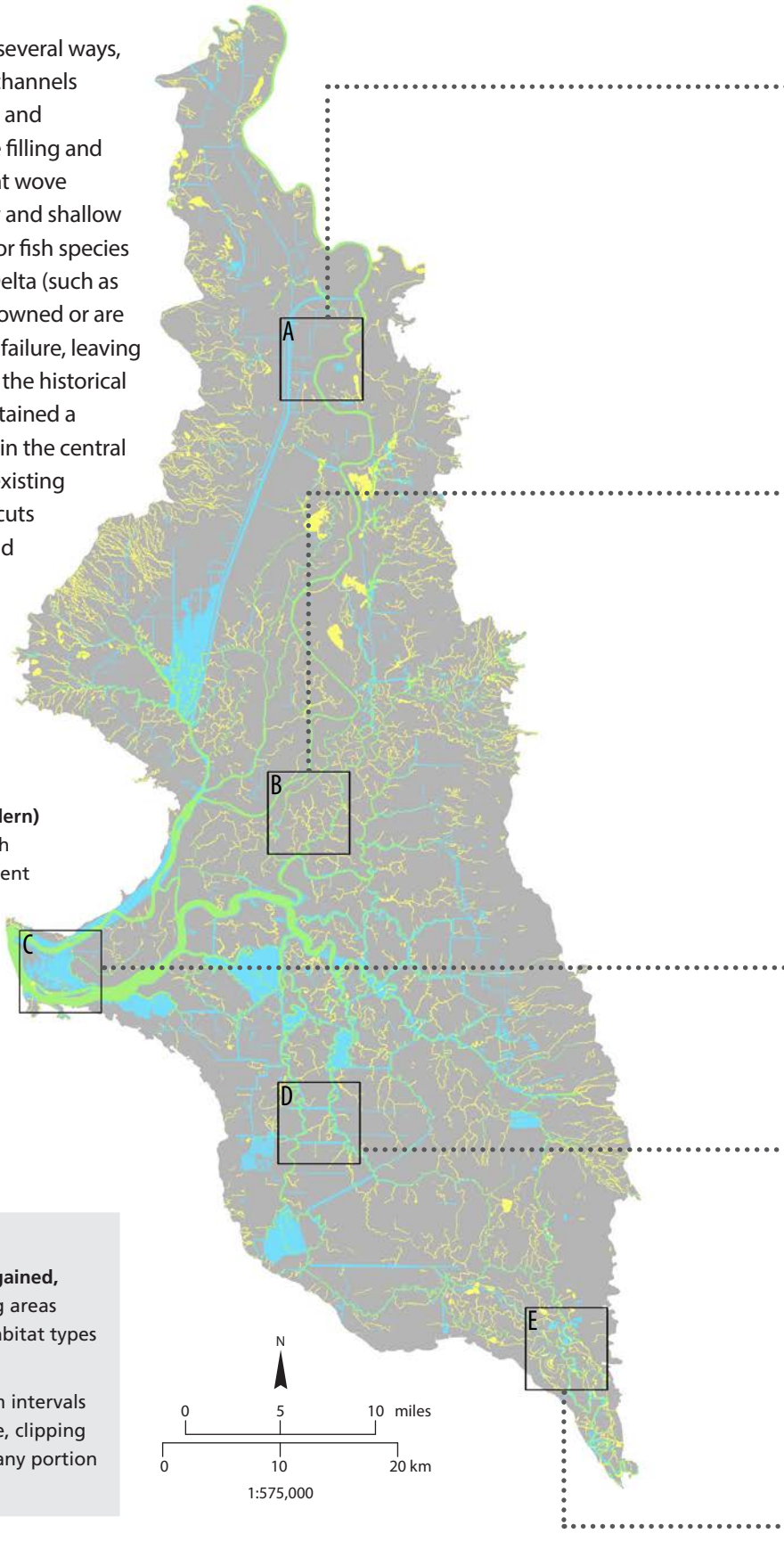


Areas dominated by non-native or invasive plants. The map **(left)** shows areas where non-native (in pink) and invasive (in red) plants are dominant over or co-dominant with native vegetation. The chart **(above)** quantifies the total proportion of each habitat type dominated by non-native/invasive vegetation.

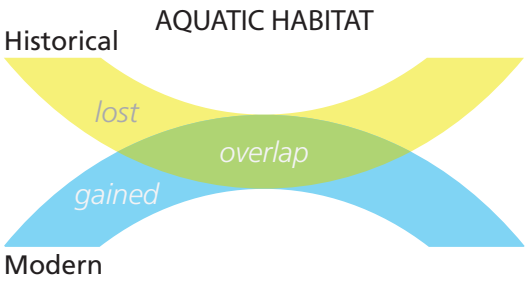
The Delta's channel network and lakes have been fundamentally altered

Some dominant native aquatic habitat types have been nearly eliminated, while other novel types have been created

The aquatic habitats of the Delta have been changed in several ways, all of which are significant to ecological functions. New channels have been dug for shipping, creating new, often straight and leveed waterways (A). Perhaps most severe has been the filling and elimination of the branching dendritic tidal channels that wove through the marshes. These channels were often narrow and shallow with high residence times providing important habitat for fish species (B). Several previously farmed and diked islands in the Delta (such as Sherman Island, Franks Tract, and Liberty Island) have drowned or are in the process of drowning due to subsidence and levee failure, leaving in their wake more open and deep water than existed in the historical Delta (C). While much of the Sacramento River has maintained a consistent width due to its natural levees, many reaches in the central Delta have been widened (A, C). Throughout the Delta, existing channels have been hyper-connected through channel cuts and meander cut-offs (D). This lowers residence times and often increases average velocities, thereby providing less nutrients, shelter, and habitat complexity for aquatic species. Finally, while the San Joaquin River has continued to migrate (more than the Sacramento), off-channel aquatic habitat such as floodplain and oxbow lakes and distributary channels has been filled (E).



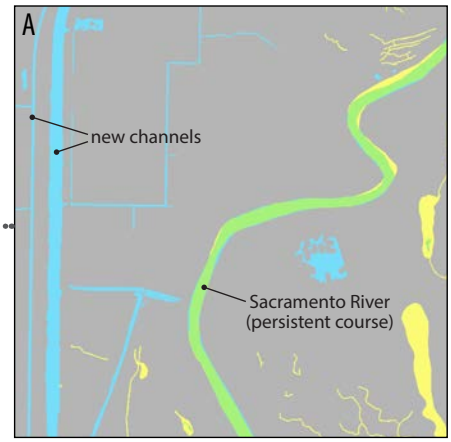
Reconfiguration of the aquatic landscape (historical and modern) (right). Historical aquatic habitats (in yellow) are overlaid with modern aquatic habitats (in blue). Areas where past and present aquatic habitat overlap are displayed as green.



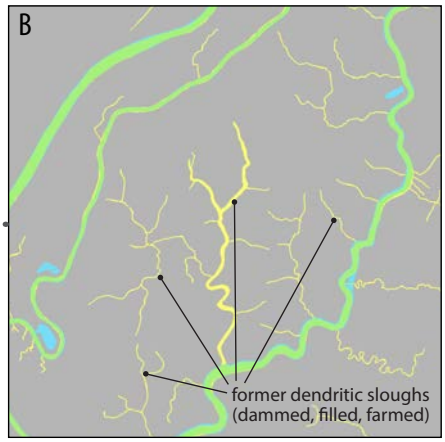
Methods: Changes in channel planform

Determining areas of aquatic habitat that have been **lost, gained, or have not changed (overlap)** was achieved by intersecting areas classified as aquatic habitat in the historical and modern habitat types layers.

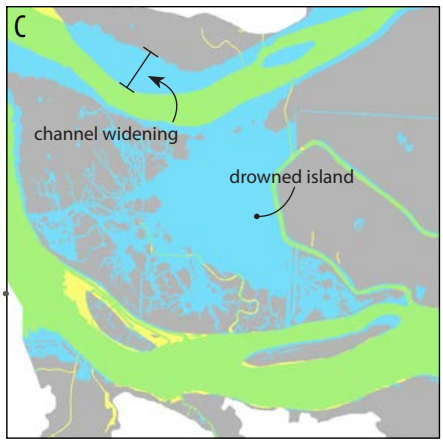
Channel width (top of facing page) was calculated at 100 m intervals by casting transects perpendicular to the channel centerline, clipping the transects to the banks of the channel, and subtracting any portion of the width associated with in channel islands.



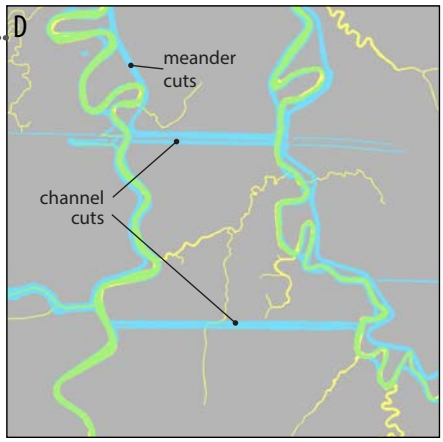
Confined by large natural levees, the course and width of the Sacramento River (here in green) is largely unchanged, but new straight channels have been created (blue).



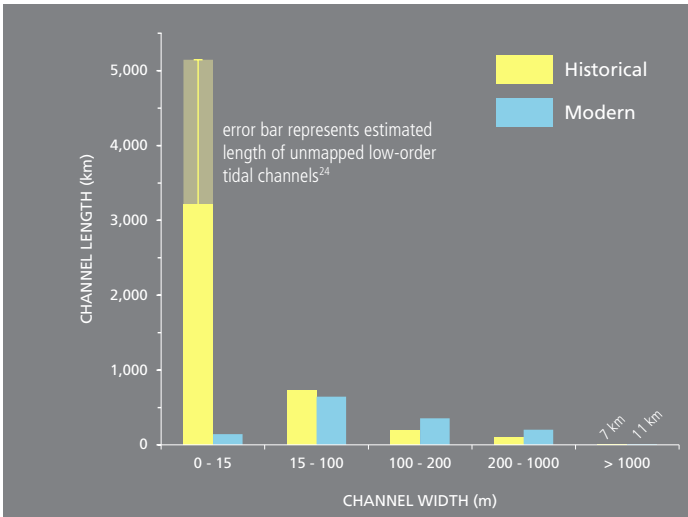
The smaller, dendritic, dead end sloughs of the Delta (here in yellow) have almost all been diked and filled.



Some channels, like the lower Sacramento, have been substantially widened. Levee breaches flood subsided islands, creating extensive new areas of open water.

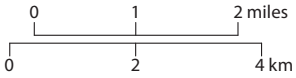


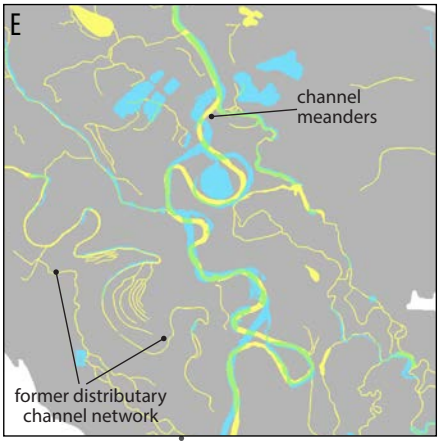
Meander cuts (between bends in a channel) and channel cuts (between separate sloughs) effectively straighten and short-circuit tidal channel networks.



The loss of narrow channels and increase in wide channels (above). The most significant change when comparing channel widths is seen in the lowest width category (0-15 m). The length of narrow channels in the Delta has decreased by two orders of magnitude, effectively eliminating more than 5,000 km of channels. The length of channels in the wider size classes (between 100-1,000 m) has essentially doubled.

Several types of reconfiguration of aquatic habitats (A-E, left and below). Small channels have been diked and filled. Large channels have been straightened, leveed, and artificially connected. Since the geometry of the Delta largely controls the dispersion and trapping of tidal waters,[25] these changes have likely had significant impacts on key physical processes and gradients (e.g., tidal flows, sediment transport and deposition, salinity transport, water residence time, water temperature, terrestrial linkages).



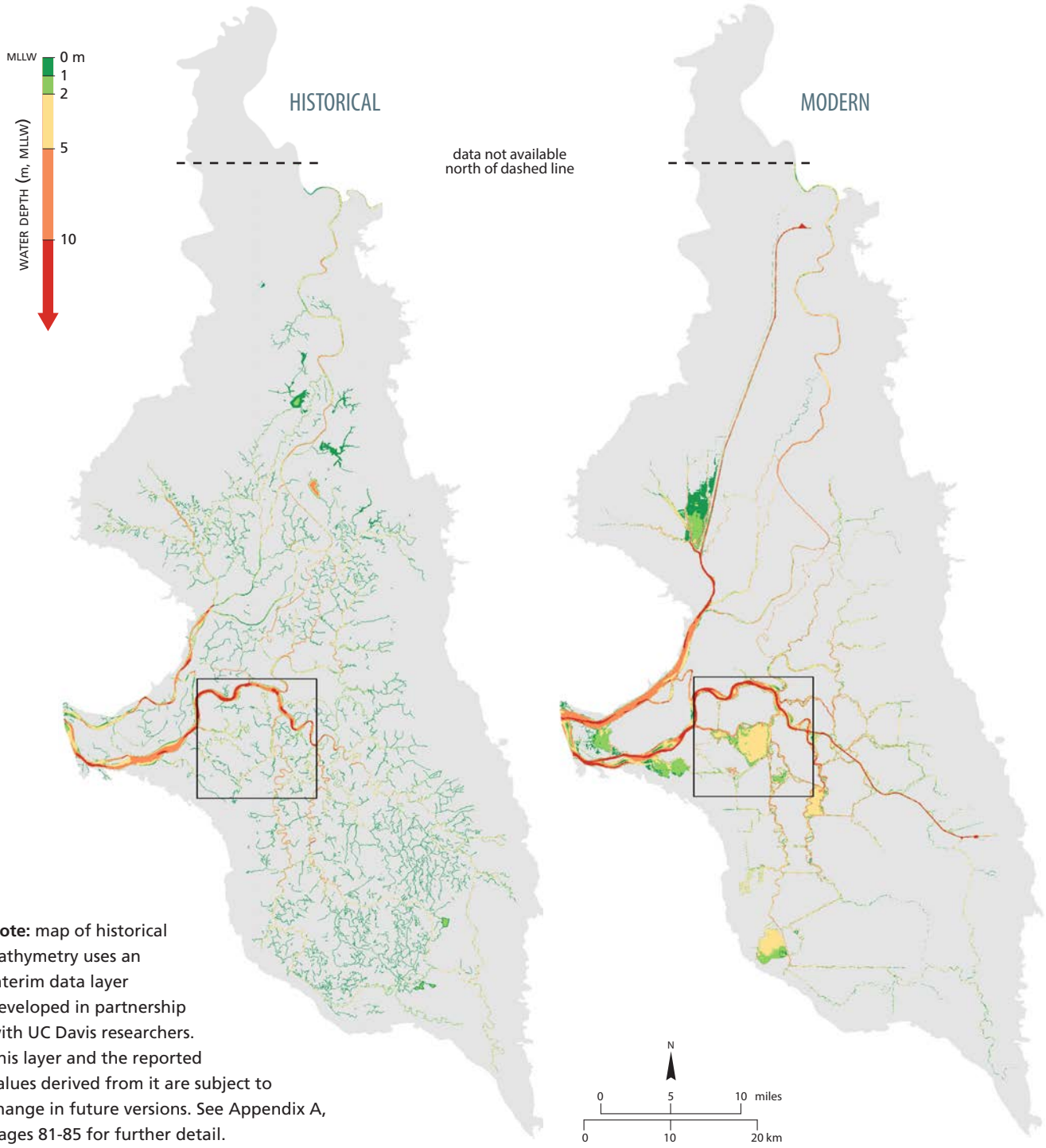


The main course of the San Joaquin has meandered over time. Its smaller floodplain channels have been mostly filled.

There is twice as much tidal shallow-water habitat in the Delta today as there was historically

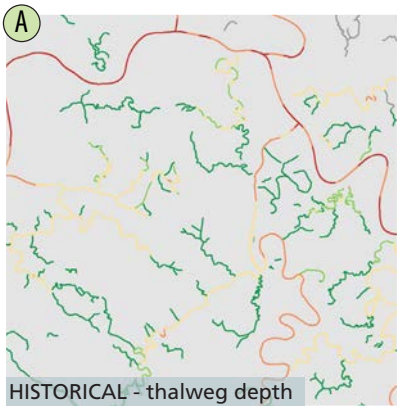
Shallow dendritic channels and lakes have been exchanged for novel flooded island habitats

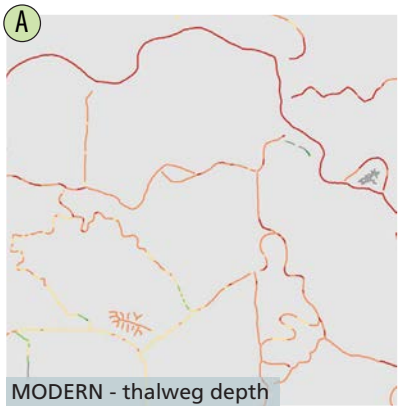
Existing tidal shallow-water habitat types are different than they were historically. The majority of areas <2 m deep today is part of large open water expanses rather than the historical small marsh channels. Shallow channel habitat is now found mainly along the edges of larger channels and flooded islands, adjacent to deep water. In fact, because of the widening of large channels, construction of new channels, and accidental flooding of subsided islands, there is more tidal aquatic habitat today in all depth classes, despite the near total loss of small marsh channel networks.

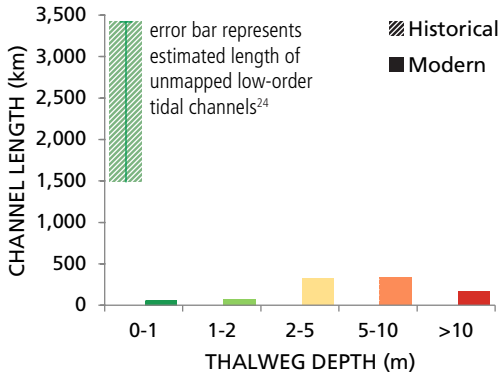


Note: map of historical bathymetry uses an interim data layer developed in partnership with UC Davis researchers. This layer and the reported values derived from it are subject to change in future versions. See Appendix A, pages 81-85 for further detail.

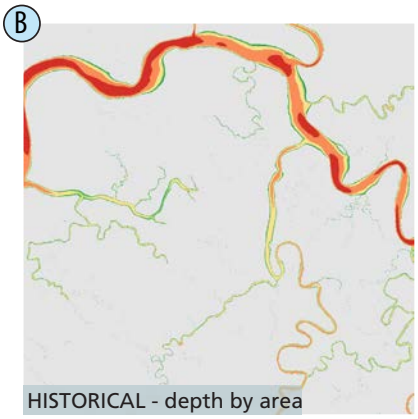
Near elimination of shallow channels; near doubling of deep channels. In the historical Delta, the vast majority of tidal channels (by length) were shallow (0-1 m). Nearly 1,500 km of low order dendritic channels in tidal channel networks likely had high water residence times and low velocities (see green channels below). These channels were almost completely eliminated during reclamation of the marshes. Large channels (the deepest classes: 5-10 m and >10 m) have greatly increased in extent, likely due to dredging and other modifications.

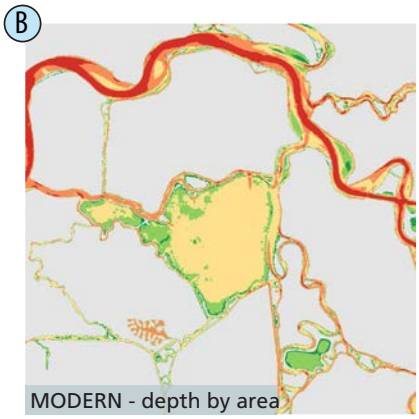


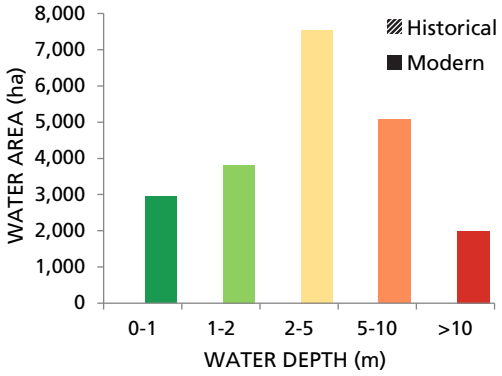




Loss of lakes; creation of novel flooded islands. There has been an overall increase in the area of aquatic habitat and, in particular, shallow water in the modern Delta. Shallow-water habitat is now mainly found in flooded islands, and widened channels. Yet shallow flooded islands are not equivalent to the historical lakes, with different hydrologic patterns, they have been largely overtaken by invasive submerged aquatic vegetation and invasive species. The shallow water on the edges of large, deep channels in the modern Delta may provide refuge for some fish, but these areas also harbor invasive aquatic species and likely do not provide the same benefits to fish as small, dendritic channels.



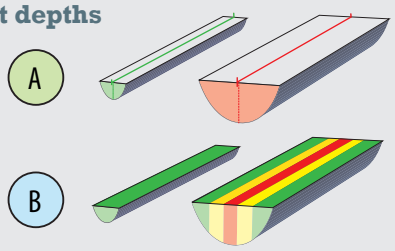




Methods: Two ways to summarize extent of aquatic habitats of different depths

A **By length:** we summed the linear extent of channels based on their thalweg depth (taken at ~100 m intervals). The thalweg is the deepest part of the channel. For all analyses on this page, depth was measured from an approximate mean lower-low water (MLLW) elevation.[26]

B **By area:** We summed the areal extent of aquatic habitat at each depth class (water column depth).



4. Life-History Support for Resident and Migratory Fish

Aquatic habitats in the historical Delta were complex and dynamic, providing many resources and opportunities for native fish. The rivers and sloughs that wove through the Delta displayed wide variation in width, depth, and sinuosity, creating heterogeneity in local hydraulics, residence time, and water chemistry. These characteristics provided diverse food resources and refuge for fish populations.[1] Historically, large channels flanked by riparian forest or marshes served as migration corridors for fish and provided resting places and refuge in undercut banks, deep pools, and inner bends.[2] Off-channel ponds and lakes were characterized by extensive shallow, slow-moving waters, which facilitated primary and secondary production for rearing populations.[3] Dendritic tidal channels that terminated in the marsh were backwaters with high residence times, and were characterized by temperature gradients beneficial for juvenile fish.[4] Delta channels were hydrologically connected to floodplains and marshes, and expanded in times of high water. Seasonally inundated floodplains offered a rich source of food and habitat for rearing and spawning.[5] Tidal flooding allowed fish access to the vegetated marsh and facilitated exchange of nutrients and organic matter between wetlands and open water habitats.[6] While the position of the large tidal channels, natural levees, and lakes in the Delta remained relatively unchanged from year to year, the seasonal and interannual variability in hydrology and weather created a complex and ever-changing portfolio of aquatic habitat available to fish through time.[7]

Historically the Delta supported an abundant and diverse fish community that included several species of anadromous fish and numerous endemic species, including two locally endemic species of smelt. The fish community included both freshwater stenohaline (narrow salinity tolerance) and euryhaline (broad salinity tolerance) species.[8] Fish confined to freshwater included hardhead, hitch, roach, Sacramento pikeminnow, and Sacramento sucker. These species also inhabited the tributaries that fed into the Delta.[9] Freshwater euryhaline species, associated primarily with freshwater but more tolerant of brackish conditions, included tule perch, Sacramento splittail, and both the longfin and delta smelt.[10] These species were found in Suisun Bay as well as the Delta. Euryhaline marine species such as staghorn sculpin and starry flounder were commonly associated with higher salinities but were able to tolerate freshwater conditions in the Delta.[11] Large numbers of anadromous fish passed through the Delta historically, taking advantage of the productive and protected Delta environment while migrating from freshwater to the ocean and back. These species included the Pacific and river lamprey, green and white sturgeon, Chinook salmon, and steelhead.[12] Chinook salmon were particularly abundant in the Delta, with four distinct runs and an estimated overall population of 1-2 million spawners per

year.[13] Many of the fish species that occupied the Delta were adapted to slower moving shallow waters and floodplains (habitats that have been largely eliminated in the modern Delta); these include the Sacramento perch (extirpated), thicktail chub (extinct), hitch, Sacramento blackfish, and Sacramento splittail.[14] Freshwater conditions predominated throughout the Delta, though high tides late in the season and during times of drought occasionally brought brackish water to the Delta mouth.[15]

Interpreting how the historical Delta supported fish is challenging because the current understanding of their natural history and ecology is based on their use of a heavily altered modern landscape. This difficulty is compounded by the dynamic nature of these aquatic habitats, which experienced tremendous temporal variability in the past. However, we can take a landscape-scale approach to understanding how the Delta historically supported fish and other aquatic wildlife. Within aquatic systems, as in terrestrial systems, different areas provide different habitat qualities, and boundaries between those areas affect the connectivity between them. These interactions take place at multiple scales.[16] Using this landscape-scale approach several aspects of the historical Delta stand out as particularly important for fish: (1) habitat heterogeneity, (2) presence of high-productivity habitats, and (3) connectivity among habitats.

Aquatic habitats were heterogeneous at multiple scales, providing support to wildlife at the individual, species, and community levels. Small-scale heterogeneity allowed individuals to escape unsuitable conditions. For example, channels, swales and microtopography on floodplains reduced stranding risk for rearing Chinook and splittail, while pockets of slow moving water, such as along inner undercut banks and submerged trees, allowed tule perch to occupy otherwise fast-flowing channels.[17] Large-scale heterogeneity allowed species to occupy different niches, preferentially occupying different positions along salinity, temperature, and turbidity gradients. While species such as thicktail chub may have been specifically adapted to slow-moving backwaters and lakes, species such as Sacramento splittail were able to take advantage of floodplain habitats, using these areas to spawn.[18] The heterogeneity of aquatic habitats allowed some species to develop multiple life-history strategies, each likely to be favored in different years and under different conditions. Chinook salmon, for example, exhibited a wide range of variability in the timing and location of spawning and rearing. This diversity in life-history strategies likely stabilized the population via portfolio effects, increasing resilience because different segments of the population were less likely to experience declines at the same time.[19]

Resident and migratory fish (below). Left to right: Sacramento splittail; Chinook salmon; Chinook salmon; tule perch.

Photo Credits: Unknown, USFWS; Dan Cox, USFWS; Blaine Bellerud, NOAA; Unknown, UC Davis

The Delta had several types of high-productivity habitats that supported the base of the food web. Within the water column, shallow water depths and high residence times likely supported high densities of phytoplankton.[20] Dendritic channels that terminated in the marsh and other backwater areas may have been particularly important in this regard.[21] Within open water habitats such as lakes, submerged and floating aquatic vegetation supported high densities of invertebrates that were important food sources for fish.[22] Periodically inundated marshes and floodplains contributed organic matter to fuel the food web. In the modern San Francisco Bay Delta Estuary, fish food webs are dependent upon autochthonous marsh materials,[23] and this dependence was likely even greater historically when more marsh habitat was available.[24] Delta fish likely varied their diet seasonally to take advantage of shifts in prey availability, while maintaining minimal dietary overlap among species, as has been observed in native fish in the modern Delta.[25] This ability to take advantage of diverse and dynamic food resources would have been beneficial to the fish community in the historical Delta.

Wetlands, including floodplains, were connected to aquatic habitats by regular, unimpeded flooding from tides, precipitation, and snowmelt. Water moved slowly through vegetated landscapes, allowing exchange between the channels and wetlands to occur and providing variation in water depths and velocities.[26] The pattern of wetland flooding, with pulses of inundation and slower recession, allowed fish to take advantage of these habitats while still being able to pass back into the river channels once floodplains began to dry. Floodplains were inundated for both short and long durations, providing temporally variable benefits to fish.[27] Connections to off-channel habitats affected water chemistry within the channels themselves.[28] Organic matter contributed by marshes would have increased turbidity.[29] Exchange of primary productivity and export of invertebrates would have affected the food web.[30] Riparian trees and shrubs contributed woody debris that altered flows, channel dynamics, and sedimentation processes, particularly in the south Delta.[31]

Floodplains were critical for fish migration, spawning, and rearing. Floodplains served as important rearing habitat for several species of resident and migratory fish.[32] Floodplain habitats provided fish with refuge from predation as well as from energetic demands and physiological stressors. These habitats had high turbidity and increased the extent of shallow-water habitat where certain species could hide.[33] The increased foraging space provided by floodplains may have reduced competition and the likelihood of encountering certain predators.[34] Native fish may have been vulnerable to predation by abundant birds, but this additional risk was likely offset by for increased growth on the floodplain and reduced predation risk later in the ocean.[35] Estuarine rearing in marshes and floodplains is important to Chinook salmon because it can reduce size-dependent mortality upon ocean entry by increasing the variation in the size and timing at which individuals reach the ocean.[36]

In the modern Delta, aquatic habitats are characterized by wider, deeper, straighter channels that are leveed off from adjacent habitats. There is now much less seasonal and spatial variation in hydrology and habitat. Connectivity between large channels has increased through connecting canals, meander cutoffs, cross-levees, and dredged and widened channels. This has homogenized conditions (e.g., salinity, temperature, nutrients, and flows) and altered tidal and flood routing through the Delta. The modern channel network no longer predictably leads to fluvial sources or dendritic channels, making the Delta a much less coherent landscape for native fish to navigate.[37] Channel systems with coherent gradients allowed fish in the historical Delta to position themselves where conditions were most suitable, despite the dynamic nature of these conditions. Delta smelt, for example, track the low salinity zone as it moves upstream and downstream seasonally. These

fish use vertical migration and other behavioral adaptations to stay in favorable areas.[38] Native fish key in on changes in flow, water temperature, and turbidity to cue their movement.[39] Furthermore, where once fish could predictably travel a short distance between one habitat (e.g., a large fluvial channel with high velocities and low residence time) and another quite different one (e.g., a small marsh channel with low velocities and high residence time), now these distances are much greater, and the path to get from one habitat to another is much less predictable.[40]

Most of the slow-water habitat, highly productive floodplains, and marsh-influenced habitats in which Delta fish species evolved are lost. The loss of wetlands, development of artificial levees, and the increase in the size and connectedness of channels has increased the speed at which water moves through the Delta. Most of the channels in the Delta today are lined by steep artificial levees that isolate the channels from adjacent habitats, and much of the habitat that was once marsh has been converted to agriculture. Flooding occurs, though in very limited areas, and is predominantly short-duration. Between 1935 and 1995, for instance, the frequency with which the Yolo Bypass experienced at least seven days of overflow in the spring decreased from ~80% of years to ~20% of years.[41] While remnants of several lakes persist, today most of the large areas of open water in the Delta are drowned islands. These deep water habitats, primarily in the central Delta, did not have functional equivalents in the historical Delta.[42]

The modern Delta is characterized by a suite of threats not faced by Delta fish communities historically. Highly managed hydrology, including diversions and pumps, alters directional flows often entraining fish.[43] Agricultural runoff and water discharges impact water quality.[44] In addition, introduced invasive species have restructured food webs, altered habitats, and directly outcompete native fish. The invasive *Corbicula* clam has dramatically reduced planktonic food resources available to fish.[45] Invasive submerged aquatic vegetation (SAV) species, such as Brazilian waterweed and water hyacinth, provide different structure and reach higher densities than native SAV species, and thus are not functionally equivalent.[46] Invasive SAV species provide habitat for non-native predatory fish and support invertebrates that are less favored in the diets of native fish species.[47]

The Delta fish community is now dominated by non-native species including sunfish, bass, catfish, and common carp.[48] Native species are generally associated with higher river flows and lower temperatures, although a few non-natives, including striped bass, white catfish, channel catfish, and American shad are also associated with high flows.[49] While floodplain inundation is critical for native fish migration, breeding, and rearing, floodplains are currently heavily used by non-native species.[50] However, native fish, adapted to the Delta's flood cycle, have been found to spawn and leave the Cosumnes floodplain earlier than non-native fish (thus avoiding stranding), and may be able to quickly take advantage of newly flooded habitats.[51] Food limitation in the modern Delta likely intensifies competition with non-native fish, as well as non-native predation on natives.[52]

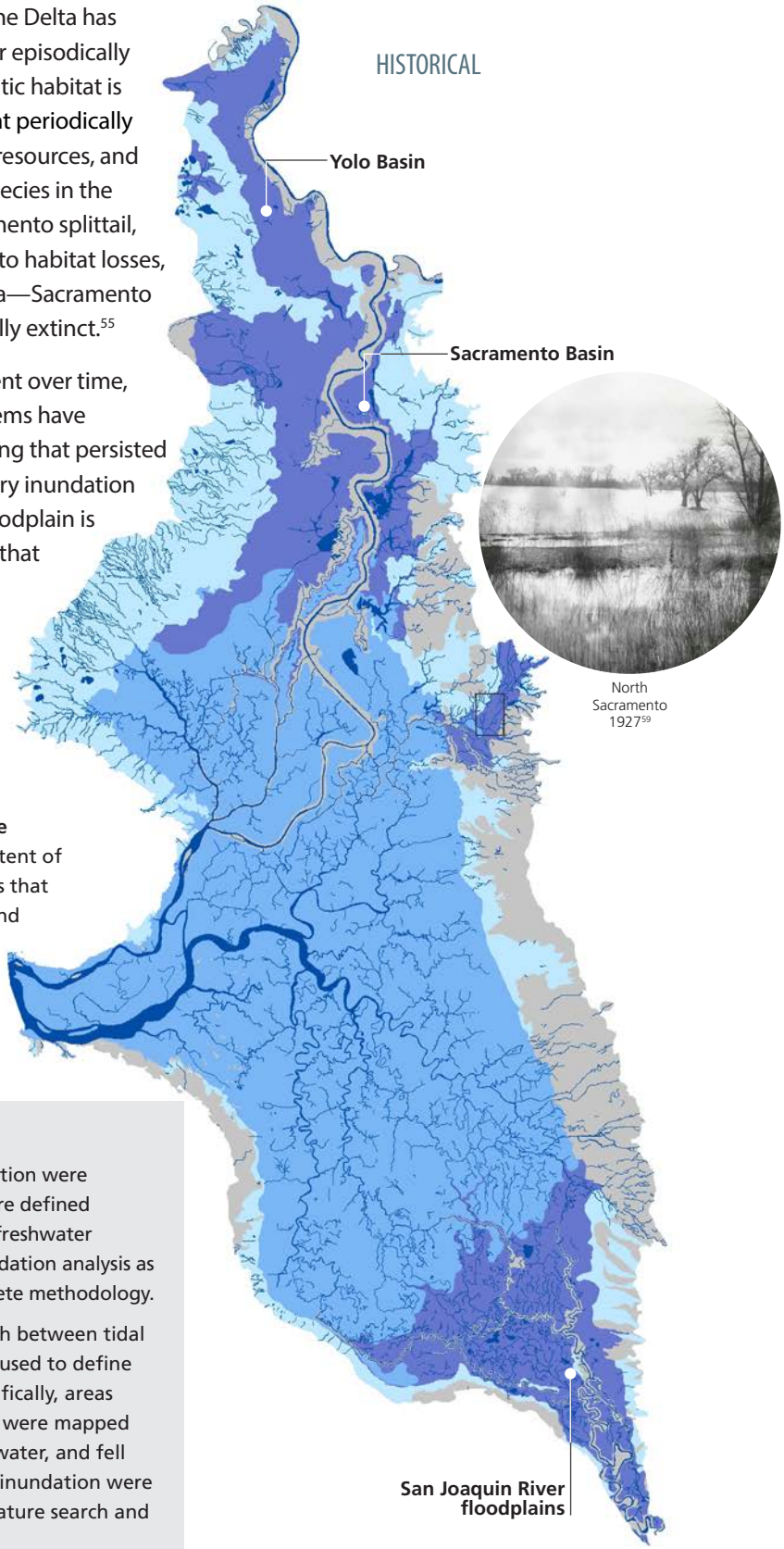
The future of threatened fish species is uncertain and threats and stressors may continue to worsen. Restoration of habitat for native fish is difficult. Competing water interests make it challenging to re-establish historical flows that favor native fish, and improvements to water quality and habitat will likely favor non-native fish to some degree. Marsh and floodplain restoration have the potential to preferentially help native fish, though restoration would need to be implemented on a large scale to increase the likelihood of success due to the large variability in fish response to restoration activities.[53]

Fish likely benefited from dynamically inundated landscapes

Most of the temporarily flooded habitat available to fish has been lost in the modern Delta

By comparing the past and present, it is apparent that the Delta has shifted from a mosaic of subtidal, tidal, and seasonally or episodically flooded habitats to a landscape where most of the aquatic habitat is permanently subtidal. Historically, fish utilized abundant periodically available habitat for spawning, rearing, additional food resources, and refuge from predators. Specific floodplain-associated species in the Delta included Sacramento perch, thicktail chub, Sacramento splittail, and juvenile Chinook salmon.[54] Today, likely in part due to habitat losses, two of these species can no longer be found in the Delta—Sacramento perch are locally extirpated and thicktail chub are globally extinct.[55]

Although all types of inundation have decreased in extent over time, altered flow regimes, artificial levees, and drainage systems have effectively eliminated the seasonal long-duration flooding that persisted for months at a time in the historical Delta. Contemporary inundation associated with the Yolo Bypass and Cosumnes River floodplain is more akin to the shallow, seasonal short-term flooding that was common to the seasonal wetlands of the historical Delta.[56] This has important consequences for species like Sacramento splittail whose life-history strategies require longer periods of sustained inundation (and potentially enables alternate rearing strategies for juvenile salmon).[57]



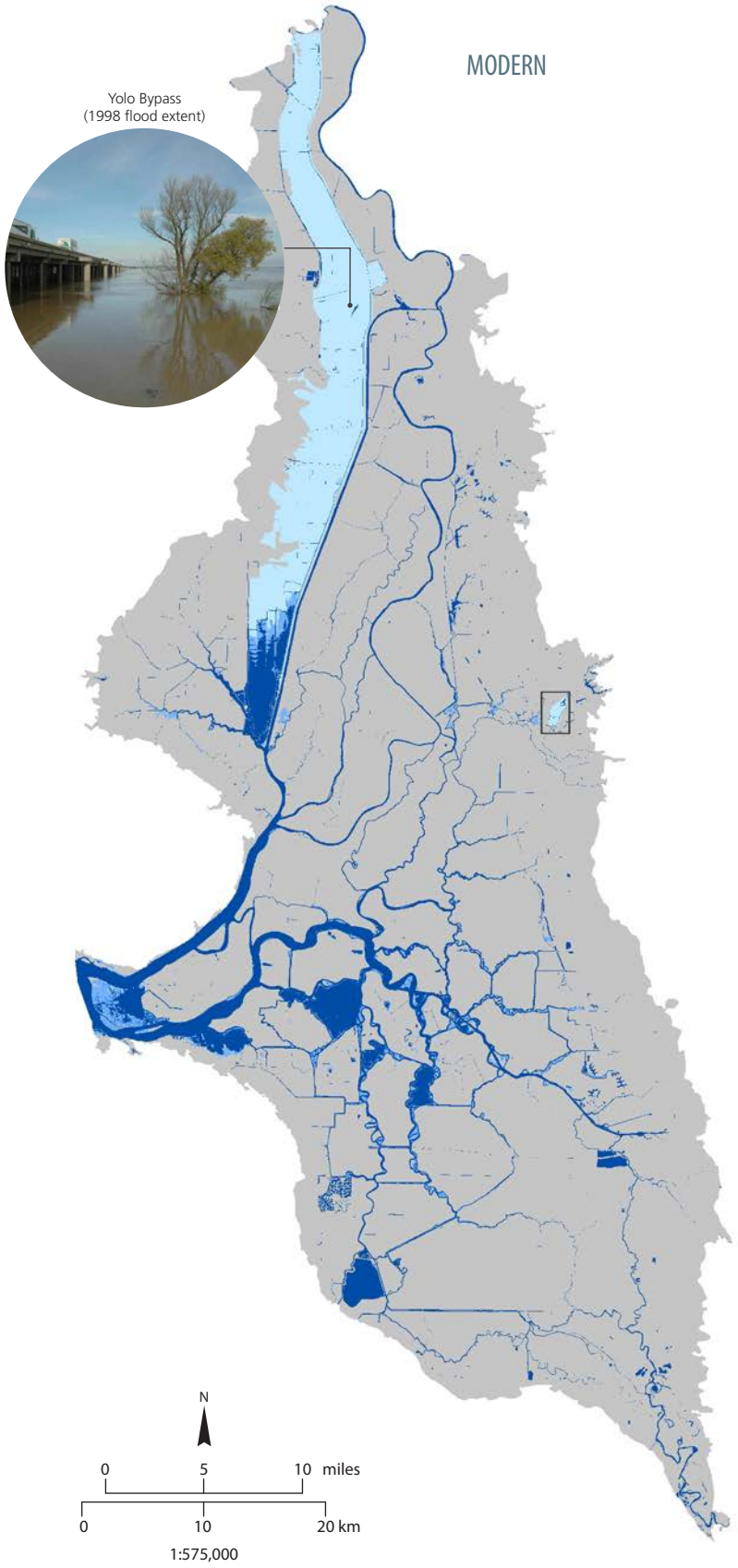
Approximate maximum extent and type of inundation in the historical (right) and modern (far right) Delta. While the extent of perennial open water features has increased over time, areas that experience tidal inundation, seasonal short-term flooding, and seasonal long-duration flooding (defined at far right) have all decreased in extent (by 144,000, 40,000, and 59,000 ha, respectively).

Photo Credits: McCurry, courtesy of California History Room, California State Library, Sacramento; Yolodave, Wikipedia Commons

Methods: Type and extent of flooding

For the historical Delta, areas regularly subjected to inundation were derived from the map of historical habitat types, which were defined in part, by their typical hydrology.[58] Areas mapped as tidal freshwater emergent wetland, for instance, were classified in the inundation analysis as areas of "tidal inundation." See Appendix A for our complete methodology.

Since the modern habitat type dataset does not distinguish between tidal and non-tidal freshwater emergent wetland, a proxy was used to define the areas that currently experience tidal inundation. Specifically, areas were assigned the "tidal inundation" classification if they were mapped as freshwater emergent wetland, were adjacent to open water, and fell within the historical extent of tidal marsh. Other areas of inundation were identified, mapped, and classified after conducting a literature search and consulting with regional experts.



SEASONAL SHORT-TERM FLOODING

Short-term fluvial inundation

- intermediate recurrence (~10 events per year)
- low duration (days to weeks per event)
- generally shallower than seasonal long-duration flooding

SEASONAL LONG-DURATION FLOODING

Prolonged inundation from river overflow into flood basins

- low recurrence (~1 event per year)
- high duration (persists up to 6 months)
- generally deeper than seasonal short-term flooding

TIDAL INUNDATION

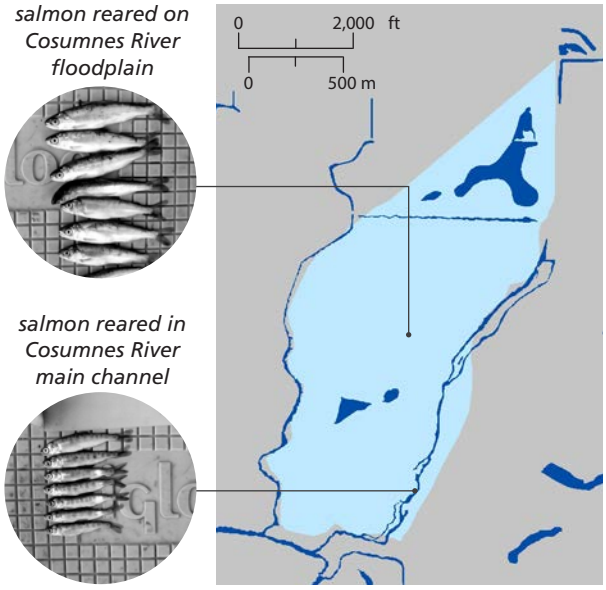
Diurnal overflow of tidal sloughs into marshes

- high recurrence (twice daily)
- low duration (<6 hrs per event)
- low depth ("wetted" up to 0.5 m)

PONDS, LAKES, CHANNELS, & FLOODED ISLANDS

Perennial open water features (with the exception of historical intermittent ponds and streams)

- recurrence not applicable (generally perennial features)
- high duration (generally perennial features)
- variable depth



Floodplains support rearing salmon. Juvenile Chinook reared in seasonal floodplain habitats of the Cosumnes River have been found to grow significantly larger than those reared only within the river's main channel.[60] Although seasonally flooded habitat once totalled more than 117,000 ha in the Delta,[61] it is now largely restricted to parts of the Yolo Bypass and Cosumnes River floodplain and totals less than 19,000 ha (a decrease of approximately 85%).

Images of juvenile salmon courtesy Springer Science+Business Media, originally published in Jeffres et al. (2008).

Dramatic loss of seasonally flooded habitats

Native fish are adapted to a complex, variable landscape with extensive aquatic resources throughout the year

The historical Delta exhibited dramatic seasonal variation in flooding (right, top). Seasonal basin flooding in the north Delta, driven by lower-elevation, rain-fed Coast Range streams, tended to occur between December and April. In contrast, elevated flows and flooding in the south Delta were driven by snowmelt, generally began in April, and continued into the summer. This seasonal variation in flooding is reflected in the life histories of the native fish species that evolved here (see bottom of this page and the chart on page 42). Today, a decrease in the extent of inundation across the Delta has been accompanied by a decrease in the spatial-temporal variability of inundation (right).

SEASONAL SHORT-TERM FLOODING

Short-term fluvial inundation

- intermediate recurrence (~10 events per year)
- low duration (days to weeks per event)
- generally shallower than seasonal long-duration flooding

SEASONAL LONG-DURATION FLOODING

Prolonged inundation from river overflow into flood basins

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Perennial open water features (with the exception of historical intermittent ponds and streams)

- recurrence not applicable (generally perennial features)
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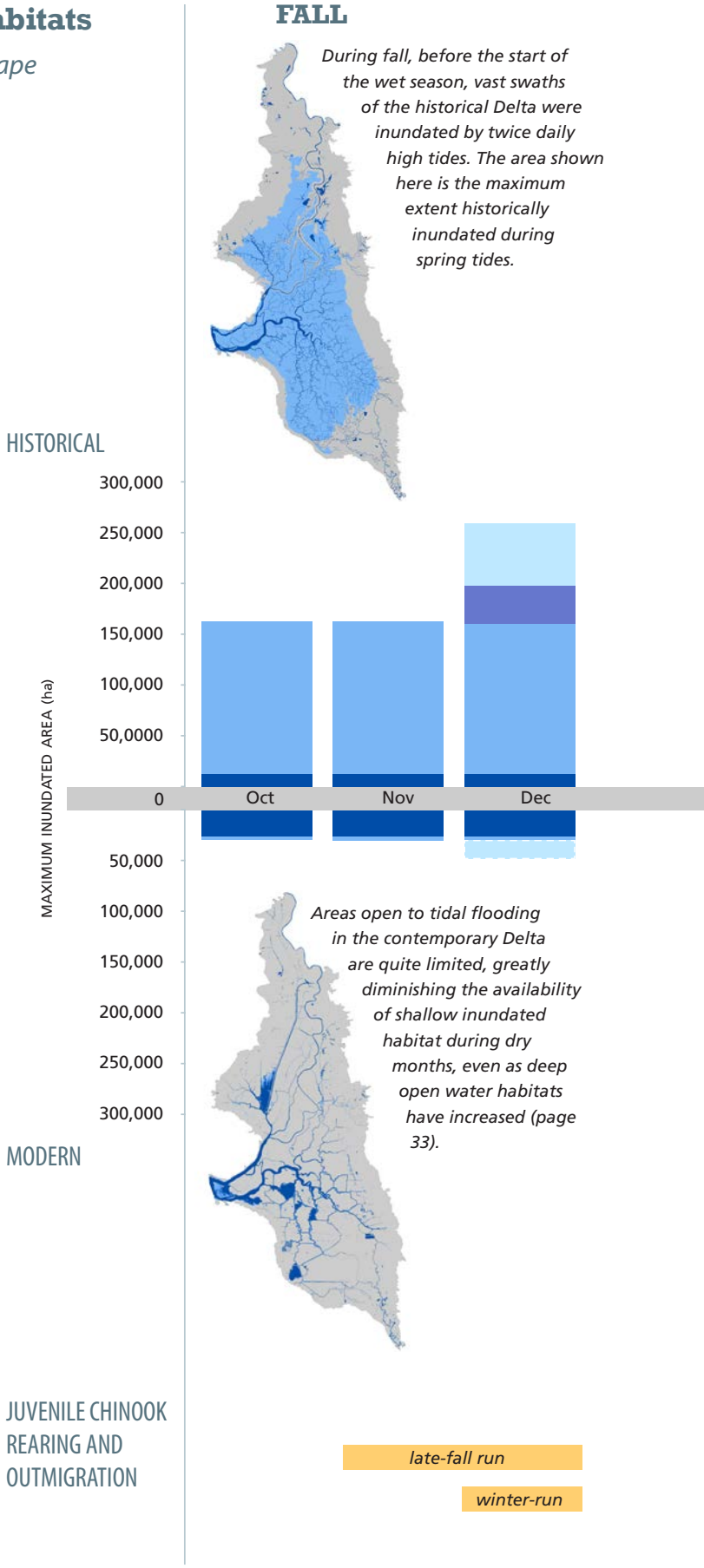
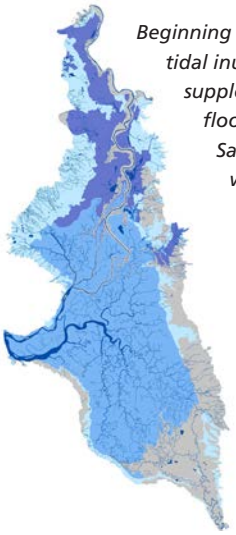
- variable depth



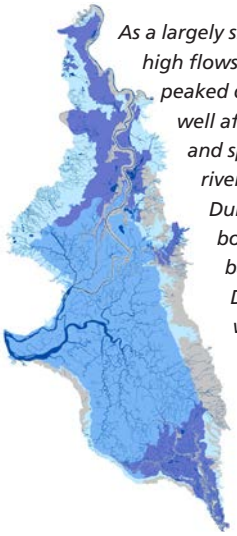
Temporal distribution of juvenile Chinook rearing and outmigration (right). The colored bars depict the periods of juvenile rearing and outmigration for each of the four runs of Central Valley Chinook salmon (named for when adults migrate into freshwater; also see page 42). The distinct salmon populations display diverse life-history characteristics that reflect the temporal variability in available habitat across a year **(above)**.[62]

WINTER



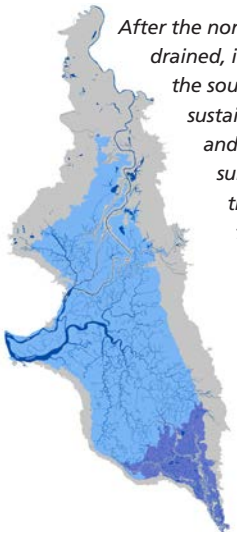
Beginning in the winter, tidal inundation was supplemented with flooding from the Sacramento River, which frequently passed much of its flow into the Sacramento and Yolo Basins. Cache and Putah creeks and also contributed floodwaters.

SPRING

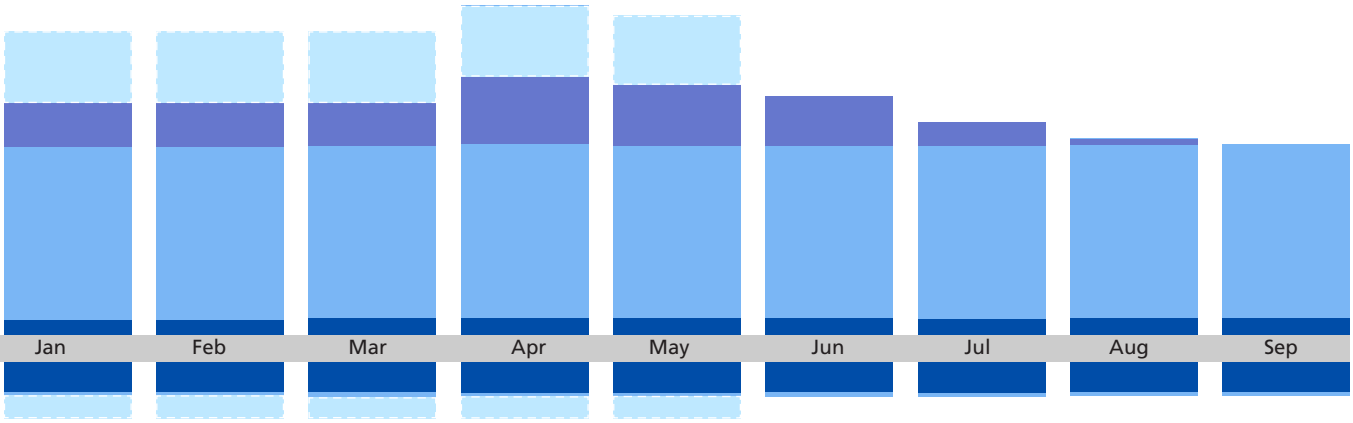


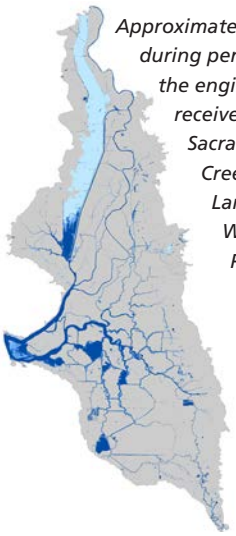
As a largely snowmelt-fed river, high flows on the San Joaquin peaked during the spring, well after winter storms, and spread across the river's floodplain. During wet years, both the north Delta basins and south Delta floodplains would have been inundated during mid-spring, creating a maximum flood extent.

SUMMER

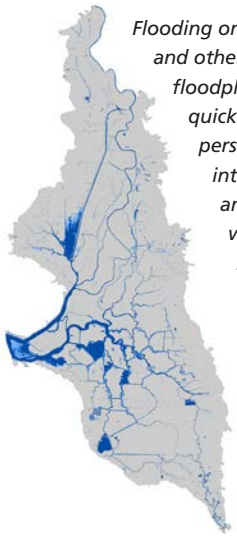


After the north Delta basins drained, inundation in the south Delta was sustained by snowmelt and persisted into the summer, extending the availability of floodplain resources.

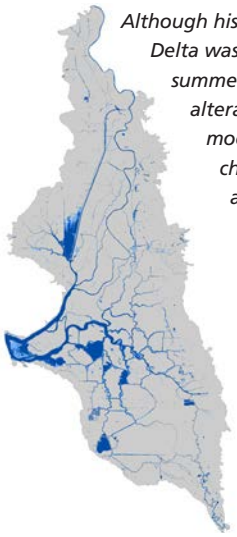




Approximately every three years, during periods of high flow, the engineered Yolo Bypass receives water from the Sacramento River, Cache Creek, the Knight's Landing Ridge Cut, Willow Slough, and Putah Creek. The floodway is designed to divert this water away from major cities and to quickly deliver it downstream to the Cache Slough Complex.



Flooding on the Yolo Bypass and other modern Delta floodplains drains quickly and does not persist for as long into the spring and summer as was common historically.



Although historically the South Delta was wettest during early summer, 160 years of flow alterations and channel modifications have changed the timing and magnitude of inundation events in the region. Aquatic habitat in the late spring and summer is now generally limited to small areas of tidal inundation and extensive areas of perennial open water habitats.

Simple life-history periodicities of BDCP Species of Special Concern (below). Habitat needs vary across fish life-history stages and, therefore, across time. Over the course of a single year, the historical Delta exhibited a great deal of spatial-temporal variability in physical processes/gradients and habitat availability. This variability is reflected in the temporal distributions of fish species that utilize the Delta during one or more phases of their lives. The table reflects modern use of the Delta by fish—it is possible that the historical temporal distributions differed. Migrating adult spring-run Chinook, for example, ascended the San Joaquin River well into the late summer—a pattern that is tied to the availability of snowmelt runoff and sufficient flows from the south Delta to upstream tributaries.[63] There may also once have been (now extinct) summer runs of Chinook and steelhead that migrated in July and August.[64] The table does not include life-history stages that occur predominantly outside of the Delta (like salmonid spawning, which occurs upstream).

Life-history stage present in Delta

		Month											
Species	**Life-history stage**	**O**	**N**	**D**	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**
Chinook salmon[65]	Fall run adult migration	■	■	■								■	■
	Fall run juvenile rearing and migration				■	■	■	■	■	■			
	Late-fall run adult migration		■	■	■								
	Late-fall run juvenile rearing and migration		■	■	■	■							
	Winter run adult migration				■	■	■	■	■				
	Winter run juvenile rearing and migration			■	■	■	■	■					
	Spring run adult migration						■	■	■				
	Spring run juvenile rearing and migration					■	■	■	■	■			
Steelhead[66]	Adult migration	■	■	■	■	■	■	■	■		■	■	■
	Rearing		■	■	■	■	■	■	■				
	Juvenile emigration			■	■	■	■	■	■	■			
Sacramento splittail[67]	Adult upstream migration towards spawning areas		■	■	■	■	■	■					
	Floodplain/river spawning					■	■	■					
	Eggs/embryo and larvae (floodplain/channel margin)					■	■	■	■				
	Juvenile floodplain use					■	■	■	■	■			
	Juvenile downstream migration						■	■	■	■			
Green sturgeon[68]	Juveniles (Delta/Bay)	■	■	■	■	■	■	■	■	■	■	■	■
	Spawning migration (Bay/Delta)					■	■	■	■	■	■		
	Post-spawn adults (River/Delta)	■	■	■	■				■	■	■	■	■
	Mature adults (Ocean/Delta)	■	■	■	■	■	■	■	■	■	■		
White sturgeon[69]	Juveniles	■	■	■	■	■	■	■	■	■	■	■	■
	Spawning migration		■	■	■	■	■	■	■				
Pacific lamprey[70]	Adult migration		■	■	■	■	■						
	Ammocoetes (larval lamprey)	■	■	■	■	■	■	■	■	■	■	■	■
	Metamorphosis to juveniles							■	■	■	■	■	
	Juvenile outmigration	■	■	■	■							■	■
River lamprey[71]	Adult upmigration	■	■										■
	Juvenile outmigration (congregation in Delta)								■	■	■		
Delta smelt[72]	Egg/embryo (sandy-gravel channel edge)					■	■	■	■	■			
	Yolk-sac/First-feeding larvae (offshore tidal freswater)					■	■	■	■	■			
	Fin-fold larvae (offshore tidal freswater)						■	■	■	■	■		
	Metamorphosing larvae (offshore tidal freshwater & LSZ)							■	■	■	■		
	Juveniles (offshore tidal freshwater & LSZ)	■	■	■					■	■	■	■	■
	Migrating adults (offshore tidal freshwater)			■	■	■	■	■					
	Spawning (tidal freshwater)					■	■	■	■	■			
Longfin smelt[73]	Spawning		■	■	■	■	■						
	Eggs			■	■	■	■	■					
	Larvae				■	■	■	■	■	■			
	Juveniles (primarily in San Francisco and Suisun bays)	■	■	■	■	■	■	■	■	■	■	■	■

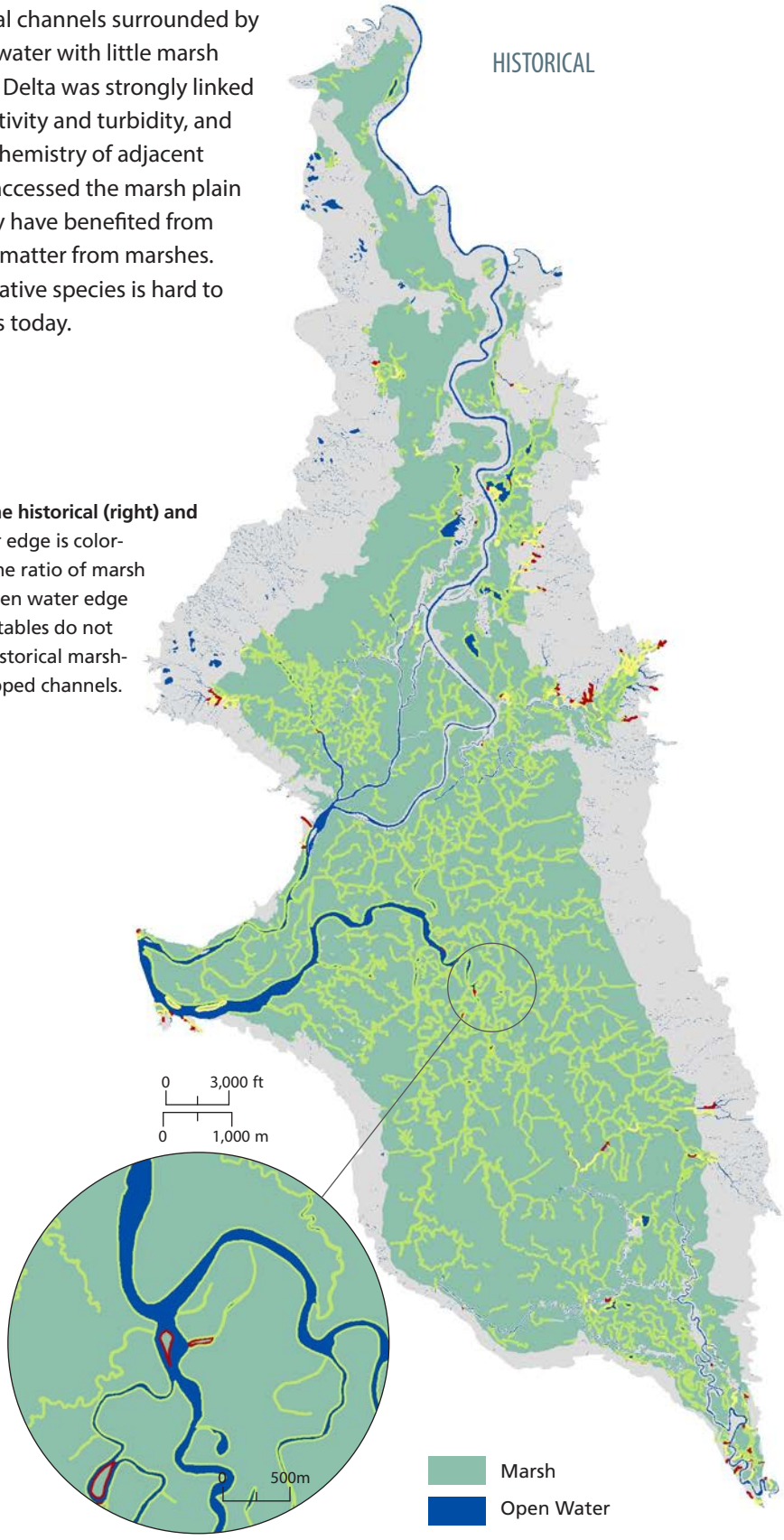
Chinook salmon in the lower American River **(top)** and at a fish hatchery **(bottom)**.

Photo Credits: Dan Cox, USFWS; Steve Martarano, USFWS

Marshes directly influenced the character and quality of aquatic habitats

There has been a 73-fold reversal in the ratio of marsh to open water area in the Delta

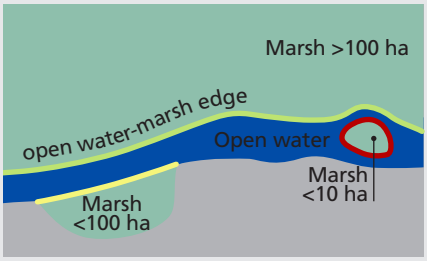
The Delta has shifted from a system of tidal channels surrounded by marsh to one dominated by leveed open water with little marsh influence. Aquatic habitat in the historical Delta was strongly linked to wetlands, which contributed to productivity and turbidity, and influenced the hydrology, structure, and chemistry of adjacent aquatic habitats. Some fish species likely accessed the marsh plain and marsh edge directly, while others may have benefited from the export of nutrients, food, and organic matter from marshes. The extent to which marshes benefitted native species is hard to determine because so little marsh remains today.

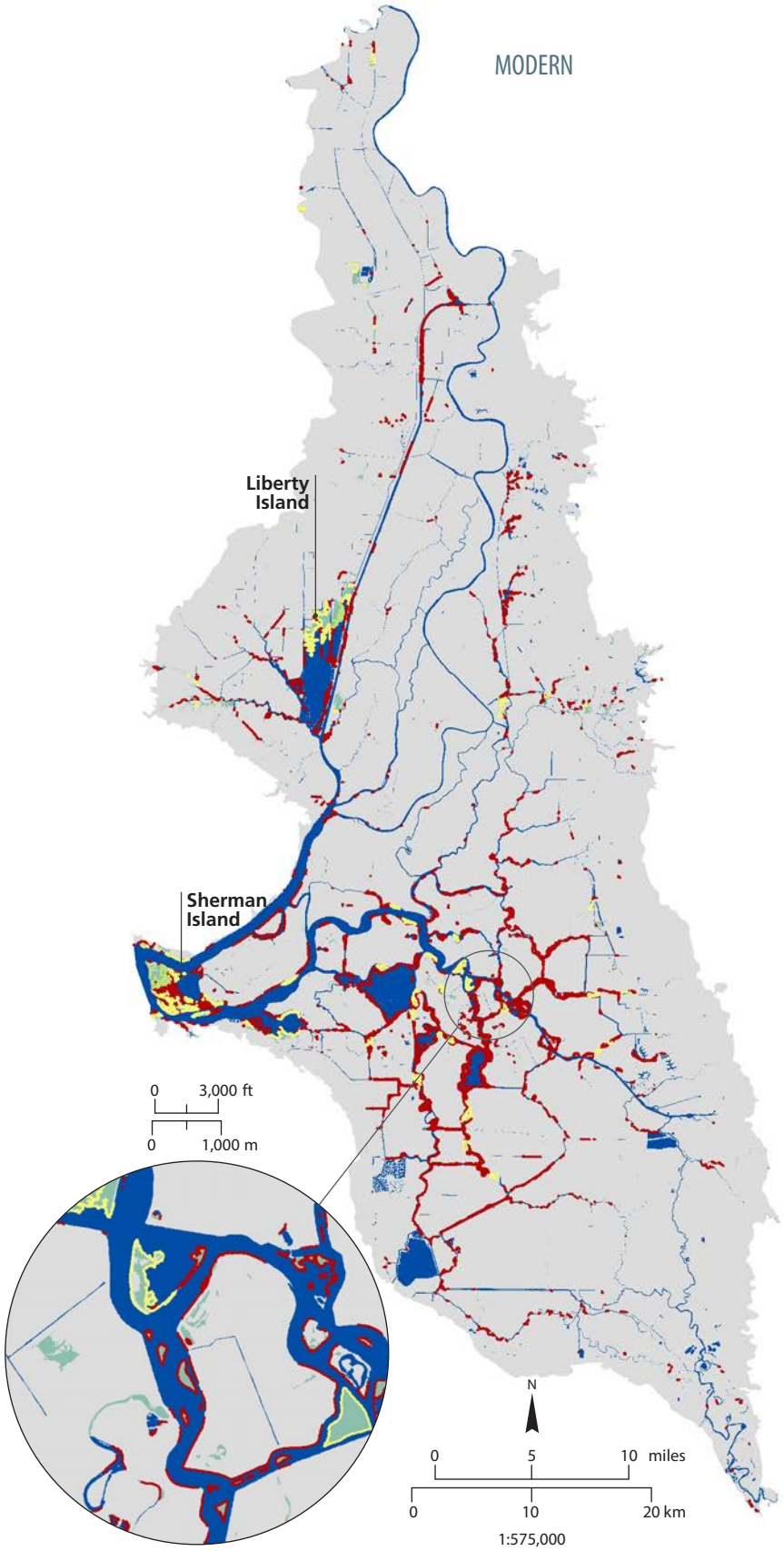


Marsh and open water habitat adjacencies in the historical (right) and modern (far right) Delta. The marsh-open water edge is color-coded by the size of the adjacent marsh. Both the ratio of marsh to open water and the total length of marsh-open water edge have decreased dramatically. These figures and tables do not include an estimated additional ~3,800 km of historical marsh-water edge associated with the smallest, unmapped channels.

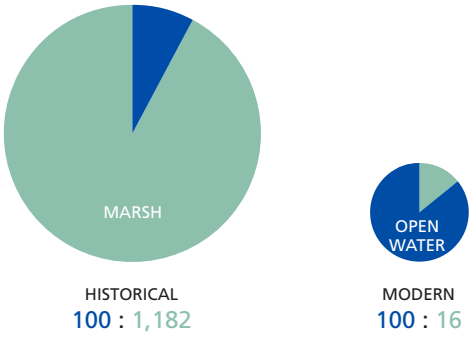
Methods: Marsh to open water ratio and edge

For the analyses on this page, we isolated all areas mapped as open water and marsh, regardless of their tidal status, connectivity, or form. Since habitat type maps represent average dry-season conditions, seasonally and tidally inundated areas are not included within the area mapped as open water. Linear areas where the two habitat types were mapped as adjacent to one another are identified as the open water-marsh edge. This edge was then classified by the size of the contiguous area of marsh from which it was drawn.



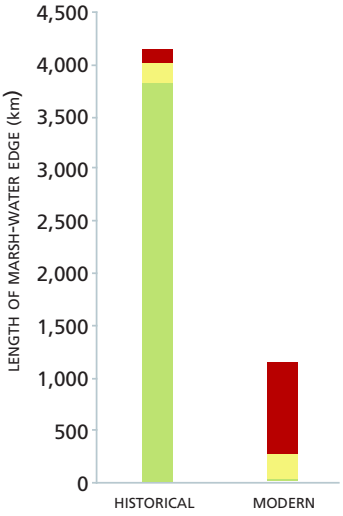


Habitat type	Total area (ha) *Historical*	*Modern*
Marsh	193,224	4,296
Open water	16,344	26,554



The reversal in marsh to open water area ratio over time (above) is the result of a 98.7% decrease in the area of marsh and a 62.5% increase in the area of open water. Where historically the Delta was characterized by narrow channels embedded within large areas of marsh, today we find tiny marshes embedded within large areas of open water.

Marsh-water edge marsh size class (ha)	Marsh-water edge length (km) *Historical*	*Modern*
>100 ha	3,823	31
10 - 100 ha	202	236
0 - 10 ha	112	874
TOTAL	**4,137**	**1,142**

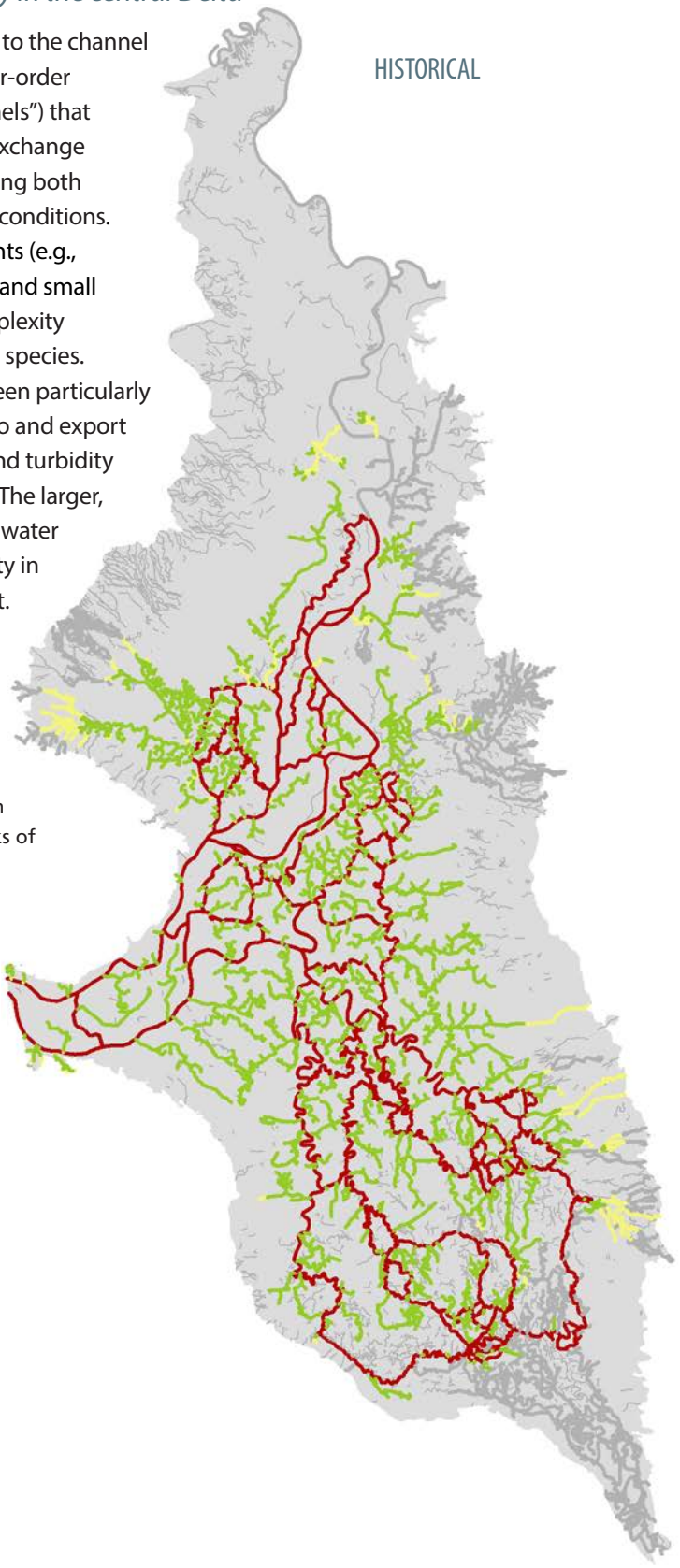


Despite fragmentation (which increases marsh edge length), the length of marsh-water edge has decreased by more than 72%. Historically there was over 3500 km of interface between open water and large (>100 ha) marsh patches The present day edge is largely associated with marsh patches <10 ha in size.

Complex dendritic channel networks likely provided high productivity habitat for fish

Most dendritic channels are now gone, especially in the central Delta

As Delta marshes were diked, connections were severed to the channel networks that wove through them. These dendritic lower-order tidal channels (also known as "dead-end" or "blind channels") that terminated within the wetland were once the capillary exchange system between the wetland and aquatic areas, promoting both food web productivity and spatial complexity in habitat conditions. They provided native fish species with a range of gradients (e.g., temperature, turbidity, and water velocity) at both large and small scales. Dendritic channel networks offered channel complexity and higher turbidities, which provided refuge for certain species. Channels that branched through the marsh may have been particularly important for salmonids because they provided access to and export of invertebrates from the marsh plain,[68] physical cover and turbidity for refuge, and slow moving water for energetic refugia. The larger, looped channels that characterize the Delta today allow water to move through and mix more quickly, with less diversity in residence time and less heterogeneity in channel habitat. The lack of large wetlands connected to channels means that there is little exchange of organic matter, organisms, or sediment between these ecosystems.



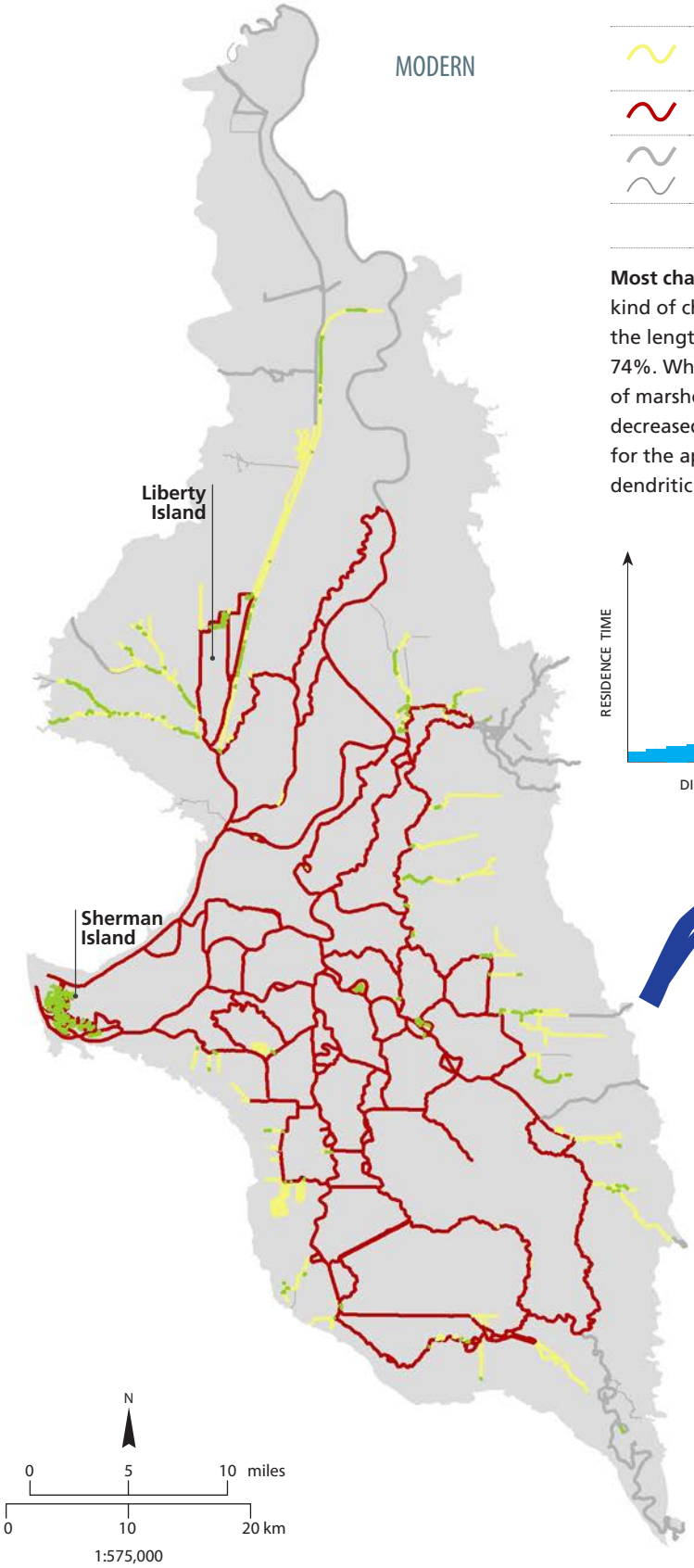
Comparing the historical (right) and modern (far right) landscape. While the skeletal framework of looped mainstem channels remains largely similar (red), the branching networks of dendritic channels (green and yellow) are mostly gone.

Methods: Classifying channel types

Channel reaches were manually classified using the following definitions:

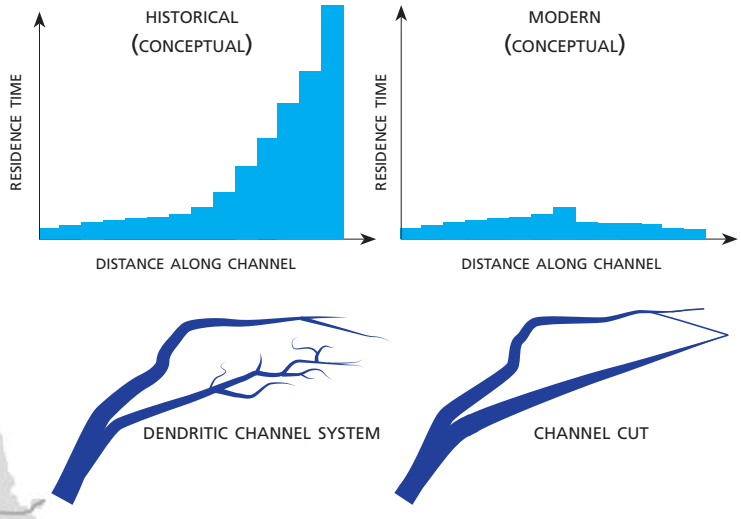
- Dendritic: tidal channel reaches connected to the tidal source by only one non-overlapping path
- Looped: tidal channel reaches connected to the tidal source (the Delta mouth) by two independent and non-overlapping paths
- Fluvial: channel reaches connected to the tidal source, but upstream of the approximate limit of bidirectional tidal flows (during spring tides in times of low river stages) AND tidal reaches between upstream perennial fluvial reaches and downstream looped reaches
- Detached: channel reaches without a direct connection to the tidal source (through the larger channel network)

Dendritic channels (segmented at 100 m intervals) were classified into those adjacent to marsh and those non-adjacent to marsh, based on the habitat-type polygon closest to the channel centerline.



Channel classification	Channel length (km) *Historical*	*Modern*
Dendritic channels adjacent to marsh	1,151	84
Dendritic channels not adjacent to marsh	153	255
Looped Channels	754	768
Fluvial Detached	2,225	298
TOTAL	**4,283**	**1,404**

Most channels in the Delta today are looped. The length of this kind of channel has slightly increased (due to channel cuts), while the length of dendritic tidal channels has decreased by more than 74%. Where dendritic channels do exist, they are generally not part of marshes—the length of dendritic channels adjacent to marsh has decreased by 93%. These figures and tables do not show or account for the approximately 1,900 km of estimated unmapped, low-order dendritic channels in the historical Delta.



Historically, the complex structure of Delta channels established gradients in residence time, a pattern heavily altered in the modern Delta (after Chris Enright, Delta Science Program). Historically, small low-order tidal creeks had high residence times, which allowed phytoplankton to accumulate and created net autotrophic conditions. Deeper sloughs, by contrast, had shorter residence times which created net heterotrophic conditions. The increased connectivity of modern channels in the Delta has led to homogenization of residence time across channel networks, increasing the reach of tidal excursion within channel networks and decreasing the occurrence of small channels with high residence time. The relationship between residence time and primary productivity in the modern Delta has been additionally complicated by the introduction of the overbite clam.

5. Life-History Support for Marsh Wildlife

Freshwater marshes dominated the Delta landscape historically. Enormous expanses of regularly inundated, highly connected, productive, and structurally complex marsh sustained large wildlife populations. Although much of the marsh was dominated by tules, overall the marsh supported a rich assemblage of both perennial and annual plant species that added to the marsh structure and complexity.[1] In this report, we use the word "marsh" to describe both tidal and non-tidal freshwater emergent wetlands, which can include non-herbaceous species, such as willows. Diverse plant species produced large quantities of seeds that accumulated as extensive seed banks in the sediment.[2] In tidal freshwater marshes both larval and adult insects were key primary consumers.[3] The amount of plant production directly influenced the potential to support secondary consumer populations by providing organic matter for detritivores, contributing to habitat structure, and other mechanisms.[4] The abundant food resources of Delta marshes supported many wetland and terrestrial vertebrates. Some terrestrial and semi-terrestrial species were restricted to the freshwater marsh, while others used it as one of several habitat options, as a migration corridor, or for a part of their life history (such as for dry-season foraging).[5]

A diverse and dynamic community of native wildlife, including humans, flourished within the marshes of the historical Delta. This community included resident birds and mammals such as rails, herons, bitterns, songbirds, mice, shrews, and voles.[6] Tidal freshwater marshes are thought to support the largest and most diverse populations of birds of any wetland type.[7] Waterbirds such as coots, moorhens, grebes, ducks, geese, and swans inhabited the channels and ponds within the Delta marshes, taking advantage of the food and shelter that marsh proximity provided. Some waterbirds also used the marsh to forage, rest, or breed (see Chapter 6). The Delta supported abundant beavers, river otters, and mink and was a major population center for these species.[8] The shallow ponds, blind channels, and backwaters of the marsh provided slow-moving habitat for littoral fish such as tule perch and the now extinct thicktail chub. Some fish inhabited the smaller marsh channels and may have ventured further into the marsh as flooding conditions allowed (see Chapter 4).[9] Tree frogs, pond turtles, California red-legged frogs, and giant garter snakes that used the marsh were likely limited to areas close to upland and seasonal wetland habitats.[10] In addition many terrestrial species, notably tule elk, but also antelope, deer, coyotes, and bears, used the marsh opportunistically to supplement foraging or escape predation and extreme conditions (see Chapter 8).[11] Raptors, including Northern Harriers and White-tailed Kites, hunted in the marsh. Compared to high salinity tidal marshes, freshwater marshes are thought to have high wildlife diversity, but low endemism.[12] However the Delta did support several endemic plants and a few regionally restricted vertebrates including the giant garter snake and Modesto Song Sparrow.[13] Finally, indigenous people benefited from and managed for this wildlife diversity, relying on the extensive marshes for food and materials.[14]

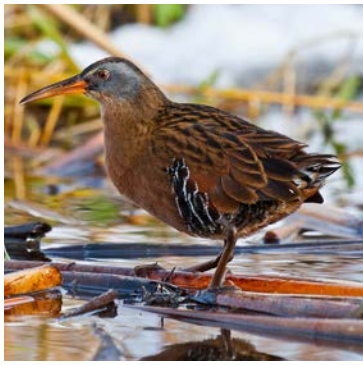
Marsh wildlife (right). Top to bottom: North American river otter, Delta tule pea, Virginia Rail, giant garter snake.

Photo Credits: Unknown, USFWS; Mark Fogiel, CalPhotos; Tom Talbott, Creative Commons; Dave Feliz, Wikipedia Commons

The considerable heterogeneity expressed by Delta marshes provided structural complexity and niche diversity to support different species. Gradients in physical characteristics such as tidal energy, river flow, and salinity, as well as subtle local variations in topography and microclimate, provided a variety of habitat features that supported wildlife under different conditions (e.g., seasonal cycles, floods, drought, temperature extremes, turbidity). These gradients also supported different species in different places, and fostered genotypic and phenotypic diversity within species. The character of the Delta marsh was particularly variable along its latitudinal gradient. Largely due to its distance from the mouth of the Delta and to

riverine influences, the north Delta flood basins contained broad zones of both tidal and non-tidal freshwater marsh that were relatively free of channels and supported dense stands of tules over ten feet tall. Channel density and sinuosity in the central Delta was greater than in the less tidally dominated northern and southern parts of the Delta because of the gradation in tidal prism. Willows were a significant component of the western-central Delta marshes, which were characterized by willow-fern-tule associations. The marshes of the south Delta were a mosaic of small ponds, patches of tule, willow thickets, rushes, grasses, and sedges[15] dependent on fluvial geomorphic influences from the San Joaquin River and tributaries. In addition to gradients, disturbances (including flood, drought, animal damage, and fires) maintained heterogeneity within the marsh. By knocking back vegetation, these disturbance mechanisms allowed disturbance-tolerant plants to grow and created small open water habitats (duck puddles) that supported waterfowl and littoral fish. The north Delta in particular supported many such small ponds.

The staggering loss of marsh in the Delta, combined with changes in connectivity and habitat quality, has led to tremendous loss of wildlife support. Over 97% of the historical marsh is now gone. What little marsh remains consists primarily of small patches surrounded by deep channels, artificial levees, and agriculture. Much of the marsh in the modern Delta is the result of accidental restoration via levee failure, and is relatively young in age (decades old rather than centuries). Marshes in the Delta no longer span broad, continuous gradients; instead, isolated patches occupy narrow spots along these gradients. Many modern marsh patches are small islands—often the cut-off tips of once larger marshes—now surrounded by riprapped levees and deep channels. The size and isolation of existing marsh patches severely limits the wildlife populations the marsh can support. The Delta's waters no longer inundate surrounding wetlands, limiting exchange of nutrients, organic matter, and dry-season freshwater input.



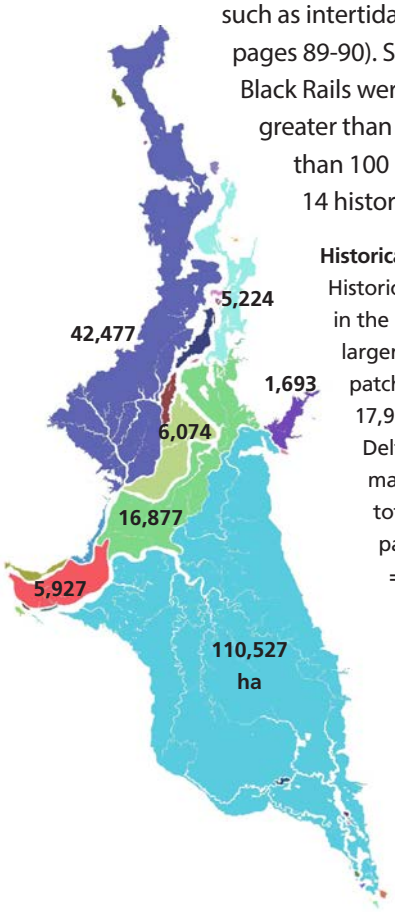
Fragmented wetlands support smaller wildlife populations because of increased edge effects, with reduced population viability and greater probability of extirpation within habitat fragments.[16] With few patches large enough to support self-sustaining populations, marsh wildlife in the Delta is particularly vulnerable to catastrophic events. The complex channel networks that were associated with these marshes historically cannot be adequately expressed in the small remaining habitat patches. In addition to these effects of fragmentation, the habitat quality of the remaining marsh patches has been altered by non-native invasive species, which compete with and prey upon native species, and by changes in water quality due to agricultural and urban runoff and habitat alteration.[17] Species that relied on the marsh historically, including waterfowl, giant garter snakes, and Tricolored Blackbirds, now increasingly rely on other habitats, including agricultural fields and blackberry thickets. Managed wetlands are critical to wildlife support in the Delta, providing habitat for wintering and nesting waterfowl (see Chapter 6) but they do not support the full native marsh wildlife community, and are often not hydrologically connected to the larger Delta system.

The freshwater marshes of the Delta were unique and extraordinarily valuable to wildlife. As part of an interior inverted delta in a Mediterranean climate, unparalleled in size within the state, the freshwater marsh in the Delta offered unique benefits to wildlife. Because so little of this habitat remains intact it is difficult to comprehend what has been lost. The majority of the Delta historically supported native marsh wildlife; now few places in the Delta do.

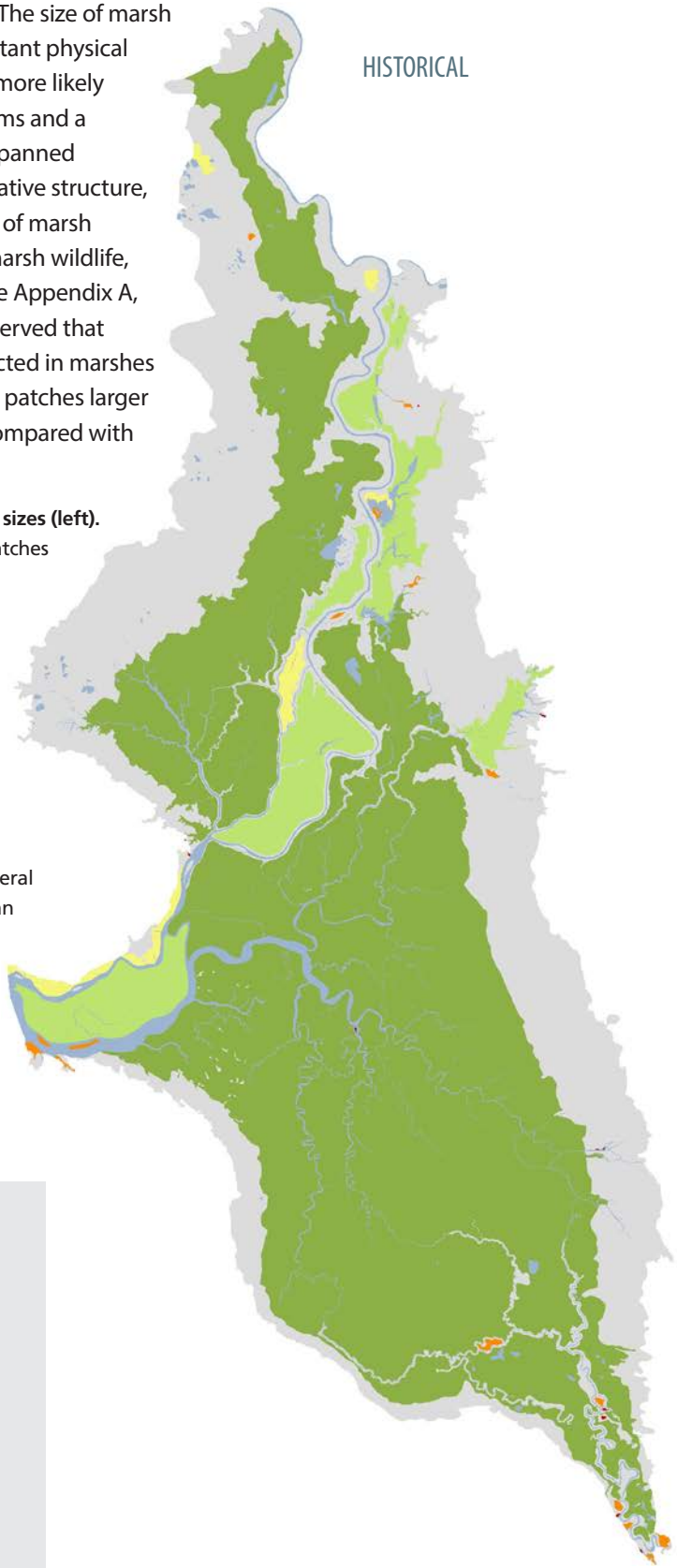
The few marshes left in the Delta are small

The current average patch size is several hundred times smaller than in the historical Delta

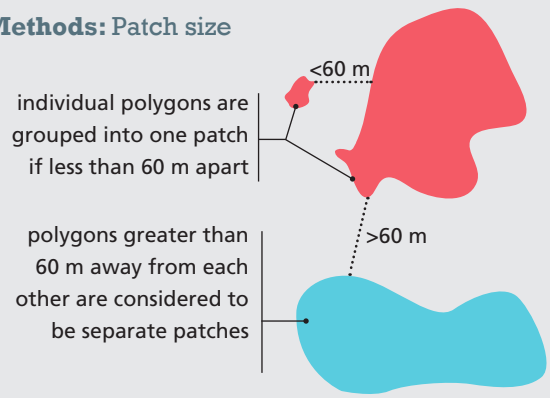
The area of marsh in the Delta has been reduced by 97%. The size of marsh patches today is small relative to the scale at which important physical and ecological processes occur. Large marsh patches are more likely than small patches to have well-developed channel systems and a range of physical and ecological features. Large patches spanned considerable heterogeneity in inundation patterns, vegetative structure, and geomorphic setting. Here we look at spatial patterns of marsh patches based on parameters relevant to marsh wildlife, such as intertidal rails (for more details see Appendix A, pages 89-90). Spautz and Nur (2002) observed that Black Rails were more consistently detected in marshes greater than 100 ha. Only three marsh patches larger than 100 ha remain in the Delta (compared with 14 historically).

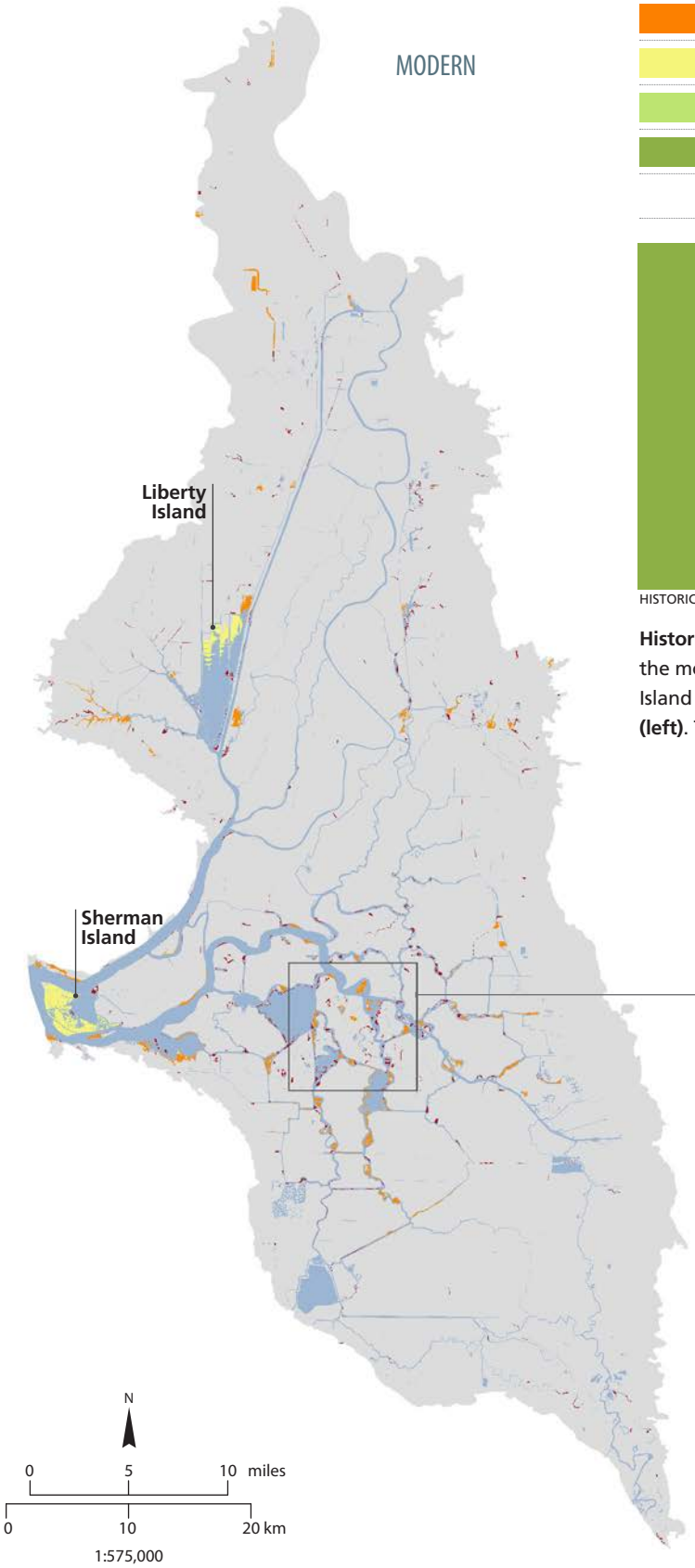


Historical marsh patches with patch sizes (left). Historically, there were 43 marsh patches in the Delta (14 of which were larger than 100 ha), with a mean patch size of 4,494 ha (SD = 17,956 ha). In the modern Delta there are many more marsh patches (1,211 in total), but they have a mean patch size of only 4 ha (SD = 24 ha), and only three are larger than 100 ha. Average patch size today is thus several hundred times smaller than it was historically. The largest single historical patch (110,527 ha) spanned the entire south and much of the central Delta.



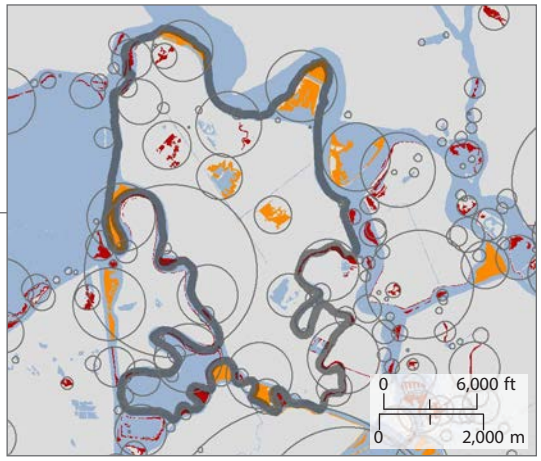
Methods: Patch size





Marsh patch size class (ha)	Total area (ha) *Historical*	*Modern*
<= 10 ha	46	1,427
10 - 100	702	1,757
100 - 1,000	2,489	1,154
1,000 - 10,000	20,105	0
>10,000	169,881	0
TOTAL	**193,224**	**4,338**

Historical marsh was composed of large patches, unlike marsh in the modern Delta **(above)**. Even today's largest patches—Liberty Island and Sherman Island—are not very big by historical standards **(left)**. The total extent of marsh is <3% of the historical area.

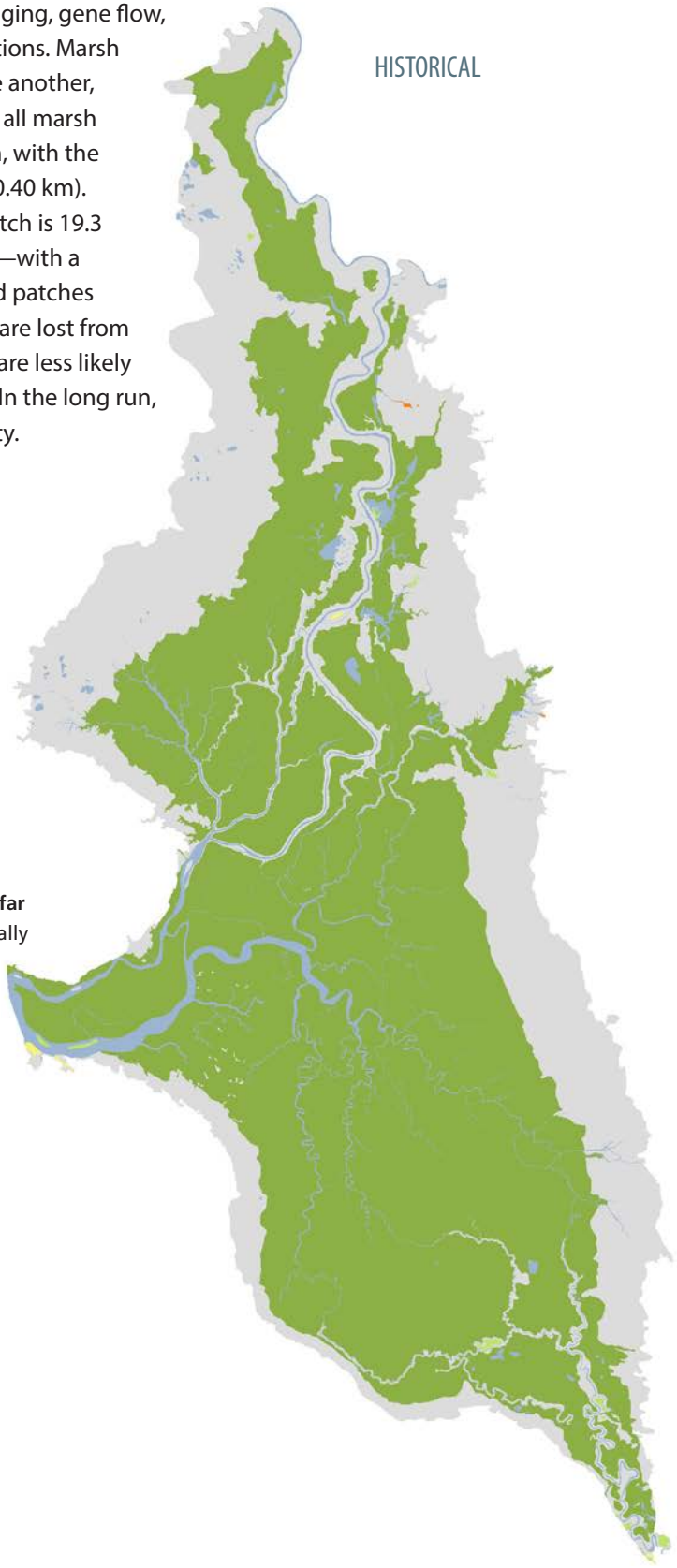


Today there are hundreds of tiny marsh patches scattered throughout the Delta (above), each represented here with a circle indicating the extent of each individual patch. Most of these are fringing marshes along channels or the tips of former large marsh islands. These scattered small remnants were cut off by the excavation of levees and widening of channels over a century ago. For example, the area outlined in grey above shows what was once a continuous historical marsh island that is now fragmented into small pieces.

Existing marshes are isolated

Average distance from a marsh patch to the nearest large marsh has increased more than 50-fold

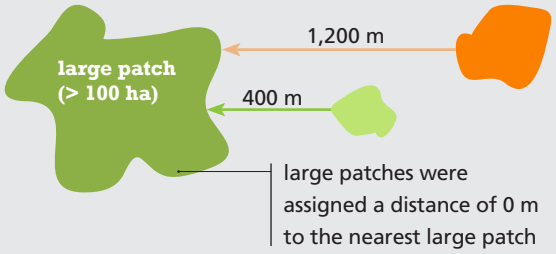
Continuous marsh habitat is essential for dispersal, foraging, gene flow, and resilience to disturbance for marsh wildlife populations. Marsh patches in the modern Delta are now isolated from one another, fragmenting populations of marsh wildlife. Historically, all marsh patches were within 1.62 km of a large (>100 ha) marsh, with the average distance to a large patch being 0.29 km (SD = 0.40 km). In the modern Delta, the average distance to a large patch is 19.3 km (SD = 11.08 km)—two orders of magnitude farther—with a maximum distance of 61.4 km. Wildlife in small, isolated patches are less likely to disperse successfully. Populations that are lost from these patches due to catastrophic or stochastic events are less likely to be re-established due to low re-colonization rates.[18] In the long run, isolated and small populations can lose genetic diversity.



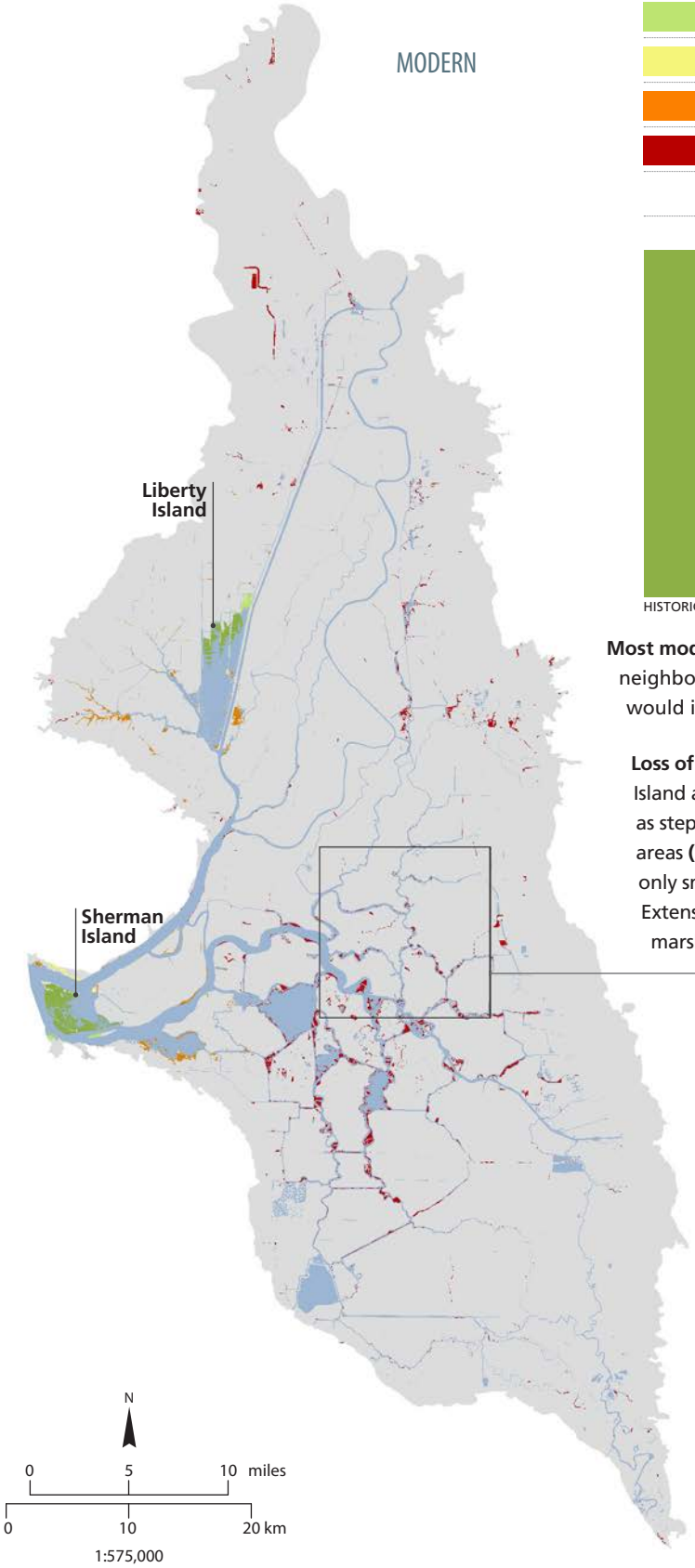
Patterns within the historical (right) and modern landscape (far right). Historically, marsh patches were close together (generally within 1 km). This landscape configuration allowed wildlife movement to maintain diversity within these small patches. Large marsh patches were separated from one another by wide stretches of river or associated riparian forest. In the modern Delta, marsh patches are significantly smaller, and more isolated.

Methods: Nearest large neighbor distance

Measuring each patch's distance to another patch of at least 100 ha

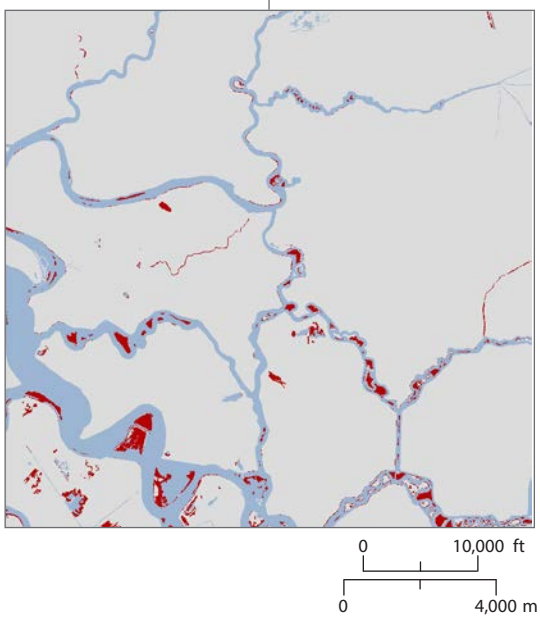


Distance from nearest large neighbor (m)	Total area (ha)	
	Historical	*Modern*
<= 100 m	192,523	1,161
100 - 500	500	143
500 - 1,000	169	87
1,000 - 10,000	32	630
>10,000	0	2,317
TOTAL	**193,224**	**4,338**



Most modern marsh patches are isolated from significantly sized neighbors **(above)**. Creation of larger marsh patches in the Delta would increase habitat value for the surrounding marshes.

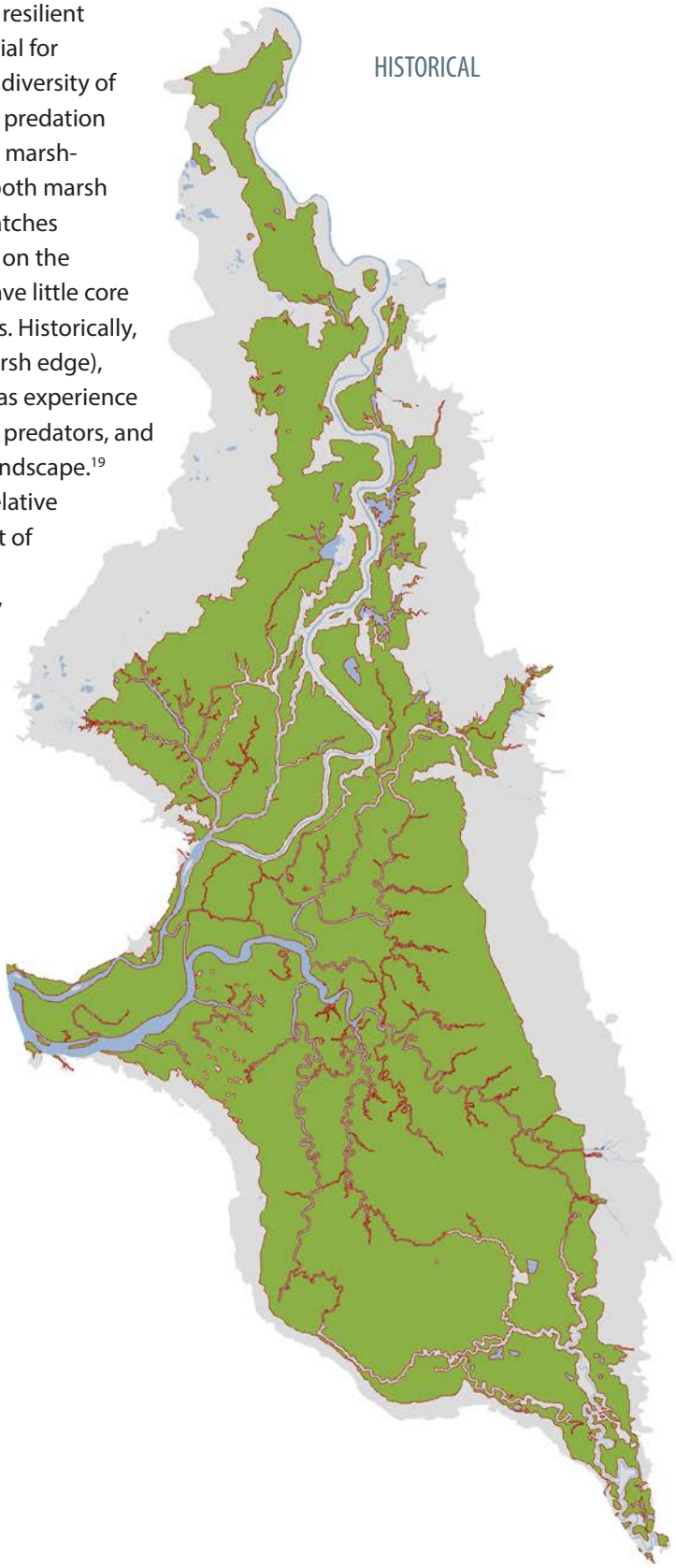
Loss of connectivity. There are few marsh patches between Liberty Island and Sherman Island (today's largest patches) that might serve as stepping stones for movement of wildlife between these two areas **(left)**. In the Central Delta, the patches that do exist are not only small, but are also isolated from the large patches **(below)**. Extensive areas of the south and north Delta are largely devoid of marsh.



Existing marshes have little core habitat

This configuration leaves marsh wildlife vulnerable to edge effects

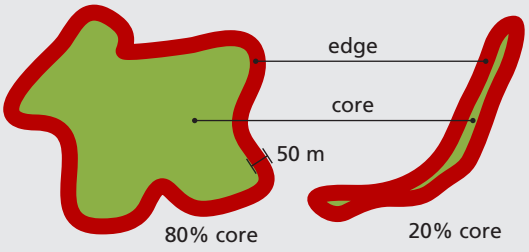
Large areas of core habitat are necessary for sustaining resilient marsh wildlife populations. While edges can be beneficial for wildlife populations—providing transition zones and a diversity of habitats—an increased edge-to-area ratio can increase predation and limit the value of core marsh areas. Historically, the marsh-channel edge was an important zone of exchange for both marsh and aquatic wildlife. Today, the small, isolated marsh patches with vastly altered hydrology have much less influence on the surrounding aquatic habitat. Modern marsh patches have little core area due to their small size and high edge-to-area ratios. Historically, 93% of the marsh was core habitat (>50 m from the marsh edge), while only 19% of marsh is core habitat today. Core areas experience different abiotic conditions, are less accessible to many predators, and are buffered from human disturbance in the modern landscape.[19] Fragmentation and development have increased the relative amount of edge habitat, although the absolute amount of marsh edge habitat in the Delta has been reduced. The character of the marsh edge has also been dramatically altered at both the upland and aquatic interfaces.

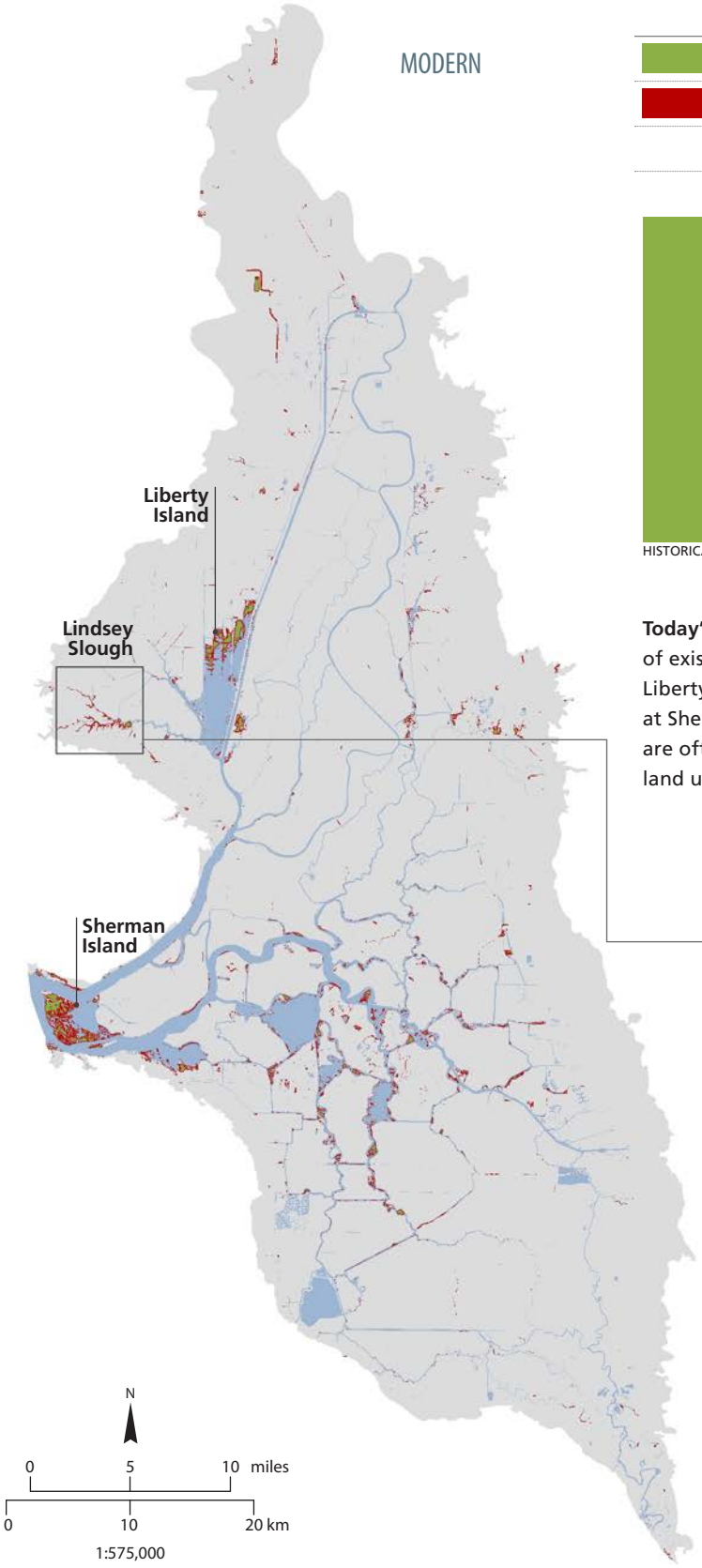


Historical (right) and modern (far right) extents of core marsh area. Historically, marsh edges transitioned to a tidal channel, riparian forest, seasonal wetland, or upland patch. In the modern Delta, edges are often steep levees, and account for proportionally more area than they did in historical marsh patches.

Methods: Marsh Core vs. Edge Area

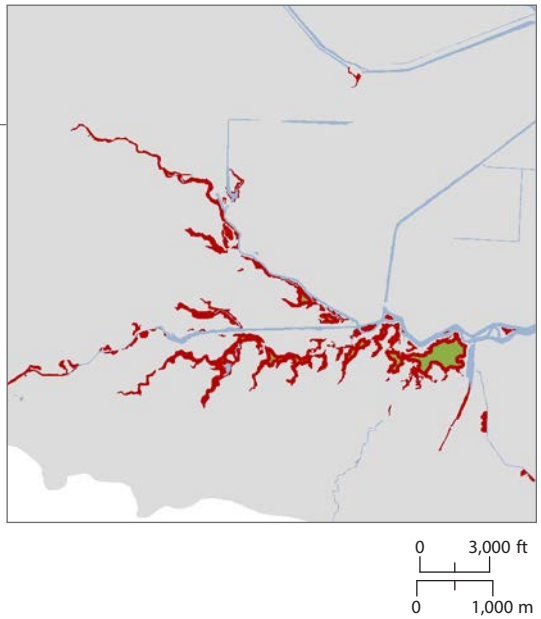
Core area was defined as at least 50 m from the outside edge of the marsh.





	Total area (ha)	
	Historical	*Modern*
Core	179,504	815
Edge	13,720	3,522
TOTAL	**193,224**	**4,338**

Today's marsh habitat is mostly edge (left and above). Over 80% of existing marsh is edge area. The two large marsh patches at Liberty Island are 38% and 56% core area. The large marsh patch at Sherman Island is 34% core area. In the modern Delta, edges are often hard structures such as levees, roads, or agricultural land uses. There has been a 99.5% decline in core marsh area.

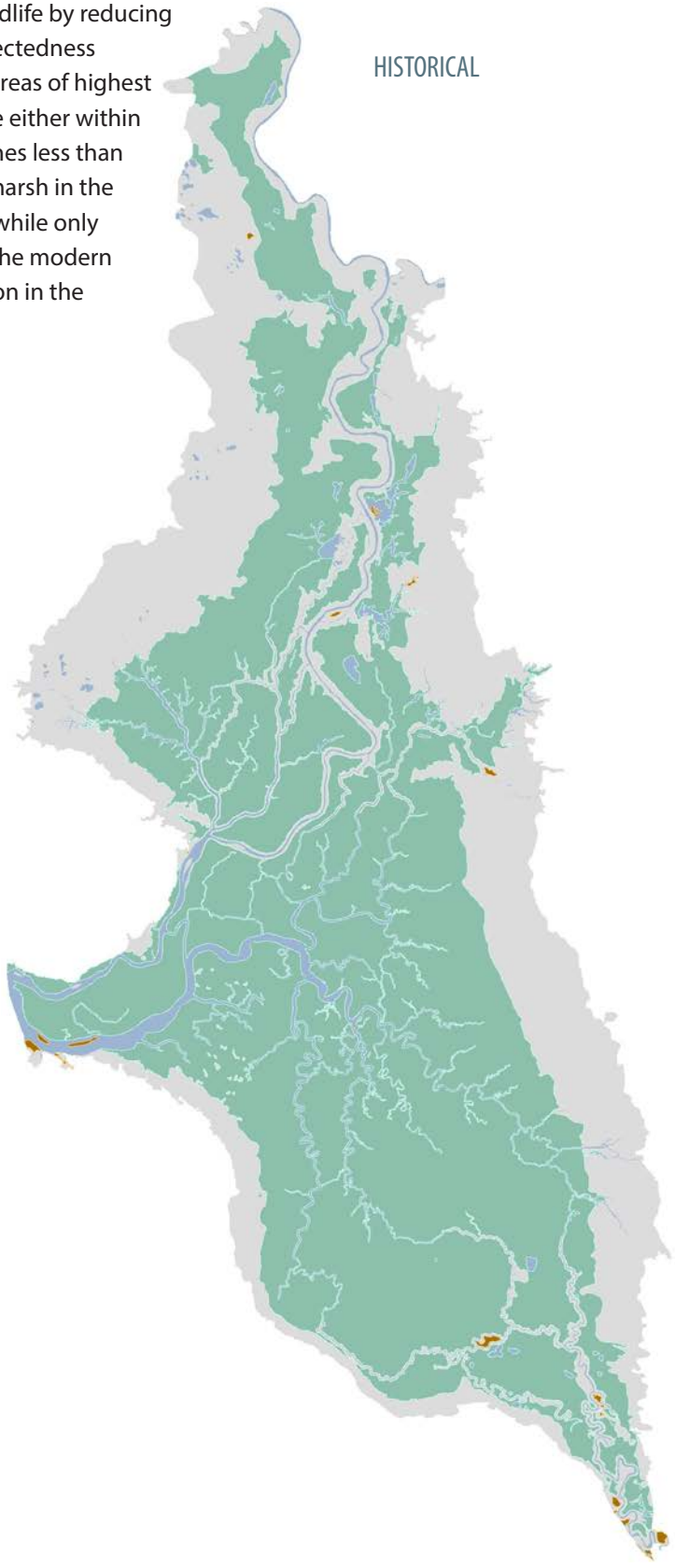


Lindsey Slough (above) is one of the largest remaining patches in the Delta (second only to Liberty and Sherman islands), but its long linear shape (14% core area) makes this marsh vulnerable to edge effects.

There are no modern analogues to the historical large, complex marshes

Even the highest quality remaining marsh patches are highly modified

Fragmentation has decreased the value of marsh to wildlife by reducing the size of marsh patches available, reducing the connectedness between marsh patches, and increasing edge effects. Areas of highest value to marsh wildlife are areas of core habitat that are either within large marsh patches (>100 ha) or are within small patches less than 1 km from a large marsh patch. Nearly all of historical marsh in the Delta met this criteria historically (179,495 ha or 93%), while only 491 ha (0.25% of the historical marsh area and 11% of the modern marsh area) meets this criteria today—a 99.7% reduction in the extent of high quality habitat.



Methods: High value marshes

Combining the previous metrics, we can define areas of highest value to marsh wildlife as areas of core habitat that are either within large marsh patches (>100 ha) or are within smaller patches that are near (<1 km) large marsh patches.

The largest current marsh patches are at Sherman and Liberty islands **(below)**. Marshes in both areas were recently formed as a result of levee failures and dredge disposal. The plant communities and channel networks at these sites differ from historical conditions as a result of the site histories.

CORE HABITAT	EDGE HABITAT	**Fragmentation index for historical and modern maps**
		Large (>100 ha) marsh patches (more likely to sustain persistent populations)
		Marsh near (<1 km) to large marsh patches (areas more likely to be recolonized and maintain gene flow)

MODERN

Liberty Island

Sherman Island

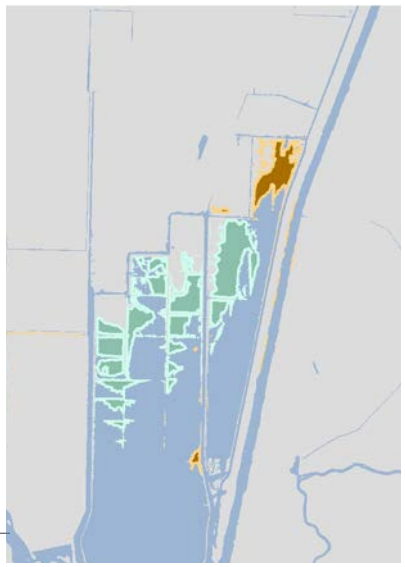
N

0 5 10 miles

0 10 20 km

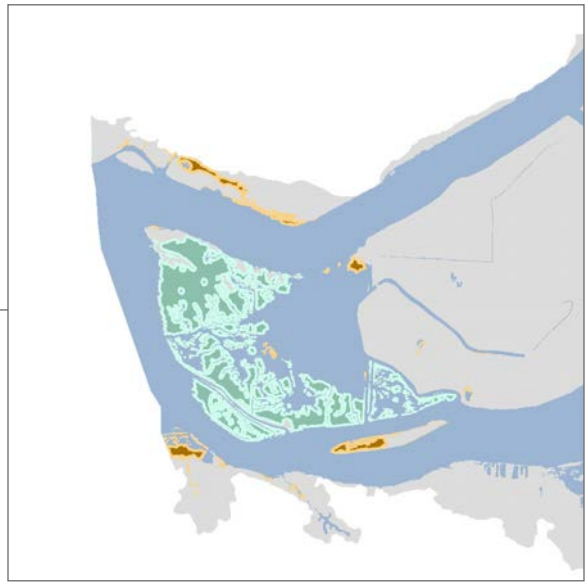
1:575,000

Liberty Island marsh (right) formed after an accidental levee failure in 1998. This marsh, which is adjacent to the Yolo bypass, is bisected by levees and artificial channels, making it very different from the tule-dominated marsh native to this area that had very few channels. However, Liberty Island displays important features of the historical Delta, including high residence time, high suspended sediment concentration, and large marsh area.



0 6,000 ft

0 2,000 m



0 6,000 ft

0 2,000 m

Sherman Island (above) was flooded when its levees failed in the early 1900s. This marsh sits at the brackish (saltier) extreme of the salinity gradient within the Delta. The site was used for the deposition of dredge spoils until the 1960s.[20] Although it is large compared to other patches, it has lots of aquatic edge surrounded by invasive aquatic plants, has few distinct marsh channels, and sits at a low elevation in the tidal frame.

6. Life-History Support for Waterbirds

The historical Delta was important to many species of waterbirds, and supported both wintering and breeding birds. Waterbirds in the Delta included ducks, geese, swans, shorebirds, grebes, cormorants, bitterns, egrets, herons, ibises, rails, and terns.[1] The wetlands of the Central Valley, including the Delta, were associated with extraordinarily high concentrations of wintering waterfowl (ducks, geese, and swans). These wetlands also supported smaller but significant populations of breeding waterfowl, particularly dabbling ducks. The Delta provided year-round support to herons, egrets, and cormorants that nested and roosted in riparian trees and foraged in the extensive adjacent marshes. Coots, moorhens, and grebes likely inhabited the marshes and open waters of the Delta year-round, and Forster's Terns and Black Terns likely nested within the marsh. Waterbird species, such as cranes and shorebirds, which now rely on managed wetlands and flooded agricultural fields, likely took advantage of suitable habitats in the historical Delta, although their exact historical habitat associations are unclear.[2]

Large numbers of waterfowl—an estimated 35-50 million birds—overwintered in the Central Valley historically.[3] This area was a key stopover along the Pacific Flyway, a north-south migration route of global importance for waterfowl and other birds. While the relative value of the Delta among these Central Valley wetlands is unclear, reports from early explorers attest to the abundance of waterfowl within the Delta.[4] Migratory waterbirds adapt to changes in the landscape at a large scale, so the relative importance of Suisun, the Delta, and the Central Valley may have varied over time in response to changes in weather, water conditions, and food availability.[5] Modern waterfowl management focuses on the importance of seasonal wetlands because of the relative abundance of moist-soil seeds in these habitats compared to permanently flooded and tidal wetlands.[6] However, historically the low seed density in tidal wetlands may have been offset by the extensive acreage, leading to high total seed abundance.[7] Other food resources, including rhizomes, may also have been more important to wintering waterfowl using the historical Delta.

Different species of wintering waterfowl likely keyed in on different food resources and habitats within the Delta. Wintering waterfowl common in the Delta historically included Tundra Swans, Snow Geese, Ross' Geese, Greater White-fronted Geese, Canada Geese, Northern Pintails, Mallards, American Wigeons, Green-winged Teals, Northern Shovelers, Gadwalls, and Canvasbacks.[8] Emergent aquatic plants, submerged aquatic vegetation, moist-soil seeds, and invertebrates were all important food sources to these waterfowl.[9] Water depth in channels, lakes, and ponds determined which species could forage most efficiently, with dabbling ducks such as Northern Pintail preferring shallower water and diving ducks such as Canvasback preferring deeper channels and ponds. Swans foraged primarily on submerged aquatic vegetation, while geese grazed in seasonal wetlands and adjacent uplands and also fed on tuberous plants in wetter areas.[10] Waterfowl were unlikely to have foraged in areas of dense tules.[11] However seasonal and perennial lakes within the Delta, along with smaller ponds embedded within the marsh, were known to have supported high densities of waterfowl historically.[12] Regular disturbance via flooding, wildlife

Waterbirds (below). Left to right: Northern Pintail, Sandhill Cranes at Merced NWR, geese migration, Mallards.

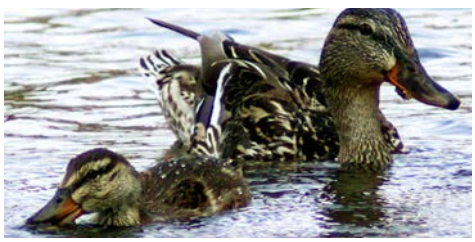
Photo Credits: Unknown, USFWS; Lee Eastman, USFWS; Unknown, USFWS; Scott Flaherty, USFWS

wallows, and burning helped maintain these open water habitats. Geese themselves helped to maintain these ponds by clearing large areas of aquatic vegetation.[13]

Migrating shorebirds using the Pacific Flyway also undoubtedly took advantage of wetland habitats within the Delta, although records of particular species are lacking. Some shorebirds may also have bred in the Delta. Habitats frequently used by shorebirds in the modern Delta (e.g., wastewater treatment facilities, agricultural fields) are without historical equivalents. The sparse extent of mudflats in the central Delta historically, in contrast to the neighboring San Francisco Bay, would have limited shorebird use there. Shorebirds likely took advantage of what mudflat was available in the Cache Slough area and the short-statured vegetation in wet meadows, seasonal wetlands, and grasslands along the periphery of the Delta.[14] Available shorebird habitat historically would have shifted in time and space as water levels changed. Curlews and ibises likely foraged in grasslands and vernal pools.[15] Sandhill Cranes typically forage in low vegetation lacking shrubs and trees that might block their view of predators, and may have also used these habitats.[16] Avocets and stilts may have nested in the Delta, particularly in areas of marsh dominated by low rushes and grasses in the south Delta.[17]

The Central Valley was an important area for breeding waterbirds historically. Duck species that bred in the Delta included Mallards, Gadwalls, Cinnamon Teals, Northern Pintails, and possibly Redheads and Canvasback.[18] Upland areas adjacent to the marsh, or higher areas (like beaver and sand mounds within the marsh), offered nesting opportunities above flood waters.[19] Areas of open water within or adjacent to freshwater emergent marsh were used as brooding habitat for young birds. Waterfowl may have moved a considerable distance between nesting and brooding sites, particularly when nesting occurred in brackish areas, such as Suisun Marsh.[20] Freshwater marshes were also important post-breeding sites for molting birds. Many species of waterfowl molt all their primary flight feathers simultaneously, rendering them temporarily flightless, and the tall, dense vegetation in these wetlands provided critical cover to these vulnerable birds.[21] Riparian forests provided nesting opportunities for cavity-nesting Wood Ducks and supported large rookeries of herons, egrets, and cormorants.[22]

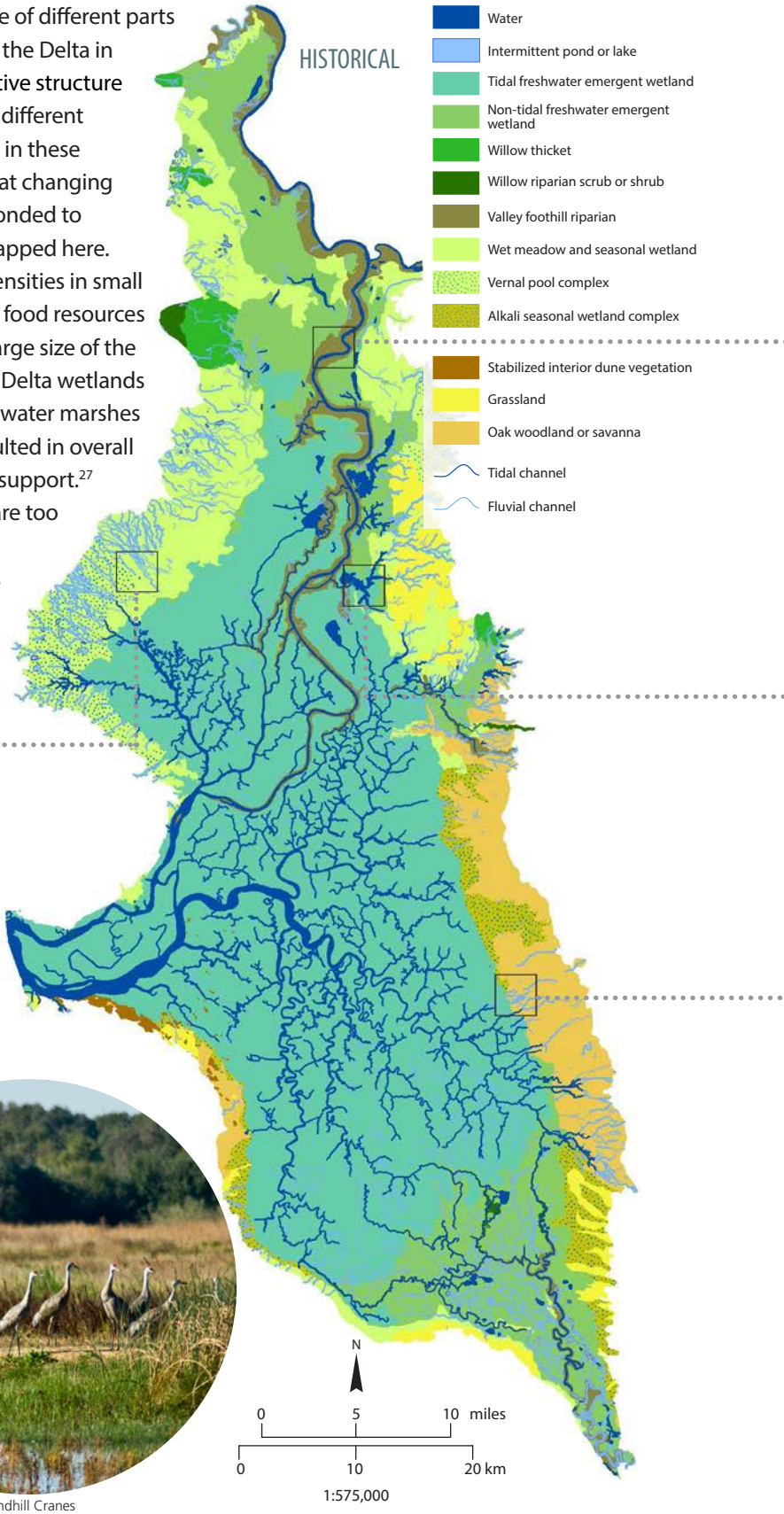
The modern Delta provides less support for waterbirds due to the extensive loss of wetland habitat. Managed wetlands and agricultural fields are key components of the modern landscape for both wintering and breeding waterbirds, as natural wetlands no longer provide adequate space or food resources for wintering waterfowl.[23] Although these managed habitats are now crucial for waterbirds they differ from historical wetland habitats in several important ways. Grain crops provide food resources that are carbohydrate-rich but sometimes nutrient-poor, and these areas lack the invertebrate communities important for particular species at certain times of year.[24] Management is often focused on supporting particular threatened and endangered species, such as Sandhill Cranes, or supporting economic interests, such as duck clubs, and may provide less support for non-target species. Water quality within flooded agricultural fields can be affected by fertilizers and pesticides. In addition, some modern waterfowl habitat may be increasingly threatened by levee failure or water shortages.[25] Restoring wetlands has the potential to shift waterbird support back to natural areas. This support is likely dependent on the size of restored areas.



Delta wetlands supported large numbers of waterbirds historically

Variable conditions in the Delta provided support for different waterbirds in different seasons

Different waterbirds species were able to take advantage of different parts of the Delta throughout the year. Waterfowl wintered in the Delta in particularly high numbers.[26] The combination of vegetative structure and flooding patterns determined habitat suitability for different waterbird species. There was a high degree of variability in these habitats, with the amount and location of suitable habitat changing significantly from one year to the next. Waterbirds responded to landscape heterogeneity on a finer scale than can be mapped here. For example, wintering waterfowl were found in high densities in small ponded areas within freshwater marshes. The abundant food resources and protection from predators were due in part to the large size of the Delta wetlands. Although waterfowl food density in the Delta wetlands may have been lower than in intensively managed freshwater marshes today, the large historical extent of marshland likely resulted in overall food supplies that rivaled or exceeded the modern-day support.[27] The remaining natural marshes and seasonal wetlands are too small to support abundant waterbirds, and thus in the modern Delta managed wetlands and agricultural fields provide most of the habitat value for waterbirds.



SANDHILL CRANES

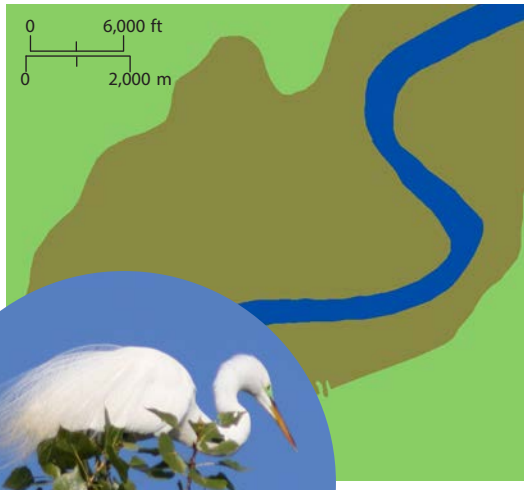
The Delta was an important wintering location for Sandhill Cranes. Areas of shallow water and short vegetation likely provided good roosting areas with easy detection of predators. Seasonal wetlands around the edge of the Delta offered this type of habitat historically.[28]

Sandhill Cranes

Photo Credits (left to right): Justine Belson, USFWS; Linda Wanczyk, SFEI; Charles Sharp, Wikipedia Commons; Dan Cox, USFWS

COLONIAL ROOSTING BIRDS

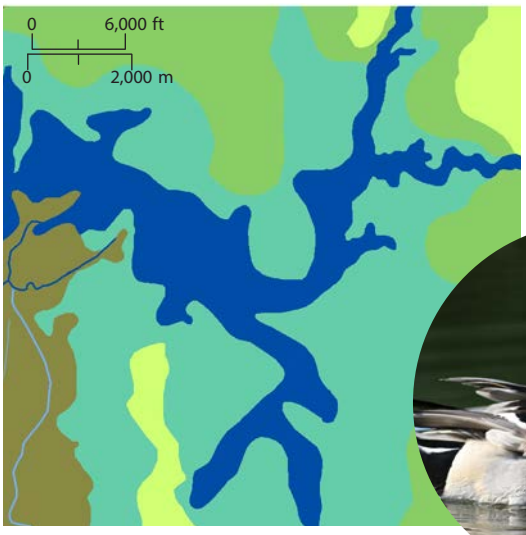
Colonies of herons, egrets, and cormorants used large trees in the riparian forests of the north Delta for roosting and nesting.[29]



Roosting heron

WINTERING WATERFOWL

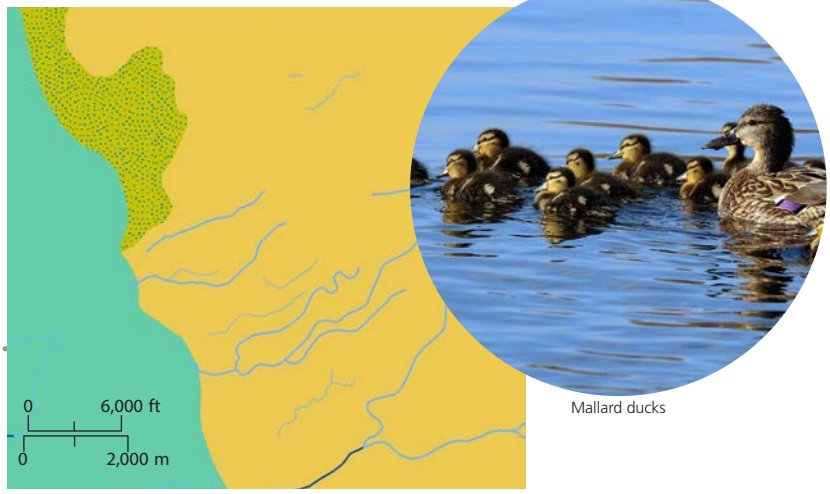
Wintering waterfowl congregated in large numbers in areas of open water within freshwater marsh. Common species included Northern Pintails, Snow Geese, Ross' Geese, and Tundra Swans. Seeds and tubers of marsh plants were particularly important food resources for these species.[30]



Northern Pintail

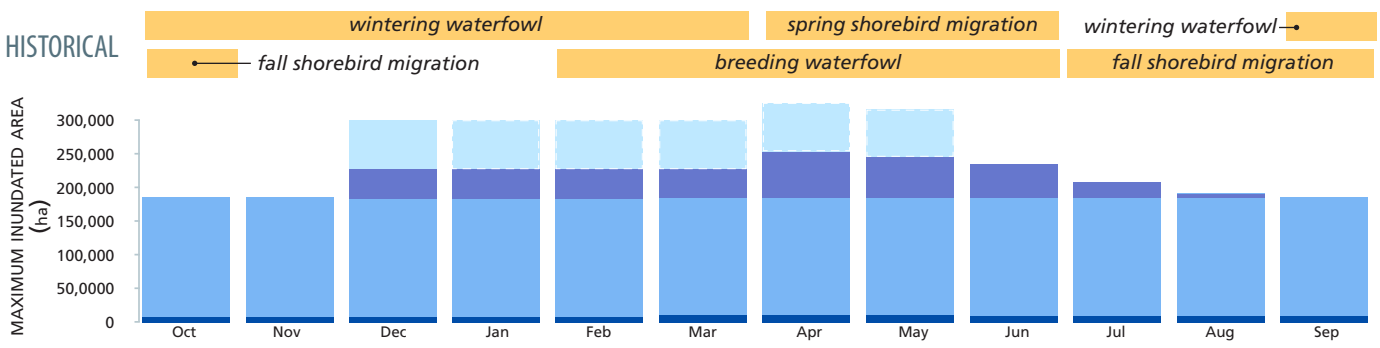
BREEDING DUCKS

Several species of dabbling ducks, including Mallards and Gadwalls, bred in the Delta in significant numbers. Areas of higher elevation, above flood waters, were critical for nesting. Areas of open water with nearby vegetative cover were needed for brooding birds.[31]



Mallard ducks

Flooding in the historical Delta (below). The diagram below relates flooding in the historical Delta (see details and legend on page 40) with patterns of waterfowl and shorebird use.[32]



7. Life-History Support for Riparian Wildlife

Woody riparian habitats form the interface between aquatic environments and adjacent areas, providing structurally complex environments that support diverse species. Historically, broad riparian forests and willow shrubs, elevated on natural levees, lined the Sacramento and San Joaquin rivers and their major tributaries. These habitat types were shaped by hydrologic and geomorphic disturbance: floods built up natural levees and stimulated successional processes of riparian forests. These natural levees extended far into the marsh, providing dryland access deep into the Delta's marshes for terrestrial species.[1] The vertical structure and plant diversity of riparian forests provided abundant food resources and sites for numerous resident and migratory birds to forage, nest, and roost.[2] The woody vegetation also provided shade and contributed allochthonous inputs to the river that supported aquatic species, including anadromous fish.[3]

There was considerable heterogeneity within woody riparian habitats, particularly between riparian forests in the north and south Delta. Riparian forests historically were largely confined to the north and south Delta because of the Sacramento and San Joaquin rivers' loss of stream power and ability to build large natural levees as they entered the central Delta. In the north Delta, riparian vegetation consisted of broad riparian forests dominated by oaks and sycamores, often a half mile wide, with a multilayered and diverse understory composed of willow, alder, buttonbush, dogwood, box elder, buckeye, grape, wild rose, and numerous herbaceous species. Riparian areas along the San Joaquin River were narrower and dominated by willows and other shrubs. There was considerable lateral and upstream/downstream heterogeneity within these habitats. Vegetation varied with the elevation of natural levees, with the highest areas supporting large trees, while the wetland and channel edges supported willows and grasses. Compared with areas farther upstream, the downstream reaches of woody riparian habitats were narrower and increasingly dominated by willows and marsh vegetation. Vegetative structure was influenced by channel size, with larger channels often supporting more extensive woody riparian habitat, due to the larger size of their natural levees. Willow-fern complexes in the central Delta may have also provided some support to riparian species, though they differed in habitat structure and continuity from other riparian habitat types.[4]

Despite comprising only a small proportion of the total area of the historical Delta (7%), riparian forests provided important habitat for a diverse suite of species. Woody riparian habitats likely served as movement corridors for far-ranging terrestrial mammals such as coyotes and mule deer as well as smaller mammals including gray fox, long-tailed weasels, and ringtails.[5] The south Delta forests provided important habitat for several endemic species, including the riparian brush rabbit, riparian woodrat, and valley elderberry longhorn beetle.[6] Riparian forests in the Central Valley were particularly important to both resident and migratory birds, supporting a diverse and abundant assemblage of species.[7] These forests contained high densities of breeding birds compared to other habitats, and provided nesting habitat for Red-shouldered Hawks, Swainson's Hawk, Western Yellow-billed Cuckoos, Willow Flycatchers, Least Bell's Vireos, Yellow Warblers, Yellow-breasted Chats, and Blue Grosbeaks.[8]

Riparian forests offered many nesting niches—on the ground, in shrubs and trees, on branches, and in tree cavities. Forests dominated by large oaks and sycamores were particularly important to cavity nesters, including Wood Ducks, Downy Woodpeckers, Oak Titmouse, and Ash-throated Flycatchers. Large riparian trees supported breeding and roosting colonies of herons, egrets, and cormorants. Oak-dominated riparian habitat supported high densities of wintering birds, especially Sharp-shinned Hawks, Hermit Thrushes, Yellow-rumped Warblers, and Golden-crowned Sparrows.[9] These habitats were also used by passing migrants, and may have been especially important to fall migrants that glean insects (e.g., Wilson's Warblers, Western Tanagers) because other green, insect-rich vegetation was sparse at that time of year.[10]

Existing woody riparian habitat occupies 40% of its historical extent, but these areas are now severely fragmented, with virtually no wide corridors of riparian forest remaining. Today's narrow patches are structurally simpler and more homogeneous than historical woody riparian habitats, often lacking the complex microtopography, moisture gradients, vegetative structure, and diversity which provided essential ecosystem services, such as erosion control and riparian forest regeneration.[11] As mapped, 90% of historical Delta woody riparian habitat was riparian forest; today only 58% is forest, and the rest is willow shrub habitat.

Riparian species once common in the Delta are in decline. The endangered Western Yellow-billed Cuckoo, Least Bell's Vireo, and other species no longer breed in the Delta.[12] The decline in nesting Cooper's Hawks and Western Yellow-billed Cuckoos is thought to be a direct result of the loss and fragmentation of available habitat, as both species require large territories to breed.[13] Riparian species have been impacted by degraded habitat quality, that is often hydrologically disconnected from adjoining rivers. Agricultural development adjacent to woody riparian habitats has facilitated movement of non-native Brown-headed Cowbirds and European Starlings into these habitats, negatively impacting native birds through nesting cavity competition and reduced nest success.[14] Levees (with hardened edges and lack of regeneration from flooding) adjacent to woody riparian habitats have allowed non-native predators (feral dogs, cats, and rats) increased access to these habitats, to the detriment of riparian brush rabbits, riparian woodrats, and other species.[15] Riparian brush rabbits have also been impacted by the lack of suitable habitat above regular flood levels that previously provided protection from weather and predators.[16]

The position of woody riparian habitats within the modern Delta landscape has become less coherent. Whereas woody riparian habitat historically lined large rivers and tributaries in continuous bands, today small disconnected riparian patches exist scattershot across the entire Delta, including the central Delta where these habitats were historically absent. In many instances "riparian habitats" are separated from the rivers that created them by artificial levees and upland areas, and are thus disconnected from the physical processes sustain them. Restoration of continuous, self-sustaining woody riparian habitats in the Delta may be particularly important in the face of climate change, because these habitats provide linear habitat connectivity, link aquatic and terrestrial ecosystems, and create thermal refugia for wildlife.[17]

Riparian wildlife (below). Left to right: riparian brush rabbit, riparian vegetation, long-tailed weasel, male valley elderberry longhorn beetle, coyote.

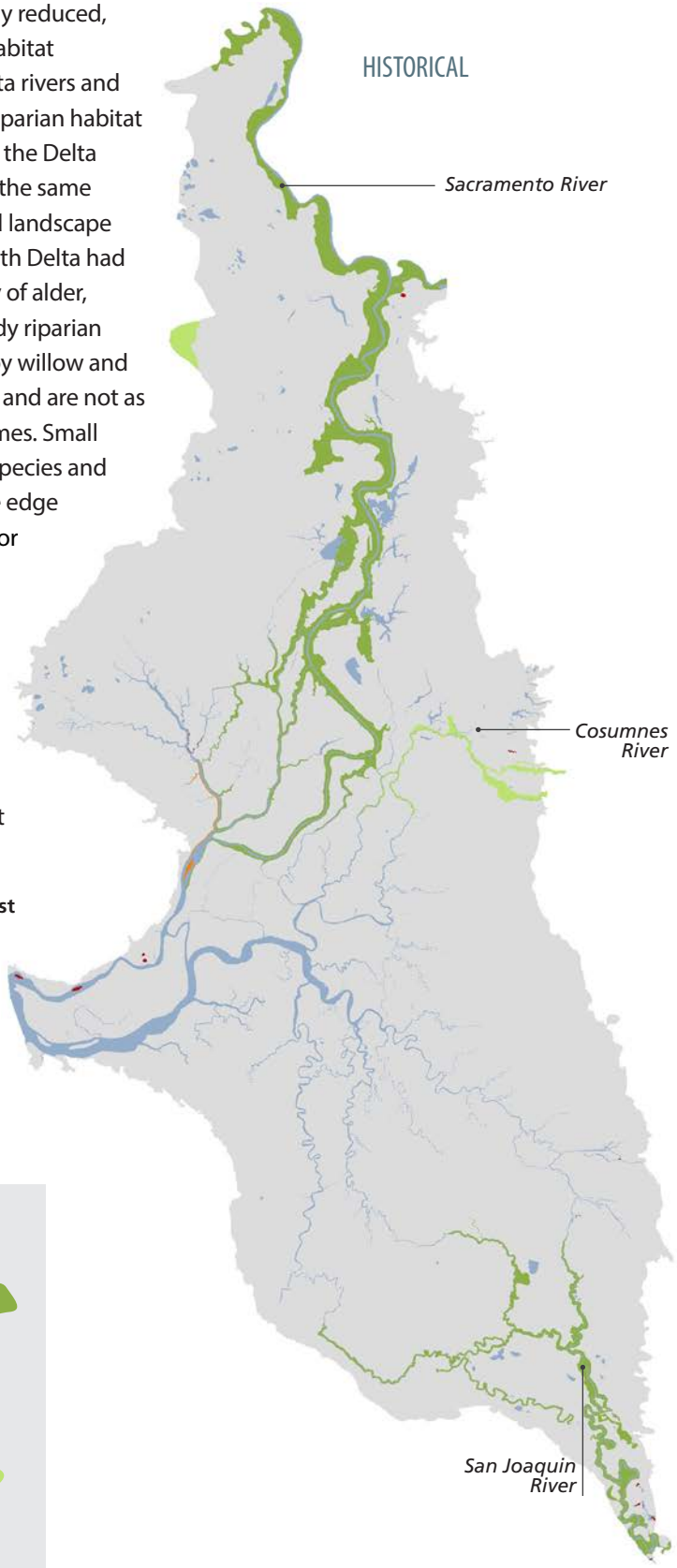
Photo Credits: Brian Hansen, USFWS; William Miller; Rick Kimble, USFWS; Jon Katz and Joe Silveira, USFWS; Steve Thompson, USFWS

Modern woody riparian habitat is highly fragmented

Large, continuous riparian forest is gone, except along the Cosumnes River

The woody riparian habitats in the Delta today are severely reduced, fragmented, and degraded. Historically, woody riparian habitat existed as large continuous corridors along the major Delta rivers and tributaries in the north and south Delta. Modern woody riparian habitat is a scattering of small discontinuous patches throughout the Delta that no longer support resident and migratory species to the same degree, due to differences in habitat quantity, quality, and landscape configuration. Historical gallery riparian forests in the north Delta had canopies of oak and sycamore with a complex understory of alder, willow, blackberry, and many other species. Modern woody riparian habitats are smaller, simpler systems, largely dominated by willow and invasive understory plants associated with narrow levees, and are not as exposed to regenerative disturbance regimes. Small habitat fragments support fewer species and smaller populations with more edge effects. Researchers found, for example, that Western Yellow-billed Cuckoos in northern and southern California are six times more likely to be found in habitat patches 40-80 ha than patches 20-40 ha (they were detected in all habitat patches larger than 80 ha).[18]

Western Yellow-billed Cuckoo



Historical riparian habitat was predominately continuous forest (right), while today woody riparian habitat is scattered throughout the Delta in small isolated patches (far right). The longest stretch of contiguous riparian forest[19] historically spanned more than 55 km (from the Feather River confluence to Miner Slough), providing a migration corridor across much of the Delta. The longest current stretch of woody riparian habitat extends 16 km (along Elk/ Sutter Slough).

Methods: Riparian patch size

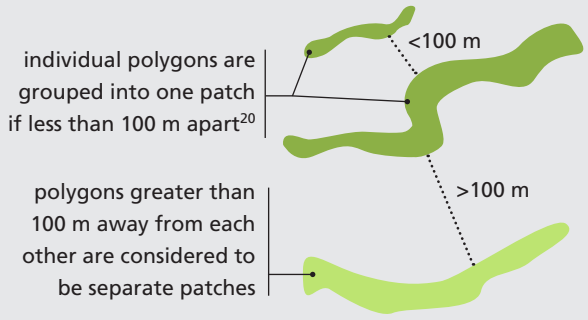
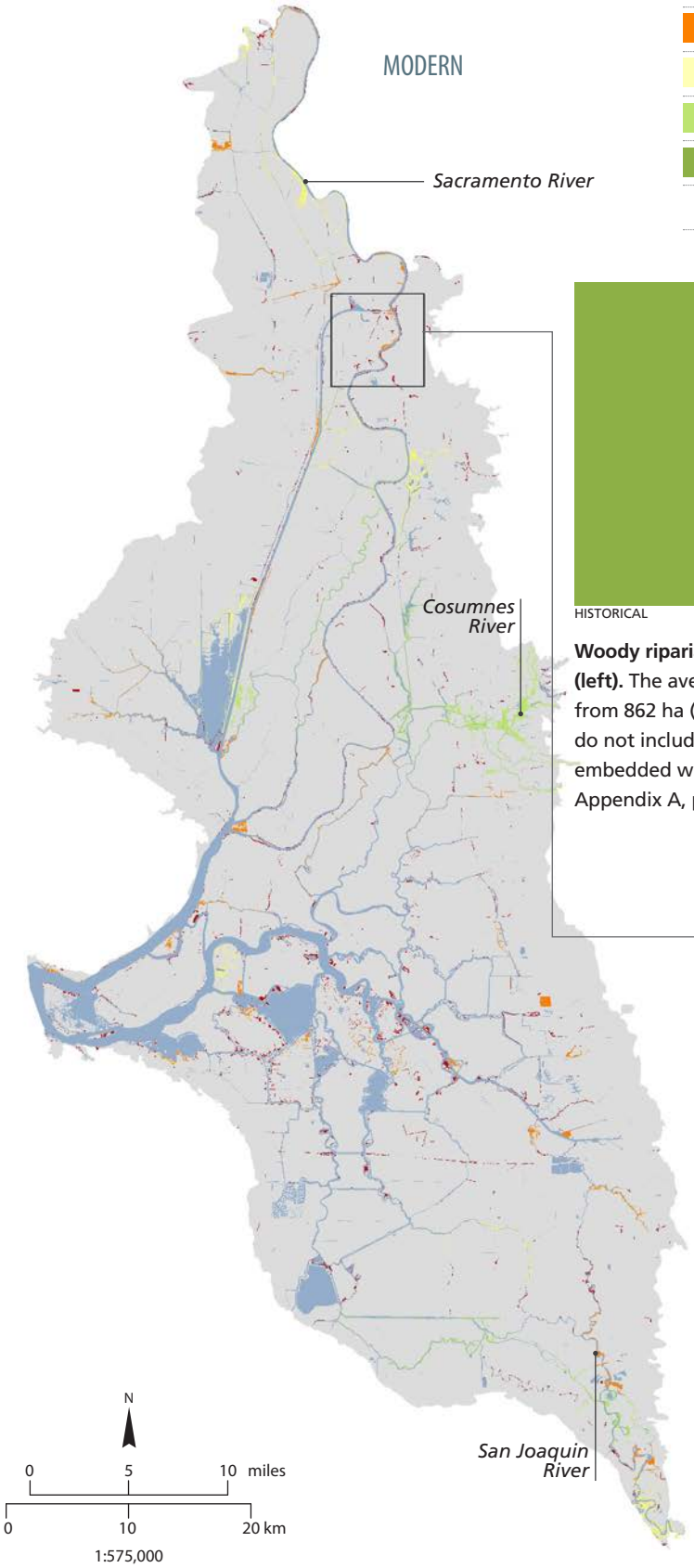
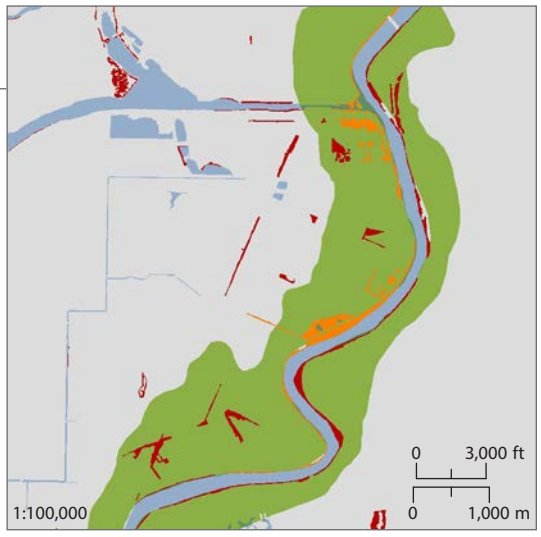


Photo Credit: Factumquintus, Wikipedia Commons

Woody riparian patch size class (ha)	Total area (ha) *Historical*	*Modern*
<= 20 ha	88	1,991
20 - 80	113	1,364
80 - 320	0	1,470
320 - 1,280	1,594	2,066
>1,280	15,449	0
TOTAL	**17,244**	**6,890**



Woody riparian habitat extent in the Delta has been reduced by 60% (left). The average woody riparian patch size in the Delta has decreased from 862 ha (SD = 2,785 ha) to 6 ha (SD = 45 ha). These maps and figures do not include an estimated 3,500 ha of unmapped willow patches embedded within the tule marshes of the historical central Delta (see Appendix A, page 91).

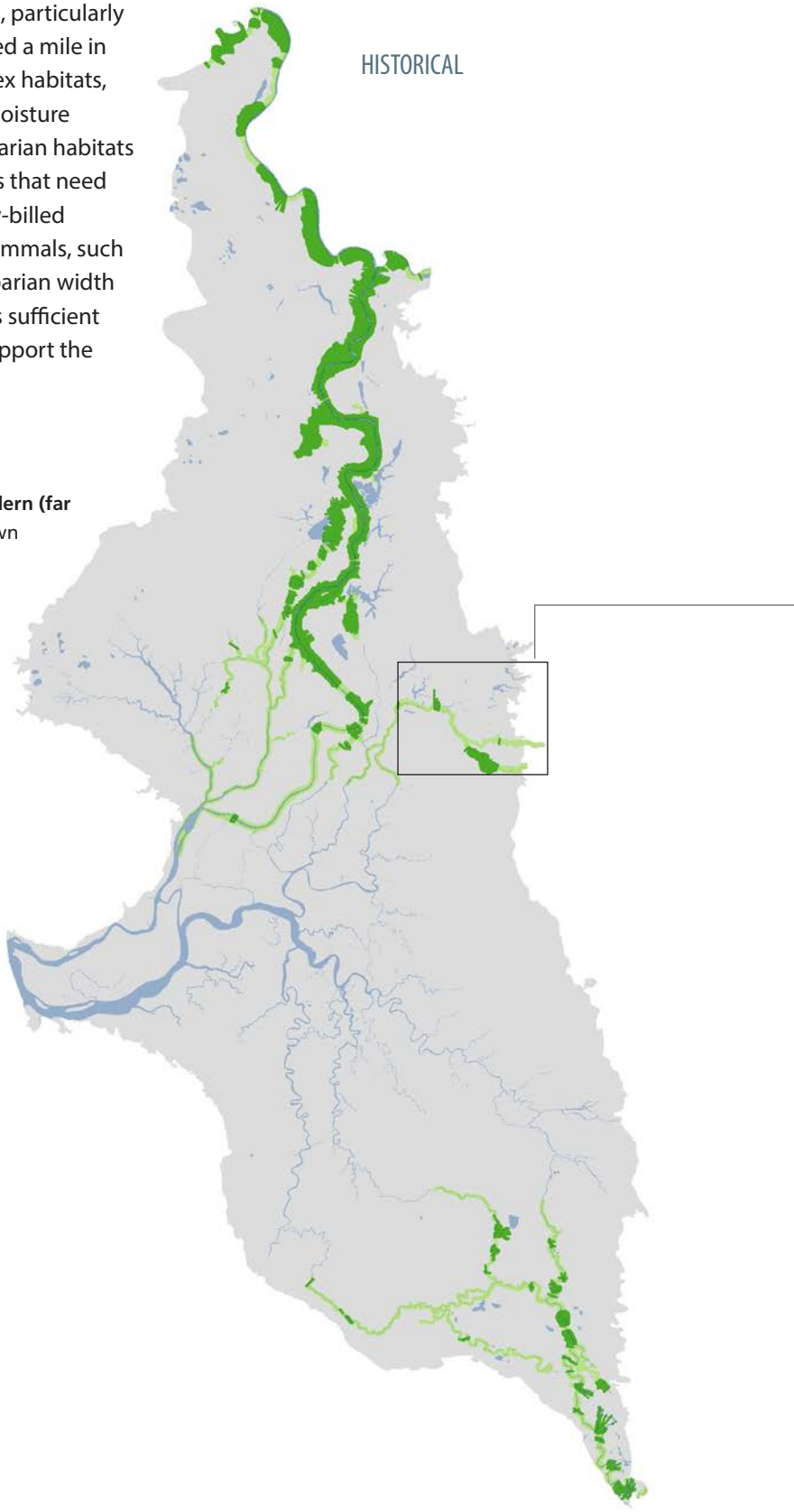


Historically, woody riparian habitat along the Sacramento River formed a wide continuous band of forest—the woody riparian habitat that exists today is made up of many small habitat fragments (above). Historical woody riparian habitat is shown in green with modern woody riparian habitat overlaid in red and orange (depending on their patch size).

Wide woody riparian habitat has declined by 72%

Wide riparian corridors provided habitat complexity and supported species with large home ranges

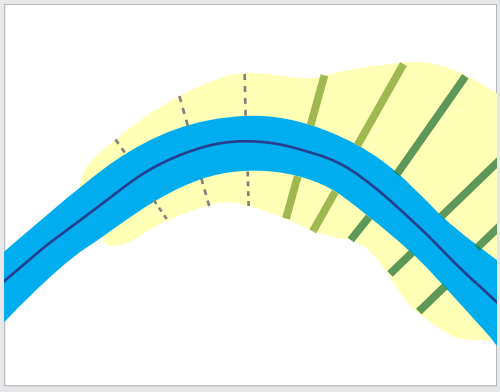
Historically, the Delta contained wide riparian corridors, particularly in the north Delta where the riparian forest could exceed a mile in width. These wide riparian corridors supported complex habitats, with many vegetative zones influenced by elevation, moisture gradients, and disturbance patterns. Interior woody riparian habitats were buffered from edge effects and supported species that need large riparian areas, particularly nesting Western Yellow-billed Cuckoos and Cooper's Hawks, as well as far-ranging mammals, such as coyotes. A review of the literature on the effect of riparian width on birds found that while a riparian width of 100 m was sufficient for many species, a width of 500 m was necessary to support the complete avian community.[21]



Wide woody riparian habitat in the historical (right) and modern (far right) Delta. Woody riparian habitat wider than 500 m is shown in dark green, and habitat wider than 100 m is shown in light green. The width of the riparian habitat was determined by the river's ability to build natural levees above the marsh of the interior Delta, creating well-drained soils that supported trees. In general, the width and height of riparian habitat declined as the large river systems spread into the central Delta.

Methods: Calculating riparian widths

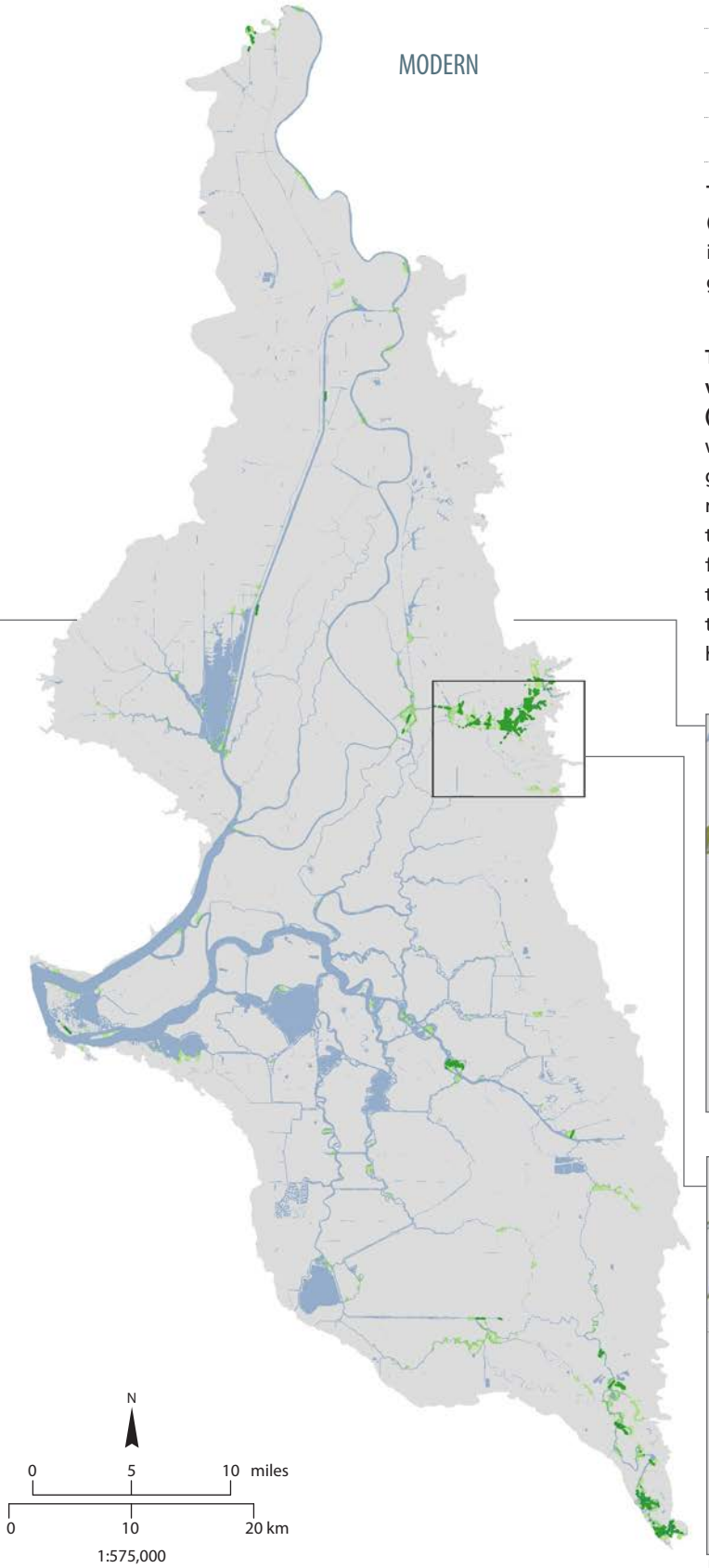
Transects were cast perpendicular to channels at 100 m intervals. The width of each transect was summed (excluding channels) where it overlapped riparian habitat (shown in yellow below). On the map and in the diagram below, transects wider than 100 m are in light green, and transects wider than 500 m are in dark green. Transects less than 100 m wide (dotted lines below) are not shown on the map. See Appendix A for details.

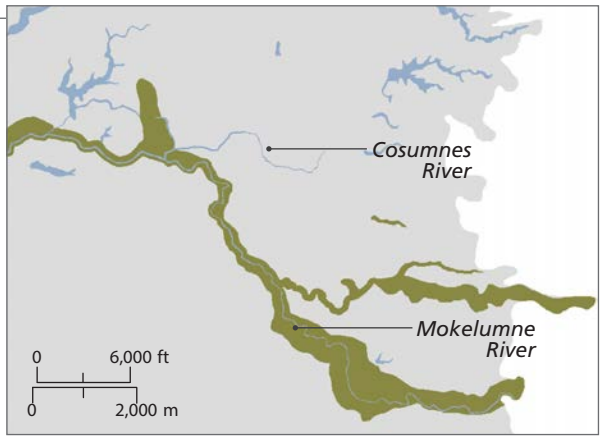


	Woody riparian habitat width (m)	Woody riparian habitat length (km)	
		Historical	*Modern*
NOT SHOWN ON MAP	0 - 100 m	37	626
	100 - 500	239	87
	> 500	116	11
	TOTAL	**393**	**723**

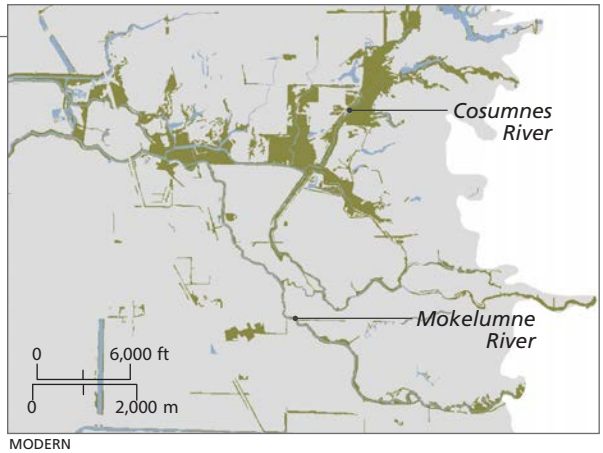
The length of wide riparian habitat has declined. Nearly all (87%) of the woody riparian habitat in the modern Delta is less than 100 m wide, and less than 2% of the habitat is greater than 500 m wide.

The largest cluster of woody riparian habitat >500 m wide is the restored habitat along the Cosumnes River (below). Historically, the Mokelumne River supported wide riparian forest on natural levees. Due to changes in groundwater levels, land use, and channel incision, the majority of woody riparian habitat is now located along the Cosumnes River in an area that historically supported freshwater emergent marsh and wet meadow.[22] However, this wide and complex riparian habitat provides many of the ecological functions that riparian habitat provided historically in other places in the Delta.





HISTORICAL



MODERN

8. Life-History Support for Marsh-Terrestrial Transition Zone Wildlife

The edge (or transition zone) of the Delta marsh provided ecological functions critical for many wildlife groups. The ecological functions of this transition zone varied depending on its position within the Delta. The extensive freshwater emergent marsh was bounded by elevation, with the upslope side transitioning into terrestrial habitats across a broad zone. Seasonal wetlands, including alkali wetlands and vernal pools, were found along the gently sloping upland transition in the northwest and southwest Delta,[1] while grasslands, oak savannas, and woodlands were found along the steeper, well-drained alluvial fans bordering the Delta to the east. The transition zone occurred primarily along the periphery of the Delta, with the exceptions of long corridors of riparian forest extending into the marsh and scattered sand dunes that punctuated the marsh in the southwest Delta. The relatively continuous transition zone along the periphery of the Delta would have supported dispersal and other movement of amphibians and reptiles dependent on both wetland and upland habitats (e.g., giant garter snake, California red-legged frog, and Western pond turtle).[2] Riparian corridors provided predators like bats, weasels, and coyotes with access to abundant prey from the productive marsh.[3] Riparian habitat also provided North American river otters with denning sites near the marsh but above frequently flooded elevations. Sand dunes (isolated upland patches within the Delta) provided important flooding refuge and predator protection.[4] The central Delta consisted of tidal marsh channels that lacked the stream power to build large natural levees, leaving this part of the Delta farther from any terrestrial transition zone.

Habitats occurring next to the marsh varied across the Delta, based on gradients in hydrology, topography, and soil. Along the northwest Delta where slopes were gradual and characterized by heavy clay soils, the marsh transitioned to seasonal wetlands interspersed with vernal pools. These seasonal wetlands were variable and complex, with inundation and vegetation patterns sensitive to small-scale changes in hydrology and topography. Seasonal wetlands in the northwest Delta were inundated by intermittent streams that lost channel definition before reaching the marsh and sometimes by the large floods of the Sacramento River. Along the eastern edge of the Delta the marsh transitioned to alkali wetland and oak savanna. Alkali wetlands, characterized by evaporative salt residues, were found in areas inundated only by extreme flooding. The oak savanna occurred on the well-drained soils of the alluvial fans that bordered the eastern side of the Delta, built by the Calaveras and Mokelumne rivers. To the south where soils were shallower, alkali wetlands were interspersed with grassland habitats. The interior dune scrub found along the southwestern edge of the Delta was a relic of Pleistocene dunes. The width and complexity of the transition zone was greater in areas with more gradual slopes, particularly areas supporting seasonal wetland.[5] These gradual transitions allowed movement and adaptation for particular species along moisture and elevation gradients.

The habitats adjacent to the marsh were key for wildlife in their own right, in addition to the transition zone species they supported. While none of these habitat types were unique to the Delta periphery, their proximity to Delta wetlands benefited the species they supported (e.g., by providing access to freshwater in the summer). The number of different habitat types adjacent to Delta marshes augmented the overall biodiversity of the region. Many of the species once associated with habitats adjacent to marsh are species of concern or otherwise important to land managers within the Delta today. Riparian forests supported migratory songbirds and several protected species of small mammals (e.g., riparian woodrat, riparian brush rabbit).[6] Seasonal wetlands provided habitat for many species of migratory waterbirds and amphibians.[7] Alkali wetlands and vernal pools supported many endemic plants and invertebrates.[8] Grasslands were important to many species now extirpated or uncommon in the Delta, including large mammals, such as grizzly bears, pronghorn, and tule elk.[9] Vernal pools, alkali wetlands, grasslands, and sand dunes are discussed in more detail below because of the number of endemic species they supported and their importance to overall Delta biodiversity.

The terrestrial transition zone was comprised primarily of seasonal wetlands which expanded the availability of wetland and aquatic habitat at certain times of the year. The majority of seasonal wetlands were found bordering the north Delta and encompassed a diverse range of plant communities, perhaps owing to variable inundation frequencies, dry-season dessication, topographic complexity, soil types, and freshwater inputs or "sinks" from tributaries. Vernal pools and alkali complexes were often intergraded with the seasonal wetlands, particularly in the southern parts of the Delta margin where drier conditions promoted the accumulation of salts in soils. When flooded, seasonal wetlands provided connectivity for terrestrial species such the giant garter snake between the nutrient-rich Delta and the surrounding valley, as well as short-term foraging habitat for certain aquatic species.

Vernal pools and alkali seasonal wetlands in particular supported many unique species. Vernal pools tend to support endemic species uniquely adapted to their hydrology. These are ephemeral wetlands characterized by shallow depressions that are inundated for too long to support upland species, but not long enough to support aquatic species.[10] Many vernal pool plants are specially adapted annuals that grow quickly as the ponds dry. Several invertebrates and amphibians use these pools to breed, taking advantage of the lack of predatory fish. Special status species supported by vernal pools included California linderiella, conservancy fairy shrimp, longhorn fairy shrimp, midvalley fairy shrimp, vernal pool fairy shrimp, and vernal pool tadpole shrimp.[11] The alkali seasonal wetlands that characterized much of the periphery of the Delta were complex habitats made up of small brackish ponds, perennially wet alkali marsh, alkali sink scrub, and seasonally inundated alkali meadow.[12] These habitats supported many unique plant species adapted to alkaline conditions, including saltgrass, swamp grass, Delta button celery, popcorn flower, iodinebush, San Joaquin spearscale, and the now potentially extinct caper-fruited tropidocarpum.[13]

The Delta edge (below). Left to right: Suisun Marsh, San Joaquin kit fox, Guadalcanal Mitigation Site, tule elk.

Photo Credits: Daniel Burmester, CDFW; Carley Sweet, USFWS; Gena Lasko, CDFW; Steve Martarano, USFWS

Grasslands were important to a diverse suite of wildlife, many of which are now locally threatened or endangered. Prior to non-native annual grasses establishing dominance, these habitats were believed to be dominated by forbs, with some annual and perennial grasses intermixed.[14] Grassland and savanna habitats were important to far-ranging large mammals that occasionally ventured into the marsh, including grizzly bears, mule deer, and tule elk. These grasslands supported many species of burrowing animals, such as California ground squirrels, California voles, and San Joaquin kangaroo rats, which created topography and structure important to Western Burrowing Owls, giant garter snakes, spadefoot toads, and California tiger salamanders. Swainson's Hawks foraged in grasslands historically.[15] The Meadowlark, Short-eared Owl, Horned Lark, Savannah Sparrow, and San Joaquin kit fox were also associated with these grasslands.[16]

Scattered sand mounds—high points of glacial-age eolian dunes—rose above the marsh plain, adding supra-tidal topographic variation and habitat complexity to the flat terrain of the western Delta. The mounds supported numerous species of plants and animals that would have otherwise been unable to persist within the Delta's tidal environment, such as lupine, the special status Antioch Dunes evening primrose, the western wallflower (Contra Costa wallflower), the endangered Lange's metalmark butterfly, and even live oaks on certain dunes with a developed soil profile. Tule elk were observed to have used these sites as protected breeding and foraging habitat, since the mounds offered some protection from larger predators less likely to venture far into the marsh. These areas of high elevation were also used and sometimes augmented by the indigenous communities who lived in and around the Delta. Sand dunes, as well as large man-made mounds, or middens, were often occupied by village sites, as they were in close proximity to the rich abundance of food and resources provided by the Delta but were protected from daily tidal flooding.[17]

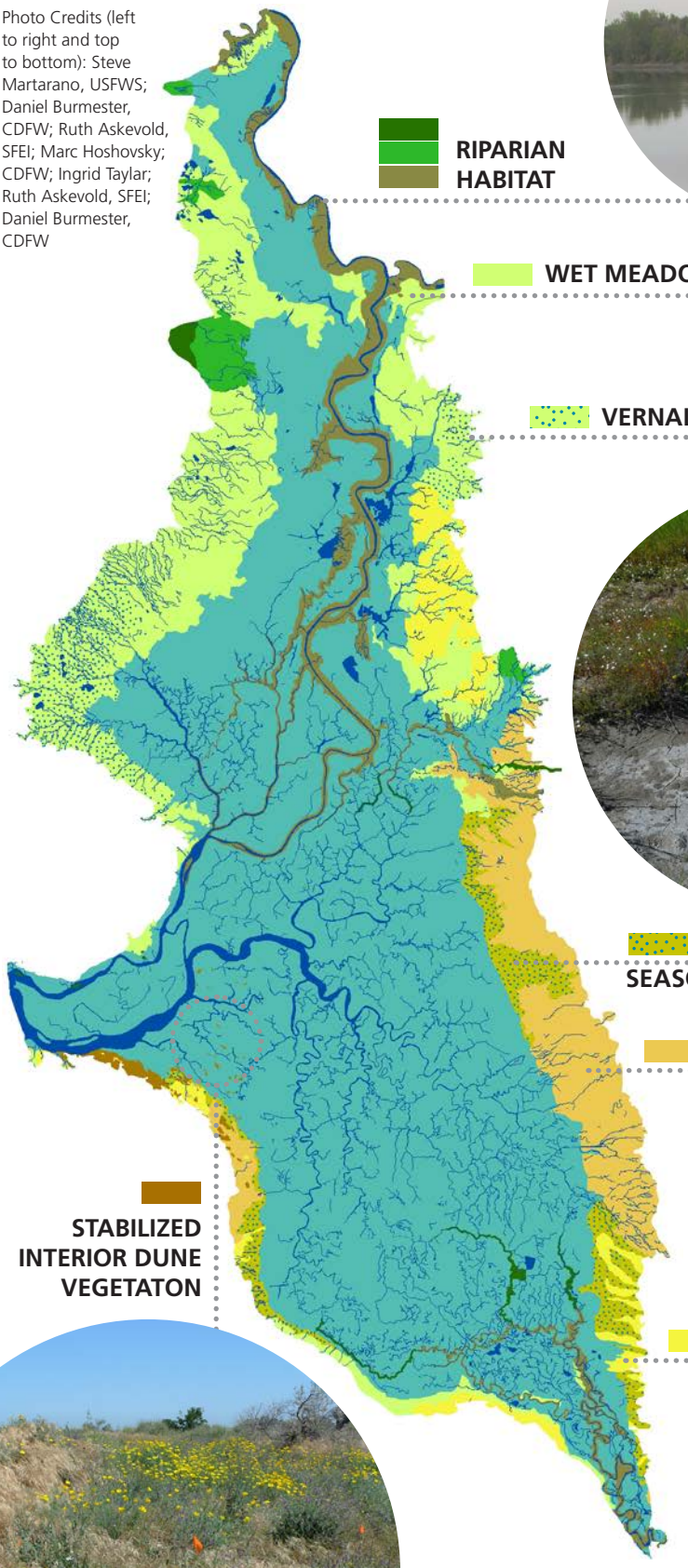
The marsh-terrestrial transition zone in the Delta has been dramatically reduced, fragmented, and degraded. This loss is largely due to the 97% reduction in marsh and the conversion of adjacent habitats to agriculture and development. Much of the remaining marsh occurs as islands in the central and west Delta, in places where the marsh-terrestrial transition zone was never present historically. The terrestrial boundary of modern marshes, where it does exist, is often characterized by an abrupt transition to upland or man-made structures, such as a steep, sparsely-vegetated rock levees and other inflexible edges that offer little in the way of cover, gradients, or habitat value. In addition, remaining marsh patches may no longer provide the same food subsidy to terrestrial species because of their greatly reduced size. The marsh-terrestrial transition zone once formed a complex but continuous band, predictable along hydrological and elevation gradients. That transition zone is now fragmented and disorganized, making it difficult for wildlife to anticipate resources available from the edge.

The terrestrial habitats that occur in the Delta today are largely disconnected from the marsh and from the processes that established and maintained these habitats historically. The dominant habitats in the modern Delta are grasslands and seasonal wetlands that occur in the center of the Delta as often as the periphery. The location of many of these habitats makes them particularly vulnerable to sea level rise. The hydrology of seasonal wetlands is heavily managed and disconnected from seasonal flooding patterns, and seasonal wetlands are now found where perennial wetlands once existed. Agricultural fields and ditches provide a limited portion of the natural functions provided by seasonal wetlands, do not support the same hydrologic regime, and experience stress from human disturbances and contaminants.

The transition zone is critical for a future Delta that can support terrestrial wildlife. Restoring gentle habitat transitions along a natural elevation gradient now will facilitate marsh transgression in the future as sea level rises.[18] The greatest marsh restoration opportunities are located along the periphery of the Delta because these areas are less subsided.

Contemporary photographs of terrestrial habitat types along the Delta's edge. These habitat types also formed marsh-terrestrial transition zones where they graded into emergent wetlands.

Photo Credits (left to right and top to bottom): Steve Martarano, USFWS; Daniel Burmester, CDFW; Ruth Askevold, SFEI; Marc Hoshovsky; CDFW; Ingrid Taylar; Ruth Askevold, SFEI; Daniel Burmester, CDFW



RIPARIAN HABITAT

WET MEADOW/SEASONAL WETLAND

VERNAL POOL COMPLEX

ALKALI SEASONAL WETLAND

OAK WOODLAND/SAVANNA

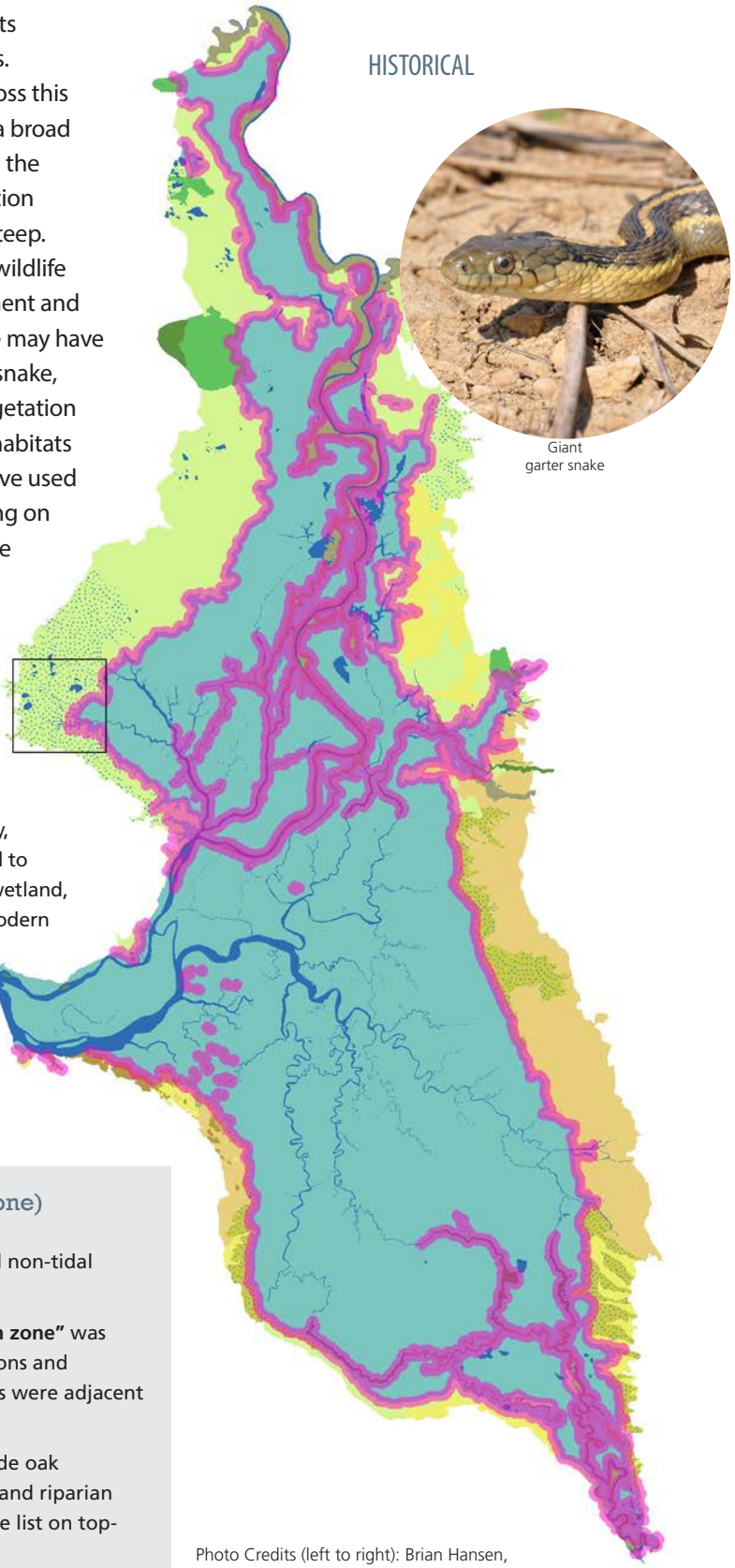
STABILIZED INTERIOR DUNE VEGETATON

GRASSLAND

The historical marsh-terrestrial transition zone was continuous and gradual

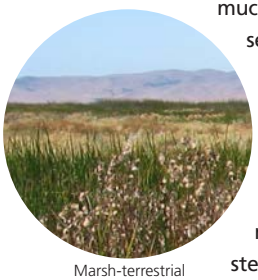
Today's marsh-terrestrial transition zones are fragmented

The transition zone between marsh and terrestrial habitats supported many wildlife species and ecological functions. Animals, organic matter, sediment, and water moved across this wide, complex, and heterogeneous area that supported a broad moisture gradient. Continuous transition zones bordered the Delta periphery and major riparian corridors. Most transition zones were wide and gradual, yet some were short and steep. This continuity and variability allowed diverse terrestrial wildlife to access wetland habitat, and was critical for the movement and dispersal of transition-zone obligates. The transition zone may have been particularly important to the endemic giant garter snake, which used aquatic habitats dominated by emergent vegetation from early spring to mid-fall, and drier, higher-elevation habitats during winter dormancy. Foraging birds and bats may have used seasonal wetlands at different times of the year depending on inundation and food production. In the modern Delta, the terrestrial edge is fragmented and narrow, providing less foraging access, cover, and movement corridors.



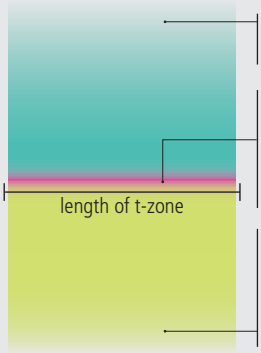
Giant garter snake

Marsh-terrestrial transition zones in the historical (right) and modern (far right) Delta, represented by pink lines. Historically, much of the marsh gradually transitioned to seasonal wetland, vernal pool, alkali wetland, or riparian forest. In contrast, the modern transition zone is discontinuous and rapidly shifts to mostly grassland. Modern grasslands are heavily altered habitats, and modern transition zones are often steep levees.



Marsh-terrestrial transition zone

Methods: Marsh-terrestrial transition zone (T-zone)

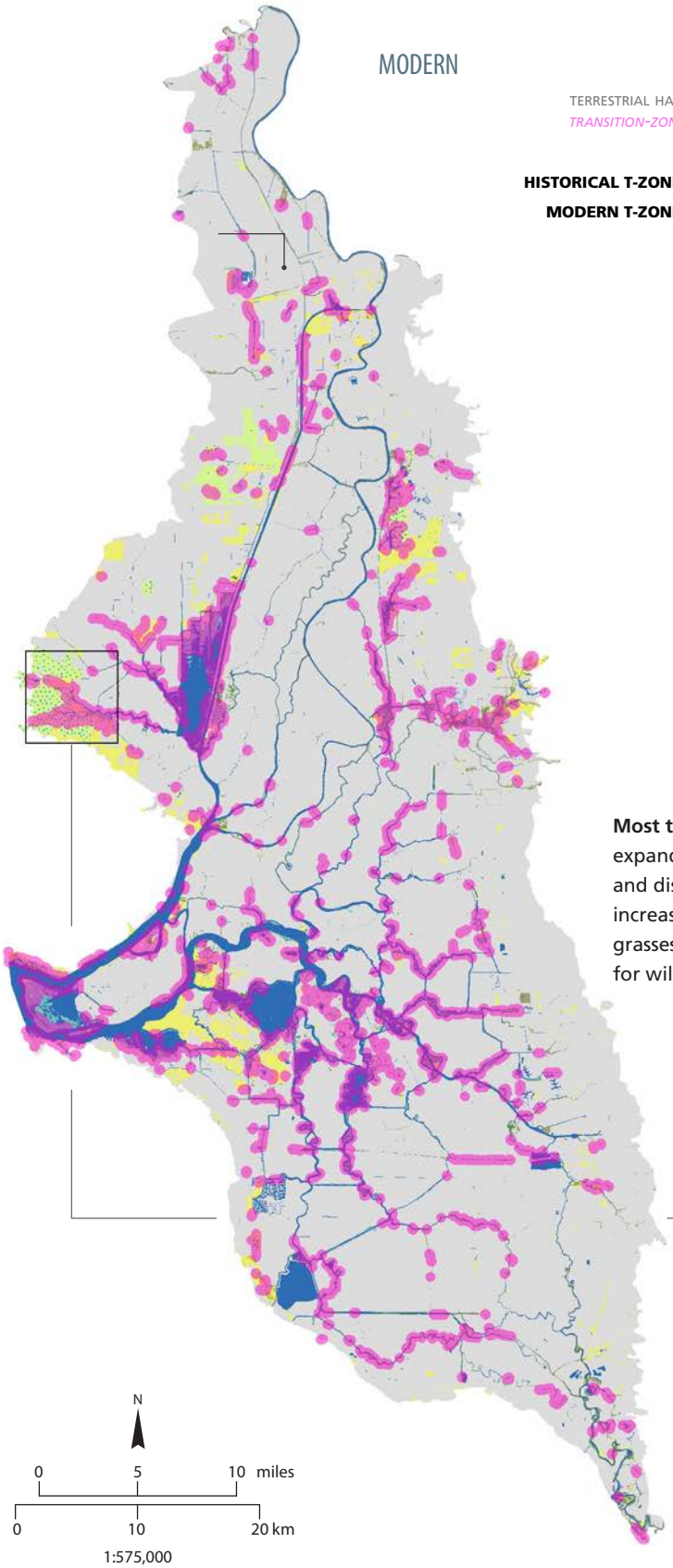


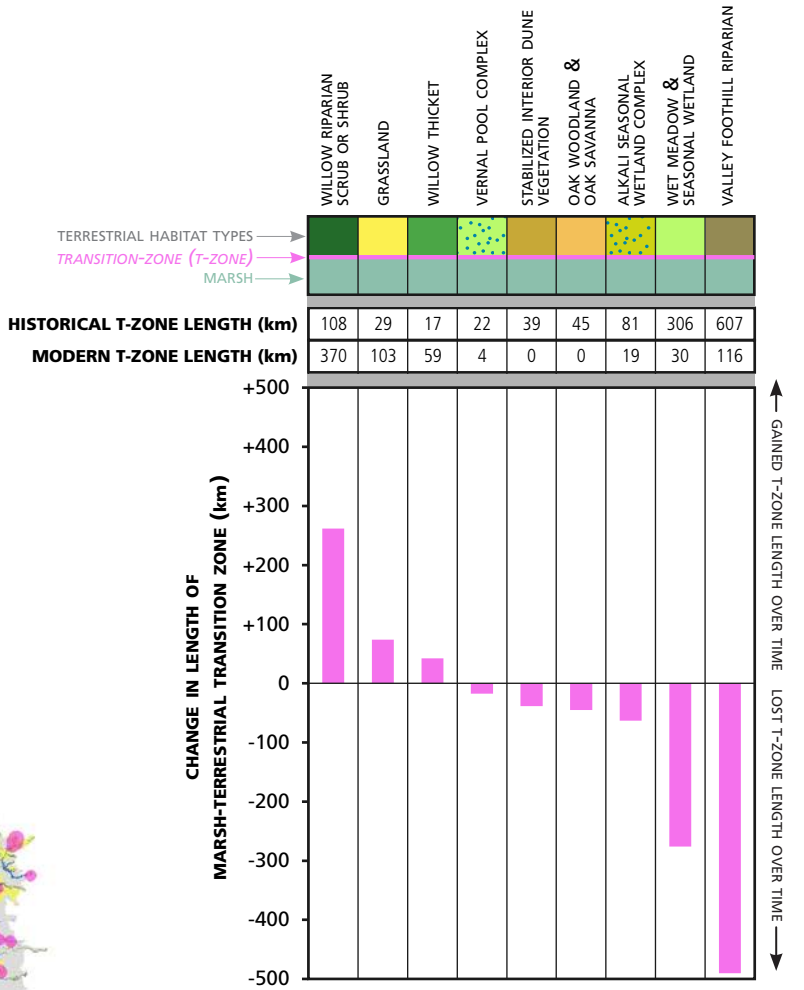
"marsh" includes both tidal and non-tidal freshwater emergent wetland

the **"marsh-terrestrial transition zone"** was mapped wherever marsh polygons and terrestrial habitat type polygons were adjacent to one another

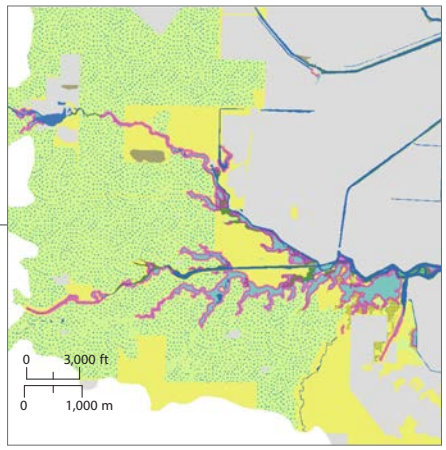
"terrestrial habitat types" include oak woodlands, seasonal wetlands, and riparian habitat types, among others (see list on top-right of facing page)

Photo Credits (left to right): Brian Hansen, USFWS; Daniel Burmester, CDFW





Most transition zone types are greatly reduced. A few types have expanded in quantity, but these tend to be relatively fragmented and disturbed. For example, although the extent of grassland has increased, modern grasslands are dominated by non-native annual grasses, which has changed the timing and availability of resources for wildlife.



The longest continuous unleveed marsh-terrestrial transition zone left in the Delta is along Lindsey Slough (above). This area offers restoration opportunities to improve support for species using the transition zone.

Conclusion

The Delta has undergone a massive physical and biological transformation during the past two centuries. The native plant and animal species that lived and evolved in the Delta now reside in a completely different environment. With the benefit of historical research and contemporary ecological knowledge, we can infer how the pre-development Delta supported native wildlife, and identify the missing functions in today's landscape.

Most fundamentally, the historical Delta was a vast wetland complex composed of an array of habitat types, primarily freshwater marsh, defined by varying cycles of inundation. Differential patterns of flooding, from both rivers and tides, created and maintained tule marshes, lakes, seasonal wetlands, willow thickets, and riparian forests. The disconnection of natural flooding processes due to the construction of levees has profoundly altered the Delta landscape, reducing the natural resilience of the Delta's landforms and wildlife populations. The excavation of channels and building of levees created a dichotomous landscape of dry land and open water where once existed much more variable and dynamic wetlands.

Severe declines in Delta wildlife and likely future impacts from climate change and other drivers motivate a desire to restore a resilient landscape with improved wildlife support functions. Yet the major physical changes to the system, as well as the impacts from invasive species, water diversions, and other stressors, make it difficult to envision how Delta ecosystems could work successfully in the future. The native ecosystems of the Delta are altered and reduced, with few functional examples to learn from. Today's novel Delta ecosystems illustrate stressors but provide few attributes to emulate. The way forward is to design functional landscapes that can take advantage of native geomorphic templates and restorable physical and biological processes to shift the current novel Delta ecosystems toward greater wildlife support functions.

The landscape metrics presented here offer a new set of tools to analyze, design, and evaluate Delta restoration scenarios and outcomes. In the next steps of the Delta Landscapes project, the metrics and other information about past, present, and projected future conditions will be used to develop conceptual restoration visions for the Delta.

For more information, please visit: www.sfei.org/projects/delta-landscapes-project.

Appendix A: Methods

1. STUDY EXTENT

Our study extent is defined by the area mapped in the SFEI-ASC *Sacramento-San Joaquin Delta Historical Ecology Investigation*.[1] As detailed in that report, this area was selected to include the full extent of the Delta's historical tidal wetlands, adjacent non-tidal freshwater wetlands, and upland transitional areas. The study area was generally defined as "the contiguous lands lying below 25 feet (7.6 m) in elevation." This differs from the extent of the legal Delta and "encompasses an area of about 800,000 acres, including parts of Sacramento, Yolo, Solano, Contra Costa, and San Joaquin counties. The boundary was defined using the National Elevation Dataset (NED) 10m-Resolution (⅓-Arc-Second) Digital Elevation Model (DEM)." The report authors "used GIS tools to generalize the boundary and removed upland (fluvial) channels less than 650 feet (200 m) wide." To avoid holes in the study area, the authors included small hillocks within the outer boundary and also included areas within the sinks of Putah and Cache creeks that were above the 25 foot (7.6 m) contour.

As in the *Sacramento-San Joaquin Delta Historical Ecology Investigation*, the western boundary of this study "was established at the west end of Sherman Island in order to match the historical ecology mapping previously completed for the Bay Area EcoAtlas and Baylands Ecosystem Habitat Goals Project (Goals Project 1999)." Upstream, "the study area falls at hydrogeomorphically logical locations. On the west side of the Sacramento River, the study area extends northward in the Yolo Basin to Knights Landing Ridge, also near where the Feather River enters the Sacramento River." Not included in this or the *Delta Historical Ecology* study was "the American Basin on the east side of the Sacramento River between the American and Feather rivers as it was completely non-tidal and extended well above the 25 foot (7.6 m) contour." The southern extent of the study area was defined as the confluence of the San Joaquin and Stanislaus rivers.[2]

2. HABITAT TYPE DATASETS

2.1 Sources for the historical Delta

GIS data depicting historical Delta habitat types were obtained from SFEI-ASC's *Sacramento-San Joaquin Delta Historical Ecology Investigation* (Table 1).[3] The dataset classifies the historical Delta into 17 habitat types, the majority of which are based on modern clas-

Table 1. Sources for historical and modern habitat type datasets.

Title	Citation	Minimum mapping unit	Minimum width	Incorporated area (ha)	Study extent coverage
Historical					
Sacramento-San Joaquin Delta Historical Ecology Investigation ***('SFEI 2012 Delta HE')***	Whipple et al. 2012	5 ha	15 m (channels only—narrower channels digitized as lines)	316,426	100%
Modern					
Vegetation and land use classification and map of the Sacramento-San Joaquin River Delta ***('CDFG 2007 Delta Vegetation')***	Hickson & Keeler-Wolf 2007	0.4 ha (water) 0.8 ha (vegetation)	10 m	253,457	80%
Central Valley Riparian Mapping Project ***('CDWR 2012 CVRMP')***	GIC 2012	0.4 hectares	≥10 m	60,761	19%
Natural Communities Mapping of the Cache Slough Complex vicinity from combined data sources ***('WWR 2013 CSCCA Natural Communities')***	WWR 2013	varies	varies	725	<1%
Bay Delta Conservation Plan Natural Communities Mapping ***('CDWR 2013 BDCP Natural Communities')***	DWR 2013	varies	varies	65	<1%
San Francisco Estuary Institute supplemental mapping ***('SFEI 2013 supplemental mapping')***	n/a	varies	varies	1,381	<1%

sification systems (Table 2, at end of Appendix A). Readers should refer to that report for detailed methods on defining and mapping each habitat type.

2.2 Sources for the modern Delta

Since no recent effort to map modern natural communities in the Delta covers the entire study extent, modern habitat data were compiled from multiple sources (Table 1) and then crosswalked, when possible, to the historical habitat types used by Whipple et al. (2012) (Table 3, at end of Appendix A; see Section 2.3 for information on the crosswalk utilized in this study). Additional habitat types were incorporated into the modern classification system when analogues to historical classifications were unavailable (e.g., 'Managed wetland,' 'Agriculture/Non-native/Ruderal,' and 'Urban/Barren').

The Vegetation Classification and Mapping Program's (VegCAMP) 2007 Sacramento-San Joaquin River Delta dataset ('CDFG 2007 Delta Vegetation')[4] served as the primary component of our modern habitat type layer. This mapping effort utilized true color 1-foot resolution aerial photography from the spring of 2002 (and from the summer of 2005 in some marginal areas) to classify 129 fine-scale to mid-scale vegetation mapping units within the extent of the legal Delta. Although the dataset is derived from imagery that is now more than a decade old, it is still the most comprehensive (with respect to extent and resolution of vegetation mapping units) available for the Delta. Eighty percent of our Modern Habitat Type layer was derived from this source.

Since our dataset extended beyond the boundaries of the legal Delta, the 'CDFG 2007 Delta Vegetation' dataset was supplemented with VegCAMP's 2012 Central Valley Riparian Mapping Project Group Level dataset ('CDWR 2012 CVRMP').[5] This mapping effort utilized 2009 National Agricultural Inventory Program (NAIP) aerial imagery, from which polygons were hand-digitized. Nineteen percent of our Modern Habitat Type layer was derived from this source.

When combined, the 'CDFG 2007 Delta Vegetation' and 'CDWR 2012 CVRMP' datasets provided coverage for more than 99% of our study extent. Remaining data gaps were filled with a combination of sources, including an unpublished natural communities dataset developed for the Cache Slough Complex Conservation Assessment (itself a combination of sources compiled by Wetlands and Water Resources, Inc.; '2013 CSCCA Natural Communities')[6] and a natural communities dataset developed for the Bay Delta Conservation Plan ('CDWR 2013 BDCP Natural Communities').[7] Polygons for the remaining areas without coverage were hand-digitized and classified by SFEI staff using Bing aerial photographs accessed in 2013 ('SFEI 2013 supplemental mapping').

A map displaying where each dataset was used to develop the modern habitat type layer can be found on page 15.

2.3 Historical-modern crosswalk

To compare the historical and contemporary landscape, we were required to crosswalk the detailed modern classifications (from each of the modern datasets listed above and in Table 1) to the habitat types utilized in the historical habitat types layer. The crosswalk from 'CDFG 2007 Delta Vegetation' mapping units to the historical habitat types was developed for the *Sacramento-San Joaquin Delta Historical Ecology Investigation*[8] with the help of local experts (Table 3, at end of Appendix A).[9] Since the historical habitat types were based on modern classification systems, the crosswalking process was generally straightforward. However, several map units classified in the 2007 mapping were challenging to associate with a historical classification. It was determined that "Distichlis spicata- Annual Grasses," for example, should be placed in the "Wet meadow or seasonal wetland" category instead of the "Alkali seasonal wetland complex" category, as the area where it was extensively mapped (in the Yolo Bypass) is characterized by conditions more similar to the wet meadow or seasonal wetland type used for mapping the historical Delta.[10] Willow-dominated communities also posed challenges. The crosswalk attempted to group the modern alliances based on the historical habitat classification of whether the willows were part of a backwater swamp community (willow thicket), the dominant species along channel banks (willow riparian forest, scrub, or shrub), or were part of a forest with oaks (valley foothill riparian forest).

Since the fine-scale (mostly Alliance level) classifications of 'CDWR 2012 CVRMP' were derived from the 'CDFG 2007 Delta Veg' map, our crosswalk developed for the 2007 Delta layer was also applicable to the 2012 Central Valley layer. The medium-scale (mostly Group level) classifications of 'CDWR 2012 CVRMP,' however, had no existing crosswalk. The crosswalk for this dataset (presented in Table 3, at end of Appendix A) was developed by SFEI staff from group characteristic vegetation descriptions[11] and with input from local experts.[12]

'CDWR 2013 BDCP Natural Communities' and '2013 CSCCA Natural Communities' layers utilized the Multi-Species Conservation Strategy NCCP Habitat Types classifications,[13] which had already been related to the historical classification types (Table 2, at end of Appendix A) and were therefore simple to crosswalk (Table 3, at end of Appendix A).

For some purposes, the classifications established by the crosswalks were modified based on additional data and criteria (see Section 2.4).

2.4 Deviations from established crosswalk

2.4.1 Willow-marsh complex

Many polygons in the modern dataset classified as 'Freshwater emergent wetland' are ringed by a strip of vegetation classified as 'Willow thicket.' Conversations with California Department of Fish and Wildlife scientists and further examination of the underlying vegetation types crosswalked to 'Willow thicket' indicated that a significant percentage of polygons contained some freshwater emergent wetland species and thus might be considered part of a larger willow-marsh complex.[14] To capture this unique landscape feature also reported historically in the Central Delta,[15] we reclassified 'Willow thicket' polygons that contained freshwater emergent wetland species (and thus indicated a lower, wetter environment) as 'Willow-marsh complex.' We also selected contiguous 'Freshwater emergent wetland' polygons that intersected the new 'Willow-marsh complex' polygons and reclassified these as 'Willow-marsh complex.' Most of the modern Delta's in-channel marsh islands are classified as 'Willow-marsh complex.' For many metrics, 'Freshwater emergent wetland' and 'Willow-marsh complex' are lumped during analysis. This reclassification was particularly important for metrics addressing the marsh-water edge (since freshwater emergent wetlands ringed by a thin strip of willow thicket would not have any such edge). A list of the map units that composed the original 'Willow thicket' habitat type and an account of which units were reclassified as 'Willow-marsh complex' can be found in Table 4.

2.4.2 Managed wetlands

For the modern habitat type layer we sought to distinguish managed wetlands (characterized by novel forms and managed hydrographs, often separated from direct tidal action by tide gates and weirs, and commonly constructed to support waterfowl) from other wetland areas. Managed wetlands were identified with BDCP's Natural Communities dataset (2009-2013). Polygons with the 'SAIC_Type' of 'Managed wetland' were extracted from the BDCP layer and incorporated into our modern habitat map with ArcGIS's 'Union' tool. Since both datasets were compiled, in large part, from CDFW's Delta Vegetation dataset,[16] alignment between the two datasets was quite high. Additional managed wetlands were identified by SFEI staff from modern aerial images.

2.4.3 Riparian connectivity

Not all polygons in the modern dataset classified as riparian vegetation types ('Valley foothill riparian' and 'Willow riparian scrub/shrub') are hydrologically connected to an adjoining channel. To distinguish between functionally riparian vegetation and hydrologically disconnected riparian-type vegetation, we created two new habitat subtypes. The 'Valley foothill alliance' and 'Willow scrub/shrub alliance' classifications represent hydrologically disconnected polygons originally classified as 'Valley foothill riparian' or 'Willow riparian scrub/shrub,' respectively. A polygon was considered hydrologically connected if it shared an edge with a polygon classified as 'Water.' Riparian polygons that were connected to water through other riparian polygons (of either type), polygons classified as 'Freshwater emergent wetland,' and/or polygons classified as 'Willow-marsh complex' were also considered hydrologically connected. This analysis was meant only to approximate hydrologic connectivity at a coarse level—it does not, for example, distinguish between standing water and creeks, nor does it consider topography or flood frequency. Not all analyses use the split classifications—for some (where vegetation type and structure is more important than hydrology), the original, more general classifications are used. See Section 16.2 for a map of hydrologically connected and disconnected riparian habitat.

2.4.4 Vernal pool complex

It became apparent that much of the 'CDFG 2007 Delta Veg' map units initially crosswalked to 'Grassland' were likely better represented as 'Vernal pool complex.' The same issue was addressed by the BDCP Natural Community Mapping effort (CDWR 2013, Appendix 2.B), which assembled a Vernal Pool Review Team to classify and map vernal pool complexes within the BDCP Plan Area. The BDCP classifications were informed by a number of datasets, including the Soil Survey Geographic Database (SSURGO), the BDCP composite vegetation GIS layer, Google Earth aerial imagery, 2007

Table 4. Reclassifying *Willow thicket* for modern habitat type layer.

Map units originally classified as Willow thicket	Reclassification
Buttonbush (*Cephalanthus occidentalis*)	Willow thicket
California Dogwood (*Cornus sericea*)	Willow thicket
California Hair-grass (*Deschampsia caespitosa*)	Willow thicket
Cornus sericea - *Salix exigua*	Willow thicket
Cornus sericea - *Salix lasiolepis* / (*Phragmites australis*)	Willow-marsh complex
Salix lasiolepis - (*Cornus sericea*) / *Scirpus* spp.- (*Phragmites australis* - *Typha* spp.) complex unit	Willow-marsh complex
Shining Willow (*Salix lucida*)	Willow thicket

LiDAR elevation data, California Natural Diversity Database (CNDDB) records, existing management and habitat conservation plans, and vernal pool expert knowledge.[17]

In light of this focused effort, we replaced polygons crosswalked as 'Grassland' in our preliminary modern habitat types layer with polygons identified as 'Vernal pool complex' by the BDCP mapping effort whenever the two overlapped. Specifically, we used the 'Union' tool in ArcGIS to replace polygons from 'CDFG 2007 Delta Vegetation' and 'CDWR 2012 CVRMP' crosswalked to 'Grassland' with those polygons from '2013 CSCCA Natural Communities' that had an "SAIC_Type" of 'Vernal pool complex' (a classification derived from the 'CDWR 2013 BDCP Natural Communities' layer). Where polygons from the two datasets overlapped, the habitat type was changed to 'Vernal pool complex' (otherwise the habitat type remained 'Grassland').

2.4.5 Swale form

'CDWR 2012 CVRMP' polygons with an "NVCS_NAME" of "California annual forb/grass vegetation" were initially crosswalked to 'Grassland.' However, when these polygons exhibited the natural swale form common to the edge of alluvial fans between ridges on the eastern and western edges of the Delta, the 'Grassland' classification was changed to 'Wet meadow/Seasonal wetland.' This reclassification better captures the hydrology and landscape position of these features, which are natural, seasonally wetted low spots on the landscape that generally offer potential for upland transgression of marshes with sea level rise. Additionally, the reclassification provides greater alignment with the habitat type assigned to these landforms by the finer-resolution 'CDFG 2007 Delta Vegetation' mapping and crosswalk.

2.5 Non-native and invasive species

We sought to map areas in the modern Delta where invasive or non-native plant species are dominant or co-dominant with native vegetation and to quantify the percent area dominated by non-native/invasive vegetation by habitat type. Individual habitat type polygons were marked as dominated by non-native/invasive vegetation if their vegetation mapping unit (generally associated with alliance- and association-level classifications) featured a non-native species (as defined by CalFlora) or invasive species (as defined by Cal-IPC). Where alliance/association-level classifications were unavailable, the non-native/invasive designation was determined based on Group-level classifications and best professional judgement. Table 5 (at end of Appendix A) lists the mapping units of the modern habitat type layer and whether or not each was classified as dominated by non-native/invasive vegetation. For the purposes of the map, we also classified areas with a habitat type of either "Agriculture/Non-native/Ruderal" or "Urban/Barren" as non-native, regardless of the more specific mapping unit classification.

3. CHANNEL VECTOR DATASETS

GIS layers of Delta hydrography were required to develop the project's suite of channel-related metrics. Since both forms of data were needed for our analyses, we obtained or generated polygon and polyline datasets of channel hydrography in the historical and modern Delta (unlike polygons, polylines are one-dimensional features with no width or area in the GIS). From these geodatasets, we developed metrics of channel length, width, adjacency, density, and sinuosity (the latter two are not presented in this report). We also classified channel reaches as either "dendritic" or "looped" (see Section 9 for definitions of these terms). Maps of these datasets can be found on page 15.

3.1 Sources for the historical Delta

Historical Delta channel polygons were obtained from the SFEI-ASC *Sacramento-San Joaquin Delta Historical Ecology Investigation*'s historical habitats layer.[18] The SFEI-ASC study generated polygons for channels at least 15 m in width and 50 m in length and incorporated these features into the map of historical Delta habitat types. For use in developing channel-related metrics, polygons classified as 'fluvial low order channel,' 'fluvial mainstem channel,' 'tidal low order channel,' or 'tidal mainstem channel' were extracted from the habitat type layer and clipped to the study extent.

Historical Delta channel polylines were obtained from the SFEI-ASC *Sacramento-San Joaquin Delta Historical Ecology Investigation*'s historical creeks layer.[19] This line layer contained all channel features longer than 50 m, regardless of their width. For channels also digitized as polygons, the polyline layer represents an approximate channel centerline. The layer was edited to ensure that channel polylines associated with polygons fell completely within the polygon boundaries.

3.2 Sources for the modern Delta

Modern Delta channel polygons were obtained from a 2013 version of the National Hydrography Dataset (NHD),[20] clipped to the project study extent, and selected by feature type to isolate features classified as 'StreamRiver' or 'CanalDitch.'

Modern Delta channel polylines were generated from the NHD polygons (described above) with a custom centerline generation tool. To best match the historical dataset, channel polylines were only generated around islands greater than 25 ha in size. If an island did not

meet this size requirement, it was considered an "in-channel" island (an island located within a single channel as opposed to an island bounded by multiple, separate channels), and dissolved with the channel polygon for the purposes of centerline generation. To generate the channel polyline layer from the NHD polygons, the centerline tool converted NHD polygons to outlines, added additional vertices to these lines every 10 meters, created points from the vertices, and calculated Theissan polygons from the points. These Theissan polygons were converted to outlines, which were then clipped to the NHD polygons and split at vertices. The tool then removed segments less than 100 m with dangling ends, merged and exploded all lines, and then deleted all lines that were not connected on both ends and consisted of only 2 vertices (leaving only the polygon centerlines). To eliminate channels associated with small man-made harbors, we manually removed resulting reaches that were both less than 500 m in length and deemed unnatural. After evaluating the resulting layer, we digitized additional channel polygons and polylines that were not in the original NHD dataset, including the tidal channel networks of Sherman Island, Mandeville Tip, the Liberty Island Conservation Bank, the Cosumnes Floodplain Mitigation Bank, and along the Yolo Bypass Toe Drain. Like with the historical dataset, there was no minimum width employed for digitizing a channel line.

4. CHANNEL RASTER DATASETS (BATHYMETRY)

To develop metrics involving channel depth, we obtained or generated rasters of channel bathymetry for both the historical and modern time periods. Using this elevation data, we developed approximations of water depth at specific tidal datums (see Section 10). As described below, the historical Delta DEM was developed for a separate project and was constructed at a 2 m resolution (to capture the smallest channels). The modern Delta DEM, a California Department of Water Resources product, is an integrated 2 m and 10 m resolution raster. Both DEMs were clipped to include only the mutually mapped areas.

4.1 Sources for the historical Delta bathymetry

It is the goal of a separate, ongoing project to characterize the hydrodynamics of the San Francisco Bay-Delta Estuary under more natural conditions (those prior to major modification of Bay-Delta geometry and hydrology beginning in the mid-19th century) through the development and use of a 3D hydrodynamic model. One critical task of this larger project is the creation of a bathymetric-topographic digital elevation model (DEM) of the early 1800s historical Delta. The development of this raster is a collaborative effort between researchers and technicians at the San Francisco Estuary Institute (SFEI), the Center for Watershed Sciences (CWS) at the University of California, Davis, and Resource Management Associates, Inc. (RMA), funded by CWS and the Metropolitan Water District. Please see Table 6 for a list of individuals who have contributed to the development of the historical Delta DEM used in this report.

A manuscript with the methods used to develop the historical Delta DEM is currently in preparation for publication.[21] Here, we provide a simplified overview of the methods used to develop the historical bathymetry raster utilized in this report. Greater details on the development of the dataset (including the topographic component, which is not used or discussed in this report) will be available in the near future. Since the project is ongoing, the historical DEM used in this report constitutes an interim product and is subject to future modification.

This report utilizes version 3.1 of the Historical Delta Topographic-Bathymetric DEM, an interim product released internally in July 2014. To create this DEM, the project team integrated 2D historical Delta channel planform and land cover data from previous mapping efforts (Whipple et al. 2012) with elevation data from numerous historical sources. Raw historical bathymetric data were obtained primarily from mid-19th century sources, including U.S. Coast Survey (USCS) hydrographic sheets and early river surveys. Different areas and components of the Delta had to be addressed separately, given data availability. Three general sets of methods were used and combined to develop the DEM bathymetry (Figure 1).

Table 6. Individuals who have contributed to the development of the historical Delta digital elevation model (DEM) used in this report (alphabetical by institution). This work is being conducted as part of a separate, ongoing project (funded by CWS and the Metropolitan Water District).

Contributors
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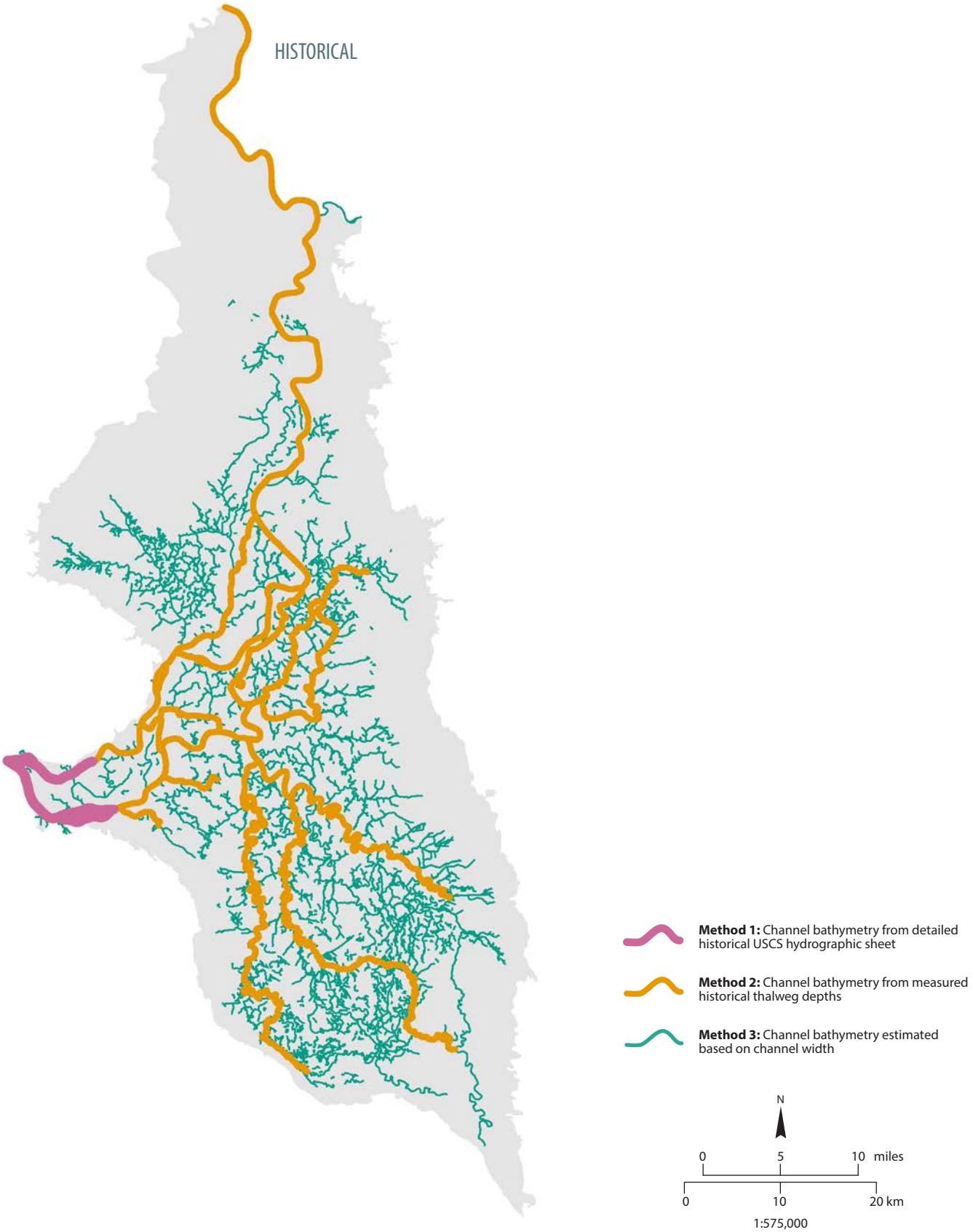

Figure 1. Three methods used to develop historical Delta bathymetry. Methodology varied based on data availability. See section 4.1 of this chapter for a more detailed description of each method.

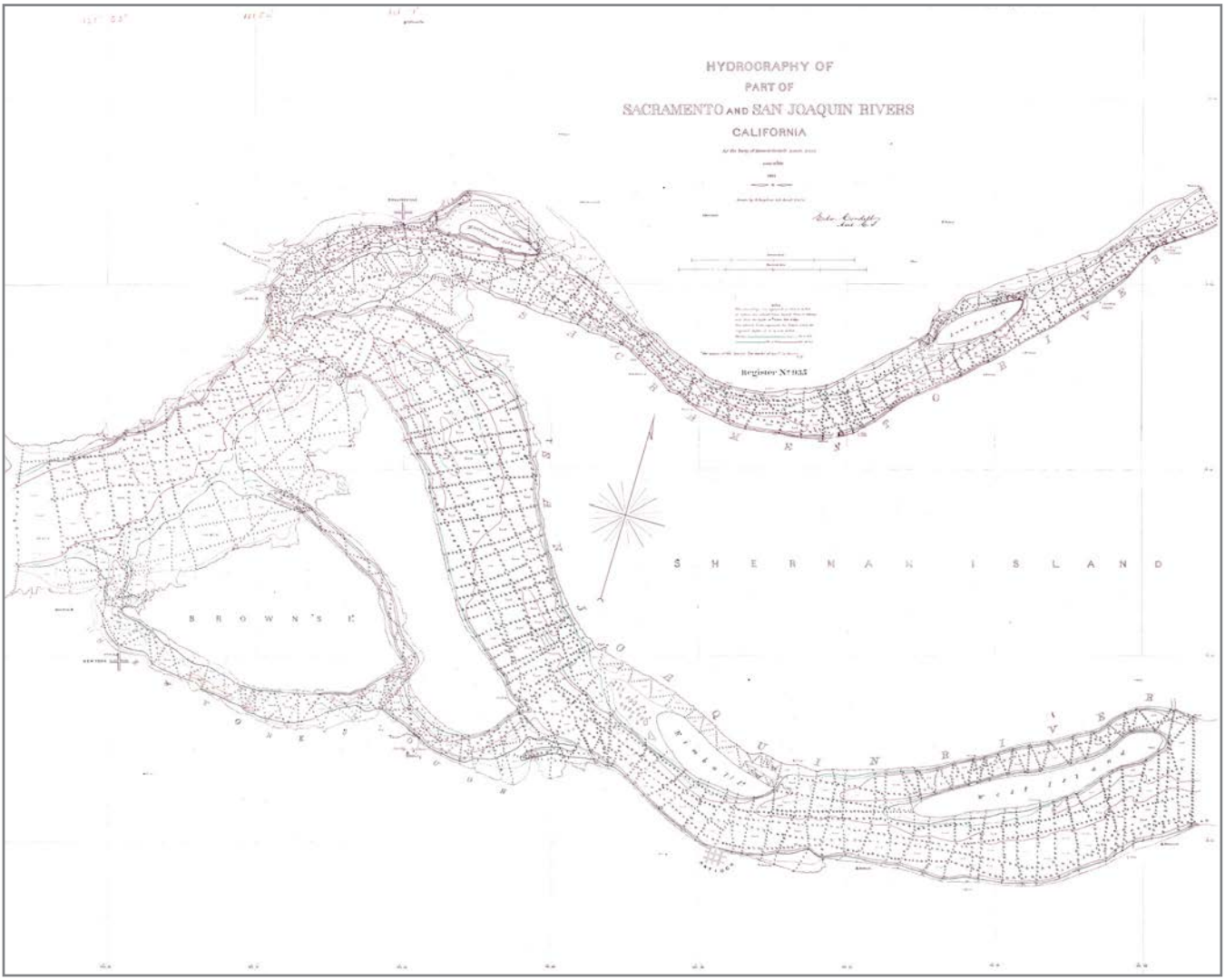

Figure 2. Cordell 1867 (United States Coast Survey), "Hydrography of part of Sacramento and San Joaquin Rivers California." This map is a hydrographic sheet ("H-Sheet") with historical bathymetry of the Delta mouth. The bathymetry seen here was digitized directly from a georeferenced version of the map.

4.1.1 Method 1: Bathymetry of the Delta mouth

A detailed 1867 U.S. Coast Survey hydrographic sheet with historical bathymetry was available downstream of Sherman Island (Figure 2).[22] The project team digitized 4,809 soundings and three bathymetric contour lines (6, 12, and 18 ft) directly from a georeferenced version of this map (which indicated depth at mean lower low water [MLLW]). After converting the digitized soundings to a modern fixed datum (NAVD88, see Section 4.1.4), the points were used directly as TIN inputs to generate continuous DEM bathymetry.

4.1.2 Method 2: Bathymetry of channels with measured historical data

The U.S. Coast Survey produced detailed 19th century bathymetric maps for the San Francisco Bay Estuary only as far upstream as Sherman Island. Bathymetry upstream of this location was derived from three historical river surveys (Ringgold 1850a, Ringgold 1850b, and Gibbes 1850), each conducted before the extensive mid- to late 19th century hydraulic mining in the Sierra Nevada foothills that altered bed elevations in the Delta. Critical locations were substituted with soundings from maps created by the California Debris Commission between 1908 and 1913.[23] Unlike the USCS (1867) hydrographic sheet, the historical river surveys generally only indicated the depth of the deepest part of the channel (the channel "thalweg"). Soundings were generally taken or adjusted by the surveyors to low water conditions. In total, the project team georeferenced 1,484 historical soundings indicating mean lower low water thalweg depth.[24] We snapped georeferenced points to a historical thalweg polyline and interpolated thalweg depths between these points using a spline function. We assumed a parabolic channel shape to generate bathymetry on either side of the thalweg.[25] Channels with bathymetry derived from this method are shown in Figure 1.

4.1.3 Method 3: Bathymetry of channels without measured historical data

Measured historical soundings were not available for much of the study extent. Because of this, we sought to determine historical channel depths by generating a regression relating channel depth to channel width. The relationship between these two variables was determined with available measured historical thalweg depths (described above). Historical channel widths (see Section 6) were spatially joined to historical soundings to create a dataset of historical channel widths with associated MLLW thalweg depths. Measured historical widths and depths were plotted against one another and fitted with a power function (Figure 3). A power function was selected because of known power relationships between width and depth in fluvial systems and because it avoided generating negative depths at smaller channel widths. While not perfect, this method was selected after extensive conversations with experts on tidal marsh morphology, and appears to provide reasonable estimates of channel depth given the available information. The function took the following form and was used to extrapolate depths for all channels:

Let y = channel depth at MLLW
Let x = channel width
$y = 0.8516x^{0.4111}$
$R^2 = 0.34$

Small historical channels (with widths <15 m) were originally digitized as polylines and thus did not have a precisely known width for use in the regression. We assigned these channels a width of 7 m (approximately half the minimum mapping unit for digitizing channels polygons) when extrapolating depths using the width-depth regression.

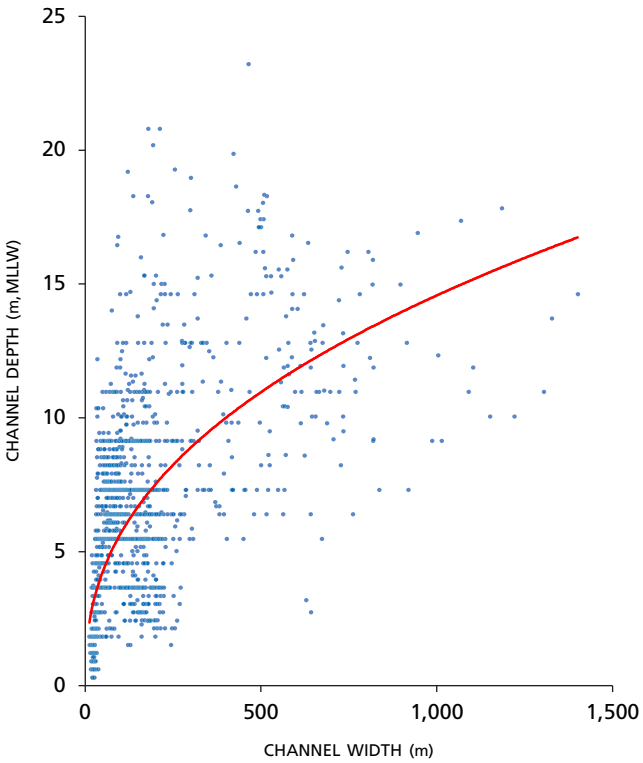

Figure 3. Scatter plot of historical channel depth vs. historical channel width. Each data point represents one historical sounding (adjusted to MLLW and representative of the thalweg depth) plotted against the width of the historical channel at the sounding's location (as derived from the historical channel polygon layer; N = 1,484). Data points have been fitted with a power function (red line) with the above equation.

4.1.4 Converting a historical tidal datum (MLLW) to modern fixed datum (NAVD88)

Historical sources for bathymetry were created well before the development of a standardized vertical datum (such as the Sea Level Datum of 1929) and were simply referenced to a low water surface. To use the historical Delta DEM in hydrodynamic models, the project team converted the historical MLLW data to a modern fixed datum (NAVD88). The method utilized in version 3.1 of the historical Delta DEM entailed two primary steps: (1) converting historical mean lower low water (MLLW) depths to historical local mean sea level (MSL) depth by adding tidal amplitude (or one-half the tidal range) to MLLW depth and (2) obtaining historical bed elevations (in NAVD88) by subtracting MSL depth from MSL elevation (in NAVD88). To implement these steps, the project team was required to determine two variables: (1) historical Delta tidal range and (2) historical Delta mean sea level elevation, both of which vary spatially. Rasters quantifying these variables across space were developed to convert historical depths to NAVD88.

The historical tidal range surface utilized in version 3.1 of the historical Delta DEM was developed by interpolating between georeferenced historical textual data using a natural neighbors method and the 'Create TIN' tool in ArcGIS. Additional points with a tidal range of 0 were created at the boundary between tidal and non-tidal channel reaches as mapped by Whipple et al. (2012). Where records were too far apart for the TIN to successfully/realistically interpolate between them, best professional judgment was used to add values between known points. In total, 75 georeferenced points of historical tidal range were used to generate the historical tidal range surface.

The historical MSL surface utilized in version 3.1 of the historical Delta DEM was modeled using the RMA-2V model of the contemporary Delta, minus Delta exports and the most significant channel cuts, gates, and barriers. This simulation also subtracted estimated sea level rise (SLR) since the historical period, assuming an average rate of 0.1-0.2 cm/yr.[26]

Adjusted bathymetry was exported as a 2 m DEM and clipped to the tidal open water portions of the historical Delta, as mapped in the Delta Historical Ecology Investigation.[27]

4.2 Sources for the modern Delta bathymetry

Modern bathymetry was extracted from a continuous topographic-bathymetric DEM of the San Francisco Bay-Delta Estuary developed by California Department of Water Resources staff.[28] To facilitate comparison with the historical bathymetry raster (which was clipped to tidal open water features), we clipped the modern raster to include only cells with subtidal elevations. Subsided islands surrounded by levees posed a problem, since these areas have elevations well below sea level but are not actually aquatic habitat. Because the modern DEM features numerical orthogonal reinforcement of levees around islands,[29] we were able to exclude subtidal elevations associated with subsided islands by using the 'Magic Erase' tool in ArcGis 10.1 (ArcScan extension). We reclassified raster cells into supratidal and inter/subtidal elevations (above and below a mean higher high water elevation of 195 cm NAVD88)[30] and then used the tool to select subtidal cells directly connected to the Sacramento-San Joaquin river confluence/tidal source. Inter/subtidal areas ringed by supratidal levees were not connected and thus not selected. This process identified two subsided islands with underresolved/unenforced artificial levees in the modern DEM. We manually modified the suspect cells to enforce these levees and exclude the subsided areas within them.

5. UNMAPPED CHANNELS

It is likely that at least one class of low-order tidal channels existed in the Delta that was not represented by historical sources and was thus under-represented in the historical mapping of the Delta.[31] To match the detail and minimum mapping unit of the modern channel dataset, we sought to estimate the length of these "unmapped" historical channels in the study extent and to account for them in our analyses.

No remnant marshes with intact channel networks exist in the modern Delta from which to estimate historical channel density. General agreement exists that the channel density observed now at Sherman Island (~70 m/ha) is higher than it was historically due to the relatively young age of the system (until recently, Sherman Island was a depository for dredge spoils and the channel network observed today is likely overly-interconnected and under-developed as a result).[32] Length of unmapped channels was therefore estimated based on observed historical tidal channel densities in regional freshwater tidal marshes. Grossinger (1995) used USCS T-Sheets to calculate historical tidal marsh channel densities in the upper reaches of the Napa River, where freshwater influence is dominant—the upper-two systems in Napa were found to have historical densities of 19 and 51 m/ha.[33] Collins and Grossinger (2004) also calculated a historical channel density of approximately 30 m/ha in the freshest Bay Area systems.[34] These values agree with the highest local mapped densities in the historical Delta of 30 m/ha.[35] Weighing this evidence, we established low- and high-end estimates of Delta channel density of 20 m/ha and 40 m/ha, respectively. Since these estimates are for regularly inundated tidal marshes with developed channel networks, they were only applied to areas classified as tidal freshwater emergent wetland within the area thought to experience daily tidal inundation (see Section 10).

Mapped channel density in the study extent (14.76 m/ha) was determined by dividing the length of mapped tidal channels within regularly inundated tidal freshwater emergent wetland (1,129,158 m) by the area of the regularly inundated tidal freshwater emergent wetland itself (76,506 ha). Given the mapped density, the additional unmapped channel length needed to reach our low (20 m/ha) and high (40 m/ha) density estimates was calculated to be 400,960 m and 1,931,080 m, respectively.

6. CHANNEL WIDTH

Channel width was determined by casting perpendicular transects from the channel polyline layer, trimming these transects with the channel polygon layer, and then attributing the lengths of the trimmed transects back to the channel polyline. Prior to this analysis, versions of the historical and modern polyline layers were smoothed with a maximum offset of 0.2 meters to eliminate small sharp angles in the polyline (legacies of the original digitization process). Transects were cast at 100 m intervals perpendicular to the smoothed polyline and then trimmed with the channel polygon layer. Trimmed transects were then used to segment the original channel polyline layer. Channel width was calculated for each of the resulting segments by averaging the length of transects intersecting the segment (generally one transect at each end of the segment).

Prior to trimming transects with the channel polygon layer, the channel polygons were first dissolved and then split manually at confluences to eliminate overestimations of channel width where channels converge. The overall channel width analysis was also complicated by the existence of numerous islands located within channels. For islands greater than 25 ha in size, separate channels were drawn on either side of the island and each assigned their own widths. If an island was less than 25 ha, however, it was considered an island within a single channel. When calculating channel width, we only measured the width of the water, excluding width associated with in-channel

islands. For the historical channel width analysis, channels digitized only as polylines were assigned a width of 7 m (approximately half the minimum mapping unit used for digitizing channels as polygons).

7. WATER DEPTH

In Section 4 above, we described the process of developing rasters of channel bed elevations (channel bathymetry) in the historical and modern Delta. This section describes the process of using these rasters to develop approximations of water depth at a specific tidal datum.

Water depths were derived from the raster datasets of historical and modern bathymetry, which were clipped to exclude supratidal habitat (described in Section 4). Since these rasters quantify bed-elevations, we were required to establish water surface elevations to determine water depth. In the absence of comprehensive spatial datasets indicating the elevations of tidal datums to relate geodetic data to tide heights (for both the historical and modern Delta), we opted to measure depth from a single water surface elevation across the Delta. In the modern Delta, the water surface was set to 0.64 m NAVD88, a mean lower low water (MLLW) elevation calculated from various monitoring data in the Cache Slough Complex.[36] For the historical Delta, we made the simplifying assumption that the only changes to the elevation of MLLW since the historical period are from sea level rise (SLR). This assumption discounts any changes in Delta water surface elevations caused by large-scale changes like channel geometry modification, channel armoring, subsidence, or water exports). Assuming a SLR rate in the Delta of 2 mm/year during the historical period, we estimated that 0.33 m of SLR occurred between 1850 and 2013. This factor was subtracted from the contemporary elevation of MLLW at the Cache Slough Complex (used as the water surface elevation in the modern analysis) to yield a historical water surface elevation of 0.31 m. The values used to bin bed-elevations (m, NAVD88) into water-depth classes (m, MLLW) based on these water surface elevations can be found in Table 7. Water-depth classes were chosen based on input from the Landscape Interpretation Team (Chapter 2, page 6) and meaningful photic zones.[37]

Table 7. The values used to bin bed-elevations (m, NAVD88) into water-depth classes (m, MLLW). The process for setting the historical and modern water surface elevations is described in Section 7.

	Bed elevation (m, NAVD88)	
Water depth (m, MLLW)	**Historical**	**Modern**
0 m (reference plane/water surface elevation)	0.31	0.64
1	-0.69	-0.36
2	-1.69	-1.36
5	-4.69	-4.36
10	-9.69	-9.36

7.1 Depth by area

Using the values listed in Table 7, we calculated the area of habitat in each depth-class using the 'Build Raster Attribute Table' tool in ArcGIS 10.1 and multiplying the cell count in each bed-elevation/water-depth range by cell area.

Historical perennial tidal lakes were not accounted for in the version of the historical Delta DEM utilized in this report (version 3.1). To account for these features in our analysis of historical depth, we extracted historical habitat type polygons classified as 'Tidal perennial pond/lake' and then assigned these polygons with depths obtained or derived from the available historical data. Some lakes (such as Secret Lake and Beaver Lake in the north Delta) have specific historical accounts describing their depths. When available, we used this information to assign the lakes a maximum depth, and then used buffers to generate concentric rings at each of the shallower depth classes (we assumed depth increased linearly from 0 m at the edge of the lake to the maximum depth at the center). The majority of mapped historical lakes, however, did not have lake-specific data on historical depths. For these features, we assigned inferred depths based on more general regional accounts. Historical sources, as reported by Whipple et al. (2012) suggest that many lakes in the north Delta (even large ones) were "only a few feet below the general elevations of the basins. Early travelers . . . could wade across." Considering this, we assigned most of the North Delta lakes a depth of 0–1 m. The centers of larger lakes (where more than 1,000 ft from the lake's edge) were placed in the 1-2 m depth class. This distance was relatively arbitrary, but was chosen to give the larger lakes a three-dimensional shape. In the south Delta, Whipple et al. (2012) note that historical descriptions of "knee-deep" water suggest relatively shallow features and that a map from 1850 "includes soundings of six to nine feet (1.8-2.7 m) of water in a lake." Weighing this evidence, we used a 300 m buffer to assign the centers of the larger south Delta lakes to the 1-2 m depth class. Small lakes and the outer edges of larger lakes were placed to the 0-1 m depth class. The area of lakes in each of these depth classes was tallied and added to the totals derived from the historical Delta DEM.

7.2 Depth by length

Methods used to calculate the linear extent of channels based on their thalweg depths differed for the historical and modern analyses. Historical thalweg depths were generated by segmenting the historical thalweg polyline (developed with/for the historical Delta DEM) at intervals of approximately 100 m and then intersecting the

segments with the historical Delta DEM. Each 100 m segment was attributed with the average bed-elevation associated with the raster cells it crossed. These thalweg bed-elevations were converted to water depths using the methods/table described in Section 7.

Modern thalweg depths were generated by intersecting the trimmed modern channel width transects (see Section 6) with the clipped modern bathymetry raster (see Section 4.2) and attributing each transect with the minimum encountered cell value (i.e., the lowest bed-elevation). This is akin to taking the minimum value from a channel cross-section. Minimum bed-elevations were then attributed to the modern channel polyline segments and converted to water-depths using the methods/table described in Section 7.

8. CHANNEL ADJACENCY

Channel adjacency was determined from the habitat type layers by extracting habitat types associated with open water or aquatic habitat (for historical: 'Fluvial low order channel,' 'Fluvial mainstem channel,' 'Tidal low order channel,' 'Tidal mainstem channel,' 'Non-tidal intermittent pond/lake,' 'Non-tidal perennial pond/lake,' and 'Tidal intermittent pond/lake,'; for modern: 'Water') and intersecting the resulting layer with all other habitat types. The output of this operation is a polyline that traces the locations where open water touches other habitat types (the "shoreline"), and includes all of the attributes of the adjacent habitat type polygons.

Also included as open water when generating the historical shoreline layer were the historical channel polylines (which, due to their size, were not represented a polygons in the habitat types layer). A buffer of 5 m was applied to each side of the polylines to give the features an area. Before shorelines were generated, the new open water polygons were incorporated into the habitat layer with ArcGIS's 'Erase' and 'Merge' tools. Shorelines were not generated for possibly exhumed channels (as marked in the channel polylines "Notes" field).

The shoreline layer was used to determine marsh-open water edge length (page 44-45). For this analysis, we selected reaches where the shoreline habitat type was either 'Tidal freshwater emergent wetland' or 'Non-tidal freshwater emergent wetland' (for the historical analysis) or 'Freshwater emergent wetland' or 'Willow-marsh complex' (for the modern analysis). These selections were symbolized by the size of the contiguous marsh polygon they were associated with. Contiguous marsh polygons (which differ from marsh "patches"; see Section 10) were generated by dissolving polygons with the marsh habitat types listed above using the 'Dissolve' tool in ArcGIS 10.1. The sizes of these polygons were attributed to the shorelines with a spatial join.

To assign shoreline data to the channel polylines, channel polylines were segmented at 100 m intervals and given the attributes (via a spatial join) of the nearest shoreline feature. Channels bordered on each side by different habitat types only received attributes from the nearest shoreline feature. We used these methods to determine which dendritic channels were adjacent to marsh (see page 46-47). For this analysis, we considered marsh to be polygons with the habitat types 'Tidal freshwater emergent wetland' or 'Non-tidal freshwater emergent wetland' (for the historical analysis) or 'Freshwater emergent wetland' or 'Willow-marsh complex' (for the modern analysis).

9. LOOPED AND DENDRITIC CHANNELS

We classified tidal channel reaches as either "looped" or "dendritic." Looped channels are interconnected, generally large distributary reaches that delineate the Delta islands and can be thought of as forming circular networks connecting back to the tidal source. They are sometimes referred to as "mainstem and subsidiary channels"[38] or "through-flow channels."[39] Dendritic channels, alternatively, are terminal sloughs that eventually dead-end and do not connect on both ends to the larger network. The term "dendritic" is derived from the typical form of historical terminal sloughs—branching, tree-like networks that terminated in wetlands and resembled dendrites. These sloughs generally drained (and were formed by) tidally introduced water, rather than runoff from associated wetlands and uplands.[40] Although terminal, dead-end sloughs do not always have the branched form today, we still refer to them as "dendritic." These channels have also been referred to as "branching dead-end channel networks,"[41] "backwater tidal sloughs,"[42] "tidal creeks,"[43] and "blind channels."[44]

Ultimately, a channel reach was considered "looped" if it was (1) tidal and (2) connected to the tidal source (the Delta mouth) via two independent and non-overlapping paths (Figure 4). Tidal channel reaches accessible from the tidal source by only one non-overlapping path were considered "dendritic." Classification was carried out manually within ArcGIS. For the historical channel polyline network, tidal channels were selected using the layer's "tidal_status" field, which classified channels as either "tidal" or "fluvial." Since most channels within the study area were at least somewhat influenced by both tidal and fluvial processes, Whipple et al. (2012) classified historical channel reaches by their probable hydrology (instead of by the dominant physical process). Specifically, a channel reach was classified as "tidal" if it likely experienced bidirectional (tidal) flow during spring tides in times of low river stages (even though the primary processes that formed and maintained the channel could be fluvial). "Fluvial" reaches—those upstream of the limit of

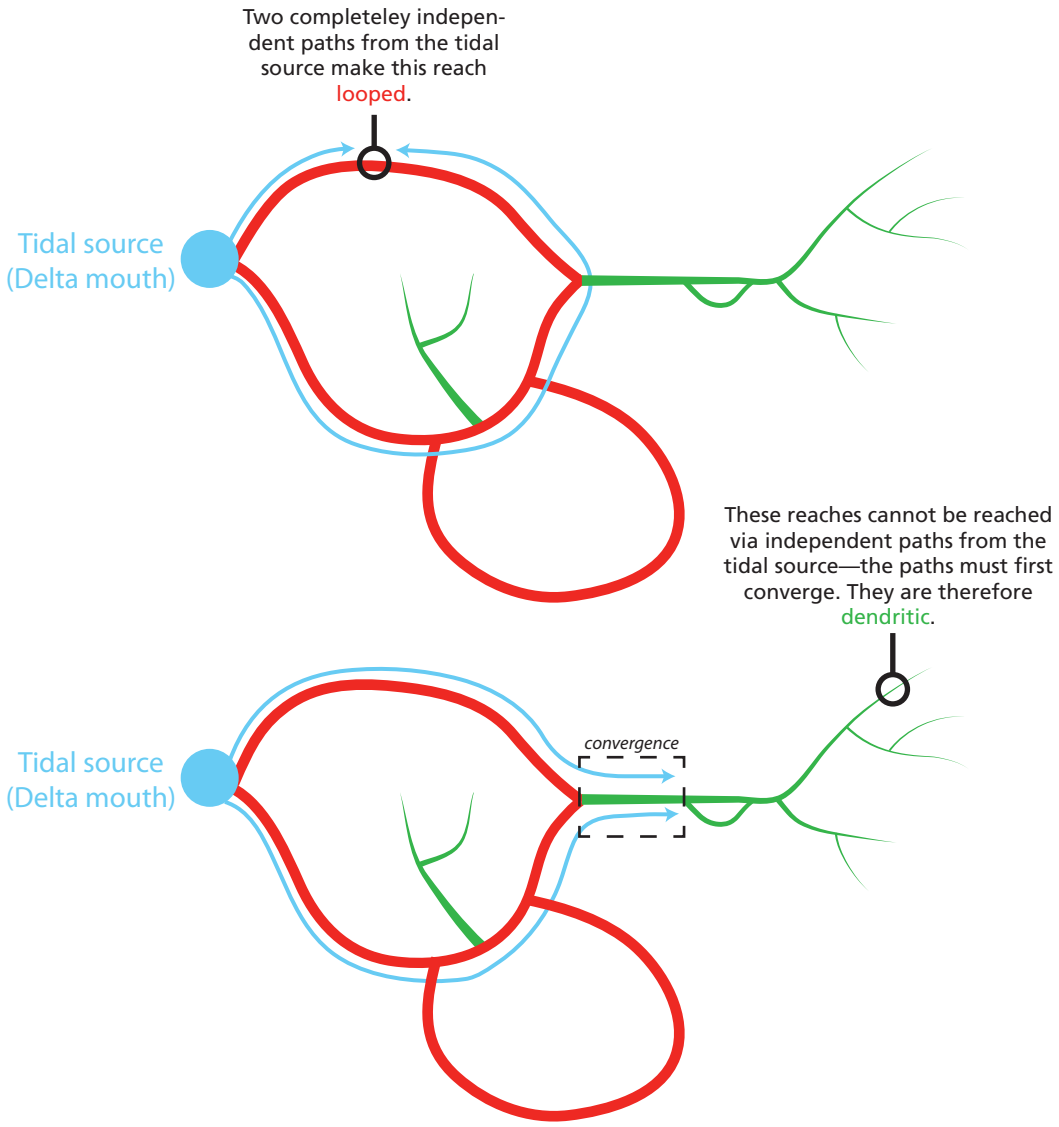

Figure 4. Classifying dendritic and looped channels.

bidirectional flow—were not classified as either dendritic or looped. To identify tidal reaches in the modern network using this definition, we drew from the work of Cavallo et al. (2012) who identified the locations along the Sacramento, San Joaquin, and Mokelumne river systems where bidirectional flows rapidly give way to unidirectional flows under multiple flow regimes.[45] Channel reaches upstream of these transition points under the authors' low-flow scenarios were considered fluvial and not classified as either dendritic or looped.

For both the historical and modern analyses, channel reaches were excluded from the looped/dendritic channel analysis if they lacked a direct, perennial connection (through the larger network) to the Delta mouth (and therefore to the tidal source). This was determined in ArcGIS with a recursive spatial selection that identified intersecting reaches extending outwards/upstream from the downstream-most channel reach at the Delta mouth. This rule excluded most upland intermittent streams, many of the possibly exhumed and disconnected channels mapped in the historical south Delta,[46] and channels in the modern Delta separated from the tides by levees, weirs, and other barriers (often identified with supplemental information).

Tidal reaches that ultimately connect upstream to perennial fluvial systems were not classified as either dendritic or looped between the perennial fluvial reaches upstream and where they first become looped channels downstream. This rule prevented major rivers like the Sacramento, San Joaquin, and Mokelumne (which are mostly tidal within the study extent) from being lumped with the true dendritic channels that terminate within the study extent.

One final exception to the classification rules described above was made for the large channels bordering Liberty Island in the modern network. Although only one independent path from the tidal source exists for these reaches (paths into the area must converge at the single access point west of the base of the Sacramento Deepwater Ship Channel), they were deemed functionally looped due to their form (a circular path around the former extent of Liberty Island via the "Stair Step" channel) and high local wind wave energy.

10. INUNDATION

10.1 Historical inundation

For the historical Delta, areas regularly subject to inundation were derived from the map of historical habitat types, which were defined, at least in part, by their typical hydrology (Whipple et al. 2012). Areas mapped as 'Tidal freshwater emergent wetland' were classified for the inundation analysis as areas of "tidal inundation"; 'Non-tidal freshwater emergent wetlands' and 'Willow thickets' were classified as areas of "seasonal long-duration flooding"; and 'Vernal pool complex,' 'Wet meadow/seasonal wetland,' and 'Alkali seasonal wetland complex' were classified as areas of "seasonal short-term flooding." Areas mapped as 'Tidal mainstem channel,' 'Fluvial mainstem channel, 'Tidal low order channel,' 'Fluvial low order channel,' 'Freshwater pond or lake,' and 'Freshwater intermittent pond or lake' were classified as "ponds, lakes, channels, & flooded islands."

The methods described above were further developed in the following ways.

(1) The area mapped by Whipple et al. (2012) as 'Tidal freshwater emergent wetland' (and thus classified as an area of "tidal inundation") represented the area "wetted or inundated by spring tides at low river stages."[47] To distinguish the smaller portion of this area that experienced daily tidal inundation, we relied on the available historical data and best professional judgment.[48] Ultimately, the mapped extent of daily tidal inundation (~76,500 ha) corresponds well with estimates of this area identified in historical records. Most early accounts state that approximately 200,000 acres (80,940 ha) or less were regularly overflowed by "ordinary" tides (i.e., daily high tides).[49] A more specific calculation from an early engineering report states that roughly 160,000 acres (64,750 ha) were "subject to inundation at each high tide, twice in twenty-four hours."[50]

(2) The tidal portion of the lower Yolo Basin, which was only inundated during spring tides (north of the area determined to be inundated daily) was classified both as an area of "tidal inundation" and as area of "seasonal long-duration flooding." This area is displayed on the maps as "seasonal long-duration flooding" during winter and spring and as "tidal inundation" during fall and summer. In the charts on pages 40-41 and 61, the area is included in both categories.

Information on the depth, timing, and duration of each inundation type was derived from Whipple et al. (2012) and other supplemental sources.[51]

10.2 Modern inundation

Since the modern habitat type dataset does not distinguish between tidal and non-tidal freshwater emergent wetland, a proxy was used to define modern areas of tidal inundation. Specifically, areas were assigned the "tidal inundation" classification if they were mapped as either 'Freshwater emergent wetland' or 'Willow-marsh complex,' were adjacent to open water, and fell within the historical extent of tidal marsh. Additional areas of modern inundation were identified, mapped, and classified after conducting a literature search and consulting with regional experts. The extent of the "seasonal short-term flooding" in the Yolo Bypass, for example, was digitized by Sommer et al. (2004) from aerial photographs of the flooding that took place in January 1998. The extent of the Cosumnes River floodplain (also classified as "seasonal short-term flooding") was digitized by SFEI staff from a map of the upper and lower floodplain.[52] We recognize that other areas of the modern Delta may experience inundation, but we only digitized areas identified by the LIT.

11. IDENTIFYING MARSH PATCHES

Historical marsh patches were created from historical habitat type polygons classified as either 'Tidal freshwater emergent wetland' or 'Nontidal emergent wetland'; modern marsh patches were created from modern habitat type polygons classified as either 'Freshwater emergent wetland' or 'Willow-marsh complex.' In the GIS, discrete marsh polygons were aggregated and considered part of a single patch if they were located within 60 m of one another. Groups of polygons separated by less than this distance were identified and aggregated using ArcGIS's 'Aggregate Polygons' tool and assigned unique patch IDs. Multipart feature layers delineating marsh patches (for both the historical and modern Delta) were generated for further analysis (the "patch layers").

The 60 m threshold for grouping marsh polygons was taken from a rule set for defining resident intertidal rail patches developed by Collins and Grossinger (2004), which was based on the best available data on rail habitat affinities and dispersal distances.[11] In the absence of more specific data, we made the assumption that the rules developed for defining intertidal rail patches in the South Bay (primarily for California Clapper Rails, which are not generally found

in the Delta) are broadly applicable to the Delta's freshwater (and often non-tidal) marshes/species. Unlike Grossinger and Collins (2004), however, our analysis only considered roads and levees as dispersal barriers if the width of these features (as mapped in the habitat type layers) exceeded the 60 m threshold. It is worth noting that this model of a binary landscape (marsh and non-marsh) simplifies the complexities of how species interact with their surroundings. It necessarily assumes that all patches of marsh are equally suitable for rails, that the routes of travel between patches are linear, and that the only barrier to rail movement is distance.[53]

12. MARSH PATCH SIZE

The size of individual marsh patches was determined with ArcGIS. In addition to determining the size of each patch, we also identified the number and distribution of "large" marsh patches, where "large" was defined based on functionality for marsh bird support. For the purposes of this analysis, a marsh patch was considered "large" if it had an area greater than or equal to 100 ha. This threshold is based on (1) regression models indicating a significant negative correlation between California Black Rail presence and distance to the nearest marsh greater than or equal to 100 ha[54] and (2) research that found that California Clapper Rail densities decrease in patches <100 ha.[55]

13. MARSH CORE VS. EDGE

For the purpose of this analysis, core area index is defined as the percent of a marsh patch's total area that is greater than 50 m from the patch's edge. The core area of each marsh patch was identified in ArcGIS using the 'Buffer' tool with an internal linear buffer distance of 50 m. This distance is based on research indicating a significant positive relationship between California Black Rail presence and marsh core area (defined as >50 m from marsh edge).[56]

14. MARSH NEAREST LARGE NEIGHBOR DISTANCE

Nearest large neighbor distance (NLND) was determined with ArcGIS's 'Generate Near Table' tool, which calculated the linear distance of each marsh patch to the nearest "large" neighboring marsh patch (>100 ha, see Section 12). Large patches themselves were assigned a NLND of 0 m. This metric is supported by research indicating a significant negative relationship between California Black Rail presence and distance to nearest 100 ha marsh.[57]

15. IDENTIFYING RIPARIAN HABITAT PATCHES

Historical riparian patches (here meaning woody riparian habitat patches) were created from historical habitat type polygons classified as either 'Valley foothill riparian' or 'Willow riparian scrub or shrub.' Modern riparian patches were created from modern habitat type polygons classified as either 'Valley foothill riparian' or 'Willow riparian scrub or shrub,' but also from some polygons ultimately classified as 'Managed wetland' (where the original classification was either 'Valley foothill riparian' or 'Willow riparian scrub or shrub'—see Section 2.4.2). Since, for this analysis, vegetation type and structure were deemed to be more important characteristics than hydrology, riparian habitat type polygons were included whether or not they were deemed hydrologically connected (see Section 2.4.3 for further explanation—this stands in contrast to the riparian width analyses, which exclude hydrologically disconnected riparian habitat polygons).

In the GIS, discrete woody riparian polygons were aggregated and considered part of a single patch if they were located within 100 m of one another. The 100 m threshold for grouping riparian polygons is based on the typical maximum gap crossing distance of dispersing songbirds, as determined by the best professional judgment of regional experts.[58] Groups of polygons separated by less than this distance were identified and aggregated using ArcGIS's 'Aggregate Polygons' tool and assigned unique patch IDs. Multipart feature layers delineating woody riparian habitat patches (for both the historical and modern Delta) were generated for further analysis (the "patch layers"). The size of individual woody riparian habitat patches (and total patch size distribution) for both the historical and modern Delta was determined using these layers with simple ArcGIS table summaries.

As was the case when defining marsh habitat patches, it is worth noting that this model of a binary landscape (woody riparian habitat and non-woody riparian habitat) simplifies the complexities of how species interact with their surroundings. It makes the assumption that all patches of woody riparian habitat are equally suitable for riparian wildlife, that the routes of travel between patches are linear, and that the only barrier to movement is distance.[59]

The thresholds defining woody riparian patch size bins used to assess patch size distribution use a geometric progression starting at 20 ha and multiplying by a common ratio of four. These bins result in thresholds at 20 ha and 80 ha, both of which have apparent ecological significance for Western Yellow-billed Cuckoos. For nesting cuckoos in California, researchers characterize willow-cottonwood patches >80 ha in size as "optimal" and set 20 ha as the minimum threshold for "marginal" habitat suitability.[60] Below this area (<20 ha for mesquite habitat and <15 ha for willow-cottonwood habitat), patches become "unsuitable." The size thresholds of the larger bins do not have specific ecological justifications.

15.1 Estimating the area of unmapped willow-fern swamps

Scattered "clumps" or "patches" of willows are known to have occurred within the tule marshes of many central Delta islands, adding a dimension of woody vertical structure to the freshwater emergent wetland plain.[61] Although not strictly a "riparian" habitat type (the willow patches were not limited to channel banks and are thought to have occurred across central Delta islands where tidal processes were dominant), we quantified the area of this vegetation community since it offers the taller woody vegetation structure that is an important component of many of the functions provided by riparian habitat (sometimes independent of actual hydrological connection to fluvial systems). While "willow-fern swamp" vegetation community was described in detail by Whipple et al. (2012), it was not mapped as a unique habitat type and was instead considered part of the 'Tidal freshwater emergent wetland' habitat type. We estimated the historical area of willow-fern swamp using a historical map made in 1850 by Charles Gibbes[62] and some of the general conclusions drawn from other historical sources by Whipple et al. (2012). In the *Sacramento-San Joaquin Delta Historical Ecology Investigation*, Whipple et al. (2012) determined that willow-fern swamps were most common within Sherman, Bradford, Webb, Venice, and Mandeville islands, and indicated the extent of 'Tidal freshwater emergent wetland' over which the vegetation community is thought to have occurred (Figure 5).[63] We estimated the number individual willow fern-swamp patches in the central Delta by multiplying this area (31,570 ha) by the willow patch density mapped by Gibbes in 1850 (0.007 patches/ha; sampled from a georeferenced version of the map in ArcGIS). The estimated area of willow-fern swamp habitat was determined by multiplying the estimated number of patches (221) by the average patch size (16 ha, determined by measuring the area of a random sample of 35 patches drawn by Gibbes; SD = 12 ha). With this simple operation (and all of its inherent assumptions), we estimated that there were approximately 3,500 ha of willow-fern swamp habitat in the historical central Delta.

16. RIPARIAN HABITAT WIDTH

For both the historical and modern Delta, we sought to visualize and quantify the length of riparian habitat (defined here as woody riparian habitat) based on the riparian habitat's width. We measured historical and modern riparian habitat widths by casting transects

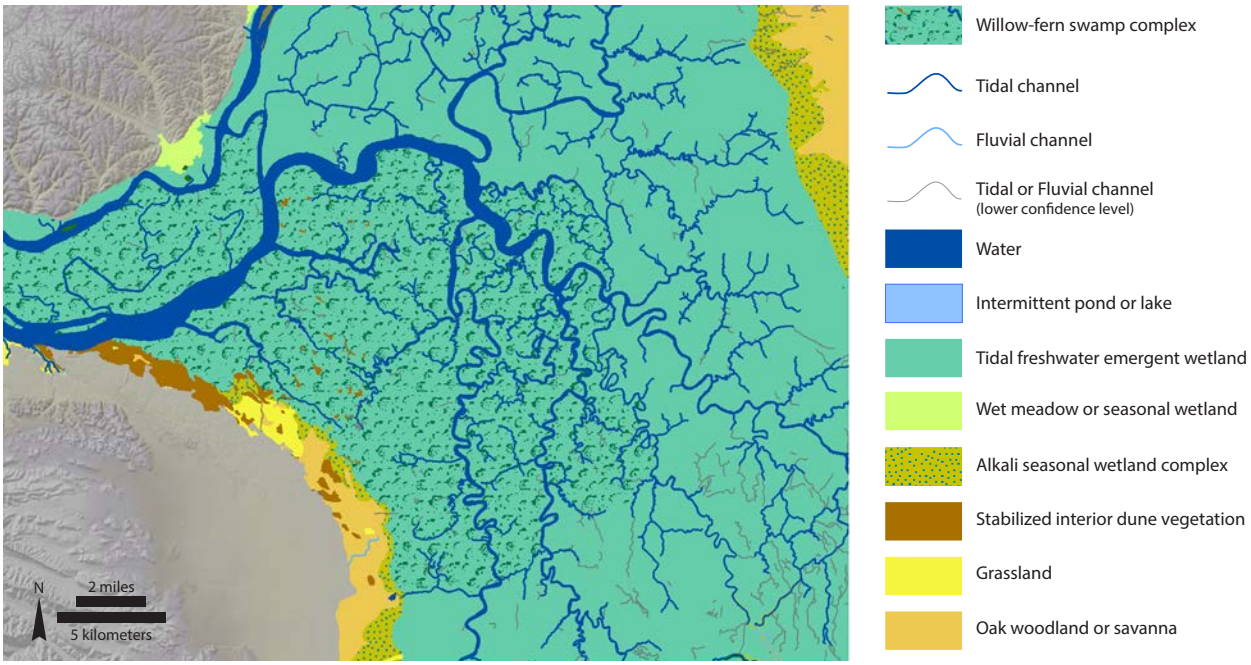

Figure 5. The generalized extent of willow-fern swamp complex (shown by the dark, clumped tree symbol) as mapped by Whipple et al. (2012). The extent was determined from various sources, none of which explicitly described the boundaries of this wetland community. Actual boundaries were likely indiscernible, as the presence of willows within the islands gradually became less prevalent moving away from this mapped area. In this report, we use the approximate extent and data on the density and size of patches sampled from an 1850 map by Charles Gibbes to estimate the total area of willow-fern swamp habitat.

perpendicular to modified channel centerlines and then trimming the transects at the edges of riparian habitat polygons (a method similar to/adapted from our analysis of channel width; see Section 6). The nature of the historical and modern datasets required two different (although generally similar) methods to determine riparian habitat width. These methods are described in detail below.

16.1 Historical riparian habitat width

For the historical layers, riparian areas classified as either 'Valley foothill riparian' or 'Willow riparian scrub or shrub' were extracted from the historical habitat types dataset and merged with adjacent open water polygons. These merged riparian "zones" (including the open water areas) were dissolved, split manually at confluences, and assigned unique identifiers. Next, we generated centerlines for each split riparian habitat zone (from which to cast perpendicular transects that measure the zone's width at regular intervals). To develop the riparian habitat centerlines, we started with the historical channel polylines, which were modified to adhere to the following rules:

- Riparian centerlines were not drawn for side channels within otherwise contiguous zones of riparian habitat (those that effectively form islands of woody riparian habitat)—these smaller side channels were merged with the larger channel and riparian zone (Figure 6, A and B).
- Riparian centerlines were not drawn for small crevasse splays (Figure 6, C).
- Riparian centerlines were straightened through sinuous areas (Figure 6, D).

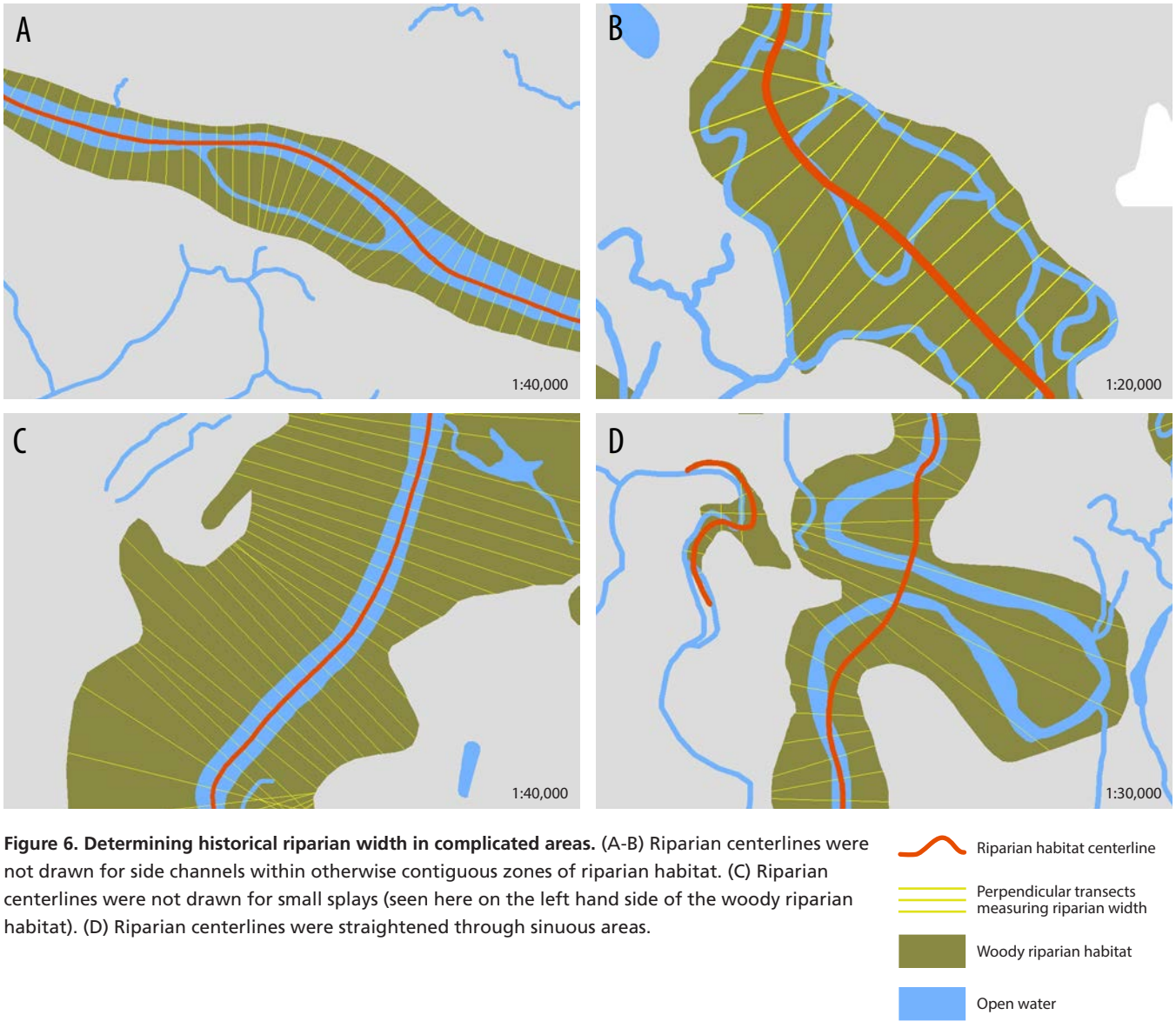

Figure 6. Determining historical riparian width in complicated areas. (A-B) Riparian centerlines were not drawn for side channels within otherwise contiguous zones of riparian habitat. (C) Riparian centerlines were not drawn for small splays (seen here on the left hand side of the woody riparian habitat). (D) Riparian centerlines were straightened through sinuous areas.

- Riparian centerlines were smoothed with a maximum offset of 2 m and generalized by 0.1 to remove sharp angles and to prevent transects from being cast at incorrect angles.

Merged lines were intersected with the riparian habitat zone polygons to associate each line with only one zone. The riparian centerlines were then segmented at 100 m intervals and transects were cast perpendicularly from the centroid of each segment (as determined by the x, y coordinates of its endpoints) 2,000 m in each direction (a distance greater than the maximum width of the woody riparian habitat zone). Transects (containing the unique identifier of the centerline/zone from which they were cast) were then intersected with riparian zone polygons (with the same identifier), thereby trimming the transects to the width of the adjacent woody riparian habitat zone. Since riparian habitat "zones" included both open water and woody riparian habitat, we erased segments of the trimmed transects that intersected open water polygons to determine only the width of the woody riparian habitat. This process was automated with a custom ArcPy script.

16.2 Modern riparian habitat width

Due to the complicated shape and distribution of woody riparian habitat in the modern Delta, we used a second set of methods to determine modern riparian habitat widths. Extensive areas of vegetation in the modern Delta classified as 'Valley foothill riparian' and 'Willow riparian scrub or shrub' are not adjacent to channel features. Since we sought to measure the length/width of riparian habitat along linear zones of open water, we only counted the width of modern woody riparian habitat if it was deemed hydrologically connected (see Section 2.4.3 for how we determined the hydrologic connectivity of woody riparian habitat types; see Figure 7 for a map of the modern woody riparian habitat classified as hydrologically "connected" and "disconnected").

To determine modern riparian habitat widths, we cast transects at 100 m intervals from the modern channel polyline dataset (described in Section 3.2) 1,500 m in each direction. To prevent counting woody riparian vegetation located behind artificial levees (and thus disconnected from the linear channel features), transects were intersected with a polyline layer consisting of artificial levee centerlines.[64] Segments of the transects falling on the far side of the levee centerlines (away from the channel) were discarded. Transects were then intersected with the hydrologically connected woody riparian habitat polygons resulting in trimmed transects with lengths equal to the width of the woody riparian habitat polygons. Trimmed transects were edited manually to remove instances of double counting (where transects cast from one channel intersected riparian habitat associated with another channel). Riparian habitat only contributed to measurements of width if was associated with the channel reach from which the intersecting transect was cast (determined by visual inspection of the riparian habitat polygons, channel centerlines, and transects). Where there were gaps in the riparian habitat, we counted the area on both sides of the gap towards total riparian width (assuming both areas met the above rule), but did not count the width of the gap itself.

Trimmed riparian width transects >100 m and >500 m were selected to display on the historical and modern maps of woody riparian habitat width. The 100 m width threshold is based on the work of Gaines (1974), who found that Western Yellow-billed Cuckoos were only present in riparian habitat patches at least 100 m wide. The 500 m width threshold is based on the work of Kilgo et al. (1998), who found that riparian forest areas at least 500 m wide were necessary to maintain the "complete avian community" in bottomland hardwood forests in South Carolina. These widths largely agree with the findings of Laymon and Halterman (1989), who (based on occupancy and nest predation rates) define riparian habitat <100 m wide as "unsuitable," habitats 100-600 m wide as "marginal" or "suitable," and habitats at least 600 m wide as "optimal" for cuckoo nesting.

17. MARSH-TERRESTRIAL TRANSITION ZONE LENGTH

The marsh-terrestrial transition zone ("t-zone") was identified using the habitat type layers by extracting habitat type polygons considered "marsh" (described below), generating contiguous polygons from these features (without interior borders), and then intersecting these contiguous polygons with all other habitat type polygons. The output of this operation was a polyline that traces the locations where marsh habitats are directly adjacent to other habitat types. We then extracted segments of this polyline associated with terrestrial habitat types (identified below). This new polyline (that traces locations where marsh shares a border with terrestrial habitat types) was deemed the marsh-terrestrial transition zone. The lengths of t-zone polyline segments (for both the historical and modern datasets) were summed by terrestrial habitat type to generate the chart on page 73.

For this analysis, marsh habitat types were 'Tidal freshwater emergent wetland' (historical), 'Non-tidal freshwater emergent wetland' (historical), 'Freshwater emergent wetland' (modern), and 'Willow-marsh complex' (modern). Terrestrial habitat types were 'Valley foothill riparian,' 'Willow riparian scrub or shrub,' 'Willow thicket,' 'Wet meadow and seasonal wetland,' 'Vernal pool complex,' 'Alkali

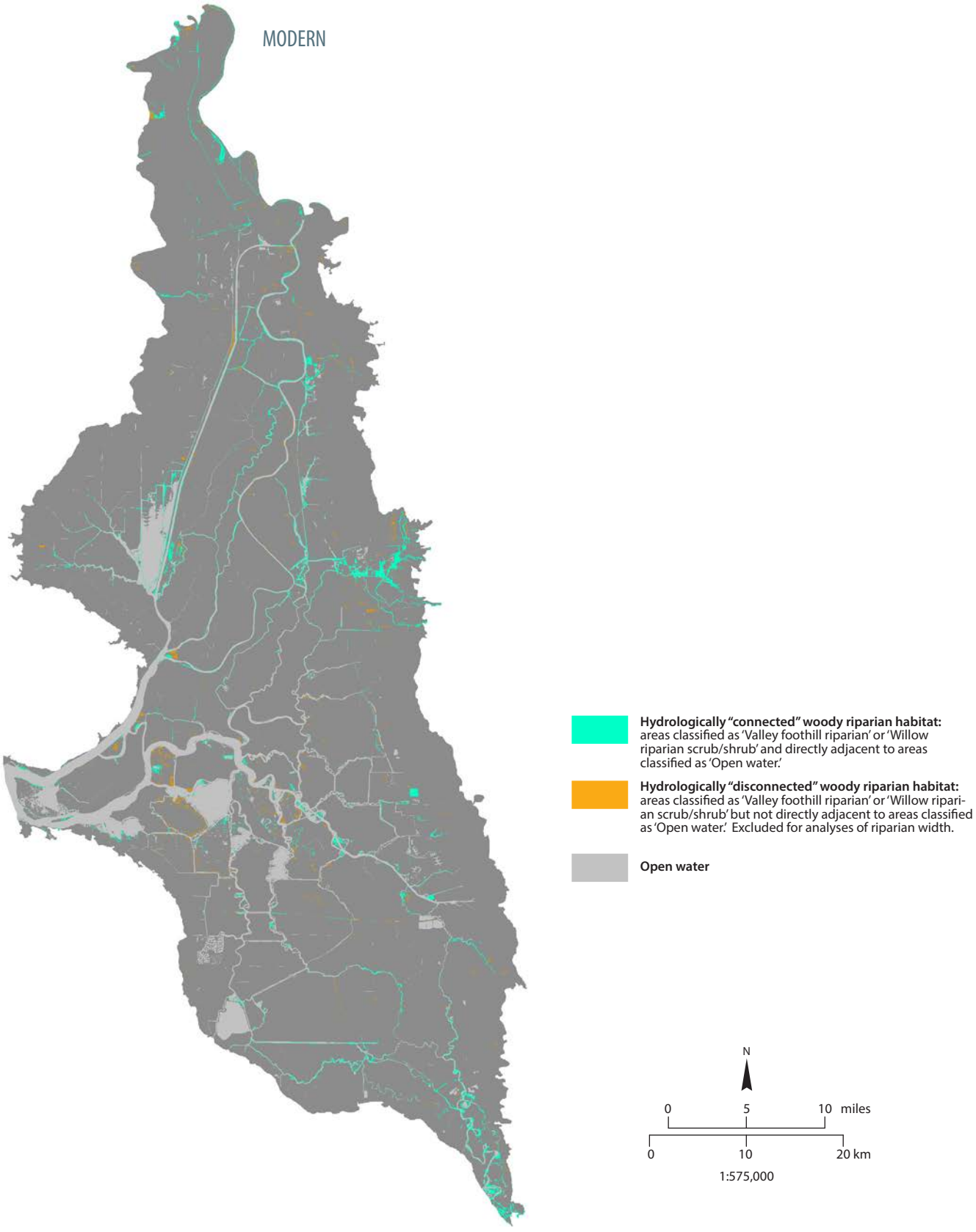

Figure 7. Hydrologically "connected" and "disconnected" woody riparian habitat in the modern Delta. We distinguished contemporary hydrologically connected woody riparian habitat from hydrologically disconnected woody riparian habitat. Only contiguous woody riparian habitat polygons that shared an edge with open water were deemed hydrologically connected. Although both types were considered when determining woody riparian habitat patch size distribution (pages 64-65), disconnected woody riparian habitat was not considered when calculating riparian width. See Section 16.2 of this chapter for more detailed methods.

seasonal wetland complex,' ' Grassland,' ' Oak woodland and savanna,' and 'Stabilized interior dune vegetation.'

18. CERTAINTY AND LIMITATIONS

18.1 Historical data certainty

Each feature in the historical Delta datasets (habitat type polygons and channels) was assessed for certainty during the mapping process. Whipple et al. (2012) describes this process in the Delta Historical Ecology Investigation:

> Our confidence in a feature's habitat type and presence (interpretation), size, and location was assigned based upon the number of kinds and quality of evidence, accuracy of digitizing source, our experience with the particular aspects of each data source, and by factors such as stability of features on a decadal scale (following standards discussed in Grossinger et al. 2007; [Table 8]). Certainty in tidal status was also included for the channel line layer. In cases where features were likely to have shifted positions over relatively short time periods, we assigned lower certainty for location and size. These attributes provide a way to estimate ranges of uncertainty associated with different locations and kinds of feature or habitat type, and allows subsequent users to assess accuracy [Table 8]. (49)

Using these classifications, the authors were able to assess and roughly quantify the uncertainty associated with the historical mapping:

> Overall, confidence in interpretation and location was fairly high, 64% and 77% respectively. The lower certainty in shape (of each mapped feature) reflects the large areas of habitats, primarily around the perimeter of the Delta, where boundaries were challenging to determine. For the channel lines layer (the network along the polygon channels plus the channels narrower than the polygon minimum mapping width), high interpretation certainty accounted for about 64% of the mapped channel length, with high shape certainty at 59% and high location at 85%. Less than 10% of the area was assigned a low interpretation certainty for either mapping layer. The fourth certainty level standard, tidal interpretation, was only included in the lines layer, where 75% of the channel length was assigned a high certainty level for its tidal interpretation. (89-90)

Mapping certainty varied by habitat type:

> Habitat types with less than 50% of the area assigned with high certainty include alkali seasonal wetland complex, grassland, tidal intermittent pond or lake, vernal pool complex, wet meadow or seasonal wetland, willow riparian scrub or shrub, and willow thicket. Habitat types associated with the highest interpretation certainty tended to be the water bodies and freshwater emergent wetland, given the many sources available confirming these habitat types (e.g., descriptions of tule to identify freshwater emergent wetland). Not surprisingly, the similar summary of the channel line layer shows the larger mainstem channels that are well-established in numerous historical sources with nearly 100% interpretation certainty, while the interpretation of lower order channels was more challenging, mostly due to the difficulties associated with distinguishing the early 1800s channels from the many signatures of ancient channels exposed by exhumed peat in the south Delta. (90-91).

For a full discussion of the uncertainties associated with the historical habitat types and channel datasets, please refer to the *Delta Historical Ecology Investigation*.[65]

Table 8. Certainty level standards assigned to each mapped historical feature for the assessment of confidence in interpretation (classification and historical presence), size, location, and tidal status. From Whipple et al. (2012).

Certainty Level	Interpretation	Size	Location	Tidal Status (line features only)
High/ "Definite"	Feature definitely present before Euro-American modification	Mapped feature expected to be 90%-110% of actual feature size	Expected maximum horizontal displacement less than 50 m (150 ft)	Channel bed definitely within or outside tidal range (<3.5 ft elevation)
Medium/ "Probable"	Feature probably present before Euro-American modification	Mapped feature expected to be 50%-200% of actual feature size	Expected maximum horizontal displacement less than 150 m (500 ft)	Channel bed probably within or outside tidal range
Low/ "Possible"	Feature possibly present before Euro-American modification	Mapped feature expected to be 25%-400% of actual feature size	Expected maximum horizontal displacement less than 500 m (1,600 ft)	Channel bed possibly within or outside tidal range (if within, no clear tidal connection)

18.2 Modern data certainty

As a compilation of multiple sources, the modern habitat types layer utilized in this report represents a conglomeration of certainty levels that vary within and between the individual sources. The two primary modern data sources combined in this report each underwent independent assessments of mapping accuracy. For the VegCAMP 2007 Sacramento-San Joaquin River Delta dataset ('CDFG 2007 Delta Vegetation'—the source for 80% of this project's study extent) accuracy was assessed using the fuzzy logic method.[66] The overall accuracy of the map was nearly 89%, while the average accuracy score per vegetation type was 83%. For the Central Valley Riparian Mapping Project Group Level dataset ('CDWR 2012 CVRMP'—the source for 19% of this project's study extent) accuracy was assessed by comparing how photo interpreters (producers) and field surveyors (users) classified the same regions.[67] The overall user's accuracy score averaged 76% and the producer's accuracy averaged 79%.

Some uncertainty was also introduced through the development of the crosswalk used to relate each of the different original classification systems (to each other and to the historical classifications). As noted by Hickson and Keeler-Wolf (2007), "The complexity and uncertainty of such relationships arise not only from independent evolution of classifications, but also from their imprecise definitions, without quantitative rules for proper interpretation. The best crosswalks are those that have been developed with a good understanding of the meaning and definitions of each classification system." By having Todd Keeler-Wolf (an author of the primary modern dataset utilized in this report) assist with the development of this project's crosswalk, we were able to minimize the uncertainty associated with a somewhat subjective process.

Since our modern mapping is from a compilation of sources, it represents a compilation of years. The oldest—the VegCAMP 2007 Sacramento-San Joaquin River Delta dataset—utilized U.S. Geological Survey High Resolution Orthoimagery taken in 2002 and 2005.[68] The most recent source—supplemental polygons digitized by SFEI staff (covering less than 1% of the study extent)—was derived from Bing aerial photos accessed in 2013. The Delta is a continually changing place and there is uncertainty associated with modern classifications that are already outdated at the time of publication; we are aware of at least seven sizeable parcels (including areas mapped as 'Grassland,' 'Wet meadow and seasonal wetland,' and 'Agriculture/Non-native/Ruderal') that have been developed since the modern habitat type datasets were generated.[69]

18.3 Issues of historical and modern data fidelity: comparing apples to apples (or at least to crabapples)

One of the fundamental goals of this report was to ensure that, when making comparisons between the historical and modern landscape, we compared the same things, at the same scale, using the same measurements. Due to the severity of change in the Delta and differences between the historical and modern datasets, this task was far from trivial. In this section we discuss the consequences of differences in historical and modern data resolution. These differences were more or less pronounced depending on the datasets used and the analyses in question. The extent to which we could control for differences in resolution also varied across analyses. While some analyses are affected by differences in data resolution (that increase the uncertainty surrounding specific numbers and the precise magnitude of the measured changes), we do not believe that these differences impact the direction of changes or the overall stories indicated by our analyses.

Generally speaking, the spatial data for the modern Delta has a higher resolution than the spatial data for the historical Delta, but these differences are not always very pronounced and were largely manageable. In our analysis of marsh core area, for example, it was important to make sure that the resolution of non-marsh features within the marsh (which effectively create marsh edge) was similar in the historical and modern datasets. When calculating historical core area ratio, we chose only to include channels mapped as polygons, because their minimum mapping width (15 m; MMW) was comparable to the MMW for water features in the modern dataset (10 m; see Table 1). Although not identical, these MMWs are well within an order of magnitude of one another. While it is true that the slightly lower MMW for water features in the modern dataset increases the amount of modern edge habitat, this difference is insignificant when comparing the core area ratios of the historical and modern marshes: the vast area of largely contiguous historical marsh ensures a higher core area ratio. Similarly, since willow patches in the historical central Delta were not explicitly mapped (due to a lack of data) and instead were lumped into the tidal freshwater emergent wetland classification, we made a concerted effort to do the same for the modern dataset (because the historical lumping effectively decreases marsh edge). This was largely accomplished through the modern data crosswalk (which included areas of marsh and some woody vegetation in the 'Freshwater emergent wetland' category) but also by generating a 'Willow-marsh complex' designation that allowed us to further lump areas of willows with freshwater emergent wetland species into the areas we considered "marsh" when calculating marsh core area ratio (see sections 2.4.1 and 11).

Decisions like this increased fidelity between the historical and modern analyses.

The historical and modern habitat type datasets also utilized different minimum mapping units (MMUs) for areal features—5 ha in the historical dataset and 0.8 ha (for vegetation) in the modern dataset. While these values are within an order of magnitude, their difference is still a concern, because the inclusion of a smaller class of features in the modern dataset that are not included in the historical dataset can increase estimates of patch number and edge length, while decreasing estimates of average patch size. Since outright exclusion of the smallest features in the modern Delta (to match the MMU of the historical Delta) would eliminate a significant proportion of most habitat types and generate unwieldy data gaps, we instead developed methodologies and analyses that minimize/manage the impact of MMU differences and consider here how the differences are likely affecting our results.

One method we used to manage the difference in minimum mapping units was to aggregate individual polygons into patches (see sections 11 and 15; marsh polygons were aggregated if less than 60 m apart, riparian polygons if less than 100 m apart). Small, highly resolved modern features, if proximal to one another, were not counted separately and were effectively lumped to a size above the historical mapping unit. Although small, unmapped areas of marsh certainly existed in the historical Delta, these areas would have had to exist more than 60 m away from a mapped marsh to impact the number of historical patches in our analysis. The same goes for unresolved gaps in the historical marsh—unless these gaps isolated an area of marsh 60 m in all directions, the total number of marsh patches was not affected. Although the process of aggregating polygons into patches minimizes the effects of different patch sizes on our analyses, many modern patches analyzed in Chapter 5 are below the minimum historical mapping unit. To assess the impact of including these patches on our landscape metrics, and the sensitivity of the modern analyses to differences in MMUs, we calculated marsh patch statistics without patches less than 5 ha in size (the historical minimum mapping unit). Doing so yielded a significant decrease in the total number of patches—from 1,211 to 43. Average patch size increased, but perhaps less dramatically—from 4 ha (SD = 24 ha) to 22 ha (SD = 66 ha). It is worth noting that 9 (of 43) historical marsh patches are also below the historical dataset's minimum mapping unit (largely due to study boundary conditions)—enforcing a 5 ha MMU would thus increase historical average patch size from 4,494 ha (SD = 17,956 ha) to 5,682 ha (SD = 20,085 ha). Although removal of the marsh patches less than 5 ha would affect the precise magnitude of change, the direction of change and larger story remain unchanged.

The fidelity of the historical and modern channel polyline datasets is quite high. Both used no minimum mapping width, and channels were digitized wherever evidence of them existed. As described in Section 5, we estimated the length of unmapped historical low-order channels that we expect are comparable in size to the smallest channels visible/digitized in the modern Delta. Although these channels are not explicitly drawn on the map, accounting for their estimated length allowed us to more effectively make comparisons with the modern channel dataset. In both datasets, channels were only digitized around islands larger than 25 ha.

Table 2. Habitat types used to map the historical habitats of the Sacramento-San Joaquin Delta.

Landcover grouping	Habitat type	Description	MSCS NCCP Habitat Types (CALFED 2000c)
Water	**Tidal mainstem channel**	Rivers, major creeks, or major sloughs forming Delta islands where water is understood to have ebbed and flowed in the channel at times of low river flow. These delineated the islands of the Delta.	Tidal Perennial Aquatic
	Fluvial mainstem channel	Rivers or major creeks with no influence of tides.	Valley Riverine Aquatic
	Tidal low order channel	Dendritic tidal channels (i.e., dead-end channels terminating within wetlands) where tides ebbed and flowed within the channel at times of low river flow.	Tidal Perennial Aquatic
	Fluvial low order channel	Distributaries, overflow channels, side channels, swales. No influence of tides. These occupied non-tidal floodplain environments or upland alluvial fans.	Valley Riverine Aquatic
	Freshwater pond or lake	Permanently flooded depressions, largely devoid of emergent Palustrine vegetation. These occupied the lowest-elevation positions within wetlands.	Tidal Perennial Aquatic, Lacustrine
	Freshwater intermittent pond or lake	Seasonally or temporarily flooded depressions, largely devoid of emergent Palustrine vegetation. These were most frequently found in vernal pool complexes at the Delta margins and also in the non-tidal floodplain environments.	N/A
Freshwater emergent wetland	**Tidal freshwater emergent wetland**	Perennially wet, high water table, dominated by emergent vegetation. Woody vegetation (e.g., willows) may be a significant component for some areas, particularly the western-central Delta. Wetted or inundated by spring tides at low river stages (approximating high tide levels).	Tidal Freshwater Emergent
	Non-tidal freshwater emergent wetland	Temporarily to permanently flooded, permanently saturated, freshwater non-tidal wetlands dominated by emergent vegetation. In the Delta, occupying upstream floodplain positions above tidal influence.	Non-tidal Freshwater Permanent Emergent
Willow thicket and riparian forest	**Willow thicket**	Perennially wet, dominated by woody vegetation (e.g., willows), emergent vegetation may be a significant component, generally located at the "sinks" of major creeks or rivers as they exit alluvial fans into the valley floor.	Valley/Foothill Riparian

Wildlife Habitat Relationship (WHR)	Representative types from California Terrestrial Natural Communities (CNDDB 2010)	Cowardin et al. (1979)/ USFWS Riparian Mapping System (USFWS 2009)	Hydrogeomorphic classification (HGM) (Brinson 1993)
Estuarine, Riverine	*Azolla (filiculoides, mexicana)* (Mosquito fern mats) Provisional Alliance (52.106.00), *Stuckenia (pectinata) - Potamogeton* spp. (Pondweed mats) Alliance (52.107.00)	Estuarine subtidal, Estuarine intertidal, Riverine	Riverine wetland, surface flow, unidirectional flow and bidirectional flow
Estuarine, Riverine	*Azolla (filiculoides, mexicana)* (Mosquito fern mats) Provisional Alliance (52.106.00), *Stuckenia (pectinata) - Potamogeton* spp. (Pondweed mats) Alliance (52.107.00)	Estuarine subtidal, Estuarine intertidal, Riverine	Riverine wetland, surface flow, unidirectional flow and bidirectional flow
Estuarine, Riverine	*Azolla (filiculoides, mexicana)* (Mosquito fern mats) Provisional Alliance (52.106.00), *Stuckenia (pectinata) - Potamogeton* spp. (Pondweed mats) Alliance (52.107.00)	Estuarine subtidal, Estuarine intertidal, Riverine	Riverine wetland, surface flow, unidirectional flow and bidirectional flow
Estuarine, Riverine	*Azolla (filiculoides, mexicana)* (Mosquito fern mats) Provisional Alliance (52.106.00), *Stuckenia (pectinata) - Potamogeton* spp. (Pondweed mats) Alliance (52.107.00)	Estuarine subtidal, Estuarine intertidal, Riverine	Riverine wetland, surface flow, unidirectional flow and bidirectional flow
Estuarine, Lacustrine	*Azolla (filiculoides, mexicana)* (Mosquito fern mats) Provisional Alliance (52.106.00), *Stuckenia (pectinata) - Potamogeton* spp. (Pondweed mats) Alliance (52.107.00), *Nuphar polysepala* (Yellow pond-lily mats) Provisional Alliance (52.110.00)	Lacustrine	Depressional wetland, surface flow and groundwater, vertical fluctuations
N/A	N/A	N/A	Depressional wetland, surface flow and groundwater, vertical fluctuations
Fresh Emergent Wetland	*Schoenoplectus acutus* (Hardstem bulrush marsh) Alliance (52.122.00), *Schoenoplectus californicus* (California bulrush marsh) Alliance (52.114.00), *Typha (domingensis, latifolia)* (Cattail marshes) Alliance (52.050.00), American bulrush marsh (52.111.00), California bulrush marsh (52.114.00), *Juncus effusus* (Soft rush marshes) Alliance (45.561.00), *Juncus articus* (Baltic and Mexican rush marshes) Alliance (45.562.00), *Salix lucida* (Shining willow groves) Alliance (61.204.00), *Eleocharis macrostachya* (Pale spike rush marshes) Alliance (45.230.00)	Estuarine intertidal persistent emergent wetland. Temporarily to seasonally flooded, permanently saturated.	Fringe wetland, surface flow including tidal, bidirectional flow
Fresh Emergent Wetland	*Schoenoplectus acutus* (Hardstem bulrush marsh) Alliance (52.122.00), *Schoenoplectus californicus* (California bulrush marsh) Alliance (52.114.00), *Typha (domingensis, latifolia)* (Cattail marshes) Alliance (52.050.00), *Juncus effusus* (Soft rush marshes) Alliance (45.561.00), *Juncus articus* (Baltic and Mexican rush marshes) Alliance (45.562.00), *Eleocharis macrostachya* (Pale spike rush marshes) Alliance (45.230.00)	Palustrine persistent emergent freshwater wetland. Temporarily to permanently flooded, permanently saturated.	Riverine wetland, surface flow, unidirectional flow
Valley foothill riparian	*Salix gooddingii* Alliance (61.211.00), *Salix laevigata* Alliance (61.205.00), *Salix lasiolepis* Alliance (61.201.00), *Salix lucida* Alliance (61.204.00), *Salix exigua* Alliance (61.209.00), *Cornus sericea* (Red osier thickets) Alliance (80.100.00), *Rosa californica* Alliance (63.907.00), *Acer negundo* (Box-elder forest) Alliance (61.440.00), *Sambucus nigra* (Blue elderberry stands) Alliance	Palustrine forested wetland. Temporarily flooded, permanently saturated. / Riparian scrub/shrub deciduous.	Riverine wetland, surface flow, vertical fluctuations

Table 2 (continued). Habitat types used to map the historical habitats of the Sacramento-San Joaquin Delta.

Landcover grouping	Habitat type	Description	MSCS NCCP Habitat Types (CALFED 2000c)
Willow thicket and riparian forest (continued)	**Willow riparian scrub or shrub**	Riparian vegetation dominated by woody scrub or shrubs with few to no tall trees. This habitat type generally occupies long, relatively narrow corridors of lower natural levees along rivers and streams.	Valley/Foothill Riparian
	Valley foothill riparian	Mature riparian forest usually associated with a dense understory and mixed canopy, including sycamore, oaks, willows, and other trees. Occupied the supratidal natural levees of larger rivers that were occasionally flooded.	Valley/Foothill Riparian
Seasonal wetland	**Wet meadow or seasonal wetland**	Temporarily or seasonally flooded, herbaceous communities characterized by poorly-drained, clay-rich soils. These often comprised the upland edge of perennial wetlands.	Natural Seasonal Wetland
	Vernal pool complex	Area of seasonally flooded depressions, characterized by a relatively impermeable subsurface soil layer and distinctive vernal pool flora. These often comprised the upland edge of perennial wetlands.	Natural Seasonal Wetland
	Alkali seasonal wetland complex	Temporarily or seasonally flooded, herbaceous or scrub communities characterized by poorly-drained, clay-rich soils with a high residual salt content. These often comprised the upland edge of perennial wetlands.	Natural Seasonal Wetland
Other upland	**Stabilized interior dune vegetation**	Vegetation dominated by shrub species with some locations also supporting live oaks on the more stabilized dunes with more well-developed soil profiles.	Inland Dune Scrub
	Grassland	Low herbaceous communities occupying well-drained soils and composed of native forbs and annual and perennial grasses and usually devoid of trees. Few to no vernal pools present.	Grassland
	Oak woodland or savanna	Oak dominated communities with sparse to dense cover (10-65% cover) and an herbaceous understory.	Valley/Foothill Woodland and Forest

Wildlife Habitat Relationship (WHR)	Representative types from California Terrestrial Natural Communities (CNDDB 2010)	Cowardin et al. (1979)/ USFWS Riparian Mapping System (USFWS 2009)	Hydrogeomorphic classification (HGM) (Brinson 1993)
Valley foothill riparian	*Salix gooddingii* Alliance (61.211.00), *Salix laevigata* Alliance (61.205.00), *Salix lasiolepis* Alliance (61.201.00), *Salix lucida* Alliance (61.204.00), *Salix exigua* Alliance (61.209.00), *Cornus sericea* (Red osier thickets) Alliance (80.100.00), *Rosa californica* Alliance (63.907.00), *Acer negundo* (Box-elder forest) Alliance (61.440.00), *Cephalanthus occidentalis* (Button willow thickets) Alliance (63.300.00)	Palustrine forested wetland. Intermittently flooded, seasonally saturated. / Riparian scrub/ shrub deciduous.	Riverine wetland, surface flow, vertical fluctuations
Valley foothill riparian	*Quercus agrifolia* Alliance (71.060.00), *Quercus lobata* Alliance (71.040.00), *Quercus (agrifolia, douglasii, garryana, kelloggii, lobata, wislizeni)* Alliance (71.100.00), *Quercus wislizeni* Alliance (71.080.00), *Juglans hindsii and Hybrids* Special stands (61.810.00), *Salix gooddingii* Alliance (61.211.00), *Salix laevigata* Alliance (61.205.00), *Salix lasiolepis* Alliance (61.201.00), *Salix lucida* Alliance (61.204.00), *Salix exigua* Alliance (61.209.00), *Acer negundo* (Box-elder forest) Alliance (61.440.00), *Cornus sericea* (Red osier thickets) Alliance (80.100.00), *Rosa californica* Alliance (63.907.00), *Platanus racemosa* Alliance (61.310.00), *Populus fremontii* Alliance (61.130.00), *Cephalanthus occidentalis* (Button willow thickets) Alliance (63.300.00)	Palustrine forested wetland. Intermittently flooded, seasonally saturated. / Riparian forested deciduous	Riverine wetland, surface flow, vertical fluctuations
Wet meadow	*Lasthenia californica - Plantago erecta - Vulpia microstachys* (California goldfields-dwarf plantain-six-weeks fescue flower fields) Alliance (44.108.00), *Elymus triticoides (*Creeping rye grass turfs) Alliance (41.080.00), *Ambrosia psilostachya* (Western ragweed meadows) Alliance (33.065.00), *Lotus purshianus* (Spanish clover fields) Provisional Herbaceous Alliance (52.230.00), *Juncus effusus* (Soft rush marshes) Alliance (45.561.00), *Juncus articus* (Baltic and Mexican rush marshes) Alliance (45.562.00)	Palustrine emergent wetland. Temporarily to seasonally flooded, seasonally saturated.	Depressional wetland, surface flow and groundwater, vertical fluctuations
Annual grassland	*Lasthenia fremontii - Downingia (bicornuta)* (Fremont's goldfields - Downingia vernal pools) Alliance (42.007.00), *Eryngium aristulatum* Alliance (42.004.00)	Palustrine nonpersistent emergent wetland.	Depressional wetland, surface flow and precipitation, vertical fluctuations
Alkali desert scrub	*Cressa truxillensis - Distichlis spicata* (Alkali weed - Salt grass playas and sinks) Alliance (46.100.00), *Lasthenia fremontii - Distichlis spicata* (Fremont's goldfields - Saltgrass alkaline vernal pools) Alliance (44.119.00), *Allenrolfea occidentalis* (Iodine bush scrub) Alliance (36.120.00), *Sporobolus airoides* (Alkali sacaton grassland) Alliance (41.010.00), *Elymus triticoides* (Creeping rye grass turfs) Alliance (41.080.00), *Frankenia salina* (Alkali heath marsh) Alliance (52.500.00)	Palustrine emergent saline wetland. Temporarily to seasonally flooded, seasonally to permanently saturated.	Depressional wetland, surface flow and precipitation, vertical fluctuations
Coastal scrub	*Lupinus albifrons* (Silver bush lupine scrub) Alliance (32.081.00), *Baccharis pilularis* (Coyote brush scrub) Alliance (32.060.00), *Lotus scoparius* (Deer weed scrub) Alliance (52.240.00)	N/A	N/A
Annual grassland, Perennial grassland	*Lasthenia californica - Plantago erecta - Vulpia microstachys* (California goldfields - Dwarf plantain - Six-weeks fescue flower fields) Alliance (44.108.00), *Elymus triticoides* (Creeping rye grass turfs) Alliance (41.080.00), *Nassella pulchra* Alliance (41.150.00), *Eschscholzia (californica)* (California poppy fields) Alliance (43.200.00), *Amsinckia* (Fiddleneck fields) Alliance (42.110.00), *Plagiobothrys nothofulvus* (Popcorn flower fields) Alliance (43.300.00)	N/A	N/A
Valley oak woodland, Blue oak woodland, Coastal oak woodland	*Quercus agrifolia* Alliance (71.060.00), *Quercus lobata* Alliance (71.040.00), *Quercus (agrifolia, douglasii, garryana, kelloggii, lobata, wislizeni)* Alliance (71.100.00), *Quercus wislizeni* Alliance (71.080.00), *Quercus douglasii* Alliance (71.020.00)	N/A	N/A

Table 3. Crosswalk for the datasets used to generate a complete modern Delta habitat type map.

	Original classifications, by dataset (with relevant field)		
Crosswalked habitat type	CDFG 2007 Delta Vegetation ("MAPUNIT")	CDWR 2012 CVRMP ("DELTAVEG" [priority] or "NVCSNAME")	WWR 2013 CSCCA Natural Communities & CDWR 2013 BDCP Natural Communities ("SAIC_TYPE")
Agriculture/ Non-native/ Ruderal	*Acacia - Robinia* Agriculture Eucalyptus Exotic Vegetation Stands Giant Cane (*Arundo donax*) Horsetail (*Equisetum* spp.) Intermittently or Temporarily Flooded Deciduous Shrublands *Lepidium latifolium - Salicornia virginica - Distichlis spicata* Microphyllous Shrubland Pampas Grass (*Cortaderia selloana - C. jubata*) Perennial Pepperweed (*Lepidium latifolium*) Poison Hemlock (*Conium maculatum*) Ruderal Herbaceous Grasses & Forbs Sparsely or Unvegetated Areas; Abandoned orchards Tobacco brush (*Nicotiana glauca*) mapping unit	Agriculture Californian warm temperate marsh/seep Exotic Vegetation Stands Giant Cane (*Arundo donax*) Intermittently or Temporarily Flooded Deciduous Shrublands Introduced North American Mediterranean woodland and forest Mediterranean California naturalized annual and perennial grassland Pampas Grass (*Cortaderia selloana - C. jubata*) Ruderal Herbaceous Grasses & Forbs Sparsely or Unvegetated Areas; Abandoned orchards	Agricultural
Alkali seasonal wetland complex	Alkali Heath (*Frankenia salina*) Alkaline vegetation mapping unit *Allenrolfea occidentalis* mapping unit *Distichlis spicata - Salicornia virginica* *Frankenia salina - Distichlis spicata* *Juncus bufonius* (salt grasses) Pickleweed (*Salicornia virginica*) *Salicornia virginica - Cotula coronopifolia* *Salicornia virginica - Distichlis spicata* Salt scalds and associated sparse vegetation Saltgrass (*Distichlis spicata*) *Suaeda moquinii* - (*Lasthenia californica*) mapping unit	Pickleweed (*Salicornia virginica*) Saltgrass (*Distichlis spicata*) Southwestern North American salt basin and high marsh	
Freshwater emergent wetland	American Bulrush (*Scirpus americanus*) Broad-leaf Cattail (*Typha latifolia*) California Bulrush (*Scirpus californicus*) Common Reed (*Phragmites australis*) Hard-stem Bulrush (*Scirpus acutus*)	Arid West freshwater emergent marsh Mixed *Scirpus* / Submerged Aquatics (*Egeria-Cabomba-Myriophyllum* spp.) complex *Scirpus acutus - Typha angustifolia* *Scirpus acutus* Pure	Tidal Brackish Emergent Wetland Tidal Freshwater Emergent Wetland

	Original classifications, by dataset (with relevant field)		
Crosswalked habitat type	CDFG 2007 Delta Vegetation ("MAPUNIT")	CDWR 2012 CVRMP ("DELTAVEG" [priority] or "NVCSNAME")	WWR 2013 CSCCA Natural Communities & CDWR 2013 BDCP Natural Communities ("SAIC_TYPE")
Freshwater emergent wetland	Mixed *Scirpus* / Floating Aquatics (*Hydrocotyle - Eichhornia*) Complex Mixed *Scirpus* / Submerged Aquatics (*Egeria-Cabomba-Myriophyllum* spp.) complex Mixed *Scirpus* Mapping Unit Narrow-leaf Cattail (*Typha angustifolia*) *Polygonum amphibium* *Scirpus acutus* - (*Typha latifolia*) - *Phragmites australis* *Scirpus acutus - Typha angustifolia* *Scirpus acutus* Pure *Scirpus acutus -Typha latifolia* *Scirpus californicus - Eichhornia crassipes* *Scirpus californicus - Scirpus acutus* *Scirpus* spp. in managed wetlands Smartweed *Polygonum* spp. - Mixed Forbs *Typha angustifolia - Distichlis spicata*		
Grassland	*Bromus diandrus - Bromus hordeaceus* California Annual Grasslands - Herbaceous Creeping Wild Rye Grass (*Leymus triticoides*) Italian Rye-grass (*Lolium multiflorum*) *Lolium multiflorum - Convolvulus arvensis* Tall & Medium Upland Grasses	California annual forb/grass vegetation California Annual Grasslands - Herbaceous Italian Rye-grass (*Lolium multiflorum*)	Grassland
Interior dune scrub	*Lotus scoparius* - Antioch Dunes *Lupinus albifrons* - Antioch Dunes		
Managed wetland			Managed Wetland
Urban/Barren	Levee Rock Riprap Urban Developed - Built Up	Barren Urban Urban Developed - Built Up	Developed
Valley foothill riparian	Black Willow (*Salix gooddingii*) - Valley Oak (*Quercus lobata*) restoration Coast Live Oak (*Quercus agrifolia*) Fremont Cottonwood (*Populus fremontii*) Hinds walnut (*Juglans hindsii*) Oregon Ash (*Fraxinus latifolia*) *Quercus lobata - Acer negundo* *Quercus lobata - Alnus rhombifolia* (*Salix lasiolepis - Populus fremontii - Quercus agrifolia*)	Black Willow (*Salix gooddingii*) Californian broadleaf forest and woodland Central and south coastal California seral scrub Coast Live Oak (*Quercus agrifolia*) Fremont Cottonwood (*Populus fremontii*) *Quercus lobata - Alnus rhombifolia* (*Salix lasiolepis - Populus fremontii - Quercus agrifolia*) *Quercus lobata - Fraxinus latifolia*	Valley/Foothill Riparian

Table 3 (continued). Crosswalk for the datasets used to generate a complete modern Delta habitat type map.

	Original classifications, by dataset (with relevant field)		
Crosswalked habitat type	CDFG 2007 Delta Vegetation ("MAPUNIT")	CDWR 2012 CVRMP ("DELTAVEG" [priority] or "NVCSNAME")	WWR 2013 CSCCA Natural Communities & CDWR 2013 BDCP Natural Communities ("SAIC_TYPE")
Valley foothill riparian	*Quercus lobata - Fraxinus latifolia* *Quercus lobata* / *Rosa californica* (*Rubus discolor - Salix lasiolepis* / *Carex* spp.) Restoration Sites *Salix gooddingii - Populus fremontii* - (*Quercus lobata-Salix exigua-Rubus discolor*) *Salix gooddingii - Quercus lobata* / Wetland Herbs Temporarily or Seasonally Flooded - Deciduous Forests Tree-of-Heaven (*Ailanthus altissima*) Valley Oak (*Quercus lobata*) Valley Oak (*Quercus lobata*) restoration	*Quercus lobata* / *Rosa californica* (*Rubus discolor - Salix lasiolepis* / *Carex* spp.) *Salix gooddingii - Populus fremontii* - (*Quercus lobata-Salix exigua-Rubus discolor*) *Salix gooddingii - Quercus lobata* / Wetland Herbs Southwestern North American riparian evergreen and deciduous woodland Valley Oak (*Quercus lobata*)	
Vernal pool complex	Vernal Pools	Californian mixed annual/perennial freshwater vernal pool/swale/plain bottomland	Vernal Pool Complex
Water	Algae Brazilian Waterweed (*Egeria - Myriophyllum*) Submerged Floating Primrose (*Ludwigia peploides*) Generic Floating Aquatics *Hydrocotyle ranunculoides* *Ludwigia peploides* Milfoil - Waterweed (generic submerged aquatics) Pondweed (*Potamogeton* sp.) Shallow flooding with minimal vegetation at time of photography Tidal mudflats Water Water Hyacinth (*Eichhornia crassipes*)	Algae Brazilian Waterweed (*Egeria - Myriophyllum*) Submerged Generic Floating Aquatics Riverine Water Western North American Freshwater Aquatic Vegetation	Alkali Seasonal Wetland Complex Non-Tidal Perennial Aquatic Tidal Perennial Aquatic
Wet meadow/ Seasonal wetland	Distichlis spicata - Annual Grasses Distichlis spicata - Juncus balticus Intermittently Flooded Perennial Forbs Intermittently or temporarily flooded undifferentiated annual grasses and forbs Juncus balticus - meadow vegetation Managed alkali wetland (Crypsis)	*Distichlis spicata* - Annual Grasses Intermittently or temporarily flooded undifferentiated annual grasses and forbs Naturalized warm-temperate riparian and wetland Rabbitsfoot grass (*Polypogon maritimus*) Seasonally Flooded Grasslands Seasonally flooded undifferentiated annual grasses and forbs	Other Natural Seasonal Wetland

	Original classifications, by dataset (with relevant field)		
Crosswalked habitat type	CDFG 2007 Delta Vegetation ("MAPUNIT")	CDWR 2012 CVRMP ("DELTAVEG" [priority] or "NVCSNAME")	WWR 2013 CSCCA Natural Communities & CDWR 2013 BDCP Natural Communities ("SAIC_TYPE")
Wet meadow/ Seasonal wetland	Managed Annual Wetland Vegetation (Non-specific grasses & forbs) Rabbitsfoot grass (*Polypogon maritimus*) Seasonally Flooded Grasslands Seasonally flooded undifferentiated annual grasses and forbs Temporarily Flooded Grasslands Temporarily Flooded Perennial Forbs	Temporarily Flooded Perennial Forbs	
Willow riparian scrub/ shrub	*Acer negundo - Salix gooddingii* *Alnus rhombifolia / Cornus sericea* *Alnus rhombifolia / Salix exigua* (*Rosa californica*) Arroyo Willow (*Salix lasiolepis*) *Baccharis pilularis* / Annual Grasses & Herbs Black Willow (*Salix gooddingii*) Blackberry (*Rubus discolor*) Box Elder (*Acer negundo*) California Wild Rose (*Rosa californica*) Coyotebush (*Baccharis pilularis*) Mexican Elderberry (*Sambucus mexicana*) Narrow-leaf Willow (*Salix exigua*) *Salix exigua* - (*Salix lasiolepis* - Rubus discolor - *Rosa californica*) *Salix gooddingii / Rubus discolor* *Salix gooddingii* / Wetland Herbs *Salix lasiolepis* - Mixed brambles (*Rosa californica - Vitis californica - Rubus discolor*) Santa Barbara Sedge (*Carex barbarae*) White Alder (*Alnus rhombifolia*) White Alder (*Alnus rhombifolia*) - Arroyo willow (*Salix lasiolepis*) restoration	*Baccharis pilularis* / Annual Grasses & Herbs Blackberry (*Rubus discolor*) Box Elder (*Acer negundo*) Narrow-leaf Willow (*Salix exiqua*) *Salix exigua* - (*Salix lasiolepis - Rubus discolor - Rosa californica*) *Salix gooddingii* / wetland herbs *Salix lasiolepis* - Mixed brambles (*Rosa californica - Vitis californica - Rubus discolor*) Southwestern North American introduced riparian scrub Southwestern North American riparian/wash scrub	
Willow thicket	Buttonbush (*Cephalanthus occidentalis*) California Dogwood (*Cornus sericea*) California Hair-grass (*Deschampsia caespitosa*) *Cornus sericea - Salix exigua* *Cornus sericea - Salix lasiolepis* / (*Phragmites australis*) *Salix lasiolepis* - (*Cornus sericea*) / *Scirpus* spp.- (*Phragmites australis - Typha* spp.) complex unit Shining Willow (*Salix lucida*)	Buttonbush (*Cephalanthus occidentalis*)	

Table 5. Table relating modern habitat type map units to non-native/invasive classifications. Values of '1' indicate that the map unit is classified as dominated or co-dominated by non-native or invasive vegetation; values of '0' indicate it is not.

Map unit	Non-native	Invasive	Non-native or invasive species
Acacia - Robinia	1	1	Acacia
Acer negundo - Salix gooddingii	0	0	
Agricultural	NA	NA	
Agricultural from 'Agriculture'	NA	NA	
Agricultural from 'Grain/Hay Crops'	NA	NA	
Agriculture	NA	NA	
Algae	0	0	
Alkali Heath (*Frankenia salina*)	0	0	
Alkaline vegetation mapping unit	0	0	
Allenrolfea occidentalis mapping unit	0	0	
Alnus rhombifolia / Cornus sericea	0	0	
Alnus rhombifolia / Salix exigua (*Rosa californica*)	0	0	
American Bulrush (*Scirpus americanus*)	0	0	
Arid West freshwater emergent marsh	1	0	
Arroyo Willow (*Salix lasiolepis*)	0	0	
Baccharis pilularis / Annual Grasses & Herbs	1	1	Grasslands assumed to be non-native/invasive
Barren	NA	NA	
Black Willow (*Salix gooddingii*)	0	0	
Black Willow (*Salix gooddingii*) - Valley Oak (*Quercus lobata*) restoration	0	0	
Blackberry (*Rubus discolor*)	1	1	*Rubus discolor*
Box Elder (*Acer negundo*)	0	0	
Brazilian Waterweed (*Egeria - Myriophyllum*) Submerged	1	1	*Egeria*, *Myriophyllum*
Broad-leaf Cattail (*Typha latifolia*)	0	0	
Bromus diandrus - Bromus hordeaceus	1	1	*Bromus diandrus*, *Bromus hordeaceus*
Buttonbush (*Cephalanthus occidentalis*)	0	0	
California annual forb/grass vegetation	1	1	Grasslands assumed to be non-native/invasive
California Annual Grasslands - Herbaceous	1	1	Grasslands assumed to be non-native/invasive
California Bulrush (*Scirpus californicus*)	0	0	
California Dogwood (*Cornus sericea*)	0	0	
California Hair-grass (*Deschampsia caespitosa*)	0	0	
California Wild Rose (*Rosa californica*)	0	0	
Californian broadleaf forest and woodland	0	0	
Californian mixed annual/perennial freshwater vernal pool/swale/plain bottomland	0	0	
Californian warm temperate marsh/seep	0	0	
Central and south coastal California seral scrub	0	0	
Coast Live Oak (*Quercus agrifolia*)	0	0	
Common Reed (*Phragmites australis*)	0	0	
Cornus sericea - Salix exigua	0	0	
Cornus sericea - Salix lasiolepis / (*Phragmites australis*)	0	0	
Coyotebush (*Baccharis pilularis*)	0	0	
Creeping Wild Rye Grass (*Leymus triticoides*)	0	0	
Developed	NA	NA	
Distichlis spicata - Annual Grasses	1	1	Grasslands assumed to be non-native/invasive
Distichlis spicata - Juncus balticus	0	0	

Map unit	Non-native	Invasive	Non-native or invasive species
Distichlis spicata - Salicornia virginica	0	0	
Eucalyptus	1	1	*Eucalyptus*
Exotic Vegetation Stands	1	1	Exotic vegetation stands
Floating Primrose (*Ludwigia peploides*)	0	1	*Ludwigia peploides*
Frankenia salina - Distichlis spicata	0	0	
Fremont Cottonwood (*Populus fremontii*)	0	0	
Generic Floating Aquatics	0	0	
Giant Cane (*Arundo donax*)	1	1	*Arundo donax*
Grassland	1	1	Grasslands assumed to be non-native/invasive
Grassland from 'California Annual Grasslands - Herbaceous'	1	1	Grasslands assumed to be non-native/invasive
Grassland from 'Degraded Vernal Pool Complex - California Annual Grasslands - Herbaceous'	1	1	Grasslands assumed to be non-native/invasive
Hard-stem Bulrush (*Scirpus acutus*)	0	0	
Hinds walnut (*Juglans hindsii*)	0	0	
Horsetail (*Equisetum* spp.)	0	0	
Hydrocotyle ranunculoides	0	0	
Intermittently Flooded Perennial Forbs	1	1	*Lepidium latifolium* Semi-natural Stands
Intermittently or Temporarily Flooded Deciduous Shrublands	0	0	
Intermittently or temporarily flooded undifferentiated annual grasses and forbs	1	1	Grasslands assumed to be non-native/invasive
Introduced North American Mediterranean woodland and forest	1	1	Group level: could contain *Eucalyptus*, *Ailanthus*, and other non-native naturalized trees
Italian Rye-grass (*Lolium multiflorum*)	1	1	*Lolium multiflorum*
Juncus balticus - meadow vegetation	0	0	
Juncus bufonius (salt grasses)	0	0	
Lepidium latifolium - Salicornia virginica - Distichlis spicata	1	1	*Lepidium latifolium*
Levee Rock Riprap	NA	NA	
Lolium multiflorum - Convolvulus arvensis	1	1	*Lolium multiflorum*, *Convolvulus arvensis*
Lotus scoparius - Antioch Dunes	0	0	
Ludwigia peploides	0	1	*Ludwigia peploides*
Lupinus albifrons - Antioch Dunes	0	0	
Managed alkali wetland (*Crypsis*)	1	0	*Crypsis*
Managed Annual Wetland Vegetation (Non-specific grasses & forbs)	1	1	Undefined, but "likely to be completely dominated by non-natives"
Managed Wetland	NA	NA	
Managed Wetland from 'Agriculture'	NA	NA	
Managed Wetland from 'Rabbitsfoot grass (*Polypogon maritimus*)'	1	0	*Polypogon maritimus*
Mediterranean California naturalized annual and perennial grassland	1	1	Grasslands assumed to be non-native/invasive
Mexican Elderberry (*Sambucus mexicana*)	0	0	
Microphyllous Shrubland	0	0	
Milfoil - Waterweed (generic submerged aquatics)	1	1	Milfoil
Mixed *Scirpus* / Floating Aquatics (*Hydrocotyle - Eichhornia*) Complex	1	1	*Eichhornia*, *Hydrocotyle*
Mixed *Scirpus* / Submerged Aquatics (*Egeria-Cabomba-Myriophyllum* spp.) complex	1	1	*Egeria*, *Cabomba*, *Myriophyllum*
Mixed *Scirpus* Mapping Unit	0	0	
N/A; Agriculture/Non-native/Ruderal	NA	NA	
N/A; Urban/Barren	NA	NA	

Table 5 (continued). Table relating modern habitat type map units to non-native/invasive classifications. Values of '1' indicate that the map unit is classified as dominated or co-dominated by non-native or invasive vegetation; values of '0' indicate it is not.

Map unit	Non-native	Invasive	Non-native or invasive species
N/A; Water	NA	NA	
Narrow-leaf Cattail (*Typha angustifolia*)	1	0	*Typha angustifolia*
Narrow-leaf Willow (*Salix exigua*)	0	0	
Narrow-leaf Willow (*Salix exiqua*)	0	0	
Naturalized warm-temperate riparian and wetland	NA	NA	
Non-Tidal Perennial Aquatic	NA	NA	
Non-Tidal Perennial Aquatic from 'Agriculture'	NA	NA	
Non-Tidal Perennial Aquatic from 'Water'	NA	NA	
Oregon Ash (*Fraxinus latifolia*)	0	0	
Other Natural Seasonal Wetland	0	0	
Pampas Grass (*Cortaderia selloana - C. jubata*)	1	1	*Cortaderia selloana*, *Cortaderia jubata*
Perennial Pepperweed (*Lepidium latifolium*)	1	1	*Lepidium latifolium*
Pickleweed (*Salicornia virginica*)	0	0	
Poison Hemlock (*Conium maculatum*)	1	1	*Conium maculatum*
Polygonum amphibium	0	0	
Pondweed (*Potamogeton* sp.)	1	1	*Potamogeton* sp.
Quercus lobata - Acer negundo	0	0	
Quercus lobata - Alnus rhombifolia (*Salix lasiolepis - Populus fremontii - Quercus agrifolia*)	0	0	
Quercus lobata - Fraxinus latifolia	0	0	
Quercus lobata / *Rosa californica* (*Rubus discolor - Salix lasiolepis* / *Carex* spp.)	1	1	*Rubus discolor*, *Carex*
Rabbitsfoot grass (*Polypogon maritimus*)	1	0	*Polypogon maritimus*
Restoration Sites	0	0	
Riverine	NA	NA	
Ruderal Herbaceous Grasses & Forbs	1	1	*Silybum marianum*, *Brassica nigra*
Salicornia virginica - Cotula coronopifolia	1	1	*Cotula coronopifolia*
Salicornia virginica - Distichlis spicata	0	0	
Salix exigua - (*Salix lasiolepis - Rubus discolor - Rosa californica*)	1	1	*Rubus discolor*
Salix gooddingii - Populus fremontii - (*Quercus lobata-Salix exigua-Rubus discolor*)	1	1	*Rubus discolor*
Salix gooddingii - Quercus lobata / Wetland Herbs	0	0	
Salix gooddingii / *Rubus discolor*	1	1	*Rubus discolor*
Salix gooddingii / Wetland Herbs	0	0	
Salix gooddingii / wetland herbs	0	0	
Salix lasiolepis - (*Cornus sericea*) / *Scirpus* spp.- (*Phragmites australis - Typha* spp.) complex unit	0	0	
Salix lasiolepis - Mixed brambles (*Rosa californica - Vitis californica - Rubus discolor*)	1	1	*Rubus discolor*
Salt scalds and associated sparse vegetation	0	0	
Saltgrass (*Distichlis spicata*)	0	0	
Santa Barbara Sedge (*Carex barbarae*)	0	0	
Scirpus acutus - (*Typha latifolia*) - *Phragmites australis*	0	0	
Scirpus acutus - Typha angustifolia	1	0	*Typha angustifolia*
Scirpus acutus Pure	0	0	
Scirpus acutus -Typha latifolia	0	0	
Scirpus californicus - Eichhornia crassipes	1	1	*Eichhornia crassipes*
Scirpus californicus - Scirpus acutus	0	0	
Scirpus spp. in managed wetlands	0	0	

Map unit	Non-native	Invasive	Non-native or invasive species
Seasonally Flooded Grasslands	1	1	Grasslands assumed to be non-native/invasive
Seasonally flooded undifferentiated annual grasses and forbs	1	1	Grasslands assumed to be non-native/invasive
Shallow flooding with minimal vegetation at time of photography	NA	NA	
Shining Willow (*Salix lucida*)	0	0	
Smartweed *Polygonum* spp. - Mixed Forbs	0	0	
Southwestern North American introduced riparian scrub	1	1	Group level: could contain *Arundo donax*, *Tamarix*, *Rubus*
Southwestern North American riparian evergreen and deciduous woodland	0	0	
Southwestern North American riparian/wash scrub	0	0	
Southwestern North American salt basin and high marsh	0	0	
Sparsely or Unvegetated Areas; Abandoned orchards	NA	NA	
Suaeda moquinii - (*Lasthenia californica*) mapping unit	0	0	
Tall & Medium Upland Grasses	1	1	Grasslands assumed to be non-native/invasive
Temporarily Flooded Grasslands	1	1	*Arundo*; Grasslands assumed to be non-native/invasive
Temporarily Flooded Perennial Forbs	0	0	
Temporarily or Seasonally Flooded - Deciduous Forests	0	0	
Tidal mudflats	NA	NA	
Tidal Perennial Aquatic	NA	NA	
Tidal Perennial Aquatic from 'Brazilian Waterweed (*Egeria - Myriophyllum*) Submerged'	1	1	*Egeria*, *Myriophyllum*
Tobacco brush (*Nicotiana glauca*) mapping unit	1	1	*Nicotaina glauca*
Tree-of-Heaven (*Ailanthus altissima*)	1	1	*Ailanthis altissima*
Typha angustifolia - Distichlis spicata	1	0	*Typha angustifolia*
Unknown	NA	NA	
Urban	NA	NA	
Urban Developed - Built Up	NA	NA	
Valley Oak (*Quercus lobata*)	0	0	
Valley Oak (*Quercus lobata*) restoration	0	0	
Vernal Pool Complex	0	0	
Vernal Pool Complex from 'California Annual Grasslands - Herbaceous'	1	1	Grasslands assumed to be non-native/invasive
Vernal Pool Complex from 'Vernal Pool - Enhanced'	0	0	
Vernal Pool Complex from 'Vernal Pool - Natural'	0	0	
Vernal Pool Complex from 'Vernal Pools'	0	0	
Vernal Pools	0	0	
Water	NA	NA	
Water Hyacinth (*Eichhornia crassipes*)	1	1	*Eichhornia crassipes*
Western North American Freshwater Aquatic Vegetation	1	1	Group level: could contain *Egeria*, *Myriophyllum*, *Ludwigia peploides*, *Cambomba*, or *Eichhornia crassipes*
White Alder (*Alnus rhombifolia*)	0	0	
White Alder (*Alnus rhombifolia*) - Arroyo willow (*Salix lasiolepis*) restoration	0	0	

Appendix B: Species

The table below lists the common and scientific names of the species mentioned in this report. Bay Delta Conservation Plan Public Draft (BDCP) covered species are marked with an asterisk (*). The Integrated Taxonomic Information System (ITIS) database was used as our nomenclatural reference, except for with names marked with a cross (†), which deviate from those validated by ITIS. The common names of all species are written in lower case, with the following exceptions: (1) the common names of all birds are capitalized, as per American Ornithologists' Union standards and (2) all proper nouns are capitalized. Although the word "Delta" is used as a proper noun throughout this report, we do not capitalize the common name of *Hypomesus transpacificus* (delta smelt), as per U.S. Fish & Wildlife Service standards.

Common name	Scientific name
Birds	
American Wigeon	*Anas americana*
Ash-throated Flycatcher	*Myiarchus cinerascens*
Black Tern	*Chlidonias niger*
Blue Grosbeak	*Passerina caerulea*
Brown-headed Cowbird	*Molothrus ater*
California Black Rail*†	*Laterallus jamaicensis coturniculus*
California Clapper Rail*	*Rallus longirostris obsoletus*
California Least Tern	*Sternula antillarum browni*
Canada Goose	*Branta canadensis*
Canvasback	*Aythya valisineria*
Cinnamon Teal	*Anas cyanoptera*
Common Moorhen	*Gallinula chloropus*
Cooper's Hawk	*Accipiter cooperii*
Downy Woodpecker	*Picoides pubescens*
European Starling	*Sturnus vulgaris*
Forster's Tern	*Sterna forsteri*
Gadwall	*Anas strepera*
Golden-crowned Sparrow	*Zonotrichia atricapilla*
Greater Sandhill Crane*†	*Grus canadensis tabida*
Greater White-fronted Goose	*Anser albifrons*
Green-winged Teal	*Anas crecca*
Hermit Thrush	*Catharus guttatus*
Horned Lark	*Eremophila alpestris*
Least Bell's Vireo*	*Vireo bellii pusillus*
Mallard	*Anas platyrhynchos*
Modesto Song Sparrow†	*Melospiza melodia mailliardi*†
Northern Harrier	*Circus cyaneus*
Northern Pintail	*Anas acuta*
Northern Shoveler	*Anas clypeata*
Oak Titmouse	*Baeolophus inornatus*
Red-shouldered Hawk	*Buteo lineatus*
Ross' Goose	*Chen rossii*

Savannah Sparrow	*Passerculus sandwichensis*
Sharp-shinned Hawk	*Accipiter striatus*
Short-eared Owl	*Asio flammeus*
Snow Goose	*Chen caerulescens*
Suisun Song Sparrow*†	*Melospiza melodia maxillaris*
Swainson's Hawk*	*Buteo swainsoni*
Tricolored Blackbird*	*Agelaius tricolor*
Tundra Swan	*Cygnus columbianus*
Western Burrowing Owl*†	*Athene cunicularia hypugaea*
Western Tanager	*Piranga ludoviciana*
Western Yellow-billed Cuckoo*†	*Coccyzus americanus occidentalis*†
White-tailed Kite*	*Elanus leucurus*
Willow Flycatcher	*Empidonax traillii*
Wilson's Warbler	*Cardellina pusilla*
Wood Duck	*Aix sponsa*
Yellow Warbler	*Setophaga petechia*†
Yellow-breasted Chat*	*Icteria virens*
Yellow Warbler	*Setophaga petechia*
Yellow-rumped Warbler	*Dendroica coronata*†

Fish

bluegill	*Lepomis macrochirus*
California roach	*Hesperoleucus symmetricus*
Chinook salmon*	*Oncorhynchus tshawytscha*
delta smelt*	*Hypomesus transpacificus*
green sturgeon*	*Acipenser medirostris*
hardhead	*Mylopharodon conocephalus*
hitch	*Lavinia exilicauda*
longfin smelt*	*Spirinchus thaleichthys*
Pacific lamprey*	*Entosphenus tridentatus*
Pacific staghorn sculpin	*Leptocottus armatus*
river lamprey*	*Lampetra ayresii*
Sacramento blackfish	*Orthodon microlepidotus*
Sacramento perch	*Archoplites interruptus*
Sacramento pikeminnow	*Ptychocheilus grandis*
Sacramento splittail*	*Pogonichthys macrolepidotus*
Sacramento sucker	*Catostomus occidentalis*
starry flounder	*Platichthys stellatus*
steelhead*	*Oncorhynchus mykiss*
striped bass	*Morone saxatilis*
thicktail chub	*Gila crassicauda*
tule perch	*Hysterocarpus traskii*
white catfish	*Ameiurus catus*
white sturgeon*	*Acipenser transmontanus*

Invertebrates

Asian clam	*Corbicula fluminea*
California linderiella*	*Linderiella occidentalis*
conservancy fairy shrimp*	*Branchinecta conservatio*
Lange's metalmark butterfly	*Apodemia mormo langei*
longhorn fairy shrimp*	*Branchinecta longiantenna*
midvalley fairy shrimp*†	*Branchinecta mesovallensis*
valley elderberry longhorn beetle*	*Desmocerus californicus dimorphus*
vernal pool fairy shrimp*	*Branchinecta lynchi*
vernal pool tadpole shrimp*	*Lepidurus packardi*

Mammals

American beaver	*Castor canadensis*
California ground squirrel	*Otospermophilus beecheyi*
California vole	*Microtus californicus*
coyote	*Canis latrans*
gray fox	*Urocyon cinereoargenteus*
grizzly bear	*Ursus arctos*
long-tailed weasel	*Mustela frenata*
mule deer	*Odocoileus hemionus*
North American river otter	*Lontra canadensis*
pronghorn	*Antilocapra americana*
ringtail	*Bassariscus astutus*
riparian brush rabbit*†	*Sylvilagus bachmani riparius*†
riparian woodrat*†	*Neotoma fuscipes riparia*
salt marsh harvest mouse*	*Reithrodontomys raviventris*
San Joaquin kit fox*†	*Vulpes macrotis mutica*†
San Joaquin Valley kangaroo rat	*Dipodomys nitratoides*
Suisun shrew*†	*Sorex ornatus sinuosus*
tule elk†	*Cervus elaphus nannodes*

Plants

alkali milkvetch*	*Astragalus tener* var. *tener*
Antioch Dunes evening primrose	*Oenothera deltoides* ssp. *howellii*
Boggs Lake hedge-hyssop*	*Gratiola heterosepala*
brittlescale*	*Atriplex parishii* var. *depressa*†
caper-fruited tropidocarpum	*Tropidocarpum capparideum*
Carquinez goldenbush*	*Isocoma arguta*
Delta button celery*†	*Eryngium racemosum*
Delta tule pea*	*Lathyrus jepsonii* var. *jepsonii*
dwarf downingia*†	*Downingia pusilla*
heartscale*	*Atriplex cordulata*
Heckard's peppergrass*†	*Lepidium latipes* var. *heckardii*
Himalayan blackberry†	*Rubus armeniacus*†
iodinebush	*Allenrolfea occidentalis*
legenere*†	*Legenere limosa*†
Mason's lilaeopsis*	*Lilaeopsis masonii*
saltgrass	*Distichlis spicata*

San Joaquin spearscale*†	*Extriplex joaquinana*
side-flowering skullcap*†	*Scutellaria lateriflora*
slough thistle*	*Cirsium crassicaule*
soft bird's-beak*	*Chloropyron molle* ssp. *molle*
Suisun Marsh aster*	*Symphyotrichum lentum*
Suisun thistle*	*Cirsium hydrophilum* var. *hydrophilum*
Welsh mudwort*	*Limosella australis*
western wallflower	*Erysimum capitatum* var. *capitatum*

Reptiles & Amphibians

California red-legged frog*	*Rana draytonii*
California tiger salamander*	*Ambystoma californiense*
giant garter snake*	*Thamnophis gigas*
Western pond turtle*	*Actinemys marmorata*

Endnotes

1 • Introduction

[1] Moyle et al. 2012.

[2] Delta Independent Science Board 2013. Notes that the goals of habitat restoration should emphasize enhancing ecosystem functions and resilience.

[3] Moyle et al. 2012, Cannon and Jennings 2014.

[4] Montgomery 2008. Jackson and Hobbs (2009) note that, "Both our ability to predict where novel ecosystems are heading, and the proactive management of these trajectories, require an understanding of the means by which novel ecosystems develop." The authors continue by stating, "Ecological restoration is rooted in ecological history. To facilitate the recovery of degraded or damaged ecosystems, knowledge of the state of the original ecosystem and what happened to it is invaluable."

[5] Whipple et al. 2012.

[6] Verhoeven et al. (2008) develop the concept of and criteria for determining Operational Landscape Units (OLUs) for restoration visions. This concept was explored for the McCormack-Williamson Tract in the Delta by Beagle et al. (2013), and recommended for further development by Delta Independent Science Board (2013).

[7] Novel ecosystems can be defined as occurring when species are found to exist "in combinations and relative abundances that have not occurred previously within a given biome (Hobbs et al. 2006)," and as the occurrence of assemblages of species that either have not co-occurred historically, or result directly and indirectly from human activities (Bridgewater et al. 2011).

[8] Hanak et al. (2013) report that most people questioned in a widely dispersed survey agreed that discharges of pollutants, direct fish management, changes in the flow regime, invasive species, and alteration of physical habitat have all contributed to the ecosystem decline.

[9] Balaguer et al. 2014.

[10] Atwater and Belknap 1980.

[11] Information on the ecological and physical processes of the historical Delta was gathered and detailed in the *Sacramento-San Joaquin Delta Historical Ecology Investigation* (Whipple et al. 2012)—the source for the summary of the historical Delta landscapes provided in this box.

2 • Project Framework and Methods

[1] Taylor et al. 1990, Brinson 1993, Smith et al. 1995, Jax 2005.

[2] NRC 1995.

[3] Smith et al. 1995.

[4] Hruby et al. 1999.

[5] Delany and Scott 2006.

[6] McGarigal 2002, Kupfer 2012.

[7] McGarigal 2002.

[8] McGarigal 2002.

[9] McGarigal 2002.

[10] Collins and Grossinger 2004.

[11] D'Eon et al. 2002.

[12] Spautz and Nur 2002, Spautz et al. 2005.

[13] Liu et al. 2012.

[14] Spautz and Nur 2002, Spautz et al. 2005.

[15] Gaines 1974.

[16] Kilgo et al. 1998.

[17] Laymon and Halterman 1989.

[18] Whipple et al. 2012.

[19] Hickson and Keeler-Wolf 2007.

[20] GIC 2012.

[21] Daniel Burmester, personal communication; Todd Keeler-Wolf, personal communication.

[22] Whipple et al. 2012.

[23] Whipple et al. 2012.

[24] Gibbes 1850, Ringgold 1850a, Ringgold 1850b.

[25] U.S. Geological Survey 2013. 'NHDArea' layer, high resolution, version 931v210.

[26] Wang and Ateljevich 2012.

[27] Whipple et al. 2012:90.

[28] See Appendix A, pages 96-97 for additional details and specific examples.

[29] Based on work of Hruby et al. (1999).

[30] Based on work of Hruby et al. (1999).

[31] Whipple et al. 2012.

3 • Overall Delta Landscape Changes

[1] Meese et al. 2014.

[2] Yoshiyama et al. 2001.

[3] Garone 2006.

[4] California Department of Water Resources 2013

[5] Mac Nally et al. 2010.

[6] Lund 2010.

[7] Kneib et al. 2008

[8] Whipple et al. 2012.

[9] See Chapter 4 (Life-History Support for Resident and Migratory Fish) for greater detail and references.

[10] Howe and Simenstad 2011.

[11] Couvet 2002, Cushman 2006.

[12] See Chapter 4 (Life-History Support for Resident and Migratory Fish) for greater detail and references.

[13] Lee and Jones-Lee 2004.

[14] Greene et al. 2011.

[15] See Chapter 4 (Life-History Support for Resident and Migratory Fish) for greater detail and references.

[16] Feyrer and Healey 2003.

[17] Atwater and Belknap 1980.

[18] Whipple et al. 2012.

[19] Hickson and Keeler-Wolf 2007.

[20] For example, there are more non-native than native fish species in some parts of the Delta (Feyrer and Healey 2003, Moyle et al. 2012). Species diversity as a restoration goal in the Delta should take into account the role of non-native species.

[21] Modern species-habitat type associations and life-history characteristics were largely derived from BDCP species accounts (California Department of Water Resources 2013), but also from other literature and best professional judgment. Best professional judgment was particularly important for species that today mostly use agricultural lands and managed wetlands. California Department of Water Resources 2013.

[22] Calflora 2013. The Calflora Database, http://www.calflora.org, accessed March 2013.

[23] California Invasive Plant Council (Cal-IPC) 2013. California Invasive Plant Inventory Database, http://www.cal-ipc.org/paf, accessed March 2013.

[24] It is likely that a class of lowest-order tidal channels existed in the Delta that was not represented by historical sources and was thus under-represented in the historical mapping of the Delta (Whipple et al. 2012). We estimate the length of these unmapped channels based on known channel densities in other freshwater marshes in the historical San Francisco Bay-Delta Estuary. See Appendix A for more detail.

[25] Thompson 1957, Enright et al. 2004, Enright 2008.

[26] Modern MLLW elevation was assumed to be 0.64 m NAVD88 (based on data from Cache Slough). Historical MLLW elevation was assumed to be 0.31 m NAVD88. We made the simplifying assumption that the only changes to MLLW since the historical period were from sea level rise (discounting any changes in water surface elevations associated with things like channel armoring, subsidence, and pumping). See Appendix A for additional details.

4 • Life-History Support for Resident and Migratory Fish

[1] Whipple et al. (2012) describe the heterogeneity within aquatic habitats of the historical Delta.

[2] Simenstad et al. (1983). Salmon in the Pacific Northwest used large channels for migration and off-channel habitat for rearing. Smokorowski and Pratt (2007) review how structural habitat complexity supports

diversity in freshwater fish. Features such as undercut banks may be particularly important because of the cover and refuge they provide (e.g., McMahon and Hartman 1989, Cowx and Welcomme 1998).

[3] Whipple et al. (2012) and sources therein.

[4] See Enright (2008) for a discussion of how complex channel networks supported gradients in residence time historically. Enright et al. (2013) explain how channel structure and marsh connection influenced water temperature through geomorphic mediation. Morgan-King and Schoellhamer (2013) describe the processes (e.g., tidal asymmetry) that contribute to the high suspended sediment concentrations observed in the "dead end channels" and "backwaters" of the Cache Slough region.

[5] Sommer et al. (2001a,b), Jeffres et al. (2008), and Opperman (2008) describe the benefits of Delta floodplains, specifically the Cosumnes River and Yolo Bypass, to native fish. Numerous other studies discuss increased prey availability for fish in floodplains in other regions (e.g., Gladden and Smock (1990)).

[6] Hering (2009) details movements of subyearling Chinook salmon to remain in small tidal channels while rearing within the Salmon River Estuary, Oregon. West and Zedler (2000) describe fish use of the marsh plain at high tide, though in a southern California salt marsh. Odum (2000) reviews support for the idea of marshes as productivity sources to estuaries and concludes that the extent of outwelling is related to the extent of marsh, tidal amplitude, and geomorphology, and that large outputs are likely occur as pulses related to storm events and spring tides.

[7] Whipple et al. 2012.

[8] Historical fish assemblages are assumed from modern fish distributions, habitat associations, and life-history requirements. See Moyle (2002) for species-specific information.

[9] Moyle 2002.

[10] Moyle 2002.

[11] Moyle 2002.

[12] Moyle 2002.

[13] Yoshiyama et al. 1998.

[14] Species habitat use is assumed from modern habitat associations and known life-history characteristics as described by Turner (1966), Moyle (2002), Moyle et al. (2004), Crain and Moyle (2011; references from Whipple et al. 2012).

[15] See Whipple et al. (2012:137-142) for discussion of salinity in the historical Delta.

[16] Wiens 2002.

[17] Sommer et al. (2005) discuss fish stranding risk in floodplains, noting that juvenile salmon seek out low-velocity areas on floodplains. The authors also note that although areas with engineered water control structures are associated with comparatively high stranding risk, overall floodplains provide a net benefit to salmon because of the rearing habitat they provide.

[18] See note 14 above.

[19] Hilborne et al. (2003), Greene et al. (2010), and Carlson and Satterthwaite (2011) describe portfolio effects in salmon.

[20] The relationship between residence time and productivity is reviewed in Lucas and Thompson (2012), who describe how the introduction of the invasive overbite clam has altered this relationship.

[21] See notes 4 and 20 above.

[22] Toft et al. 2003.

[23] Howe and Simenstad 2011.

[24] Dependent on allochthonous marsh materials, and likely more so historically. Howe and Simenstad (2011) used stable isotopes to link estuary consumers to primary producer groups in the SF Estuary and found that nearly all sampled organisms relied heavily on allochthonous marsh material. Whitley and Bollens (2014) studied stomach contents of fish at Liberty Island and found tidal marsh was important feeding habitat for many species, including delta smelt, which supplemented their zooplankton-based diet with larval insects in the spring and amphipods in the winter.

[25] Whitley and Bollens (2014) found that prey composition and biomass varied seasonally between fish species at Liberty Island (based on stomach content analysis). Fish maintained stomach fullness with little overlap in diet between species, potentially reducing competition through their flexibility in diet.

[26] Whipple et al. 2012, Opperman 2012.

[27] See note 5 above.

[28] See note 4 above.

[29] Odum (2000) and Kneib et al. (2008) discuss outwelling of organic matter from marshes, though neither discuss the impacts to turbidity directly.

[30] Kneib et al. (2008) and references therein, Howe and Simenstad 2011.

[31] Harmon et al. (1986) and Gregory et al. (1991), among others, review the benefits of large woody debris to anadromous fish. Whipple et al. (2012) describe the location of woody vegetation in the historical Delta.

[32] Sommer et al. 2013.

[33] McIvor and Odum 1988.

[34] Sommer et al. 2001b.

[35] Peter Moyle, personal communication. Also see note 60 below.

[36] Bottom et al. (2005) found that Chinook salmon in the Salmon River Estuary migrated to the ocean over a broader range of sizes and time periods after marsh restoration, suggesting that wetland restoration has expanded life-history variation in the population by allowing greater expression of estuarine-resident behaviors.

[37] See note 39 below. In addition to the loss of environmental cues, Kimmerer (2011) describes the increased risk for passively moving species from water diversions and entrainment.

[38] Bennett et al. (2002) investigated how fish behavior and distribution in multiple species enhanced transport to and retention in nursery habitats in the low salinity zone in the SF Estuary. Fish in this study exhibited behavioral flexibility in different environmental conditions to maximize retention and enhance feeding success. Hering (2009) found salmon moved into and out of tidal marsh channels mostly with the tide, but with some evidence of active movement to enter channels against ebb tides (possibly to maximize foraging efficiency on invertebrate prey exported from the marsh).

[39] Temporally predictable environmental variability can cue reproduction, migration, and other life-history events in Delta fauna (Jassby et al. 1995, Nobriga et al. 2005). See Drinkwater and Frank (1994) for a more general discussion of impacts of river regulation and diversion on fish.

[40] Enright et al. (2013) describes the greater "distance to difference" in modern channel conditions.

[41] Williams et al. 2009. As measured before (1935-1943) and after (1944-1995) the construction of the Shasta Dam.

[42] Whipple et al. 2012.

[43] Kimmerer 2011.

[44] E.g., Werner et al. 2000, Weston and Lydy 2010.

[45] Jassby et al. 2002, Lucas and Thompson 2012, Kimmerer and Thompson 2014.

[46] Toft et al. 2003.

[47] Toft et al. 2003, Brown 2003.

[48] E.g., Moyle 2002, Feyrer and Healey 2003, Nobriga et al. 2005.

[49] Feyrer and Healey (2003) mention striped bass and white catfish as non-natives associated with high flows. Peter Moyle (personal communication) also mentions channel catfish and American shad as additional examples.

[50] Sommer et al. (2013) suggests, however, that invasive species cannot be controlled by changes in hydrology alone.

[51] Peter Moyle, personal communication.

[52] Lab experiments conducted by Marchetti (1999) showed that native Sacramento perch showed reduced growth when placed with non-native bluegill, but only under conditions of food limitation. Peter Moyle (personal communication) notes that food limitation likely also intensifies predation of non-native species on natives. Stephanie Carlson (personal communication) notes that many non-native fish (especially the Centrarchids) are predators. Finally, Sommer et al. (2001a) hypothesize that following flood events the Yolo Bypass becomes a "clean slate" for native fish, who are more adapted to its flood cycle, and thus more able to take advantage of its resources.

[53] Roni et al. (2010) reviewed and modeled coho salmon and steelhead population responses to habitat restoration in Puget Sound and concluded that considerable restoration is needed to produce measurable changes in fish abundance at a watershed scale: "The percentage of floodplain and in-channel habitat that would have to be restored in the modeled watershed to detect a 25% increase in coho salmon and steelhead smolt production (the minimum level detectable by most monitoring programs) was 20%. However, given the large variability in fish response (changes in density or abundance) to restoration, 100% of the habitat would need to be restored to be 95% certain of achieving a 25% increase in smolt production for either species."

[54] Sommer et al. 2001a, Jeffres et al. 2008, Opperman 2008.

[55] Moyle (2002) lists habitat destruction as a possible contributing factor to the decline of Sacramento perch, along with embryo predation and interspecific competition. Thicktail chub "most likely became extinct because they were unable to adapt to the extreme modification of valley floor habitats," and because of the introduction of alien predators.

[56] The timing, frequency, and duration of inundation in the Yolo Bypass is better characterized as 'seasonal short-term flooding' than 'seasonal long-duration flooding.' Historically, water remained on the surface of the Yolo Basin and was available to floodplain-associated fish species for up to six months of the year (it was activated approximately one out of every two years). Since 1944, overflow events into the Bypass of seven days or

longer between mid-March and mid-May occurred in only approximately one out of every four years (Williams et al. 2009). When flooded, the Bypass drains quickly and the extent of inundated habitat varies substantially on the order of days (Sommer et al. 2004).

[57] Sommer et al. (1997) found that strong year classes of splittail, which are obligate floodplain spawners, are not produced unless there are at least three weeks of sustained inundation during the March-April spawning/rearing period. Waples et al. (2009) found that although salmon are equipped with life-history strategies that allow them to persist in disturbance prone environments and across a range of habitats, temporal and spatial access to these ranges of habitats has been limited, resulting in decreased resilience in populations.

[58] Whipple et al. 2012.

[59] This 1927 photograph of North Sacramento shows flooding along the Sacramento River. Photo by McCurry, courtesy of the California History Room, California State Library, Sacramento, California.

[60] Jeffres et al. 2008. This is important because larger juvenile salmon have a higher overall survival rate to adulthood and are more likely to return as spawning adults (Unwin 1997, Galat and Zweimüller 2001). Potential mechanisms for the observed beneficial effects of floodplains include the increased habitat area associated with inundated floodplains (relative to just the adjacent river habitat), which would be expected to reduce resource competition and predator encounter rates (Sommer et al. 2001b), and increase invertebrate prey availability (Gladden and Smock 1990, Sommer et al. 2001b).

[61] This figure represents the combined extent of areas classified as "seasonal short-term flooding" and "seasonal long-duration flooding."

[62] Based on a study from Vogel and Marine (1991) with input from Steve Lindley, personal communication.

[63] Yoshiyama et al. 2001 and Lindley et al. 2004 in Williams 2006:43.

[64] Commissioners of Fisheries 1875, McEwan 2001, and Moyle 2002, as cited in Williams 2006. Williams notes that "the Commissioners of Fisheries (1875:10) also described a summer-run that migrated up the San Joaquin River in July and August that appeared to be '. . . of the same variety as those in the Sacramento, but smaller in size.' The Commission was particularly interested in them because their tolerance of high water temperature '. . . would indicate that they will thrive in all the rivers of the southern states, whose waters take their rise in mountainous or hilly regions. . . .'"

[65] With the exception of spawning, the temporal distributions of the Chinook life-history stages are derived from Vogel and Marine 1991, figure 1, "Life History Characteristics of Sacramento River Chinook Salmon." The noted timing of spawning for each run is taken from Williams 2006 (page 119, table 6-1, "Sacramento River ranges" for fall run; page 120, table 6-2 for late-fall run; page 120, table 6-3 for winter run; and page 121, table 6-4 for spring run). Yoshiyama et al. 2001 and Lindley et al. 2004 in Williams 2006:43.

[66] McEwan 2001:11, figure 3, "Central Valley steelhead life stage periodicity."

[67] Adult migration timing is taken from Moyle et al. 2004, as cited in Kratville 2008:10. The temporal distributions for floodplain/river spawning, embryo and larvae, and juvenile floodplain use are taken from Kratville 2008:3, table 1, "Life stages by biological measures." The listed juvenile downstream migration timing is derived from Moyle et al. 2004, as cited in Kratville 2008:12. Kratville also notes a second life-history strategy for outmigrating juveniles that is not reflected in this table: "a less well studied strategy is to remain upstream through the summer into the next fall or spring and then migrate downstream (Baxter 1999, Moyle et al. 2004). This latter strategy occurs in Butte Creek and the main stem Sacramento River."

[68] Israel and Klimley 2008.

[69] Israel et al. 2009.

[70] USFWS 2012.

[71] Nobriga and Herbold 2009.

[72] Rosenfield 2010.

[73] Gray et al. 2002.

5 • Life-History Support for Marsh Wildlife

[1] Whipple et al. 2012, Vasey et al. 2012.

[2] Described from East Coast marshes by Odum (1988). Moyle et al. (2014) hypothesize that although tidal marshes have lower seed density than managed marshes the extensive acreage of historical marshes in the Bay and Delta would have led to an accumulation of seeds, providing abundant food resources for waterfowl and other wildlife.

[3] Odum 1988.

[4] Reviewed by the DRERIP Tidal Marsh Model and sources therein, Kneib et al. (2008). See Nur et al. (2006) for a description of effects of vegetative structure on the marsh bird community.

[5] Greenberg et al. 2006.

[6] See Herbold and Moyle (1989) and California Department of Water Resources (2013). Mammal species occupying the historical Delta are assumed from distribution of modern native species.

[7] Mitsch and Gosselink (1986) cited in Odum (1988).

[8] Grinnell et al. 1937, Seymour 1960, Gould 1977, Lanman et al. 2013. Description of beavers in the Delta as quoted in Lanman et al. 2013: "There is probably no spot of equal extent in the whole continent of North America which contains so many of these much sought animals (Farnham 1857:383)."

[9] See references in Chapter 4 (Life-History Support for Resident and Migratory Fish).

[10] See Jennings and Hayes (1994) and California Department of Water Resources (2013) for distribution and life-history information on Delta amphibians. These species all require upland habitat for part of their life, which likely prevented them from inhabiting the interior Delta marshes.

[11] See references in Chapter 8 (Life-History Support for Marsh-Terrestrial Transition Zone Wildlife).

[12] Odum 1988.

[13] Based on life-history account of giant garter snake in California Department of Water Resources (2013). Based on life-history account of the Modesto Song Sparrow in Shuford and Gardali (2008). The Modesto Song Sparrow distribution is only slightly broader than the Delta and distinct from the more riparian/upland associated subspecies.

[14] Milliken 1991, Anderson 2005, Manfree 2014 in Moyle et al. 2014.

[15] Whipple et al. 2012.

[16] Lindenmayer and Fischer 2006.

[17] Whigham 1988, Fuji 1998, and Werner et al. 2000.

[18] Lindenmayer and Fischer 2006.

[19] Lindenmayer and Fischer 2006.

[20] CDFG 2007.

6 • Life-History Support for Waterbirds

[1] Historical species occurrences are assumed from modern distributions, life histories and habitat associations. See Herbold and Moyle (1989), California Department of Water Resources (2013), Garone (2011).

[2] Assumptions about waterbird habitat use and ecology were discussed during two meetings with local waterbird experts (Dave Shuford, Daniel Burmester, Dan Skalos, Hildie Spautz, Dave Zezulak) on March 11, 2014 and April 22, 2014. Assumptions of habitat use for particular waterbirds were determined by the best professional judgment of these experts, with the acknowledgement that the magnitude of change in the Delta paired with the large scale at which most waterbirds use the landscape make it difficult to interpret some aspects of waterbird use of the historical Delta. Shorebird habitat associations and the degree to which smaller shorebirds used the Delta were highlighted as areas of particular uncertainty.

[3] Garone 2011.

[4] Central Valley Joint Venture 2006, Whipple et al. 2012.

[5] Garone 2011, Whipple et al. 2012.

[6] Central Valley Joint Venture 2006.

[7] Moyle et al. 2014.

[8] Herbold and Moyle 1989.

[9] See note 2 above.

[10] See note 2 above and Garone 2011.

[11] See note 2 above.

[12] Whipple et al. 2012.

[13] Garone 2011, Whipple et al. 2012.

[14] See note 2 above and Whipple et al. 2012.

[15] See note 2 above.

[16] Ivey et al. 2011, Ivey et al. 2014.

[17] See note 2 above.

[18] See notes 1 and 2 above.

[19] See note 2 above.

[20] Moyle et al. 2014.

[21] Moyle et al. 2014.

[22] Gaines 1980.

[23] Central Valley Joint Venture 2006.

[24] See Miller et al. 2000 and references therein (from Oklahoma). "Agricultural plants are often high in energy, and waterfowl spend more time feeding on crops in the evening to prepare for cold nights. However, feeding exclusively on agricultural crops may not satisfy their protein or mineral requirements. Waterfowl must also include foods that fulfill protein and lipid requirements. Natural plants found in wetlands and invertebrates constitute foods high in protein and amino acids, as well as many minerals."

[25] Mount and Twiss 2005.

[26] See note 2 above.

[27] Moyle et al. 2014.

[28] See notes 1 and 2 above.

[29] See notes 1 and 2 above.

[30] See note 2 above and Garone 2011.

[31] See note 2 above.

[32] Time ranges for wintering and migrating birds are multi-species approximations based on discussions with experts. The breeding waterfowl time range shown is for Mallards.

7 • Life-History Support for Riparian Wildlife

[1] Whipple et al. (2012) describe the position and structure of riparian forests in the historical Delta. The use of riparian forests as movement corridors is well-established (see Hilty and Merenlender (2004) and Fellers and Kleeman (2007) for examples in California).

[2] E.g., Finch 1989.

[3] E.g., Opperman 2002.

[4] Whipple et al. 2012. For Neotropical songbirds, willow-fern marshes may have provided habitat; however, for many less mobile or more terrestrial species, these habitats would have been inaccessible.

[5] See, for example, Brinson et al. (2002) for a discussion of the importance of riparian habitat as a movement corridor for wildlife.

[6] California Department of Water Resources 2013. These species are found primarily in the south Delta today. Whipple et al. (2012) found that the riparian brush rabbit occurred in riparian forests throughout the historical Delta as well.

[7] Gaines 1980 in Sands 1980.

[8] See note 7 above.

[9] See note 7 above.

[10] Geoff Geupel, personal communication.

[11] Thompson (1957) notes that where riparian cover developed historically, "the velocity of sediment laden water was checked," causing natural levees to build up and facilitate more growth of riparian vegetation (a positive feedback cycle).

[12] California Department of Water Resources 2013.

[13] Gaines 1980.

[14] Small 2005, Small et al. 2007, Golet et al. 2008.

[15] Whisson et al. 2007, California Department of Water Resources 2013.

[16] California Department of Water Resources 2013.

[17] Seavy et al. 2009.

[18] Laymon and Halterman 1989.

[19] Measured as the maximum geodesic distance (as the crow flies) an organism can travel away from a starting location within a single contiguous woody riparian habitat polygon (defined by the minimum mapping unit).

[20] The 100 m threshold for grouping riparian polygons into patches is based on the typical maximum gap crossing distance of dispersing songbirds, as determined by best professional judgment (Geoff Geupel, personal communication).

[21] Fischer 2000.

[22] Whipple et al. (2012) mapped the dominant habitat types, so while the Cosumnes area appears to be absent of woody riparian vegetation, there were likely some wooded sloughs and willow thickets that were too small to map.

8 • Life-History Support for Marsh-Terrestrial Transition Zone Wildlife

[1] Whipple et al. 2012, "Pattern of edge."

[2] Assumed from life-history characteristics. See BDCP species accounts (California Department of Water Resources 2013) and references therein.

[3] See Chapter 7 (Life-History Support for Riparian Wildlife) for greater detail and references.

[4] Whipple et al. 2012, "Tule elk breeding on dunes."

[5] Whipple et al. 2012, "Variable seasonal wetlands."

[6] California Department of Water Resources 2013. Species of Concern.

[7] See Chapter 6 (Life-History Support for Waterbirds) and California Department of Water Resources 2013.

[8] California Department of Water Resources 2013.

[9] Trapp 2011.

[10] Barbour et al. 2007.

[11] California Department of Water Resources 2013.

[12] Whipple et al. 2012.

[13] California Department of Water Resources 2013.

[14] Whipple et al. 2012, Schiffman 2011.

[15] Schiffman 2011, Trapp 2011, California Department of Water Resources 2013.

[16] Trapp 2011.

[17] Milliken 1991, Anderson 2005, Manfree 2014 in Moyle et al. 2014.

[18] Goals Project 2014 (in development).

Appendix A: Methods

[1] Whipple et al. 2012.

[2] Whipple et al. 2012.

[3] Whipple et al. 2012, available for download at http://www.sfei.org/sites/default/files/Delta_Historical_Ecology_GISdata_SFEI_ASC_2012.zip.

[4] Hickson and Keeler-Wolf 2007.

[5] GIC 2012.

[6] WWR 2013.

[7] California Department of Water Resources 2013.

[8] Whipple et al. 2012.

[9] Daniel Burmester and Todd Keeler-Wolf, personal communication.

[10] Whipple et al. 2012.

[11] Buck-Diaz et al. 2012.

[12] Daniel Burmester and Todd Keeler-Wolf, personal communication.

[13] CALFED 2000.

[14] Todd Keeler-Wolf, personal communication.

[15] Whipple et al. 2012.

[16] Hickson and Keeler-Wolf 2007.

[17] See California Department of Water Resources 2013, appendix 2.b for detailed methodology.

[18] See note 3 above.

[19] See note 3 above.

[20] U.S. Geological Survey 2013. 'NHDArea' layer, high resolution, version 931v210.

[21] CWS et al. 2014. Manuscript in preparation.

[22] Cordell 1867.

[23] California Debris Commission (Debris Commission) 1908-1913. Since the Debris Commission surveys took place after substantial alteration of Delta waterways from hydraulic mining debris, channel cuts, and dredging, we limited our use of Debris Commission bathymetric data to channel reaches with minimal apparent physical alteration.

[24] The maps produced by Ringgold (1850a & 1850b) and Gibbes (1850) lack the spatial accuracy of the USCS hydrographic sheet and have no known projection or features from which to establish reliable control points. We were thus unable to directly digitize historical soundings from georeferenced maps. The soundings recorded by Ringgold and Gibbes were instead georeferenced by matching channel meanders

and confluences on the historical maps with meanders and confluences in the Delta Historical Ecology channel centerline layer (soundings were generally taken at the apex of meanders) and placing the soundings relative to these features. Any soundings that were difficult to place were discarded.

[25] The parabolic channel shape was chosen after conversations with experts on tidal channel morphology. While this shape inevitably simplifies channel morphology, we felt it best represented channel cross-sectional area given the available data. CWS technicians applied the parabolic shape by calculating parabolic channel cross-sections between the historical channel thalweg and shoreline (set to a depth of 0 m/MLLW) at 100 m intervals and outputting these cross-sections as a series of points. These points were converted to modern fixed datum (NAVD88, see Appendix A, Section 4.1.4) and then used as TIN inputs to generate continuous DEM bathymetry.

[26] Atwater et al. 1977.

[27] Whipple et al. 2012.

[28] Wang and Ateljevich 2012, version 3.

[29] Wang and Ateljevich 2012.

[30] cbec 2010.

[31] Whipple et al. 2012.

[32] Phil Williams, personal communication.

[33] Grossinger 1995.

[34] Collins and Grossinger 2004.

[35] Whipple et al. 2012.

[36] cbec 2010.

[37] See Lopez et al. 2006.

[38] Simenstad 1983.

[39] Ashley and Zeff 1988.

[40] Simenstad 1983, Collins 1998.

[41] Ashley and Zeff 1988.

[42] Morgan-King and Schoellhammer 2013.

[43] E.g., Pethick 1992.

[44] Simenstad 1983, Collins 1998, Hood 2006.

[45] Cavallo et al. 2013.

[46] Whipple et al. 2012:331-333.

[47] Whipple et al. 2012:38.

[48] Alison Whipple, personal communication. Dense tidal channel networks served as an indicator of daily tidal inundation, especially in the lower/southern portion of the Yolo Basin tidal area. Historical quotes about tides flowing in and out of lower Grand, Staten, and Tyler islands increased confidence that the Cache Slough region experienced daily tidal inundation.

[49] Whipple et al. 2012:127-128.

[50] Rose et al. 1895 in Whipple et al. 2012:128.

[51] Most information on depth, duration, and timing is derived from Whipple et al. (2012). Additional information on the depth of historical inundation was obtained from historical General Land Office surveys of the Delta.

[52] Pasternak et al. 2004.

[53] D'Eon et al. 2002.

[54] Spautz and Nur 2002, Spautz et al. 2005.

[55] Liu et al. 2012.

[56] Spautz and Nur 2002, Spautz et al. 2005.

[57] Spautz and Nur 2002, Spautz et al. 2005.

[58] Geoffrey Geupel, personal communication.

[59] D'Eon et al. 2002.

[60] Laymon and Halterman 1989.

[61] Whipple et al. 2012:178-183.

[62] Gibbes 1850. See Whipple et al. 2012, figure 4.49.

[63] From Whipple et al. 2012, figure 4.50.

[64] DWR 2014. California Levee Database Centerlines, Version 3, Release 2.

[65] Whipple et al. 2012.

[66] Hickson and Keeler-Wolf 2007.

[67] CDFG 2011.

[68] Hickson and Keeler-Wolf 2007.

[69] Daniel Burmester, personal communication.

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Recent state policy sets ambitious goals for ecosystem restoration in the Sacramento-San Joaquin Delta. *The Delta Plan and California Water Code, as well as other regional documents, identify the need to go beyond small-scale habitat restoration to create larger functional landscapes of interconnected habitats. Yet there is little quantitative guidance available to help design the complex spatial systems that are likely to achieve these goals. This report provides the first analysis of landscape ecology metrics in the pre-disturbance and contemporary Delta to help define, design, and evaluate functional, resilient landscapes for the future.*

Exhibit C

SALMON SCOPING TEAM GAPS ANALYSIS REPORT

PRESENTATION TO CSAMP – OCTOBER 24, 2016

JOHN FERGUSON (Co-Chair)
CHUCK HANSON (Co-Chair)
PATRICIA BRANDES (USFWS)
REBECCA BUCHANAN (UW)
BARBARA BYRNE (NMFS)
SHEILA GREENE (Westlands Water)
BRETT HARVEY (DWR)
RENE HENERY (UNR, Trout Unlimited)
JOSHUA ISRAEL (USBR)
DAN KRATVILLE (DFW)
MICHAEL HARTY (Facilitator)
BRIANA SEAPY (Asst. Facilitator)

CONTEXT - VIABLE SALMONID POPULATIONS (VSP)

DEFINITION

- McElhany et al. (2000) Viable salmonid populations and the recovery of evolutionarily significant units. NOAA Technical Memorandum NMFS-NWFSC-42.

  - Abundance
  - Productivity
  - Spatial structure
  - Diversity (genotypic and phenotypic)

APPLICATION

- Monitoring: Crawford, B.A and S.M. Rumsey. 2011. Guidance for monitoring recovery of Pacific Northwest salmon and steelhead listed under the Federal Endangered Species Act. Idaho, Oregon, and Washington, National Marine Fisheries Service, NW Region.
- Recovery planning: Lindley et al . 2007. Framework for assessing viability of threatened and endangered Chinook salmon and steelhead in the Sacramento-San Joaquin basin. San Francisco Estuary and Watershed Science. Vol. 5, Issue 1 [February 2007]. Article 4.
- Harvest: Hilborn, R., T.P. Quinn, D.E. Schindler, and D.E. Rogers, 2003. Biocomplexity and fisheries sustainability. Proc. Nat. Acad. Sci. 100:6564-6568.

VALIDATION

- The "portfolio effect" of spreading risk across stocks
  - Schindler et al 2010. Population diversity and the portfolio effect in an exploited species. Nature 465:609-613.
- Strengthening population resilience to environmental variability (including climate change) requires expanding habitat opportunities to allow expression of life-history strategies
  - Bottom, D., K. Jones, C. Simenstad, and C. Smith, 2011. Reconnecting societal and ecological resilience in salmon ecosystems. In Pathways to Resilience; Sustaining Salmon Ecosystems in a Changing World. Oregon Sea Grant Report ORESO-B-11-001, pgs 3 39.
- Fry, parr, smolts all contribute to the spawning population, but saw greater fry contributions in the wetter year and greater smolt contributions in the drier year
  - Sturrock et al. 2015. Reconstructing the Migratory Behavior and Long-Term Survivorship of Juvenile Chinook Salmon under Contrasting Hydrologic Regimes. PLoS ONE 10(5)

SST - SCOPE AND REPORT STRUCTURE

Scope:

We focused narrowly on the effects of SWP and CVP operations on salmonid migration and survival in the Delta

- Inflow
- Exports
- Temporary Agriculture Barriers
- Delta Cross Channel
- Head of Old River Barrier

Volume I

- **FINDINGS AND RECOMMENDATIONS**

Volume 2

- **RESPONSES TO MANAGEMENT QUESTIONS**

PRESENTATION OUTLINE

- Primary findings and information gaps - Rebecca Buchanan (University of Washington)
- Responses to CAMT's management questions - Sheila Greene (Westlands Water) and Barb Byrne (NMFS)
- Technical disagreements - Pat Brandes (USFWS)
- Recommendations - Pat Brandes (USFWS)

SUMMARY

- Salmon survival in the South Delta is low
- A number of gaps have been identified
- The performance of various management actions on salmonid survival is uncertain
- The SST recommends:
  - Implement actions to improve survival at the SWP and CVP export facilities
  - Continue to monitor salmonid survival in the south Delta while completing additional analyses of existing data to provide a foundation for developing a long-term, hypothesis-based adaptive management program to experimentally assess salmonid migration, survival, underlying mechanisms, and management action performance
  - Develop and implement a long-term monitoring, research and adaptive management program

SCOPE AND REPORT STRUCTURE

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Volume I

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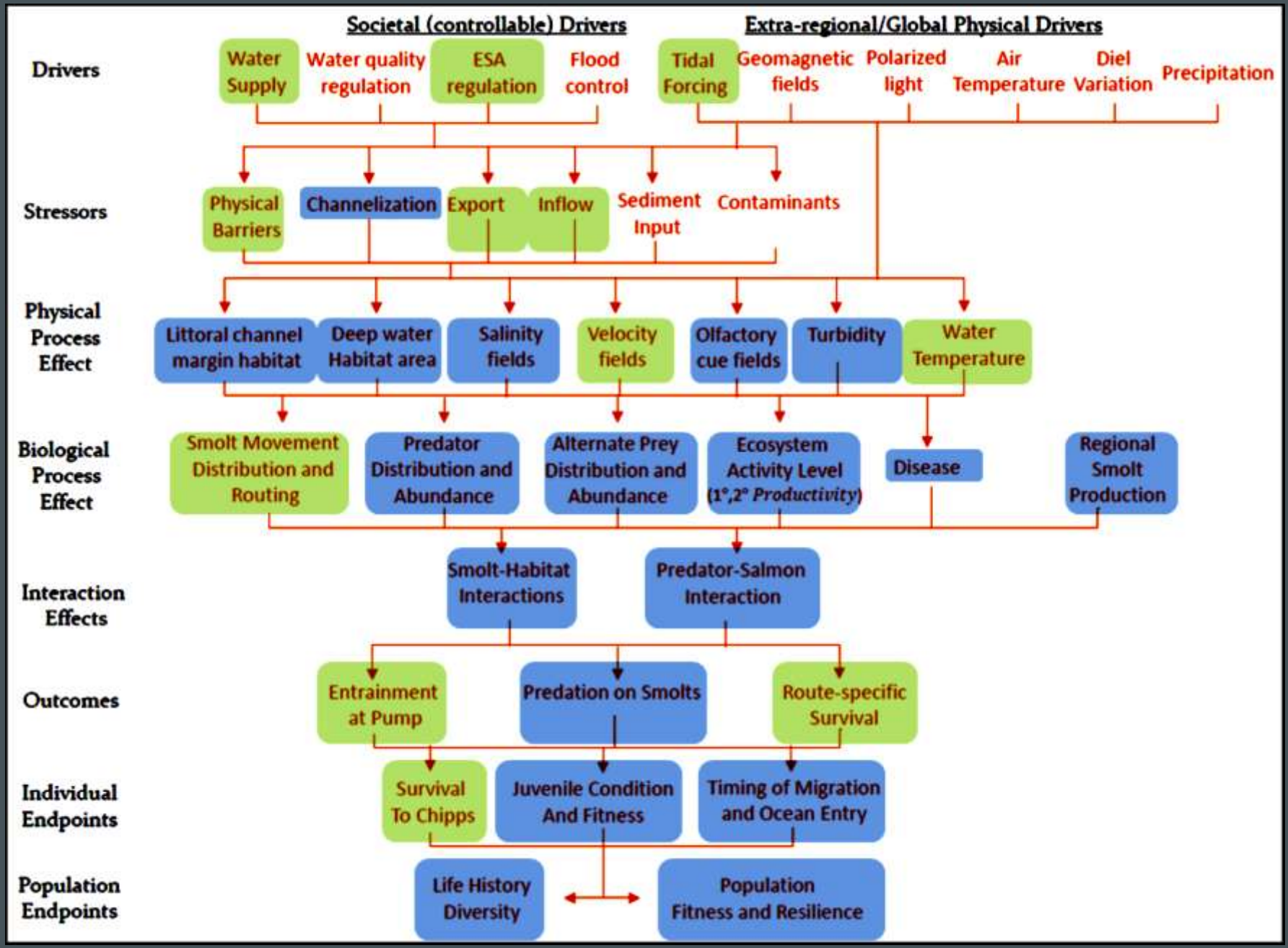
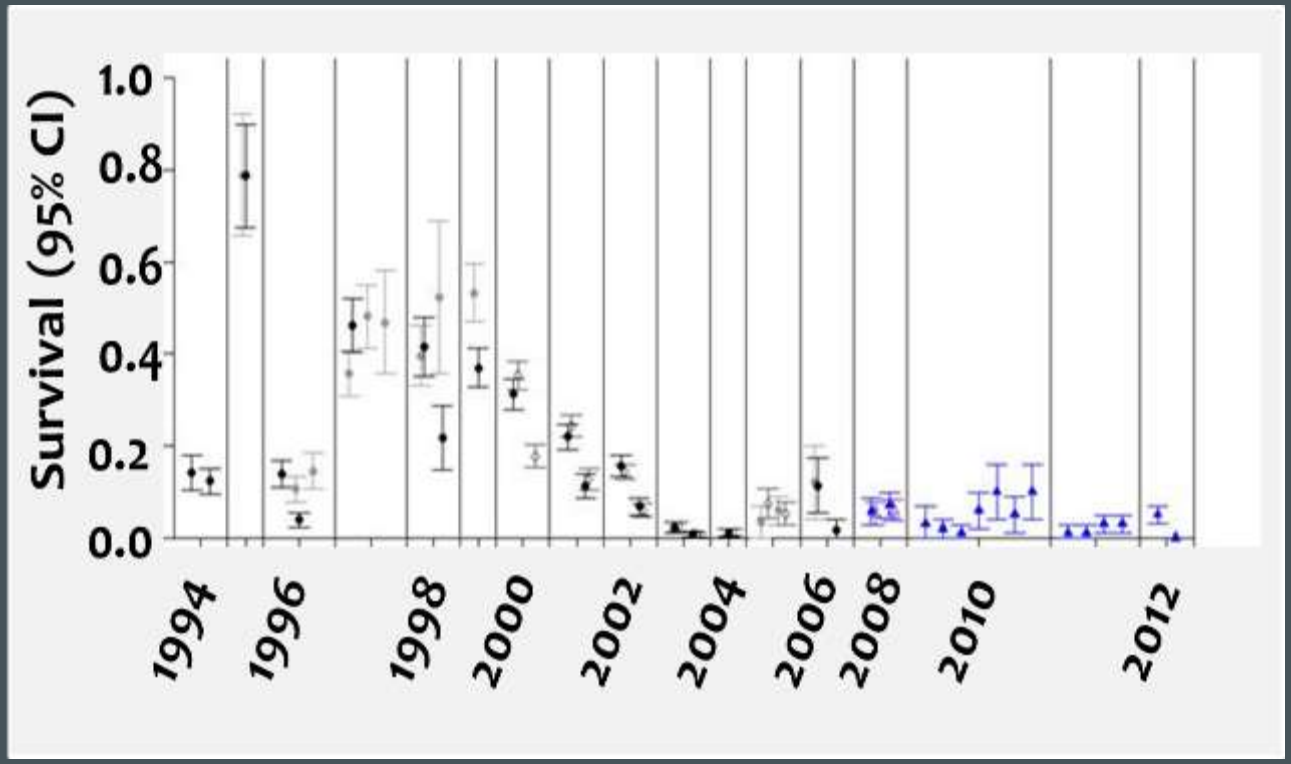
CONCEPTUAL MODEL



THROUGH-DELTA SURVIVAL

- Through-Delta survival has been consistently low for San Joaquin River Chinook salmon



San Joaquin River Fall-Run Chinook Salmon

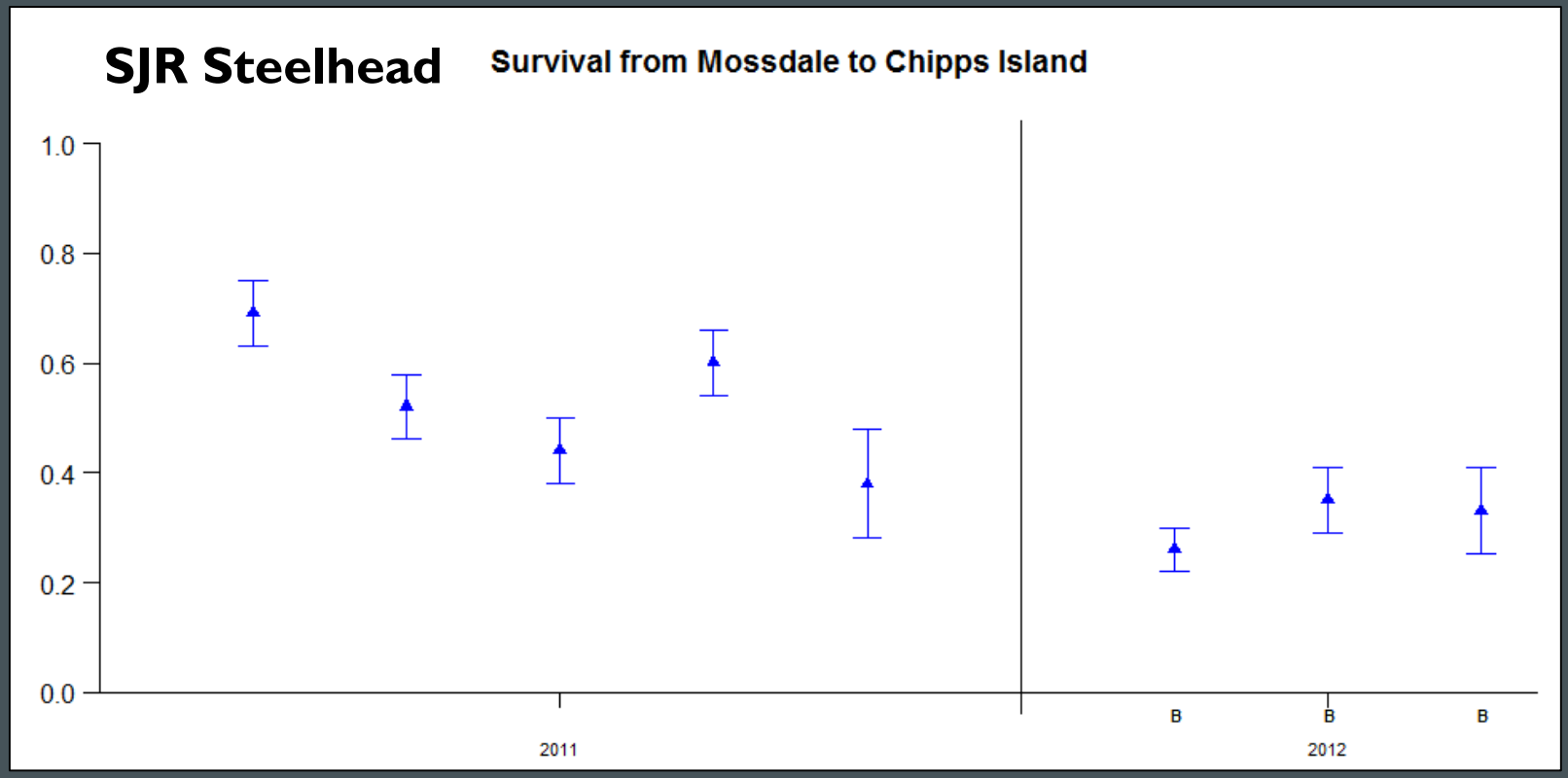
THROUGH-DELTA SURVIVAL

Sacramento River Chinook Salmon

Run	Year	Estimate
Winter	2013, 2014	0.32, 0.35
Spring	2013, 2014	0.30, 0
Fall/Spring	2013	0.17
Fall	2013	0
Late-Fall	Dec 2006, Jan 2007	0.351, 0.543
	Dec 2007, Jan 2008	0.174, 0.195
	Dec 2008, Jan/Feb 2009	0.368, 0.339, 0.64
	Dec 2009, Jan/Feb 2010	0.464, 0.374, 0.52

THROUGH-DELTA SURVIVAL: STEELHEAD

River Basin	Year	Estimate
Sacramento	2009, 2010	0.57, 0.47
San Joaquin	2011, 2012	0.54, 0.32



GAPS IN SURVIVAL DATA

- Most survival and migration data are from San Joaquin River fall-run Chinook salmon
- Only 2 years of San Joaquin River steelhead data analyzed (6 years collected)
- No time series of survival data for Sacramento River Chinook or steelhead
  - Have 2 to 4 years of data for each Sacramento River run/species
- We need data to estimate Delta survival

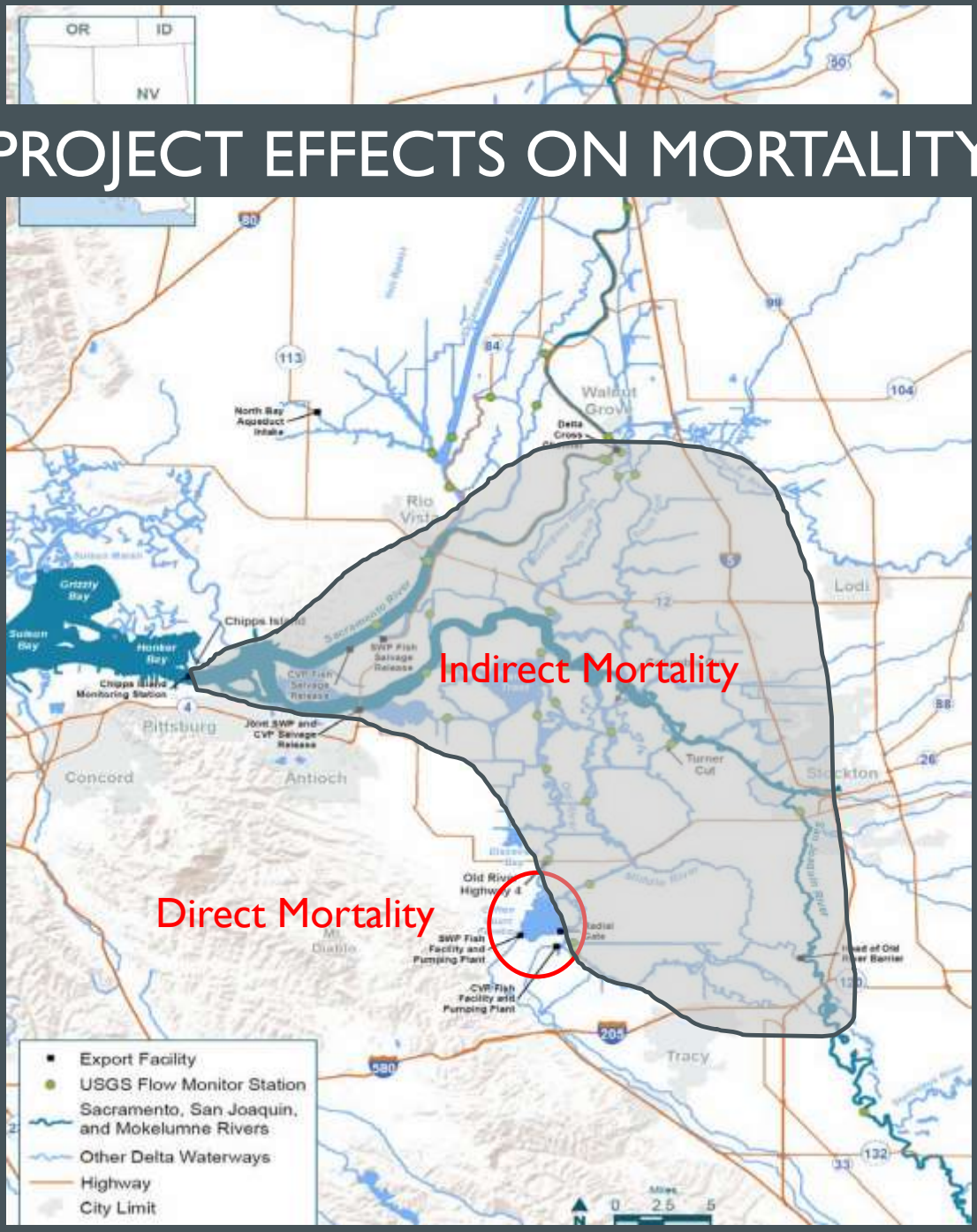
EFFECTS OF FISH SIZE

- Multiple lines of evidence indicate smaller fish respond to conditions differently and usually experience lower survival than larger fish
  - Larger fish have higher survival in the Delta
  - Louver (i.e. fish guidance) efficiency at CVP/SWP fish facilities depends on fish size

GAPS IN FISH SIZE AND SURVIVAL DATA

- Juvenile salmonids of all sizes use Delta throughout year
- Acoustic tags are not suitable for fry-sized fish (<70 mm)
- It is unknown if relationship between fish size and survival is the same for wild fish as for hatchery fish

PROJECT EFFECTS ON MORTALITY

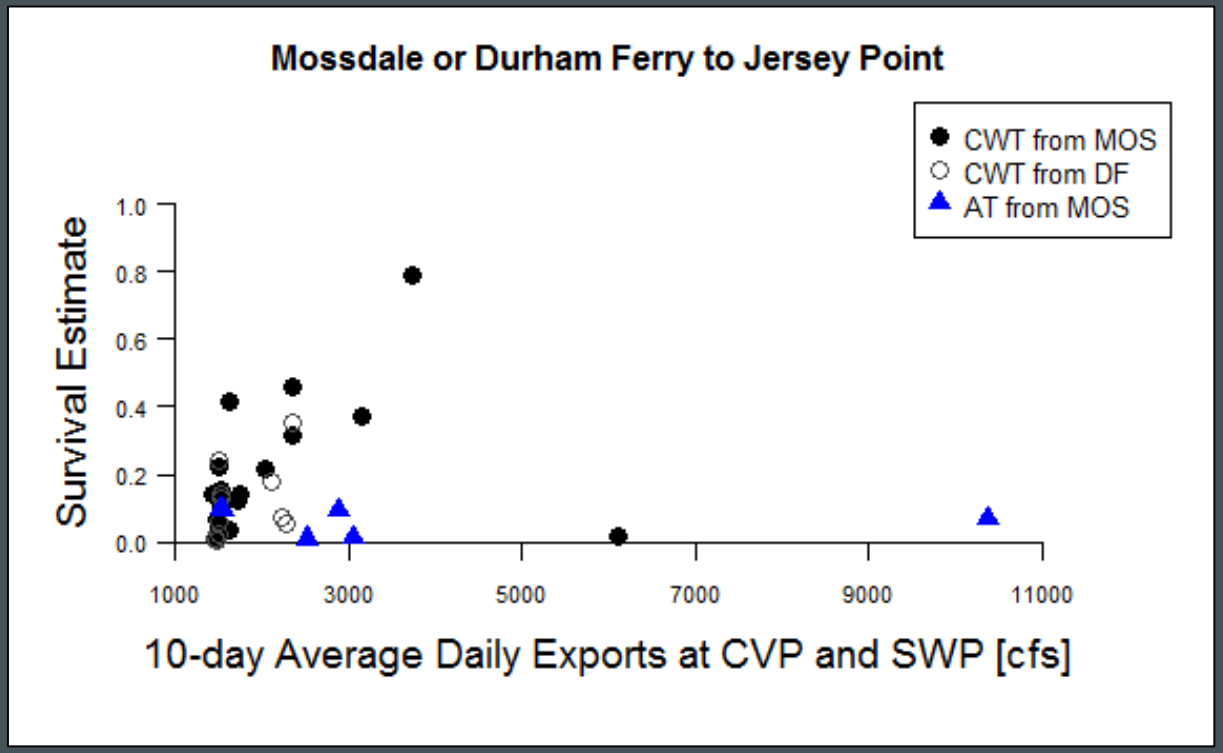


PROJECT EFFECTS ON MORTALITY

- Hypothesized mechanisms of indirect effects outside the facilities
  - Changes in local Delta hydrodynamics (flows, velocities), gate operations that affect routing
  - Delays or extended migration duration that increases exposure to predators
  - Changes in physical habitat conditions (e.g., channelization, riprap) that may increase predator effectiveness
- Despite efforts to reduce mortality via direct and indirect effects, through-Delta survival remains low (SJR Chinook)
- Inconclusive evidence of a relationship between exports and through-Delta survival

PROJECT EFFECTS ON MORTALITY

San Joaquin River Fall-Run Chinook Salmon



SPATIAL AND TEMPORAL COMPLEXITY

- The Delta is a complex and dynamic environment
- The relative influence of tides, inflow, and exports on hydrodynamic conditions (flow and velocity) varies temporally and spatially throughout the Delta

MINIMUM VELOCITY TIDE - FLOOD
INFLOW-12,000 cfs EXPORT-2,000 cfs

MINIMUM VELOCITY TIDE - FLOOD
INFLOW-38,000 cfs EXPORT-2,000 cfs

MINIMUM VELOCITY TIDE - FLOOD
INFLOW-38,000 cfs EXPORT-10,000 cfs

TIDES

TIDE - EBB
XPORT-2,000 cfs

MINIMUM VELOCITY TIDE - EBB
INFLOW-38,000 cfs EXPORT-2,000 cfs

MINIMUM VELOCITY TIDE - EBB
INFLOW-38,000 cfs EXPORT-10,000 cfs

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MINIMUM VELOCITY TIDE - FLOOD
INFLOW-38,000 cfs EXPORT-10,000 cfs

INFLOW

MINIMUM VELOCITY TIDE - EBB
INFLOW-12,000 cfs EXPORT-2,000 cfs

MINIMUM VELOCITY TIDE - EBB
INFLOW-38,000 cfs EXPORT-2,000 cfs

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MINIMUM VELOCITY TIDE - FLOOD
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EXPORTS

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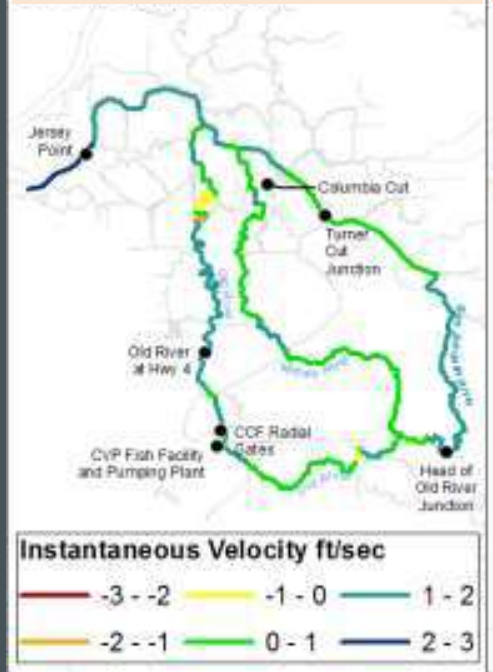
INFLOW-12,000 cfs EXPORT-2,000 cfs



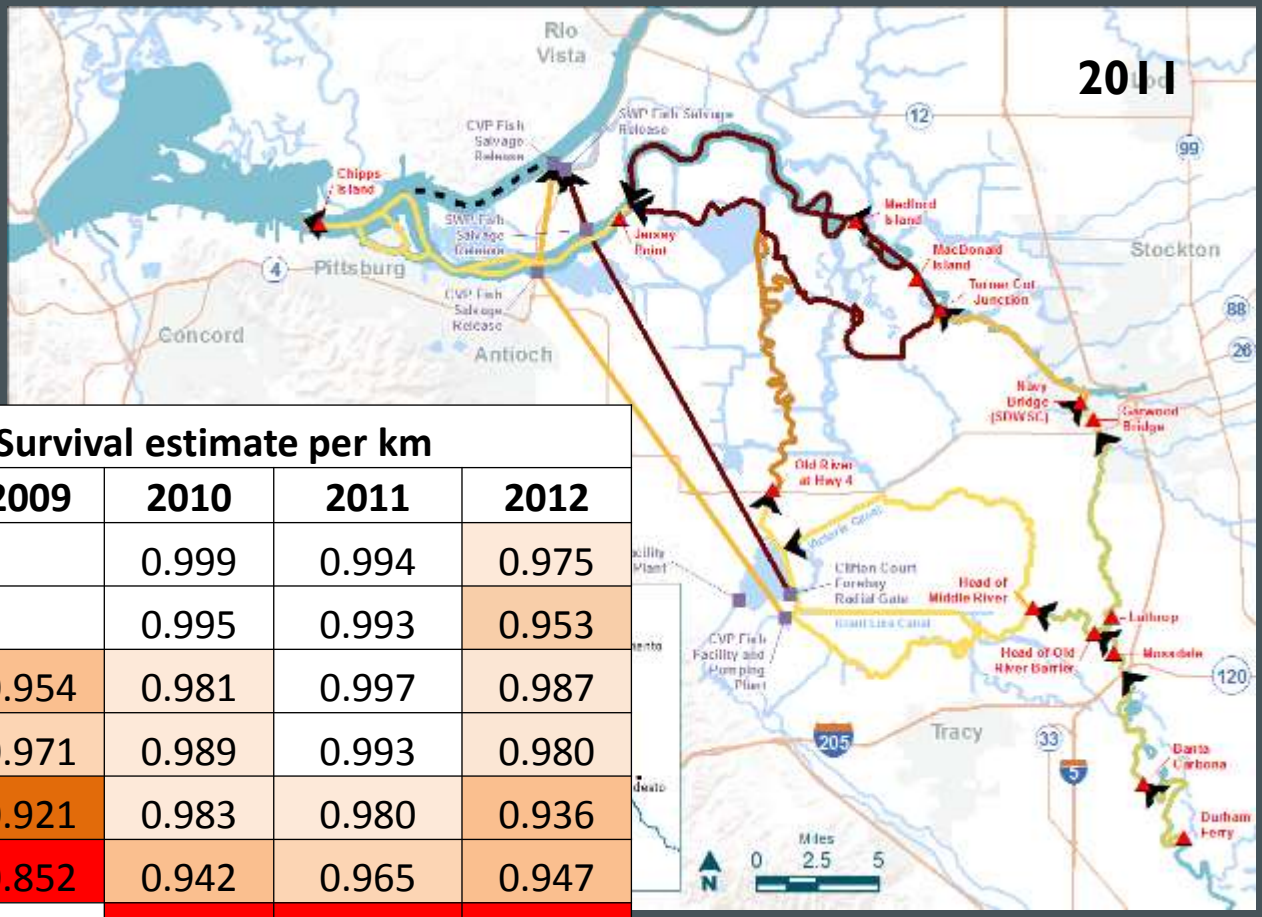
MINIMUM VELOCITY TIDE - EBB
INFLOW-38,000 cfs EXPORT-2,000 cfs

MINIMUM VELOCITY TIDE - EBB
INFLOW-38,000 cfs EXPORT-10,000 cfs

SPATIAL HETEROGENEITY IN SURVIVAL

SJR Fall-Run Chinook

	Survival estimate per km				
Reach	**2008**	**2009**	**2010**	**2011**	**2012**
DF to Banta Carbona			0.999	0.994	0.975
BCA to Mossdale			0.995	0.993	0.953
Mossdale to OR	0.967	0.954	0.981	0.997	0.987
Lathrop to Garwood	0.986	0.971	0.989	0.993	0.980
Garwood to SDWSC	0.955	0.921	0.983	0.980	0.936
SDWSC to Turner Cut	0.958	0.852	0.942	0.965	0.947
MacDonald to Medford			0.863	0.833	0.852
Turner Cut to Jersey Pt (Interior Route)	0			0	0
Medford to Jersey Pt				0.881	0.964
Jersey Pt to Chipps Is	0.981			0.983	0.971



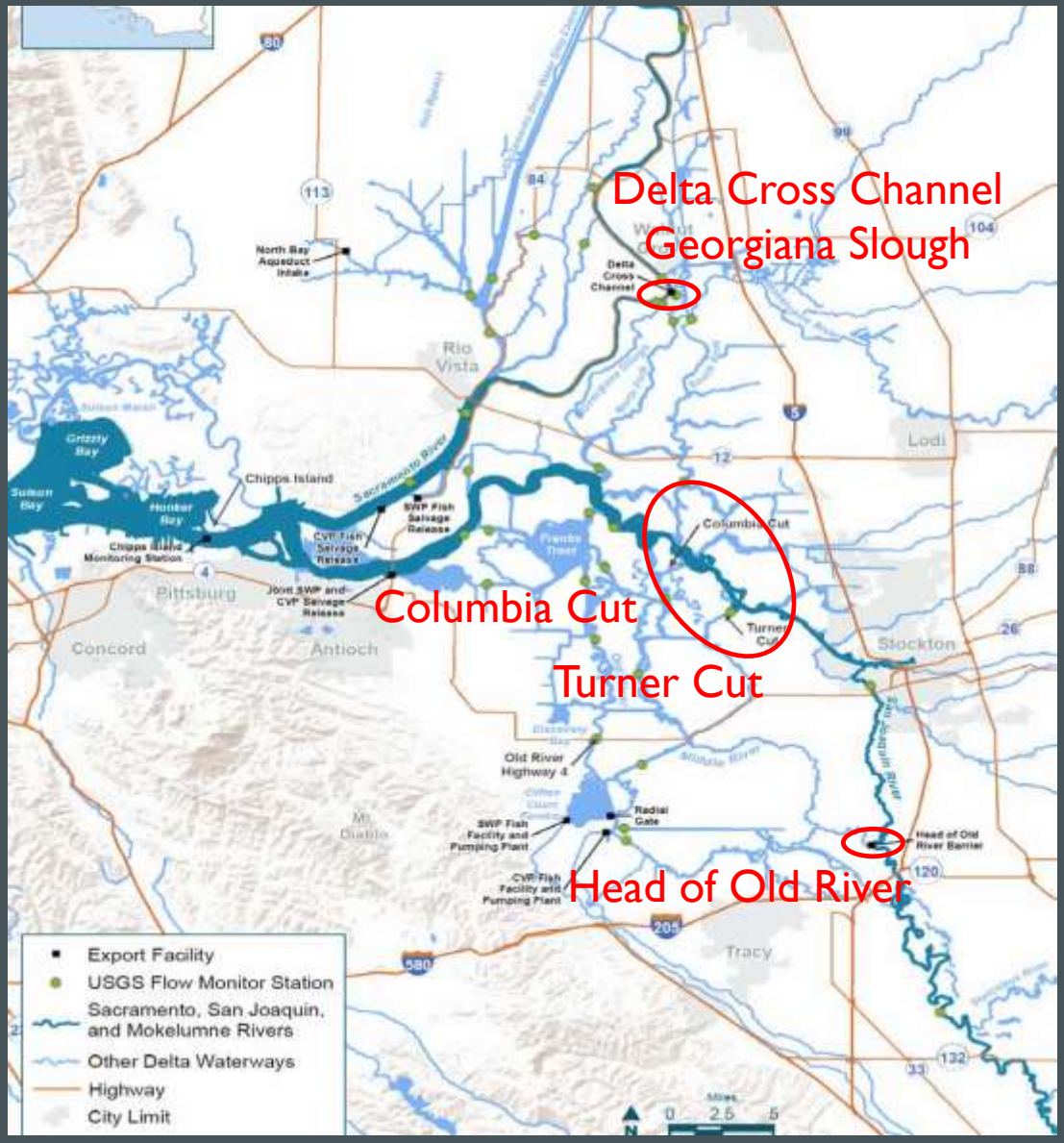
HYDRODYNAMIC MODELS

- The hydrodynamics models were developed for water project planning
  - They were calibrated and validated on a spatial and temporal scale appropriate for the intended purpose
- Calibration and validation at appropriate spatial and temporal scales are needed for the application to fish behavior
- There are some limitations common to all hydrodynamic models related to input data
  - e.g., Clifton Court inflow, bathymetry data, consumptive use data

CURRENT MANAGEMENT ACTIONS

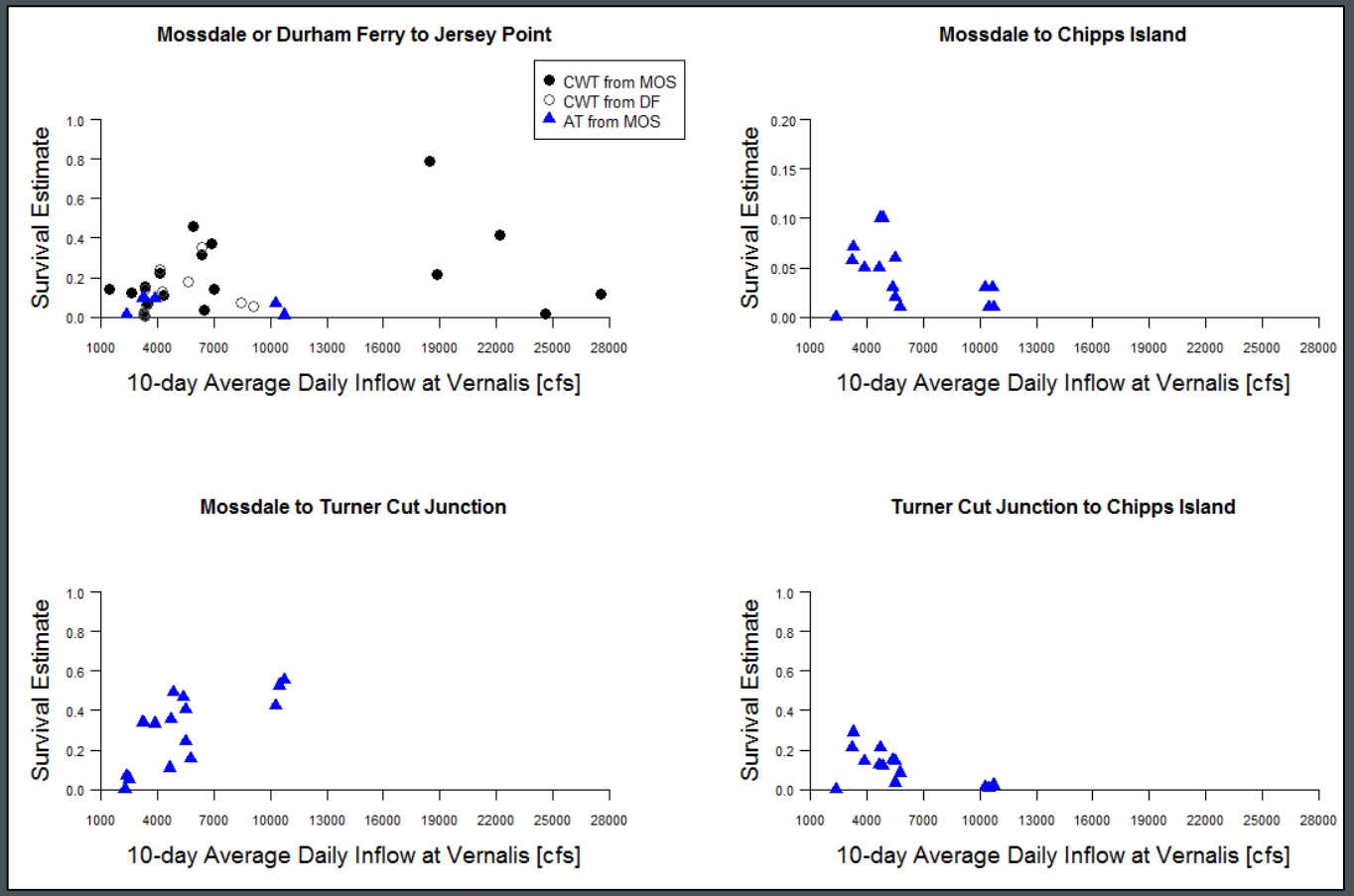
- Gates and barriers
- San Joaquin River inflow
- San Joaquin River I:E
- Reduced negative Old and Middle River (OMR) flows
- Delta E:I

GATES AND BARRIERS



DELTA SURVIVAL VS INFLOW

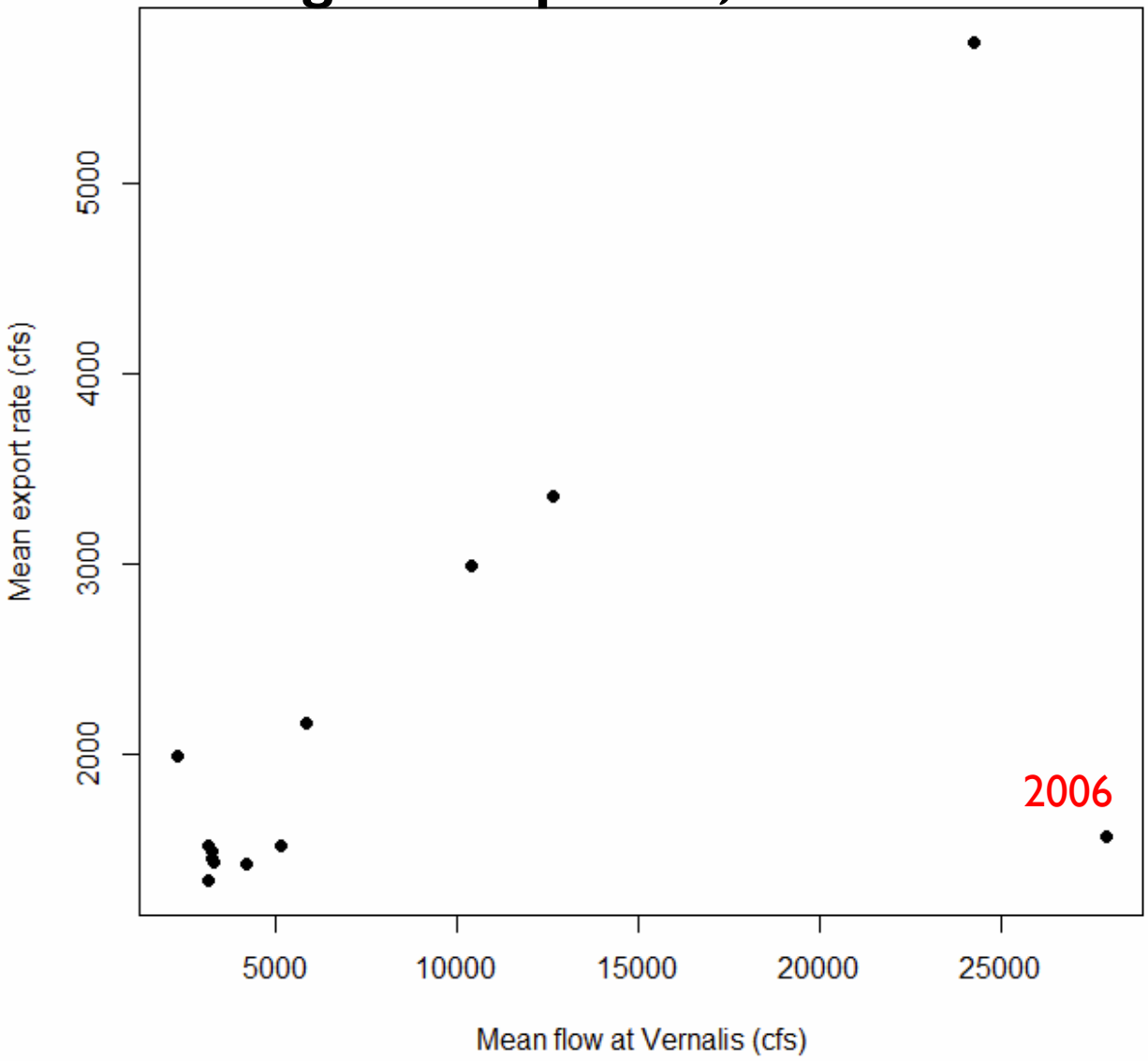
San Joaquin River Fall-Run Chinook Salmon



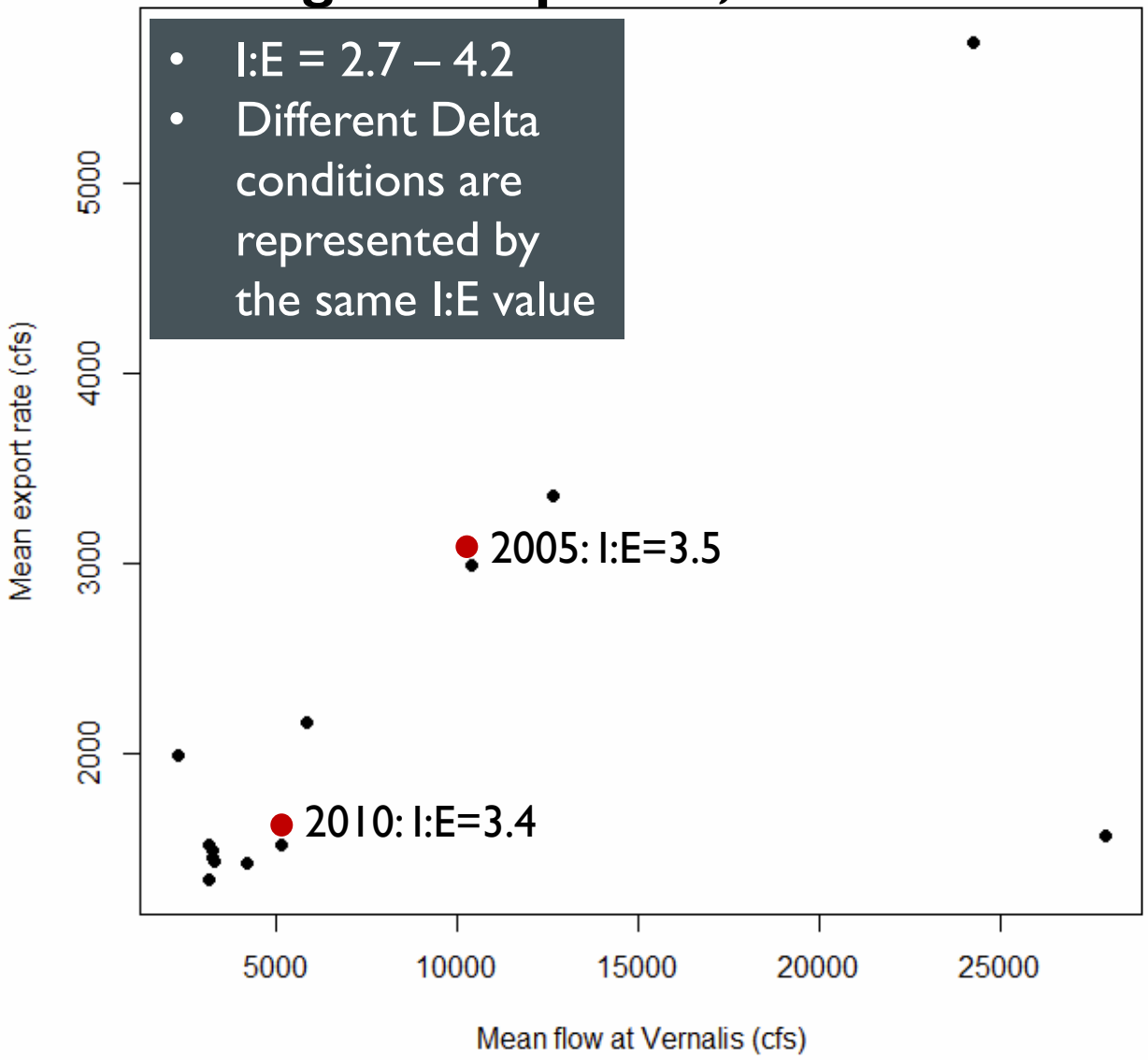
GAPS IN INFORMATION REGARDING MANAGEMENT ACTIONS

- Formal analysis of the relationships between I:E, inflow, exports, and survival is incomplete for existing data (SJR Chinook, steelhead)
- The variability in survival at higher levels of I:E, inflow, and exports is not well-characterized by available data
  - Those conditions have not occurred often during the studies
- Inflow and exports are correlated
  - → Isolating the survival effect of a single factor is difficult or impossible

Observed mean SJR inflow and exports during VAMP period, 2000 - 2011



Observed mean SJR inflow and exports during VAMP period, 2000 - 2011



CONSTRAINTS ON UNDERSTANDING

- All observations are in the presence of management operations (I:E, E:I, OMR restrictions), which makes it difficult to assess their effectiveness
- There has been low variability and limited replication in conditions during tagging studies
  - Most observations of smolt survival have been at low levels of inflow and exports
- Low overall survival makes it difficult to detect changes in survival
- Biological objectives for Delta survival have not been agreed to, which makes it difficult to design studies to test effectiveness of management actions (what is the target?)

SCOPE AND REPORT STRUCTURE

Scope:

We focused narrowly on the effects of SWP and CVP operations on salmonid migration and survival in the Delta

- Inflow
- Exports
- Temporary Agriculture Barriers
- Delta Cross Channel
- Head of Old River Barrier

Volume I

- **FINDINGS AND RECOMMENDATIONS**

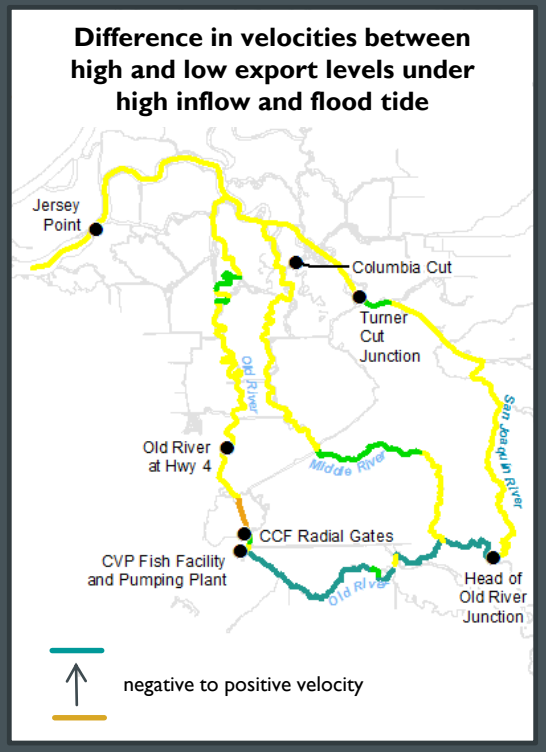
Volume 2

- **RESPONSES TO MANAGEMENT QUESTIONS**

RESPONSES TO 8 MANAGEMENT QUESTIONS FROM CAMT

EFFECTS OF EXPORTS ON FLOW AND VELOCITY

- Export effects vary with distance from facilities (decrease), export level (increase), inflow, and tides
- Largest export effect was estimated in Old River near the SWP and CVP intakes
- Almost no effect at junctions off Sacramento River such as Georgiana Slough
- Small effect at junctions leading off San Joaquin River, except for HOR

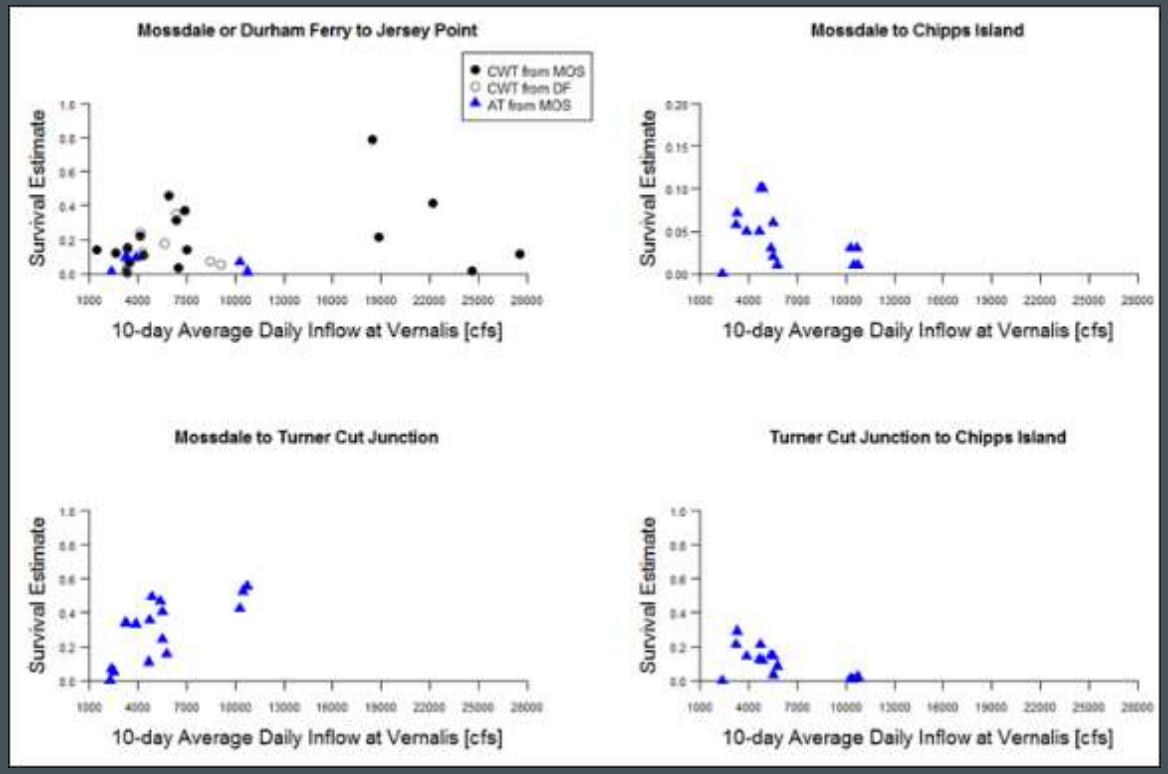


USE OF AVAILABLE HYDRODYNAMIC MODELS

- Useful for isolating one factor at a time by holding other factors constant
- Informed flow and velocity changes in Delta channels, but there is uncertainty for channels that were not validated
- Some limitations, common to all models, are related to input data such as outdated bathymetry, Delta consumptive use, Clifton Court radial gate measurements, and hydrologic monitoring station calibration (particularly at high flows)
- Their application for biological monitoring depends on the question, spatial/temporal resolution needed, and required accuracy for the location

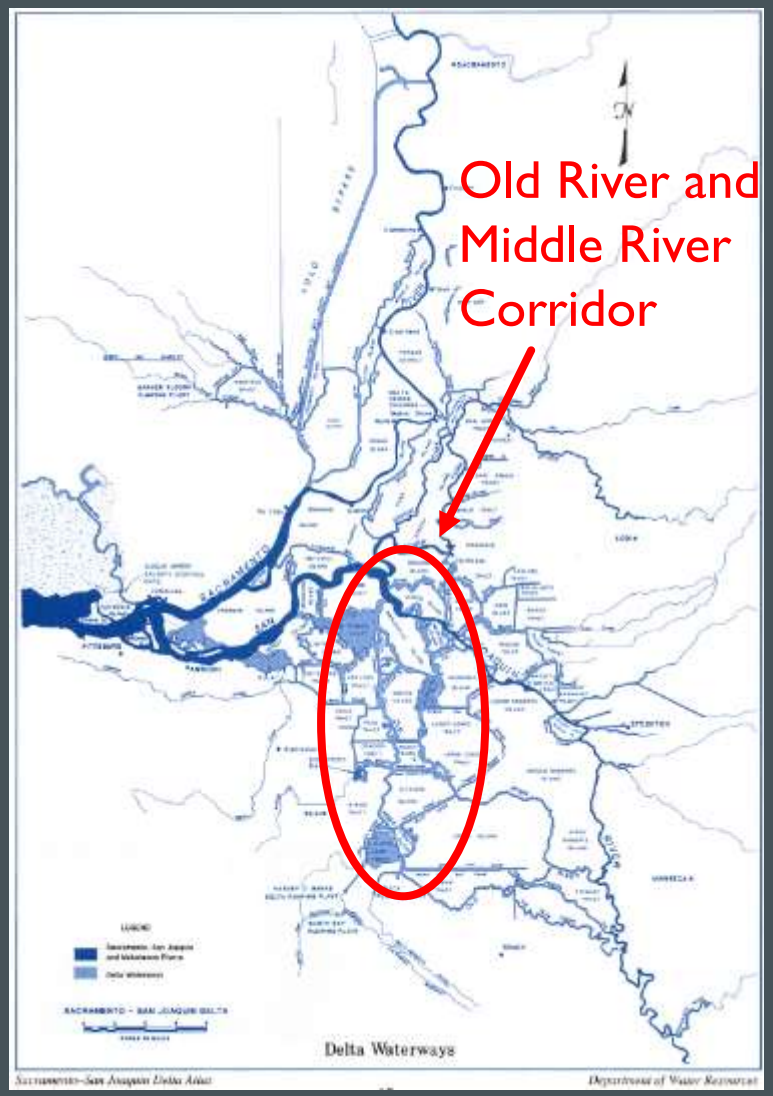
EFFECTS OF EXPORTS AND INFLOWS ON SAN JOAQUIN RIVER JUVENILE SURVIVAL

- Varies in space & time
- Limited data over entire flow range
- Uncertainties remain



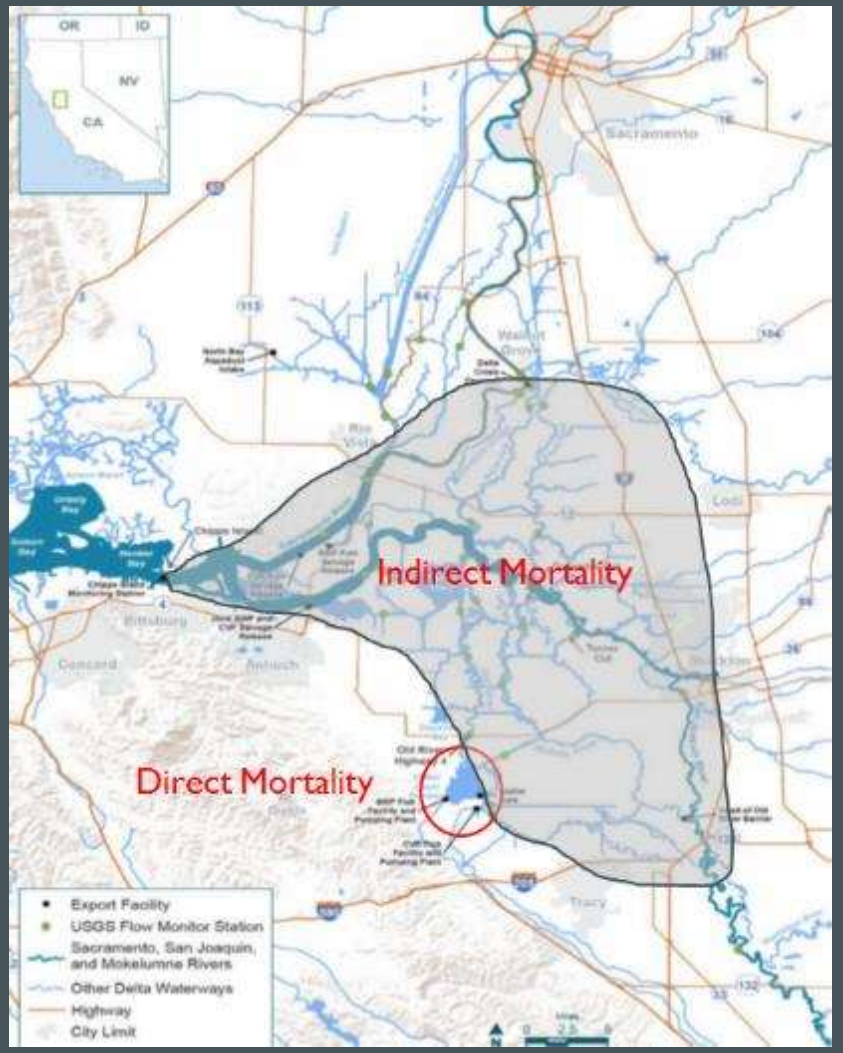
OMR FLOW MANAGEMENT: JANUARY 1st ONSET

- Coincides with juvenile presence in Delta of ESA-listed species in most years
- If based on first detection in Delta, would usually begin earlier



OMR FLOW MANAGEMENT: SALVAGE-DENSITY-BASED EXPORT RESTRICTIONS

- OMR restrictions likely reduce direct mortality
- Effects on indirect mortality are hypothesized; data are limited



ALTERNATIVE FLOW METRICS

- 5 metrics were identified that could be developed and tested to potentially refine water project operations to improve juvenile salmonid survival:
  - Net flow in the lower San Joaquin River (QWEST)
  - Hydraulic residence time in the South Delta
  - Percent positive flow in the OMR Corridor
  - Relative proportion of CVP exports
  - Proportion of Sacramento River water in exports

BIOLOGICAL RESPONSE METRICS

- 8 metrics were identified that could be developed and tested for assessing management actions to improve juvenile salmonid survival:
  - Fish routing into Interior Delta
  - Survival at the route and reach scale
  - Survival at the Delta scale
  - Condition of fish entering and leaving Delta
  - Contribution of fry rearing to survival and adult production
  - Probability of export facility entrainment
  - Direct (salvage) mortality relative to population abundance
  - Juvenile abundance exiting Delta

ADDRESSING CONCERNS ABOUT SURROGATES

- Few studies using wild salmonids are available to evaluate surrogate relationships
- Development of correction factors will require additional study
- Use of surrogates and questions about their use will continue until target populations are abundant or permitted for use in studies
- Surrogacy issue is best addressed on a case-by-case basis during study design development

CAMT MANAGEMENT QUESTIONS: NEXT STEPS

- Limited or inconclusive data for some questions

- Uncertainty and some disagreements

- Recommendation: Use this information to inform development of the long-term monitoring, research, and adaptive management plan

DISAGREEMENTS

- Very few SST disagreements were related to the interpretation of data
- Most disagreements were related to uncertainty due to limited data
- Disagreements were used to inform recommendation for long term study plan

SOME DISAGREEMENTS IN THE SST

1. Whether analysis of exports and relative survival for fish released into Georgiana Slough was conclusive of a relationship between survival and exports
2. The magnitude of change in flow or velocity needed to influence salmonid behavior or survival that is biologically relevant
3. Whether limiting OMR flow to -5,000 cfs prevents increased routing into the interior Delta and increases survival
4. Whether to recommend PIT tag technology in the Delta

OVERARCHING CONSIDERATIONS

- The Delta is a very complicated environment
- The Delta should not be perceived as a singular region, but a suite of regions defined by different physical forcing factors.
- Numerous key questions remain and will require new analyses and experimental approaches
- Questions should be integrated and shift to:

  what can be tested (science),

  what needs to be tested (management)

  what can be put into place for testing (operations)

- Future decisions will have to be made with uncertainty; need to develop tools to help

RECOMMENDATION 1

- Continue existing survival studies, monitoring, and analysis of data (foundation for expanded, future studies)
  - Current studies provide information about survival and junction-specific routing
  - Continuing to estimate through-Delta survival will provide continuity for assessing current status, inter-annual variability and long-term trends
  - Additional analyses of present data to further improve understanding of linkages between water project operations and migration and survival

RECOMMENDATION 2

- Implement short-term actions to improve salvage facility operations (disagreement on whether to recommend short term actions or premature to do so)
  - Determine if current operations at salvage facilities could be improved to reduce losses
    - Actions to reduce direct mortality
    - Other actions to reduce facility loss

RECOMMENDATIONS 3 AND 4

- Develop and implement a long-term monitoring, research, and adaptive management plan
  - To more fully assess the effects of water project operations
  - With stable and reliable funding for implementation for a period of at least 15 years.
  - Base it on monitoring, modeling, and direct manipulation of factors

RECOMMENDATIONS 3 AND 4

- Develop and implement a long-term monitoring, research and adaptive management plan
  - Requires a policy commitment to a range of management actions to be tested
  - Requires agreement on the level of precision needed
  - Requires agreement that operational experimental conditions can be achieved

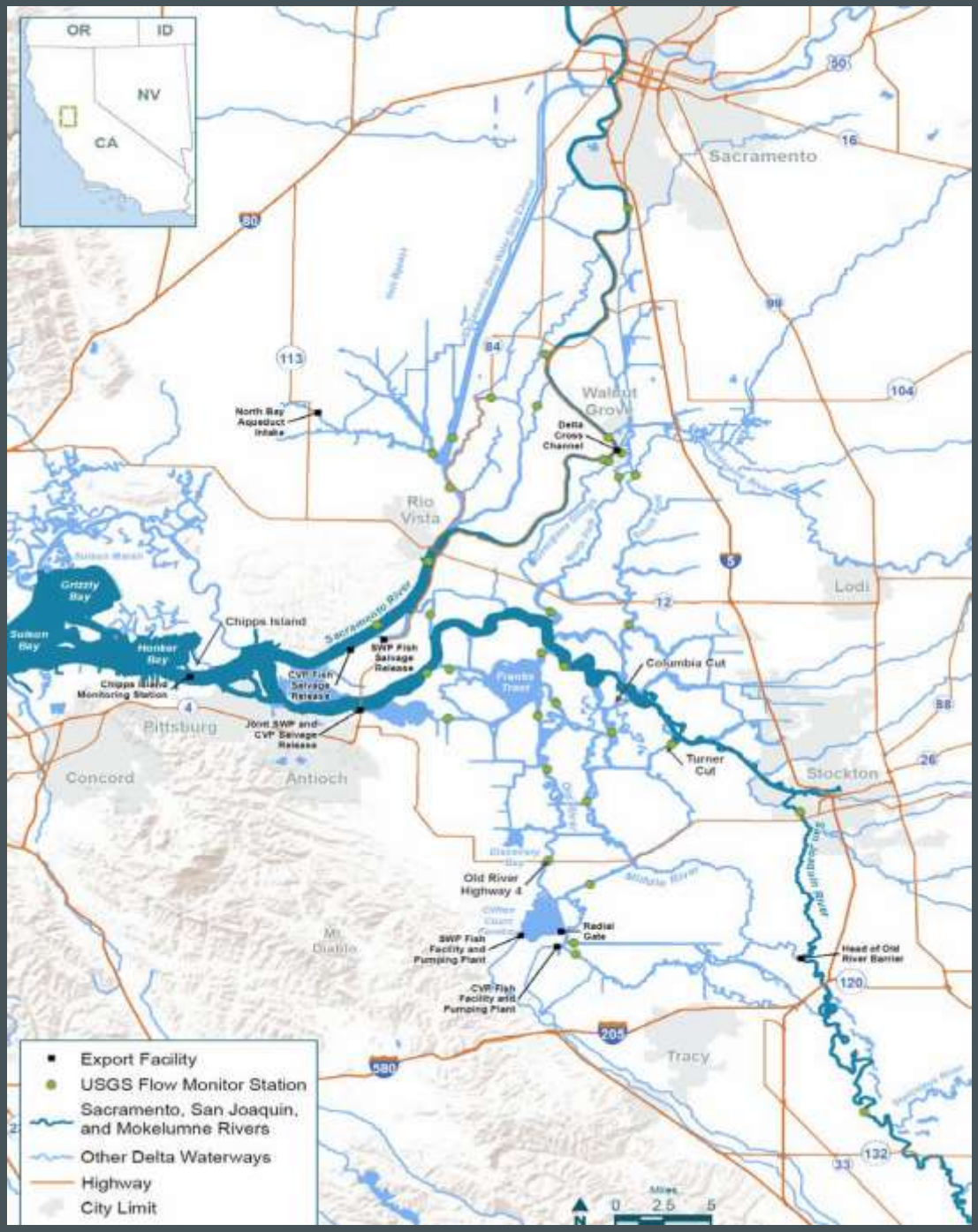
RECOMMENDATIONS 3 AND 4

- Develop and implement a long-term monitoring, research and adaptive management plan
  - Plan should augment and expand the scope of current studies in terms of breath, depth and number of analyses, monitoring studies and experiments conducted
  - A suite of integrated studies organized in hierarchical structure that is adjusted as new information is obtained.
  - Focus on causal mechanisms at appropriate time and space scales

SUMMARY

- Salmon survival in the South Delta is low
- A number of gaps have been identified
- The performance of various management actions on salmonid survival is uncertain
- The SST recommends:
  - Implement actions to improve survival at the SWP and CVP export facilities
  - Continue to monitor salmonid survival in the south Delta while completing additional analyses of existing data to provide a foundation for developing a long-term, hypothesis-based adaptive management program to experimentally assess salmonid migration, survival, underlying mechanisms, and management action performance
  - Develop and implement a long-term monitoring, research and adaptive management program

REFERENCE SLIDES


OR
ID
NV
CA
Sacramento
Walnut Grove
Rio Vista
Lodi
Stockton
Tracy
Pittsburg
Concord
Antioch
Mt. Diablo
North Bay Aqueduct Intake
Delta Cross Channel
Grizzly Bay
Suisun Bay
Honker Bay
Chipps Island
Chipps Island Monitoring Station
Sacramento River
SWP Fish Salvage Release
CVP Fish Salvage Release
Joint SWP and CVP Salvage Release
Columbia Cut
Turner Cut
Old River Highway 4
Radial Gate
SWP Fish Facility and Pumping Plant
CVP Fish Facility and Pumping Plant
Head of Old River Barrier
Export Facility
USGS Flow Monitor Station
Sacramento, San Joaquin, and Mokelumne Rivers
Other Delta Waterways
Highway
City Limit
Miles
0 2.5 5

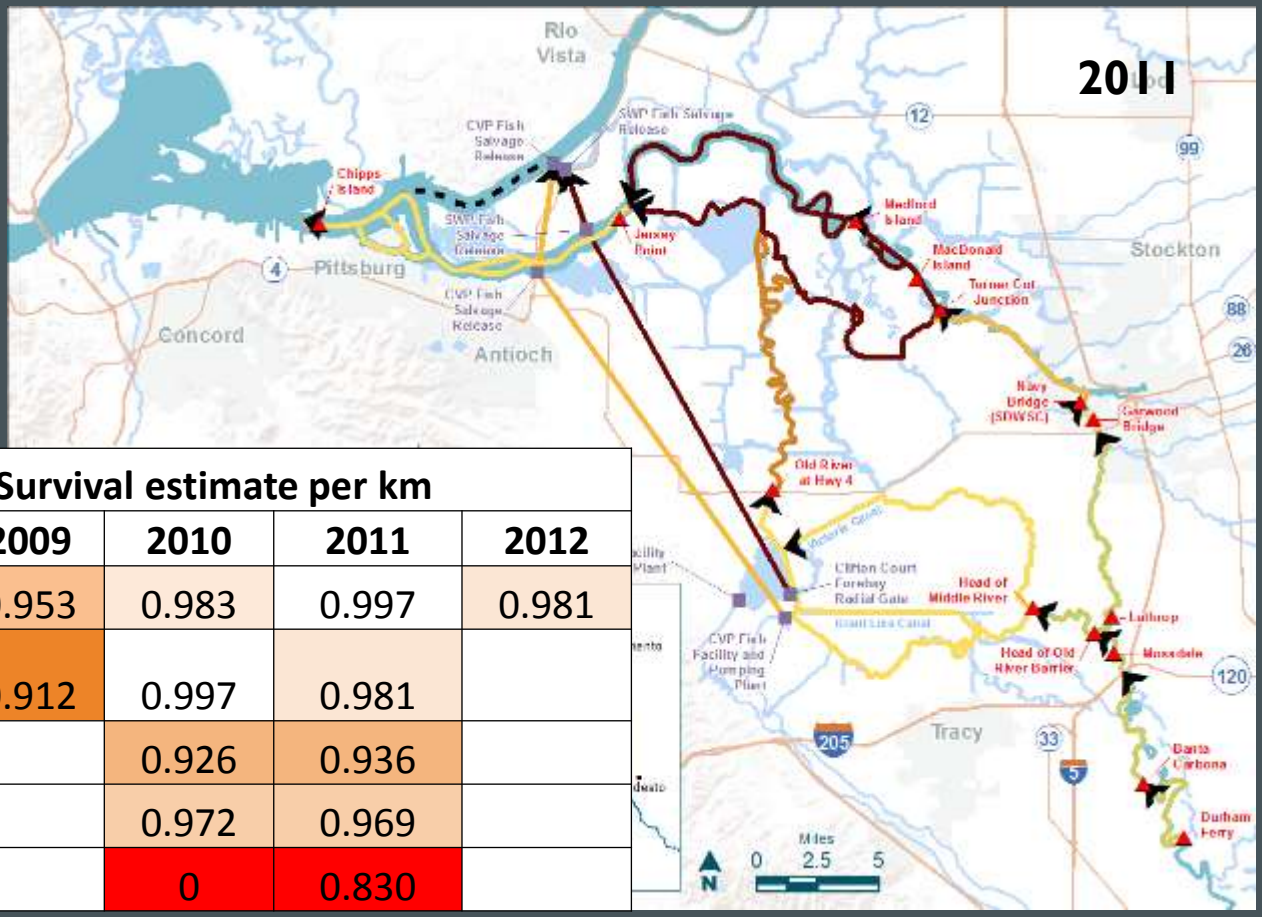
PROJECT EFFECTS ON MORTALITY

- Direct mortality contributes to salmonid mortality in the Delta
- … But direct mortality does not account for the majority of the mortality experienced in the Delta
- The mechanism and magnitude of indirect effects on Delta mortality is uncertain

SPATIAL HETEROGENEITY IN SURVIVAL

SJR Fall-Run Chinook

	Survival estimate per km				
Reach	**2008**	**2009**	**2010**	**2011**	**2012**
Old R to Middle R		0.953	0.983	0.997	0.981
Middle R to CVP/CCF/HWY4		0.912	0.997	0.981	
OR-HWY4 to Jersey Pt			0.926	0.936	
CVP tank to Chipps Is	0.845		0.972	0.969	
CCF gates to Chipps Is	0.904		0	0.830	



PRIMARY FINDINGS – FISH SIZE MATTERS

- Multiple lines of evidence indicate smaller fish respond to conditions differently and usually experience lower survival than larger fish
- Evidence that larger fish have higher Delta survival
  - CWT studies of Sacramento River Chinook (Newman and Rice 2002, Newman 2003; check direction; E.4.1.1)
  - CWT studies of San Joaquin River Chinook (Zeug and Cavallo 2013; water quality model performed as well; E.2.2)
  - AT study of Sacramento River late-fall-fun Chinook (Perry 2010)
  - Similar positive survival response to Delta inflow for different sized fish: 81mm (CWT, Newman 2003) vs. 156 mm (AT, Perry 2010)
  - In 2011 and 2012, AT steelhead had higher survival than AT Chinook (San Joaquin River) (Section E.2.1.2)

PRIMARY FINDINGS – COMPLEX EFFECTS OF WATER PROJECT OPERATIONS

- Water export operations contribute to salmonid mortality in the Delta via direct mortality at the facilities (Section E.3.1)
- 3 components of direct mortality
  - Prescreen mortality, entrainment into water project intakes, within-facility ("salvage") mortality
  - Predation occurs within the facilities – direct and indirect evidence
- Pre-screen mortality estimates:
  - At SWP: 0.64 – 0.99 for Chinook salmon (Gingras 1997), 0.78 – 0.82 for steelhead (Clark et al. 2009)
  - No estimates at CVP; assumed value is 0.15 (Anonymous 2013)
- Intake canal entrainment mortality and total facility mortality ("loss") are estimated as functions of salvage counts
  - Salvage rates increase with export rates (Kimmerer 2008, Zeug and Cavallo 2014)
  - No studies directly test relationship between salvage and total mortality at the facilities
- Efficiency of secondary louver system at CVP
  - 0.85 (Chinook), 1.00 (Steelhead): March 1996 – November 1997 (Bowen et al. 2004)
  - Higher louver efficiency for higher channel velocity (i.e., higher export rates) (Bowen et al. 2004, Sutphin and Bridges 2008): <40% for velocity < 1 ft/s, >80% for velocity > 4 ft/s (Sutphin and Bridges 2008)

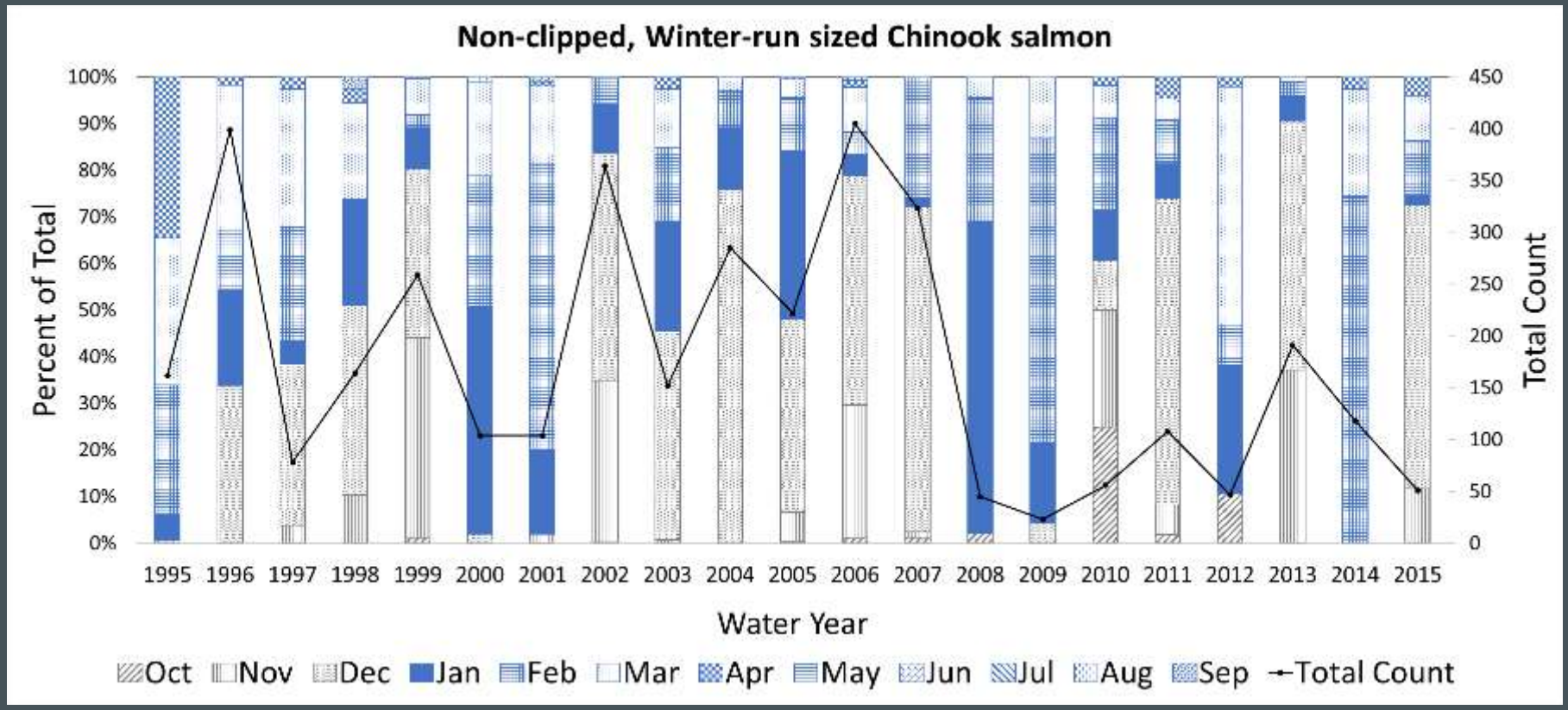
ACTIONS TO REDUCE DIRECT MORTALITY

- Control predator populations (CCF B and CVP trash racks);
- Control secondary louver efficiency (control of bypass velocities);
- Keep primary and secondary louvers free from debris; reduce time when they are inoperable for cleaning;
- Improve salmon passage within the CVP, and decrease predator passage within the CVP;
- Consider alternate truck release locations of salvaged fish to prevent large predator assemblages ;
- Verify the assumption that pre-screen losses at the CVP intake are 15% and substantially lower than losses at the SWP; and
- Test using the CVP for export instead of the SWP to reduce losses of salmonids in CCF.

OTHER ACTIONS TO REDUCE FACILITY LOSS

- Test how CCF radial gate openings affect velocities and fish entrainment
- Evaluate filling the scour hole inside the CCF radial gates reduce predator habitat and predation
- Review and potentially adjust the fish facilities design and operational criteria
- Review past studies and evaluate truck transport release alternatives

JANUARY 1ST ONSET OF OMR



Timing of Delta entry for winter-run-sized Chinook salmon

JANUARY 1ST ONSET OF OMR

Table 4-1. Date of Earliest Salvage of Genetic Winter Run Chinook from 1997 to 2015

Water Year	Earliest Salvage
1997	11/26/1996
1998	10/3/1997
1999	10/25/1998
2000	11/22/1999
2001	11/6/2000
2002	12/5/2001
2003	12/23/2002
2004	12/8/2003
2005	12/21/2004
2006	12/20/2005
2007	12/30/2006
~~2008~~	~~1/26/2008~~
~~2009~~	~~2/21/2009~~
2010	12/8/2009
2011	12/6/2010
~~2012~~	~~2/14/2012~~
2013	12/13/2012
~~2014~~	~~03/03/2014~~
~~2015~~	~~no salvage~~

Timing of Delta entry for genetic winter-run Chinook salmon

Exhibit D
List of published literature on salmonids in the Delta since 2009 BiOp

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Lindley S. T., C. B. Grimes, M. S. Mohr, W. Peterson, J. Stein, J. T. Anderson, L. W. Botsford, D. L. Bottom, C. A. Busack, T. K. Collier, J. Ferguson, J. C. Garza, A. M. Grover, D. G. Hankin, R. G. Kope, P. W. Lawson, A. Low, R. B. MacFarlane, K. Moore, M. Palmer-Zwahlen, F. B. Schwing, J. Smith, C. Tracy. R. Webb, B. K. Wells, and T. H. Williams. 2009. What caused the Sacramento River fall Chinook stock collapse? Report to the Pacific Fishery Management Council. Available at: ftp://ftp.pcouncil.org/pub/Salmon%20EFH/169_Lindley_et_al_2009.pdf.

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Newman, K. B., and P. L. Brandes. 2010. Hierarchical modeling of juvenile Chinook salmon survival as a function of Sacramento-San Joaquin Delta water exports. North American Journal of Fisheries Management 30:157-169.

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Available:
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