Management Tools for Landscape-Scale Restoration of Ecological Functions in the Delta

Proposal to:

Ecosystem Restoration Program
California Department of Fish and Game

Project Principle Investigators:

Robin Grossinger, Primary Investigator
Letitia Grenier, Co-Primary Investigator

AQUATIC SCIENCE CENTER

March 1, 2011

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ERP Proposal Application Form

For DFG use only	
Proposal No.	Region

Section 1: Summary Information

1. Project title:	Management Tools for Landscape-Scale Restoration of Ecological Functions
2. Applicant name:	Aquatic Science Center
3. Contact person:	Alison Whipple
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9. Agency Type:	Federal Agency ☐ State Agency ☐ Local Agency **X** Nonprofit Organization ☐ University (CSU/UC) ☐ Native American Indian Tribe ☐
10. Certified nonprofit organization:	Yes ☐ No X
11. New grantee:	Yes ☐ No X
12. Amount requested:	$875,000
13. Total project cost:	$875,000
14. Topic Area(s):	Shallow Water and Marsh Habitat (primary); Hydrodynamics, Sediment Transport and Flow Regimes; Lowland Floodplains and Bypasses; Riparian Habitat; River Channel Restoration; Upland Habitat and Wildlife Friendly Agriculture
15. ERP Project type:	Research (primary), Planning
16. Ecosystem Element:	Fresh Emergent Wetland (primary), Natural Floodplain and Flood Processes, Delta Sloughs, Essential Fish Habitats, Freshwater Fish Habitats, Nontidal Perennial Aquatic Habitat, Perennial Grassland, Riparian and Riverine Aquatic Habitats, Seasonal Wetlands, Tidal Perennial Aquatic Habitat
17. Water Quality Constituent:	Turbidity and Sedimentation (primary), Salinity
18. At-Risk species benefited:	Potentially all at-risk Delta species if tools developed by project are effectively implemented (e.g., Chinook salmon, Delta smelt, Least Bell's vireo).
19. Project objectives:	The project will develop tools for implementing and communicating restoration strategies that establish landscape-scale ecological function, significantly improving the environmental outcomes of conservation and restoration investments in the Delta.
20. Time frame:	Three year timeline: Task 1 completed by the end of the 3rd quarter, Task 2 completed at the end of the 7th quarter, Task 3 at the end of the 11th quarter, Task 4 at the end of the 12th quarter, and Task 5 at the end of the 12th quarter.

Section 2: Location Information

1. Township, Range, Section: and the 7.5 USGS Quad map name.	Includes part or all of: T11NR3E, T10NR3E, T9NR3-4E, T8NR3-5E, T7NR2-5E, T6NR1-5E, T5NR1-6E, T4NR2-6E, T3NR1-6E, T2NR1-6E, T1NR3-7E, T1SR3-7E, T2SR4-7E, T3SR6-7E, T4SR7E. USGS Quad maps include: Antioch North, Antioch South, Birds Landing, Bouldin Island, Brentwood, Bruceville, Brush Lake, Byron Hot Springs, Clarksburg, Clifton Court Forebay, Courtland, Crows Landing, Davis, Denverton, Dixon, Dozier, Elmira, Florin, Galt, Grays Bend, Gustine, Hatch, Holt, Honker Bay, Isleton, Jersey Island, Knights Landing, Lathrop, Liberty Island, Lodi North, Lodi South, Manteca, Midway, Rio Vista, Ripon, Sacramento East, Sacramento West, Saxon, Stevinson, Stockton East, Stockton West, Taylor Monument, Terminous, Thornton, Tracy, Union Island, Vernalis, Verona, Westley, Woodward Island.
2. Latitude, Longitude (in decimal degrees, Geographic, NAD83):	Points of farthest extent: -121.626, 38.786 (North); -121.231, 37.875 (East); -121.205, 37.617 (South); -121.848, 38.062 (West). Please refer to Figure 1 of Section 6.
3. Location description:	Sacramento-San Joaquin River Delta Ecological Management Zone and along the 25-ft elevation contour, from the Feather River to the Stanislaus River
4. County(ies):	Sacramento, San Joaquin, Solano, Contra Costa, Yolo
5. Directions:	Not Applicable
6. Ecological Management Region:	Delta
7. Ecological Management Zone(s):	Sacramento-San Joaquin River Delta Ecological Management Zone
8. Ecological Management Unit(s):	North Delta EMU, East Delta EMU, South Delta EMU, and Central and West EMU
9. Watershed Plan(s):	Not Applicable
10. Project area:	775,000 acres
11. Land use statement:	Not Applicable
12. Project area ownership:	Not Applicable % Private_______ % State________ % Federal________ *Enter ownership percentages by type of ownership.*
13. Project area with landowners support of proposal:	Not Applicable

Section 3: Landowners, Access and Permits

1. Landowners Granting Access for Project: (Please attach provisional access agreement[s]) Not Applicable	
2. Owner Interest: Not Applicable	
3. Permits:	Not Applicable
4. Lead CEQA agency:	Not Applicable
5. Required mitigation:	Yes ☐ No **X**

Section 4: Project Objectives Outline

1. List task information:

This project will help ERP meet many of its objectives. In particular, the project addresses Habitats (Goal 4), Objective 1 of the ERP Strategic Goals and Objectives, which is to "restore large expanses of all major habitat types, and sufficient connectivity among habitats." The project is designed to answer the question of how restoration of major habitat types can best proceed in order to achieve greater ecological function in the Delta. The proposal objectives are centered on providing tools needed to help establish a practical guiding vision of landscape-scale restoration. These tools can be used by agencies, managers and restoration practitioners to design, implement, and evaluate restoration investments so that they are more effectively integrated with longer term landscape restoration strategies and provide the greatest benefits with the least amount of cost. These tools include refined conceptual models of habitats, landscape-scale conceptual models, and design principles and target metrics. Furthermore, project objectives include the development of landscape metrics, such as connectivity among and between habitats (part of Objective 1 above), linked to the expected ecological functions provided by landscape characteristics. The project will meet ERP Strategic Goal 4, Objective 1 by incorporating knowledge of how habitats are arranged at the landscape scale, what physical processes are related, and what ecological functions they provide. The project will provide a basis for ERP restoration project selection, design, and performance evaluation that is currently not available.

2. Additional objectives:

Perhaps equally significant, this project addresses the Ecological Processes goal by providing information on how the rehabilitation of natural processes can most effectively proceed in order to provide needed Delta ecological functions. Overall, the project will establish linkages between landscape pattern and process. The project objectives include addressing uncertainties in current habitat conceptual models and establishing landscape-level conceptual models, which will facilitate establishment and maintenance of hydrologic and hydrodynamic regimes (Objective 1), increased estuarine productivity (Objective 2), creation and maintenance of channel morphology and shallow water habitat (Objective 3), reestablishment of floodplain processes (Objective 6), and the enhancement of pre-1850 river channel forms (Objective 8). Our linking of specific ecological functions to landscape-scale restoration will also support the establishment of self-sustaining populations of many native species (Goal 1).

3. Source(s) of above information:

The approach of using historical ecological research to increase the success of landscape-scale restoration is well supported in the scientific literature (e.g. Hulse et al. 2002, Collins et al. 2003, Montgomery 2008, Greiner 2010, Grossinger et al. 2011). The need to identify recoverable historical landscape features and ecosystem complexity in the Delta has been identified in recent Delta planning documents (e.g. Teal et al. 2009, CDFG 2010a and b, Moyle et al. 2010, Atwater 2011, DSC 2011).

Section 5: Conflict of Interest

To assist ERP staff in managing potential conflicts of interest as part of the review and selection process, we are requesting applicants to provide information on who will directly benefit if your proposal is funded. Please provide the names of individuals who fall in the following categories:

- Persons listed in the proposal, who wrote the proposal, will be performing the tasks listed in the proposal, or who will benefit financially if the proposal is funded; and/or
- Subcontractors listed in the proposal, who will perform tasks listed in the proposal, or will benefit financially if the proposal is funded.

Primary Contact for Proposal: Alison Whipple

Primary Investigator: Robin Grossinger

Co-Primary Investigator: Letitia Grenier

Supporting Staff: Ruth Askevold, Julie Beagle, Erin Beller, Shira Bezalel, Kristen Cayce, Angelina Clark, Josh Collins, Todd Featherston, Patty Frontiera, Kelleen Griffin, Rainer Hoenicke, Jamie Kass, Marcus Klatt, Lawrence Leung, Mike

May, Aroon Melwani, Jeff Mueller, April Robinson, Linda Russio, Micha Salomon, Bronwen Stanford, Chuck Striplen, Linda Wanczyk, Meredith Williams

Subcontractors and/or those who will perform tasks listed in the proposal:

Graphic designers and artists: Laura Cunningham, David Diethelm, Jennifer Natali

Landscape Interpretation Team*: Michael Barbour (UC Davis), Brian Collins (University of Washington), Chris Enright (Delta Science Program), Geoffrey Geupel (PRBO Conservation Science), Todd Keeler-Wolf (DFG), William Lidicker (UC Berkeley), Jay Lund (UC Davis), Peter Moyle (UC Davis), Anke Mueller-Solger (Bay-Delta Interagency Ecological Program), Dave Zezulak (DFG)

* Several of the non-governmental team members will receive stipends.

Provide the list of names and organizations of all individuals not listed in the proposal who helped with proposal development along with any comments.

Last Name	First Name	Organization	Role
Dahm	Cliff	Delta Science Program	Provided concept review
Wilcox	Carl	Department of Fish and Game	Provided concept review

Section 6: Project Tasks and Results Outline

1. Detailed Project Description

ABSTRACT

Restoration goals for the Sacramento-San Joaquin Delta focus on the establishment of large areas of interconnected habitats. However, the fundamental issue of how to integrate this large-scale thinking with small-scale, on-the-ground restoration projects remains. To address this issue, the ASC and collaborators propose to 1) quantify landscape-scale metrics based on historical landscapes, 2) develop an understanding of historical ecological functions and compare them to contemporary ones, 3) refine conceptual models of Delta ecological function, 4) develop restoration design principles and guidelines based on this new understanding, and 5) present explicit landscape illustrations and other visualizations to be used to create guiding images for the future Delta. This project has been strategically designed in close conversation with local scientists and agency managers to complement current restoration planning efforts and to provide the specific tools that managers need for landscape-level restoration of ecological functions.

PROBLEM STATEMENT

Much of how the Sacramento-San Joaquin Delta will look and function in the future depends on decisions we make today. This project will provide tools to help build and support the guiding vision that is critically needed to make these decisions (Palmer et al. 2005). Prior to Euro-American modification, the Sacramento-San Joaquin Delta was a heterogeneous ecosystem in which latitudinal and longitudinal gradients in major physical factors (e.g., tide range, watershed runoff, sediment input, mean temperature, precipitation) produced distinct mosaics of major habitat types, aggregated into larger scale landscape units (Thompson 1957, Atwater 1979, Grossinger et al. 2010, Whipple et al. 2010). Today, the challenge is to reestablish functional elements of these landscape units within the contemporary Delta in order to support native species and to increase and sustain overall ecosystem health. Many restoration project plans are underway. This project provides the tools and knowledge needed to integrate these existing and future efforts with a landscape-scale planning vision.

Over the past 150 years, the Delta ecosystem has been transformed to the extent that it no longer sustains healthy populations of numerous native species of fish and other wildlife. Due to multiple stressors, this has resulted in severe shifts in ecological communities and degradation of ecosystem resilience (Baxter et al. 2010, Moyle et al. 2010, Atwater 2011). As implementation of the CALFED Program moves into Stage 2 (2008-2030), the status quo is now acknowledged as inadequate to meet desired goals for ecological function, resulting in the need for substantial ecosystem restoration (Lund el al. 2007, Isenberg et al. 2008, BDCP 2010). Furthermore, the Delta Reform Act has established the critical statewide importance and the legal requirement of “protecting, restoring, and enhancing the Delta ecosystem” (Water Code Section 8505).

To achieve the ambitious goal of ecosystem restoration in the Delta, current environmental planning efforts—such as the Ecosystem Restoration Program (ERP), the Bay Delta Conservation Plan (BDCP), and the Delta Plan—all call for large-scale restoration that treats the Delta as a heterogeneous landscape of interconnected habitats with functional linkages (BDCP 2010, CDFG et al. 2010a, DSC 2011). Despite the recognized importance of such an approach, however, there remains significant uncertainty about what large-scale restoration could or should look like. Very little technical information is available to guide landscape-level restoration planning; we lack subregional priorities, patch size and habitat connectivity guidelines (as well as other landscape-scale metrics), and clear understanding of expected ecological functions associated with restoration of particular habitats. For example, would restoring small patches of tidal marsh provide substantial primary production benefits, refugia large enough to increase survival of juvenile fish, or enough connectivity to allow gene flow among marsh obligate species? Furthermore, landscape-level performance measures have not been set that would enable evaluation and monitoring of individual restoration projects. In the absence of these large-scale restoration strategies and design criteria, restoration actions are likely to occur in a piecemeal fashion that fails to consider the broader context and overall system drivers (Greiner 2010, DSC 2011). As a result, there is a significant risk of large investments of time and money towards restoration without substantial improvements to wildlife populations and overall ecosystem function.

Recent plans recognize this information gap in a number of ways. The draft Delta Plan (DSC 2011) identifies the challenge of determining how to "prioritize ecosystem recovery strategies and actions at a broad scale." The ERP Proposal Solicitation Package prioritizes research to understand the ecological benefits of tidal marsh and shallow water habitat, as well as the effects of seasonal and annual variability (CDFG et al. 2010b). The Delta Regional Ecosystem Restoration Implementation Plan (DRERIP) Evaluation Summary Report identifies the need for a "focused suite of restoration design principles" and more clearly defined tidal restoration measures (Essex Partnership 2009). In addition, the DRERIP Tidal Marsh Conceptual Model recommends the development of a landscape-level conceptual model (Kneib et al. 2008). These and other evaluations point to the need for a landscape-level framework for recovering ecological functions along existing and anticipated physical gradients (Teal et al. 2009).

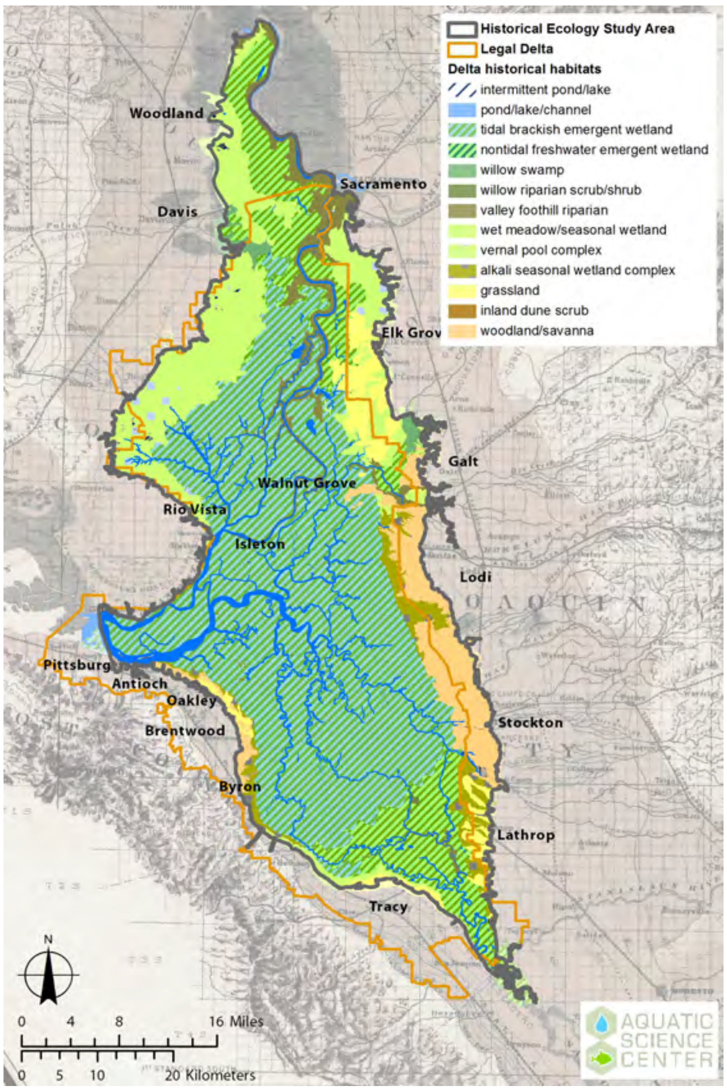

Figure 1. Draft map of the Delta landscape prior to significant Euro-American modification.

To begin to address these questions, the Aquatic Science Center (ASC), in collaboration with the California Department of Fish and Game (DFG), is conducting the Delta Historical Ecology Study (completion date December 2011). This study is documenting for the first time the habitat types and spatial patterns of the Delta prior to Euro-American land-use modification (Fig. 1). These new data on the Delta landscape under largely natural regimes provide an opportunity to better understand the ecological functions that supported Delta species, their spatial patterns, and their relationship to physical drivers. Rather than a template for returning the Delta to its historical state, this information should be used to understand the relationship between process and function and help develop a guiding vision for the future Delta. This proposal presents a collaborative scientific effort to translate this new information into a set of practical, landscape-scale tools for successful restoration of ecological functions in the Delta.

PROJECT GOALS AND OBJECTIVES

The proposed project, *Management Tools for Landscape-Scale Restoration of Ecological Functions,* is a cross-disciplinary project designed to augment the current restoration planning process with the tools needed to design and evaluate large-scale restoration. The project will not develop extensive new data, but rather will analyze and synthesize existing data and knowledge to provide new resources. The overarching goal of the project is to integrate the new information produced by the Delta Historical Ecology Study with contemporary knowledge to develop a landscape-scale understanding of Delta ecological functions past and present and their relationship to physical processes. This synthesis of historical and present-day data will then be used to address identified DRERIP uncertainties about habitat function, to develop landscape conceptual models that link DRERIP habitat-scale conceptual models, and to provide landscape-level criteria and performance measures for ecological restoration. These tools for landscape-scale restoration will be considered in terms of the current Delta and expected future physical conditions. Finally, since ecological restoration of the Delta is a societal endeavor requiring an informed public and decision-makers (Teal et al. 2009), we will develop outreach tools for communicating this information more broadly.

The proposed project has been developed in close conversation with senior Delta managers and scientists to fill these recognized information gaps and will be carried out in close connection with the ERP restoration implementation process. Those involved in the project include senior scientists from the ERP, the Delta Science Program (DSP), the Bay-Delta Interagency Ecological Program (IEP), and the Independent Science Board (ISB), enabling the project to provide high-level, applied science that is aligned with agency needs. The project is designed to supplement these existing efforts and provide information directly needed for the emerging plans, restoration actions, and eventual adaptive management measures of these entities.

> **Box 1. Ecological Functions.** For the purposes of this proposal, we see ecological functions as the interaction between organisms and each other or their environment. Examples include primary production, refugia from predation, physical habitat alteration, and maintenance of breeding sites.

The project will support adaptive management by providing new ways to target restoration of ecological function, thus augmenting current acreage targets and strategies for single species recovery. The project products are designed to provide a scientific basis for management actions by using both historical and contemporary knowledge to link habitats to appropriate landscape contexts and related ecological functions (Box 1). With this information, design targets and evaluation criteria can be more effectively tailored to a desired future suite of ecological functions critical to building a resilient ecosystem. The proposed project will include identification of areas of opportunity in the contemporary Delta, where functional landscape components can be restored along physical gradients with the potential to adapt over time to changing conditions. It is expected that, through the application of target metrics, landscape-level conceptual models, and design principles developed in this project, there will be greater potential for projects in ERP Restoration Opportunity Areas (ROAs) to have population-level effects on wildlife support. There is also the possibility that certain landscapes and/or ecological functions will be identified that cannot be restored within the ROAs. Although it will not be possible to restore all elements of particular landscapes, this research intends to provide design principles and restoration criteria that can lead to more effective and appropriate targeting of ecological functions at available sites. This approach will increase the likelihood that restoration projects will provide the greatest benefits with the least amount of cost.

A perhaps equally significant project goal is to provide tools with which to communicate understanding of the Delta ecosystem and long-term restoration objectives to scientists, decision-makers, resource managers, and the public. To meet this goal, the project will produce visuals that show, for instance, what landscape connectivity or complexity might look like in the future Delta and how associated habitats and species might vary depending on the physical setting.

The project has four major goals:

<u>Goal 1: Quantify historical and contemporary landscape attributes.</u>

OBJECTIVE: Determine information needed to link habitats, mosaics, and landscapes to ecological functions.

OBJECTIVE: Analyze historical and contemporary data using landscape ecology metrics to understand the amount, distribution, and configuration of target habitat elements under different physical settings within the Delta.

<u>Goal 2: Determine historical ecological function and compare to current functions.</u>

OBJECTIVE: Develop a matrix showing habitats and landscape characteristics that offer key ecological functions for species of concern and wildlife in general.

OBJECTIVE: Based on quantified ecological attributes, annotate historical and contemporary maps with associated ecological function linked to habitats and landscape characteristics.

OBJECTIVE: Compare past and present ecological function.

<u>Goal 3: Identify landscape-level restoration principles and long-term monitoring metrics, calibrated to DRERIP conceptual models.</u>

OBJECTIVE: Integrate knowledge of past ecological function provided by habitats and landscapes with DRERIP habitat conceptual models, including addressing model uncertainties.

OBJECTIVE: Develop landscape-level conceptual models that illustrate ecological functions associated with landscape attributes.

OBJECTIVE: Define and describe design principles and appropriate design targets for habitats within subregional Delta landscapes.

OBJECTIVE: Describe available opportunities for restoring functional landscapes in the contemporary and future Delta.

Goal 4: Communicate a vision of past landscapes and potential future landscapes that includes landscape-scale rehabilitation of ecological function.

OBJECTIVE: Develop visual representations of historical and potential future landscapes of the Delta based on understanding of necessary landscape components and likely future physical setting.

OBJECTIVE: Present a publicly accessible, illustrated website and illustrated report describing change in Delta landscapes.

PROJECT TRAJECTORY

Over the course of three years, ASC and an interdisciplinary team of scientific experts, the Landscape Interpretation Team (LIT), will link habitat mosaics to ecological function, calibrate and develop conceptual models, and create landscape-scale restoration visions in the form of design principles and guidelines with associated illustrations. In the first phase (1st to 3rd quarter), work will be done to assess historical landscape-scale attributes that provided particular ecological functions for subsequent creation of maps and visuals that represent conceptual Delta landscapes. The LIT will meet initially to help define necessary metrics from which to identify ecological function, and project staff will then perform analyses to quantify and describe these metrics and functions. This analysis may require additional data collection focused on particular species or communities and their use of the historical landscape. This task will also include any necessary preparation of contemporary data for the purpose of comparison to historical function. In the second phase (3rd to 7th quarter), past and present ecological function will be compared to inform conceptual models. In the third phase (7th to 11th quarter), DRERIP conceptual model uncertainties will be addressed and landscape-level conceptual models and associated design principles and target metrics will be developed. Finally (7th to 12th quarter), project products will be translated into publicly accessible materials and visuals. As befits a study of large-scale process and function, the project's spatial extent is appropriately comprehensive, incorporating the Sacramento-San Joaquin River Delta Ecological Management Zone (EMZ). Additional areas within the boundary of the current Delta Historical Ecology study area and within the historical extent of wetlands well-connected to the Delta may also be included, extending as far as the historical Yolo and Sacramento basins to the north and the Stanislaus River to the south.

SCIENTIFIC AND RESTORATION DESIGN QUESTIONS ADDRESSED

We aim to address the following questions with the proposed work:

- How widely or narrowly distributed was each habitat within Delta landscapes?
- What ecological functions were provided by historical habitats, mosaics, and landscapes that supported target species?
- What metrics and necessary physical conditions can be used to describe these habitats, mosaics, and landscapes?
- Are there definable landscapes that provided an array of functions for multiple species in a synergistic fashion over different lifestages?
- What ecological functions does the contemporary Delta provide?
- What specific habitat, mosaic, and landscape attributes are needed to restore critical ecological functions at appropriate scales to improve wildlife support?
- How can small-scale restoration projects fit into a larger vision of restorable functioning Delta landscapes?
- Where are the best opportunities to pursue such restoration, and what landscape-scale guidelines and performance measures will most improve restoration outcomes?

Our current research in collaboration with DFG on the historical ecology of the Delta adds new understanding of Delta habitat mosaics and landscapes, their controlling physical processes, and ecological functions. Our results indicate that while there was great heterogeneity and variability at many spatial and temporal scales, landscape patterns were also predictable along major physical gradients (Grossinger et al. 2010, Whipple et al. 2010). For instance, the historical Delta exhibited distinct subregions with distinct ecological functions: tidal channel density varied dramatically depending on relative fluvial versus tidal influence (Fig. 2), large shallow lakes were found in certain places but not others (Fig. 3), riparian forest characteristics varied along gradients of natural levee height. Each habitat, habitat mosaic, and landscape supported a set of ecological functions and was associated with particular physical controls.

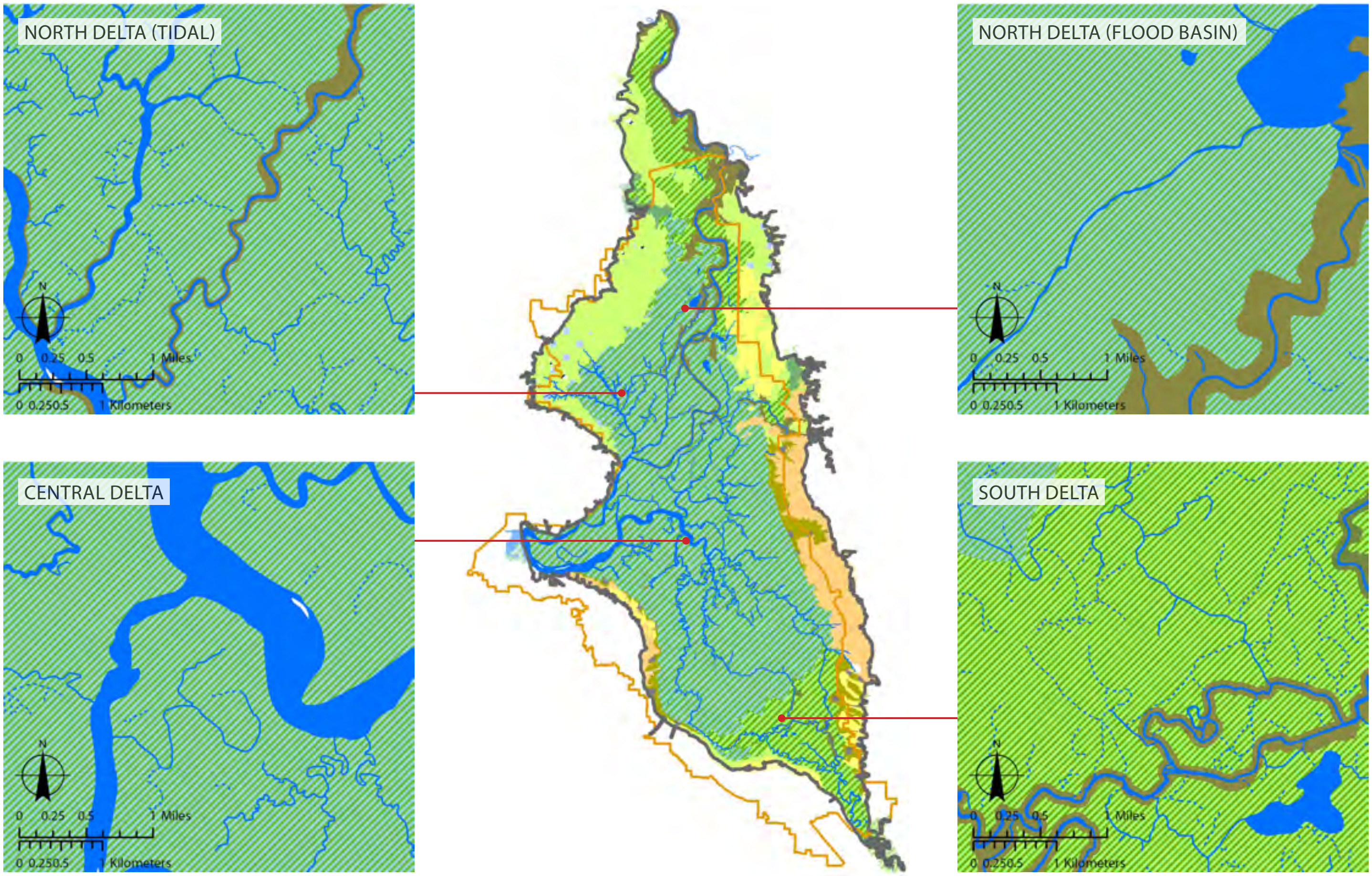

Figure 2. The historical Delta habitat map suggests that tidal channel density varied substantially. In the proposed project, we will quantify channel density by channel order under different physical settings, and describe the expected ecological functions. These metrics will be directly useful to local restoration project design and performance evaluation. Presently there is little or no available information on this topic.

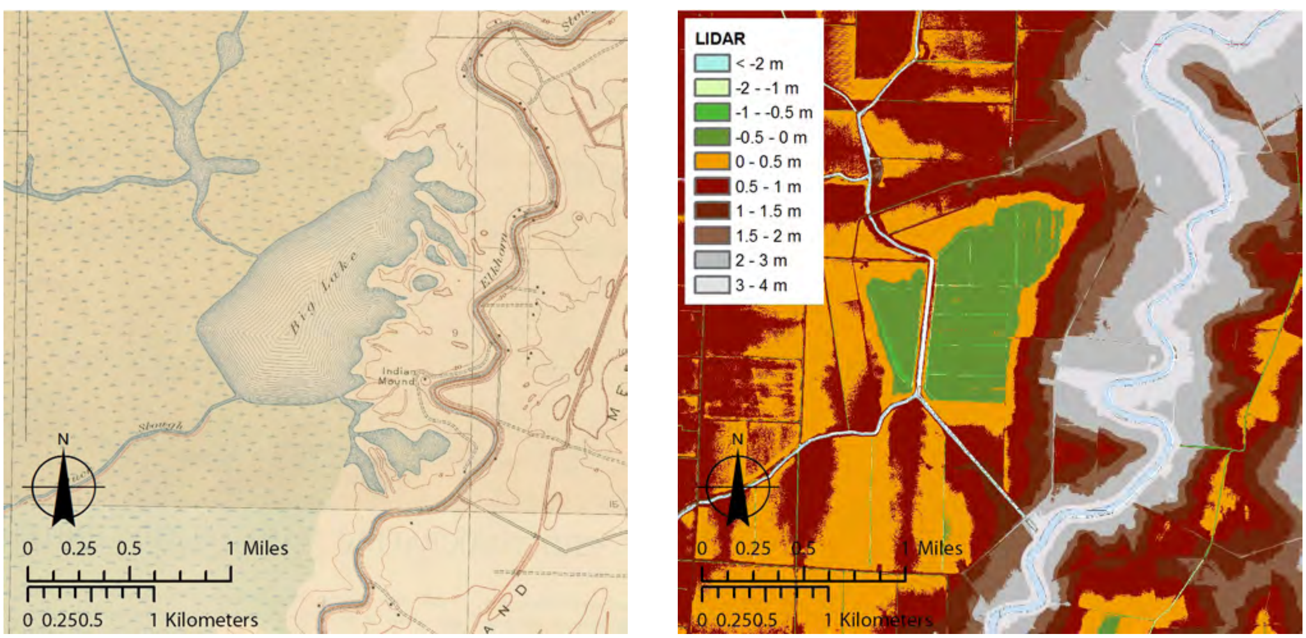

Figure 3. A natural Delta lake (at left), as shown in a 1916 USGS topographic quad, abuts the natural levee along Elkhorn Slough. The lower elevation associated with this lake is still evident in the contemporary LIDAR data, as well as the existing natural levee (at right). Our research indicates that ponds and lakes were significant features of the historical Delta, frequented by duck hunters who found them to be surprisingly shallow and quite difficult to reach owing to dense surrounding tule. While these lakes have not been considered in restoration planning to date, they may have provided important functions for small fish, waterfowl, and other wildlife. This project will apply landscape metrics to this habitat type of the tidal marsh landscape and assess its potential ecological value for restoration.

The proposed project will integrate these historical data with contemporary knowledge to address fundamental scientific and restoration design questions. The study's specific hypotheses are associated with uncertainties outlined in existing conceptual models and restoration planning documents. The project is based on testing the underlying hypothesis that complex, connected habitat mosaics within the historical landscape provided ecological functions that are not supported by the contemporary, highly altered Delta (Moyle 2010, DSC 2011, CDFG et al. 2010a). We predict that the historical landscape provided greater ecological benefits than that of today.

The project will test the emerging concept of Delta landscape complexity (Moyle 2010, DSC 2011) by linking historical ecological function to habitats, landscape characteristics, and physical drivers and subsequently determining which functions are lost and could potentially be regained within the current or restored Delta ecosystem. More specifically, spatial and temporal (seasonal and annual) variability will be examined in terms of their relationship to the condition of habitats and the range of ecological functions they supported. This will address the hypothesis that such features provide substantial benefit to native species. For example, the general term "shallow water" historically included large and small tidal channels, sandbars and flats, and shallow ponds and lakes surrounded by marshland, all of which likely had different hydrodynamics, residence time, and resulting ecological functions. Additionally, by linking habitat mosaics and landscapes to the system's physical gradients through space and over time, this project will test the hypothesis that areas of opportunity to restore landscape-scale function do exist in the contemporary and projected future landscape.

2. Background and Conceptual Models

BACKGROUND

The conceptual approach, goals, and design of this project are based on a strong foundation of ecological theory and research about landscape-scale restoration in the fields of restoration ecology, landscape ecology, and historical ecology. The project applies strategies developed through other major wetland and riverine restoration efforts.

Understanding the complex and interdependent elements of physical drivers, habitats, and biological communities is critical to selecting appropriate actions that restore needed ecological functions in large, degraded systems like the Delta. Meaningful application of this knowledge includes clearly defined long-term goals for landscape-scale restoration that are informed by conceptual models of pattern and process and governed by design principles (Palmer 2005, Greiner 2010, Mika et al. 2010). With this foundation, effective performance measures and specific design criteria can be developed (Vivian-Smith 2001). Otherwise, restoration actions may be chosen for reasons other than building and sustaining ecological function in the long-term, such as single-species concerns or ease of implementation (Palmer 2008, Greiner 2010). The science of restoration ecology has shown that selecting and prioritizing restoration actions within a unified landscape-level framework that uses landscape ecology principles is critical to re-establishing ecological functions (Simenstad et al. 2006). The disciplines of restoration ecology, landscape ecology, and historical ecology address these issues and have informed the conceptualization of the research proposed here.

Restoration ecology and numerous large-scale restoration projects have shown the value of using conceptual models to understand complex relationships between habitats, governing physical processes, ecological functions, and system stressors (King and Hobbs 2006, Mika et al. 2010). These models offer a means to evaluate potential actions to relieve stressors by illustrating how actions are linked back to ecological benefits and related habitats (CDFG et al. 2010a). Models are a critical tool for adaptive management and a means to communicate cause and effect between parties involved in restoration actions, including the public and policy-makers (Ogden et al. 2005).

Conceptual models are often improved by knowledge of historical function, because many complicating anthropogenic influences are removed and fundamental connections between process and function can be studied more closely (Vivian-Smith 2001, Evans et al. 2006). Instead of providing a template to recreate past landscapes, historical ecology offers knowledge of the landscapes and associated physical characteristics within which native species evolved. Thus, historical ecology can facilitate identification of essential ecological functions in need of restoration (Swetnam 1999, Egan and Howell 2001, Choi 2007, Baxter et al. 2010, Greiner 2010, Atwater 2011). Historical conditions indicate what the landscape has a tendency to support in which areas (i.e., what can be restored with the highest probability of success and lowest maintenance cost). Restoring aspects of historical landscapes under similar physical processes is a strategy for restoring the niches that listed species are particularly adapted to, increasing their chances of recovery in the face of stressors (Moyle et al. 2010). Concrete descriptions of historical heterogeneous habitat mosaics linked to ecological functions can give a meaningful, defensible basis for selecting performance measures and implementation actions (e.g., HCP/NCCPs, OCAP BO, Delta Plan; Greiner 2010).

Historical research has proven useful in other large and highly degraded systems (e.g., Dahm et al. 1995, Goals Project 1999, Radeloff et al. 2000, Hulse et al. 2002, Collins et al. 2003, Foster 2002, Grossinger et al. 2007, Whipple et al. 2011). For example, in the Puget Sound large-scale restoration effort, the historical perspective re-calibrated assumptions about habitats and governing physical processes and how they varied throughout the watershed, giving insight into potential restoration opportunities (Collins et al. 2003). Studies have also shown that, in the absence of historical perspective, there is significant risk of large investment without substantial ecosystem improvements (Hamilton 1997, Kondolf et al. 2001, Montgomery 2008).

Efforts to restore the ecological functions of the Delta face major constraints, including land use, land subsidence, river regulation, contaminants, and invasive species. Accordingly, the Delta Plan states that "restoration to the historical Delta is not possible" (DSC 2011). Yet the Delta Plan and other documents recognize the presence of existing historical landscape features and potentially suitable physical settings (e.g., intertidal elevations, floodplains) that can form the foundation for restoration. Projects could ultimately cover thousands, if not tens of thousands, of acres. This extent is a small fraction of the approximately 500,000 acres of historical Delta wetlands, but still many times larger than any native Delta habitats have been for over a century. The vision of a much more functional ecosystem can only be realized if projects are designed as integral components of habitat mosaics and within an interconnected landscape context that maximizes ecological benefits.

The success of restoration efforts to recover target ecological functions will depend on how effectively and accurately specific projects are positioned along physical gradients to re-introduce landscape-level processes and linkages (Simenstad et al. 2006). For instance, meeting an acreage target for a particular habitat type will result in greater ecological benefit if it is connected to other habitat types at appropriate scales and in a location with the physical processes to sustain it. Thus, considering the landscape context of restoration projects (physical gradients, patch size, patch composition, habitat adjacency, and connectivity) is perhaps as important, if not more important, than setting total acreage goals. With the limited options available, it is critical for restoration ecologists and managers to identify the habitat restoration actions that have the greatest potential to return needed ecological functions (Falk et al. 2006, Greiner 2010).

Landscape ecology explores the complex interactions that occur between habitats, habitat mosaics, and landscapes, the effects of physical drivers, and emergent ecological functions (Forman & Gordon 1986, Urban et al. 1987, Turner 1989, Leitão & Ahern 2002). Such understanding supports the development of restoration design guidelines and criteria that are better targeted toward actions that reintroduce landscape-level function (Bell et al. 1997, Gwin et al. 1999, Simenstad et al. 2006). The principles of landscape ecology demonstrate the benefits to ecosystem process and function that are derived from restoration projects associated with larger restored areas and greater connectivity (Greiner 2010, Atwater 2011). For instance, a study of island units and tidal channels in the Skagit Delta marshes revealed the scale at which tidal channel length and area were maximized, giving concrete evidence that only larger restored areas would provide desired ecological benefit (Hood 2007). In many contexts, small-scale restoration projects that are isolated from larger landscape processes can be too small to have population-level effects. For a system like the Delta that has lost function at many spatial scales and for many ecosystem components, large-scale planning is necessary for individual actions to have an impact (Teal et al. 2009, Greiner 2010). Knowing the landscape setting of habitats and the quantified metrics that describe habitat mosaics is critical to large-scale planning. Each individual project must fit into and add up to a greater whole that amounts to rehabilitation of some of the key ecological processes that are currently severely impacted.

One challenge in large-scale restoration is agreeing to a collective vision into which individual projects can fit (Vivian-Smith 2001, Teal et al. 2009, Mika et al. 2010). Establishing a unified, long-term vision is an important link between understanding the system and taking action, and it provides a needed template from which to design restoration and measure success (Palmer et al. 2005, Dahm, pers. comm.). Current conceptual models and habitat restoration targets are important components to convey the process and character of restoration desired. However, landscape-level conceptual models help establish that broader vision by illustrating how habitats are connected and showing the functions provided by those connections. This vision of the future needs to be communicated to restoration managers, politicians, and the public with engaging visuals that depict how certain areas might look and the species that might be found there.

CONCEPTUAL MODEL

The proposed work applies these principles to complement current restoration planning in the Delta. The conceptual basis of large-scale restoration in degraded ecosystems such as the Delta is that ecosystem health can be achieved through restoration of ecological process and function (Palmer 2005). The approach is also based on the assumption that successful restoration is more likely to occur when restoration actions apply design principles developed from knowledge of what the components of a healthy system are and how they relate to one another, often drawing on understanding of historical conditions (Greiner 2010). The Delta restoration planning process, similar to other efforts worldwide, identifies ecosystem stressors, sets targets for ecological condition (BDCP), mitigates for the stressors in part through restoration projects that coincide with conceptual models of ecological function, and monitors and evaluates target metrics through adaptive management (CDFG et al. 2010a).

Conceptually, this project fits into restoration planning in two ways: 1) it contributes to conceptual understanding of process and function, and 2) it provides necessary tools to develop a guiding image for restoration, including landscape-level design principles and target metrics.

This project responds to the first consideration listed above by linking landscape metrics and design principles to particular ecological functions, such that particular actions can be better targeted toward restoring function. With a landscape-scale perspective, projects can be more effectively evaluated in terms of relative potential ecological benefits. For example, after working with the landscape restoration tools developed in this project, two individual restoration projects of similar design and size may be shown to have disproportionate potential benefits due to the configuration of habitat mosaics and connectivity to other surrounding habitats. The conceptual models of habitat, ecological functions, and stressors that have been developed through the ERP planning process (DRERIP) would be supported by the landscape conceptual models and design principles established by this project. The project products are designed to complement, rather than replace, current restoration planning and implementation steps.

The second conceptual relationship to restoration strategies addresses the fact that regional planning is currently conveyed, in part, by regional habitat acreage targets, which are met through the accumulation of individual restoration projects (BDCP 2010, CDFG 2010a). The communication of regional plans will be addressed in the proposed project by a focus on building more concrete illustrations and descriptions of how individual restoration projects might fit together to form a landscape of connected and heterogeneous habitats serving diverse ecological functions. For instance, current Ecological Management Unit (EMU) priorities, as stated in the ERP Stage 2 Implementation document, could be significantly enhanced as an outcome of this project. As one example, the "mosaic of seasonal floodplain, riparian, shallow subtidal, and tidal marsh areas" identified for the South Delta EMU would become a more detailed and specific picture linked to a landscape conceptual model that describes the configuration of habitats within the mosaic and how they are expected to provide benefit.

These tools can then be used by project proponents and engineers to help design appropriate projects. Figure 4 illustrates how each major component of the proposed project would contribute to restoration efforts, leading to more effectively designed projects that, over time, would yield landscape-level ecological functions. Integrating such landscape planning into current restoration strategies will minimize cost and risk of failure while maximizing return on investment.

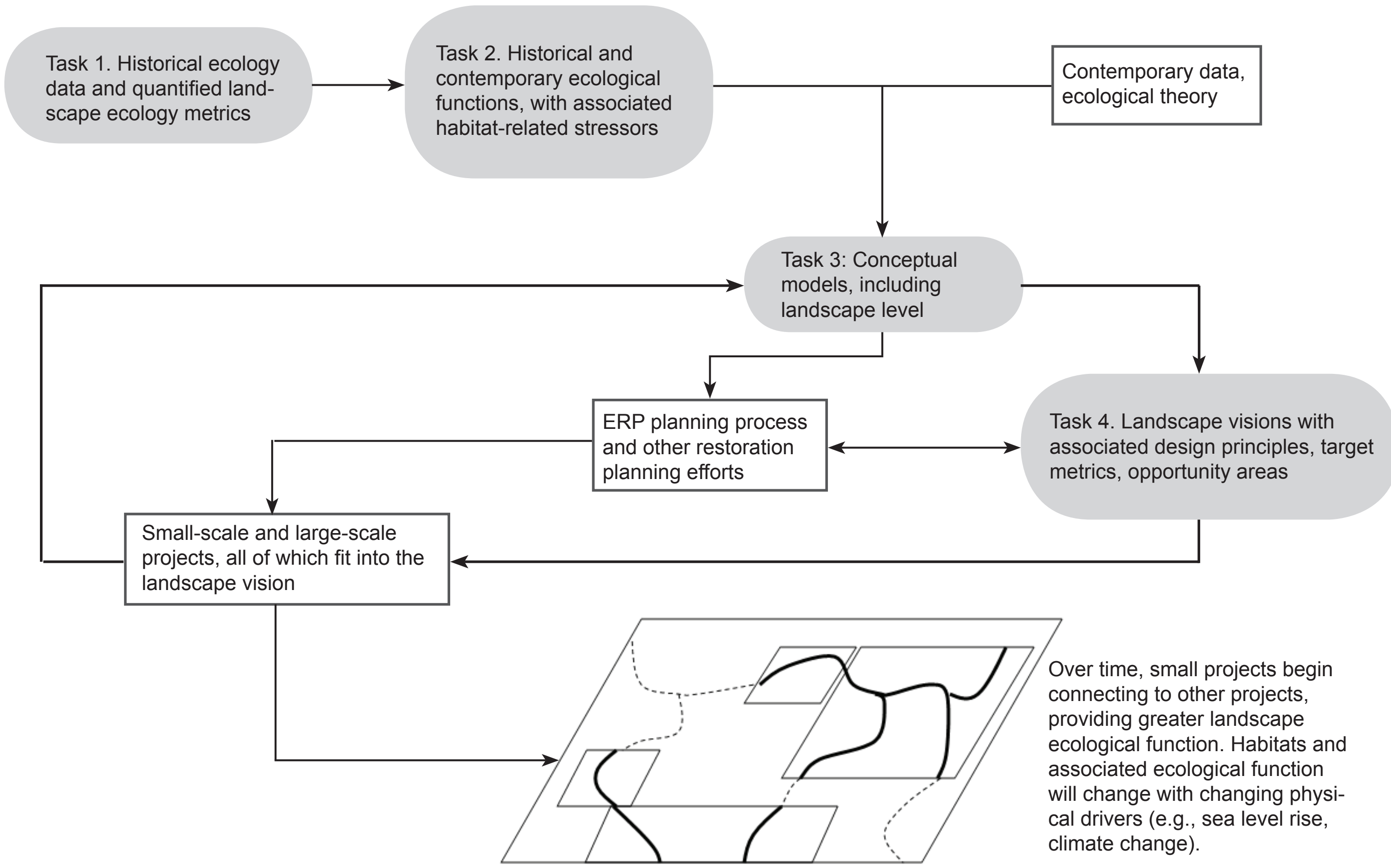

Figure 4. Conceptual diagram illustrating how the proposed project fits within the context of Delta restoration planning and improves the expected outcomes of that restoration.

3. Approach and Scope of Work

LANDSCAPE INTERPRETATION TEAM (LIT)

The success of this project rests on the application of interdisciplinary science, large-scale thinking, and ecosystem restoration planning concepts. The challenging task of exploring Delta ecological functions at the landscape-scale and defining restoration principles and target metrics will necessarily involve the collective best professional judgment of a team of experts. For this reason, a group of high-level scientists will work with project staff at critical points in the project. The LIT currently includes: Michael Barbour (UC Davis), Brian Collins (University of Washington), Chris Enright (DSP), Geoff Geupel (PRBO Conservation Science), Todd Keeler-Wolf (DFG), William Lidicker (UC Berkeley), Jay Lund (UC Davis), Peter Moyle (UC Davis), Anke Mueller-Solger (IEP), and Dave Zezulak (DFG). Their fields of expertise include geology, geomorphology, hydrodynamics, water resource planning and management, landscape ecology, fish and wildlife ecology, and plant ecology. Additional roles may be identified and other scientists recruited at a later date. ASC will lead this working group of expert scientists to 1) infer ecological function, 2) develop landscape-level restoration design principles, and 3) define target metrics from quantitative and qualitative analysis of the historical and contemporary landscapes. Additionally, review by the Delta ISB (an entity established to review Delta restoration planning) will be sought, and several members of this board are expected to participate in the LIT. It is also expected that information developed in this project will benefit review of other planning efforts.

TASK 1: HISTORICAL AND CONTEMPORARY LANDSCAPE ANALYSIS

This task is to create information required for subsequent tasks by analyzing the GIS and associated data from current research on Delta historical ecology as well as contemporary habitat mapping. Landscape ecology metrics identified by the LIT will be applied to quantify the extent, distribution, and configuration of habitat elements under different physical settings.

Initially, ASC staff will meet with LIT members to identify criteria for selection of key ecological functions and species or biological communities that require those functions. Next, we will select metrics appropriate to describe ecological function and driving physical processes at the landscape scale. The landscape metrics will be designed to provide information about these selected ecological functions and biotic indicators. Likely, landscape analysis will be interpreted with a range of species that represent different effective patch sizes and dispersal patterns, prioritized according to the species in the Multi-Species Conservation Strategy (CALFED 2000). These metrics will likely include common landscape metrics such as patch size distribution, patch richness (habitat diversity), edge-to-area ratio, adjacency of critical habitat types, and distribution of nearest neighbor distances, as well as habitat characteristics such as channel density, tidal excursion/bifurcation index, riparian length/width, hydrologic connectivity, pond size, etc. (Bay Goals 1999, Leitão & Ahern 2002, Evans et al. 2006, Greiner 2010). For example, because tidal channel network characteristics indicate marsh process and function, metrics such as channel length, channel count, and channel area compared across island area and island location will help determine design guidelines, such as smallest island areas that can maintain tidal channels (Hood 2007). Such landscape analysis for the Delta has not been conducted to date.

Subsequently, historical and contemporary datasets will be assembled and prepared for analysis. At this time, additional data needs may be identified, such as historical species-specific information. In such cases, targeted research will be performed online and at local and regional archives. Additionally, historical and modern datasets may need modification for comparisons to be meaningful. It will be necessary to review mapping methods and compare such characteristics as minimum mapping units and standards for mapping particular habitat types. Crosswalks between historical and contemporary habitat types will also be created. Mapping method will be important to consider due to the reliance on this mapping to infer ecological function. For instance, riparian forest mapped based on vegetation community may need an added topographic factor in order to determine the area of potential allochthonous input (i.e., if the backside of a levee is mapped as riparian forest, it will not be providing allochthonous input).

Finally, we will analyze the historical and contemporary Delta landscapes using common toolsets for ESRI's ArcGIS software (e.g. Spatial Analyst) as well as other landscape analysis software (e.g. FRAGSTATS) and spatial statistical techniques. For example, riparian width will be estimated by measuring the width at equal intervals of mapped polygons of riparian forest and calculating average width for each reach between major tributaries or distributaries.

For the historical Delta, analysis will go one step further to identify landscape units that depict how habitats and habitat mosaics were arranged and related to physical drivers. Findings from the ongoing Delta historical ecology study indicate that there was not one but many Delta landscape types, and the analysis performed in this task will provide needed information to define such landscapes and their physiographic position within the Delta system. Quantitative as well as qualitative analysis will define these landscape units, which can then be used in subsequent tasks and can be guiding, though not prescriptive, templates for restoration planning.

TASK 2: DESCRIPTION AND COMPARISON OF PAST AND PRESENT ECOLOGICAL FUNCTION

Assignment of ecological functions will begin by developing a matrix with the LIT that links key support functions (e.g., primary-production, predator refugia, breeding sites) of species or communities of concern (as defined by ERP) to historical and contemporary habitats and landscape variables. The matrix will draw from the scientific literature, including the DRERIP conceptual models, and the best professional judgment of the LIT. This process is expected to reveal that different habitat mosaics and landscapes provided different functions and that physical gradients are a key organizing principle. For instance, findings about function at the landscape scale may indicate that some historical landscapes were better at supporting waterfowl and others fish, suggesting the importance of specific restoration targets (Box 2).

Once these relationships are established, key ecological functions will be mapped for both the historical and contemporary Delta and the change in functional capacity described. Data from Task 1 will provide the needed

Box 2. Salmon at El Pescadero: a brief example of project approach. Historical evidence suggests that El Pescadero of present-day Salmon Slough area was particularly important for salmon (Figure 2, South Delta). Through the landscape analysis of Task 1, we would characterize the attributes of this landscape that made it unique, including logjams ("raft"), side channels, and adjoining lakes. In Task 2, the team would evaluate the ecological functions that this landscape likely provided (e.g., high invertebrate productivity, refuge from predators, cool temperatures from riparian vegetation shading) and their availability today. To reestablish these functions would require sufficient width of riparian forest, woody debris for habitat complexity, associated flood flows, and appropriate location in the Delta—design guidelines that would be developed in Task 3 and illustrated in Task 4.

information to complete this analysis. Products will take the form of annotated maps likely along taxonomic themes, such as waterfowl support functions (Bay Goals 1999, Collins et al. 2007). In addition to showing physical context and location of ecological function, the mapping exercise will help visualize the configuration and scale at which certain functions were achieved. This approach allows for functions to be grouped by landscapes in order to explore the synergistic properties and complexity of interacting conditions at the large scale.

Once these maps are complete for the past and present Delta, ecological functions will be compared among the time periods to discover what landscape variables are necessary to achieve particular functions. For example, it may be found that historically the adjacency of particular habitats provided feeding and roosting areas for waterfowl with very little energy expended on commuting between them. This task will quantify those habitat mosaics to develop design guidelines for restoring waterfowl support. Given the complex and interdisciplinary nature of this task, much of this comparison will be conducted through facilitated discussion with the LIT. At least five meetings will be necessary:

- Meeting 1: Presentation of the governing physical processes in the historical and contemporary Delta by the physical scientists to the natural scientists.
- Meeting 2: Develop the matrix.
- Meeting 3: Create annotated map of historical ecological function.
- Meeting 4: Create annotated map of contemporary ecological function.
- Meeting 5: Compare past and present function.

TASK 3: DEVELOPMENT OF LANDSCAPE-SCALE CONCEPTUAL MODELS, RESTORATION PRINCIPLES, AND TARGET METRICS

This task will produce landscape level conceptual models, restoration principles and long-term monitoring metrics. It will translate the results from previous tasks to produce the project's primary technical tools for restoration project designers and planners. Insights gained from the previous tasks will help generate tools that improve understanding of appropriate landscape restoration variables such as target patch sizes, the subregional distribution of habitats along physical gradients, habitat connectivity and nearest neighbor considerations, and governing physical drivers.

The first subtask will be to review current conceptual models of habitats produced by the DRERIP process and address uncertainties in these models by integrating the knowledge of past ecological function provided by habitats and landscapes. Missing functions or physical links are expected in the current conceptual models. Findings will be reviewed by the LIT.

In a second subtask, landscape-level conceptual models will be created to illustrate how habitats relate to one another at the landscape scale and what resulting synergistic ecological functions are provided by those relationships. This

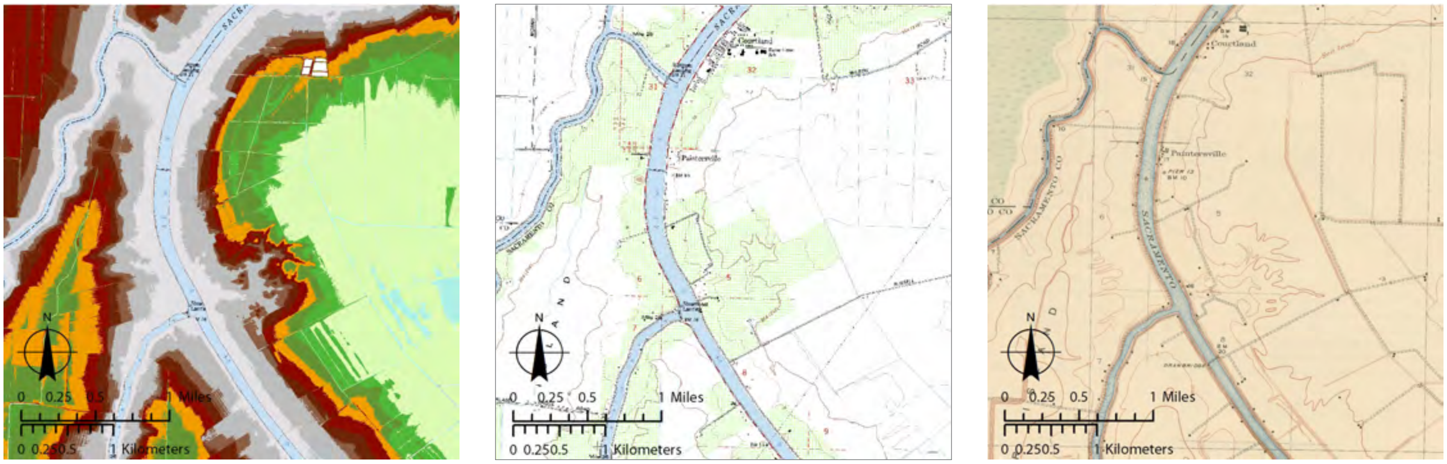

Figure 5. Natural river levees past and present. These images show the presence of elevated fluvial deposits along the Sacramento River revealed by the topography shown in the 1916 USGS topographic quad (left) and similar patterns today, as exemplified by the orchards depicted in contemporary USGS topographic quads (center) and elevations in LIDAR imagery (right). Because of their mineral sediments, these features have been relatively unaffected by subsidence. Potential riparian functions have shifted, and will continue to shift, upstream or downstream in response to changes in land use, sea level, and inundation frequency.

output directly addresses the identified need for conceptual models that help connect variations in physical features to species-level effects. Using the landscape units defined in Task 1 and the functions in Task 2, these conceptual models will illustrate the connections between habitats and habitat mosaics within a landscape and the functions associated with them. These conceptual models go beyond the annotated maps of Task 2 by removing landscapes from their actual location within the Delta and diagrammatically presenting the interconnected and synergistic physical processes and ecological functions associated with landscape attributes.

At this point, using the conceptual models from Task 2 and landscape metrics from Task 1, the LIT will work with ASC to develop a set of restoration design principles, accompanied by target metrics where appropriate, that later can be brought into the larger ERP process of developing criteria and metrics for Delta restoration. These products are similar to those outlined in Greiner's *Principles for Strategic Conservation and Restoration* (2010), where criteria and metrics are developed after establishing restoration principles.

The final step of Task 3 will identify opportunities on the ground for applying these landscape-level criteria to the contemporary Delta landscape. Using the understanding developed in previous tasks of how ecological functions and landscape units relate to physical gradients, similar physical gradients will be evaluated in the contemporary Delta, although they may be compressed or in entirely new locations. For example, while the broad natural levees of the historical Delta have been converted to other land uses and protected from flooding with artificial levees, they remain as large-scale physical features (Fig. 5). Drivers such as river regulation (causing reduced frequency of inundation) and climate change (likely to increase flooding through sea level rise and increased spring runoff) will affect potential riparian functions: at their downstream end, the natural levees will gradually be submerged by rising sea level, while upstream portions may be higher and drier than they were historically. Along this gradient, which will gradually shift upstream, the range of historical riparian functions (identified in Task 1) is presumably available as potential restoration scenarios. Similarly, gradients from brackish subtidal (e.g., Suisun Bay) to freshwater river mouth will continue to exist, but along more compressed distances, considering future sea level rise, potential levee failures, and/or regulated freshwater input. This task will explore the general viability of re-establishing landscape-scale functions within the highly modified Delta. This will be done at a conceptual landscape scale and will not consider socio-economic or political limitations, in order to discover a more full range of possibility. This task will apply the conceptual models to show potential future landscapes along physical gradients and the possible ecological functions provided by them. Equally important, this analysis will identify fundamental constraints to landscape restoration, helping to calibrate expectations and focus resources on what is achievable.

TASK 4: COMMUNICATION AND OUTREACH

This task will make the overall findings of the first three technical tasks accessible to managers, stakeholders, and the public by creating a general audience report, public presentations, and an interactive website. To illustrate these fairly abstract ideas, a key element will be the development of 3-D visualizations showing past landscapes and possible restoration of landscape-level ecological function in the future. There exists a profound need for all those involved in Delta planning to have a visual sense of what achieving the broad goal of ecosystem health could look like (Lund et al. 2007, Wilcox, pers. comm.). Engaging visuals are tools that restoration managers can use to communicate how a landscape-level approach can be applied to provide myriad ecological benefits and achieve a whole that is greater than the sum of its parts.

This task, like previous tasks, will provide information to help make decisions about restoration scenarios, while also showing what the results of those decisions could look like. To do this, past, present, and possible future landscapes will be

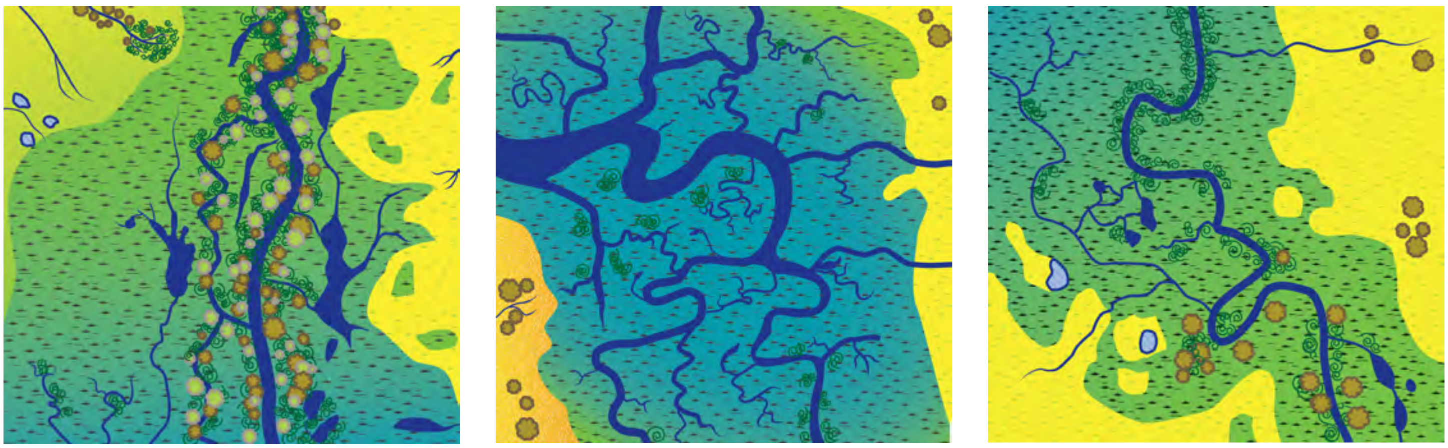

Figure 6. Emerging models of subregional Delta landscapes from the Delta Historical Ecology Project. These preliminary plan-view sketches illustrate how the distribution and arrangement of landscape elements, such as channels, ponds, and riparian forests, differed in different parts of the Delta. To make these general observations usable for Delta ecosystem restoration, we will develop metrics to describe these systems, identify the ecological functions they provided, and depict them in engaging and informative graphics (e.g., 3D visualizations).

Figure 7. Illustrations of landscape patterns and functions for public outreach. This drawing, by the biologist and artist Laura Cunningham, was produced for *Bay Nature* magazine based on ASC research on the historical Delta. Accessible illustrations are essential for both scientists and non-scientists to understand ecological restoration efforts. This is an example of one way the landscape units defined by the project will be depicted. While this illustration shows historical conditions, visualizations of potential future conditions will also be developed, illustrating both the opportunities and constraints for landscape-level restoration in today's Delta.

depicted and placed along conceptual physical gradients (Fig. 6). Temporal variability will also be introduced, by depicting the landscapes at various seasons. The creation of such illustrations will necessarily draw upon the landscape units of Task 1, the ecological functions associated with them in Task 2, and the conceptual models of Task 3. Visuals will be designed for general audience accessibility, using engaging cartography, graphics, artwork, and animations and accompanied by a written narrative of landscape change and future potential. Several talented science-based artists, some of whom ASC has collaborated with in the past, will produce illustrated landscapes depicting appropriate habitat mosaics, vegetation, and biota, and they will construct conceptual profiles depicting key physical properties, including target metrics where possible, and associated ecological functions of different landscapes (See Appendix A; Fig. 7).

Project maps, selected conceptual models and diagrams, and the 3-D visualizations will be made available through an illustrated project report and a website that allows users to explore the project data as well as download products. (See www.caltsheets.org/ for an example of the web-GIS envisioned for this website.) These products will tell the story of the pre-modification Delta landscape, its transformation, and its future potential using well-developed graphics to communicate technical content and engaging, accessible manner. Project data will also be made available through the California Wetlands Portal (co-developed by ASC).

TASK 5: PROJECT MANAGEMENT

Aquatic Science Center staff will manage the project, including developing a workplan, writing invoices and progress reports, and negotiating the contract and subcontracts. This task also encompasses the coordination of the LIT and workgroup meetings, and other communication necessary to maintain project progress within the project team.

4. Deliverables

Task	Product	Due Date
1	**Historical and contemporary landscape analysis**	
	1.1 Summaries of meetings with the LIT	Ongoing
	1.2 Technical memo presenting the metrics measured for the historical and contemporary Delta and presenting landscape units of the historical Delta as defined by these metrics (10-40 pp)	9 months after approval date
2	**Description and comparison of past and present ecological function**	
	2.1 Summaries of meetings with the LIT	Ongoing
	2.2 Maps of historical and contemporary Delta ecological functions, likely with annotations along themes such as species or taxonomic groups	18 months after approval date
	2.3 Memo on key changes in ecological function between the past and present Delta (20-40 pp)	21 months after approval date
3	**Development of landscape-level restoration principles, target metrics, and conceptual models**	
	3.1 Summaries of meetings with the LIT	Ongoing
	3.2 Memo on addressed uncertainties in DRERIP conceptual models (5-20 pp)	24 months after approval date
	3.3 Landscape-scale conceptual models describing ecological functions and physical drivers associated with landscape units (20-40 pp)	30 months after approval date
	3.4 Design principles and suggested performance criteria and metrics (5-10 pp)	30 months after approval date
	3.5 Memo on available opportunities for restoring functional landscape components in the contemporary and projected future landscape context (10-20)	33 months after approval date
4	**Communication and outreach**	
	4.1 Synthesis report about the Delta landscape past, present, and future, using documents, maps, and artwork developed in Tasks 1-3 (50-80 pp)	36 months after approval date
	4.2 Five public presentations	Ongoing
	4.3 Interactive website with maps, graphics, and artwork presenting project products	36 months after approval date
5	**Project management**	
	5.1 Invoices and progress reports	Ongoing
	5.2 Final report as a compendium of work completed for all tasks	36 months after approval date

5. Feasibility

To accomplish this ambitious effort, the project has been efficiently designed to add value to existing information. The analysis and product development as outlined within this proposal is feasible within a three-year timeline. The four tasks can overlap in time somewhat, such as the visuals being completed throughout the project as their scientific content is developed. Task 1 will be completed by the end of the 3rd quarter post-contract; Task 1 does not involve seasonal fieldwork, permitting, or substantial generation of new datasets. Datasets and other information needed for this project have been identified and will require minimal effort to apply for the purposes of this project. While Tasks 1 and 2 could be quite extensive if defined broadly, this project will limit analyses to those that are needed to accomplish Task 3. We will focus on ecological functions provided by landscape-level characteristics for species and communities of concern identified in ERP planning documents. Task 2 will be completed by the end of the 7th quarter, leaving time for interaction with the LIT. Task 3 will be completed by the end of the 11th quarter. Work on graphics, artwork, animations and the website associated with Task 4 can begin at the start of Task 3, as landscape units and associated functions and physical drivers will already be established. Task 4 will continue until the end of the project, the last quarter focusing on completing the publicly-accessible illustrated report and finalizing the website with completed products. Task 5 will continue throughout the project.

Each phase of the project requires the involvement of the LIT, but this does not translate to lengthy time commitments for the members. The primary commitment is a minimum of twelve workgroup meetings where, over the course of the three years, scientists would guide the analysis of landscape metrics; evaluate landscape units; discuss links between ecological function and habitats, habitat mosaics, and landscapes; and review design principles, target metrics, and landscape conceptual models. Aside from the first meeting, these could take place as video or teleconferences, which are cost-effective, less burdensome, and easier to schedule. Members would also provide review and potentially co-author products. These scientists are all committed to and engaged in the project and aware of the scope of work. ASC has extensive experience developing and managing science advisory groups for complex topics, including for the San Francisco Estuary Regional Monitoring Program for Water Quality and for the California Wetland and Riparian Area Protection Policy.

For the successful development of the visuals in Task 4, ASC will collaborate with artists and graphic designers with whom working relationships have already been established in past projects. These individuals are committed to working on this project and would be able to meet the needs within the budget and timeline allowed. ASC also has significant graphical, animation, and web-GIS capacity, which will assist the execution of Task 4.

While Task 4 does include the potentially challenging subtask of visualizing how and where landscapes may look in the future, sufficient data on physical conditions (e.g., elevation in the form of LIDAR, potential sea-level rise, groundwater levels, flows and flood frequencies, vegetation maps) exist with which to make reasonable conclusions about appropriate locations for restoring landscape-level functions in the Delta. This proposal does not address the challenge of economic, political, or social feasibility of particular actions. This subtask is an exercise in implementing the tools developed in this

		Year 1				Year 2				Year 3			
Task	**Description**	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Q7**	**Q8**	**Q9**	**Q10**	**Q11**	**Q12**
1.0	Historical and Contemporary Landscape Analysis												
2.0	Description and Comparison of Past and Present Ecological Function												
3.0	Development of Landscape-level Restoration Principles, Target Metrics, and Conceptual Models												
4.0	Communication and Outreach												
5.0	Project Management												

project to provide a broad vision of potential opportunity, rather than to produce particular engineering templates for direct implementation.

Project management will ensure the project is well-planned, stays on track, and remains relevant to the larger team. It has been carefully budgeted to provide sufficient resources for project coordination, management, and subcontracting. ASC will use standard project management techniques to ensure the project meets project deliverables, deadlines, and objectives. Project management will include three phases: planning, monitoring, and quality assurance. The planning phase will be iterative throughout the life of the project, and will include development of a detailed work plan, budget, and schedule. The detailed schedule will incorporate critical chain management techniques to identify task dependencies. The project work plan can be adjusted as needed to reflect the project evolution. Monitoring will measure various project parameters against expected outcomes. For example, the percentage of a task's completion will be measured against the percentage of the budget used on a monthly basis, allowing for necessary adjustments to be made to scope, budget, or schedule in a timely fashion. As part of monitoring, team objectives and priorities will be compared to each task to ensure the task/project is moving in the right direction to meet those objectives. Finally, quality assurance tools will be built into each task, which will not only check task results but also evaluate task methods against project objectives. Possible risks will be evaluated for each task as well.

6. Relevance to the CALFED ERP

The proposal directly addresses several needs expressed in Delta restoration planning documents. It targets the second listed ERP PSP priority—to test hypotheses and address uncertainties identified in DRERIP, OCAP, and BO documents—by providing information on 1) ecological characteristics of shallow water habitat, as well as other habitats, beneficial to native species, 2) seasonal and annual variability through evaluation of physical processes and associated ecological function, and 3) landscape-level characteristics associated with riverine function. We will identify the range of different "shallow water" habitats that characterized different parts of the Delta and infer their ecological functions, directly increasing our currently-limited understanding of the target characteristics that will successfully support native species. This proposal also informs the first ERP PSP priority requesting restoration projects that enhance aquatic habitat by developing tools that will aid design, evaluation, and monitoring of such restoration projects.

The project also has characteristics of high value to the ERP. First, it is inherently interdisciplinary; translating habitat into ecological functions, describing function along physical gradients, and developing conceptual models of landscape-scale relationships together require scientific understanding of geomorphic and hydrologic process, landscape ecology, and species-specific natural history. Second, this proposal relies on analysis of existing data and knowledge of landscape processes to synthesize new tools for restoration management. The historical ecology dataset must be integrated with current thinking to produce needed landscape-level solutions to ecosystem restoration. Lastly, collaboration with scientific experts from a variety of institutions and agencies is a key element of the proposal, such that all ideas and products will be vetted by a number of specialists.

The proposal meets other restoration planning needs as well, such as needs expressed in the DRERIP Evaluation Summary Report for a "focused suite of restoration design principles" and more clearly defined tidal restoration measures (Essex Partnership 2009). While this report states that uncertainties concerning the benefits of tidal marsh restoration can be addressed through large-scale pilot projects or through studying existing restoration projects, this proposal offers a third alternative, which is to explore the knowledge of functions (benefits) provided by historical tidal marshes. The proposal also responds to the Tidal Marsh DRERIP conceptual model recommendation for a landscape-level conceptual model (Kneib et al. 2008). Also, the project will support the identification of performance measures and the development of science standards, which are goals for implementation of the ERP Stage 2 Conservation Strategy. It will develop tools valuable to monitoring and adaptive management. Research findings will give concrete information to support the ERP goals to "rehabilitate natural processes" and "protect and/or restore functional habitat types." Delta historical ecology and the new landscape perspective it offers will provide a vision of a future, healthy Delta and will fill a knowledge gap in current efforts to design appropriate, synergistic restoration actions that succeed at restoring Delta ecological functions.

7. Expected Quantitative Results

As a research project, results will not be in the form outlined by the quantitative measures given in Appendix E. This project instead will improve additional quantitative measures, as well as refined conceptual models and restoration design principles and guidelines, to be used in evaluating how restoration projects contribute to landscape-level ecological function. By synthesizing and integrating existing data and utilizing best professional judgement, the project is designed to provide tools with which restoration managers can evaluate quantitative results of future projects in their capacity to yield improved ecological function.

8. Other Products and Results

In addition, this project will make publicly accessible explicit landscape illustrations and other visualizations to be used to create a guiding image of a more functional and resilient future Delta.

9. Qualifications

The Aquatic Science Center (ASC) is a Joint Powers Authority of the State of California, administered by the San Francisco Estuary Institute (SFEI), an environmental non-profit organization dedicated to providing high-quality science for ecosystem management. It employs 45 scientists and technicians who oversee an annual budget of about $7,000,000 for innovative programs in wetland science, watershed science, conservation biology, historical ecology, water quality monitoring, and information technology. The project team includes outside scientists from leading regional and national institutions and staff drawn from several ASC/SFEI programs, including Historical Ecology, Conservation Biology, Wetlands Science, GIS, and Information Technology.

ASC/SFEI conducts innovative, large-scale environmental research projects in support of natural resource management. Collins and Grossinger directed the historical mapping and led teams of contemporary scientists to produce the highly successful landscape-scale restoration strategy for San Francisco Bay wetlands (Goals Project 1999). The Baylands Ecosystem Goals Project catalyzed tidal marsh and other wetland restoration at unprecedentedly large scales. Grenier, Collins, and Grossinger conducted landscape-scale comparisons of past and present ecological function for the Marin Ecological Connectivity Project (Collins et al. 2007). In this study, a science advisory group with expertise in the local landscape and wildlife ecology reviewed SFEI's historical and modern habitat maps to assess how ecological function of the landscape had changed with land conversion and habitat loss. The Marin County Board of Supervisors considered the results of this study as they updated the General Plan to understand where further development would cause the least impact to ecological connectivity between extensive wetlands and the upland. ASC/SFEI also co-leads the development of the 1-2-3 tool kit for wetland assessment that is being implemented through State agencies and the USACE Districts operating in California.

ASC/SFEI is currently working closely with Delta scientists and restoration managers to develop the Delta Historical Ecology Study in collaboration with DFG (completion date December 2011, ERP grant number P0883005). As mentioned elsewhere in this proposal, the information generated by this current project will leave ASC and partners well-positioned to carry out this next level of analysis. ASC also leads the development of the Delta Regional Monitoring Program in collaboration with the EPA and the Regional Board.

ASC/SFEI is uniquely qualified to translate high-quality science into public outreach tools. We produce the popular annual *Pulse of the Estuary*, which is regularly featured by major media outlets, and we are currently developing public exhibitions in collaboration with the California Academy of Sciences and Exploratorium. In our highly popular *BayBoards* project, we worked with artists to translate historical ecology findings into compelling visual images, which were displayed on commercial billboards as part of an environmental education effort. Our reports are well-recognized for their accessible presentation of technical material (e.g. Grossinger 2011).

ASC/SFEI's Environmental Data Information and Technology (EDIT) team leads GIS analysis and website development. EDIT supports stewardship of the California environment by providing technological tools to enhance the understanding of environmental conditions, capturing both temporal and spatial changes in aquatic resources, water quality, and habitats. The EDIT team generates new datasets and analyses, as well as new standards, methods, and tools for spatial data (e.g., spatial modeling, georeferencing, etc.) and other data types. The GIS team at SFEI is comprised of eight highly skilled staff that specialize in spatial analysis, photo interpretation, cartography, web mapping, and modeling. For example, SFEI is nearing completion of the Bay Area Aquatic Resources Inventory (BAARI), a multi-year effort to map the region's aquatic resources that will produce a standardize geospatial dataset of wetlands, streams, and riparian areas (www.sfei.org/baari). We will also be releasing a geospatial model that maps functional riparian areas based on readily available input datasets (www.sfei.org/projects/wrmp). Both products were designed and developed to assist in the monitoring and managing of aquatic resources.

ASC/SFEI also develops tools that integrate spatial and tabular data through web interfaces. We develop these tools using leading technologies, and then maintain those tools and the infrastructure needed to keep them operational. For example, SFEI's Web Query Tool enables users to perform spatial queries of water quality data from the Regional Monitoring Program for Water Quality in the San Francisco Estuary (RMP) as well as other water quality datasets (www.sfei.org/rmp/wqt). We recently released an interactive website providing access to mapping of the historical wetlands of Southern California (www.caltsheets.org/; USFWS funding). Another website product, the Wetland Tracker, is an interactive, map-based tool that serves as a repository of information related to habitat and restoration activity throughout California (www.californiawetlands.net/tracker/ba/map).

The proposed project draws upon ASC/SFEI's interdisciplinary breadth to provide the experience and expertise needed to accomplish this ambitious effort. Scientists Grenier, Collins, and Grossinger are experts on California wetlands and riparian systems, including developing assessment and management tools for agencies such as the Department of Fish and Game, the State Coastal Conservancy, the State Water Control Board, EPA, the Army Corps, and others. Dr. Grenier, who will lead the landscape ecology and ecological functions components of the project, directs ASC/SFEI's Conservation Biology program and has extensive experience coordinating high-level science advisory teams. Grossinger works with leading scientists throughout the state to compare historical and contemporary conditions for the purpose of identifying restoration strategies. Meredith Williams, leader of our EDIT team, and Kristen Cayce, our GIS Manager, will apply previous experience on regional GIS analyses and website development to this project. Project Manager Ruth Askevold is well-experienced at managing large, multi-partner projects and budgets.

ASC/SFEI staff expertise will be supplemented for this project with a high-level team of regional and national experts. The Landscape Interpretation Team (LIT) will promote synthesis of existing knowledge and application of best professional judgment. Jay Lund (UC Davis), Chris Enright (DSP), and Brian Collins (University of Washington) bring extensive expertise in fluvial and wetland geomorphology, estuarine hydrodynamics, and hydrology to interpret historical landscape drivers and evaluate contemporary restoration scenarios. To translate landscape characteristics into ecological functions, the LIT brings together senior expertise in native plant communities (Michael Barbour, UC Davis; Todd Keeler-Wolf, DFG), fish (Peter Moyle, UC Davis), birds (Geoff Geupel, PRBO Conservation Science), mammals (Dave Zezulak, DFG), aquatic food web ecology (Anke Mueller-Solger, IEP), and landscape ecology (William Lidicker, UC Berkeley).

To assist the project team in illustrating these complex concepts, we have recruited several talented graphic artists. Laura Cunningham is an artist and naturalist whose popular recent book *A State of Change: Forgotten Landscapes of California* was recently named a California Classic by the San Francisco Chronicle (Cunningham 2010). David Diethelm has developed innovative 3-D visualization tools for landscape ecological restoration, including the *Willamette River Basin Planning Atlas: Trajectories of Environmental and Ecological Change* (Hulse et al. 2002). Jennifer Natali has a background in landscape architecture and river restoration, and has developed illustrative cross-sections for historical ecology studies and restoration plans on the Napa River, Ventura River, Santa Clara River, and others.

Please see Appendix B for team member bios.

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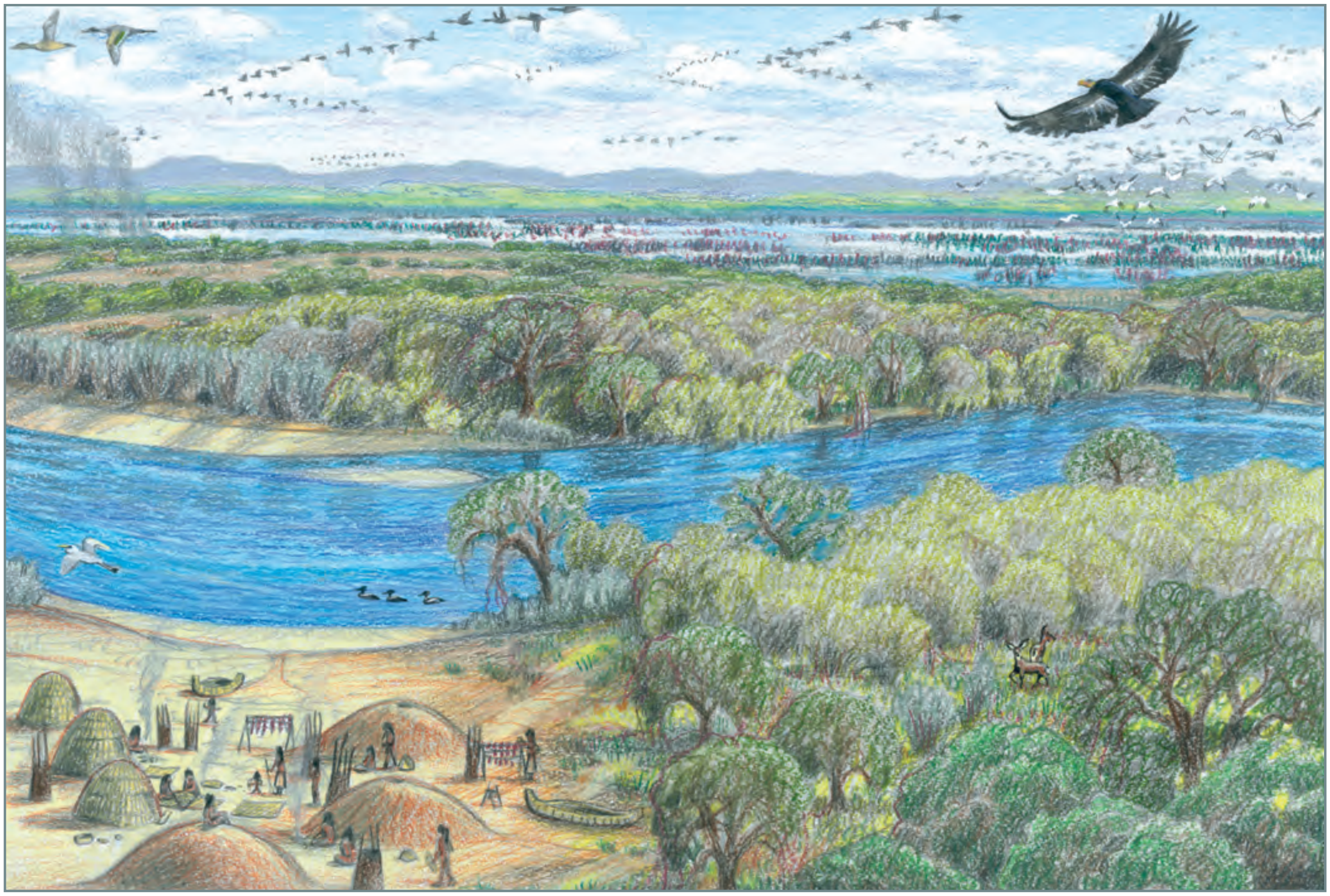
Appendix A: Landscape visualization examples

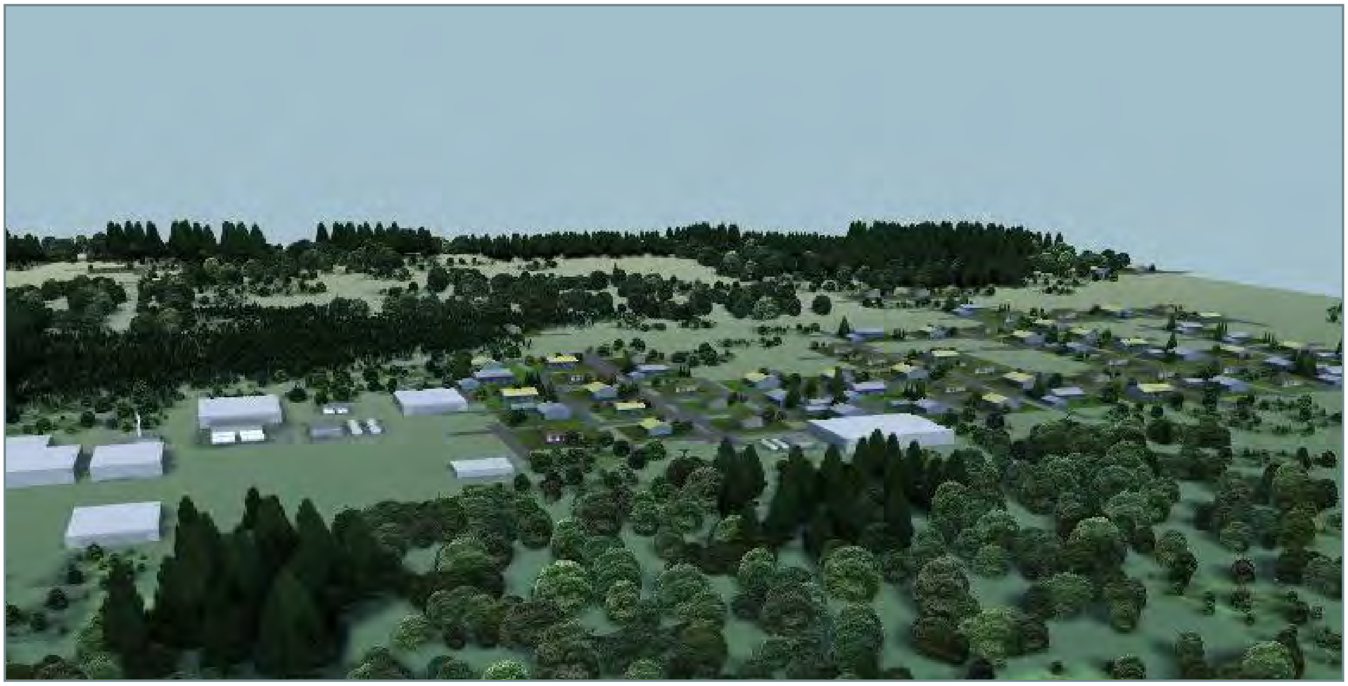
As part of Task 4, Communication and Outreach, we will develop landscape visualizations that help convey Delta landscape concepts and restoration scenarios to both technical and general audiences. Below are examples of previous work by project team members.

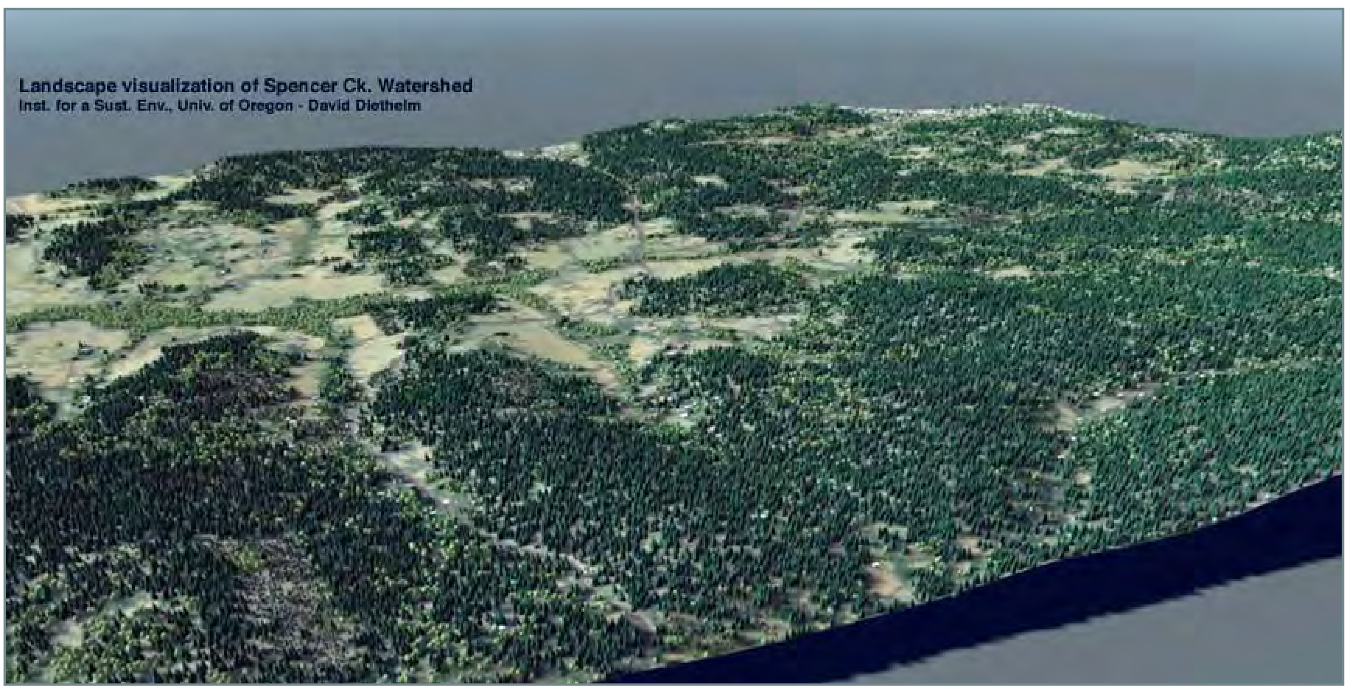
LAURA CUNNINGHAM



Early spring scene along the Sacramento River with mixed riparian forest on natural levees bordered by "backswamps" and large ponds. By Laura Cunningham (a-state-of-change.com/index.html) based on ASC research. Originally published in Bay Nature magazine (June 2010).

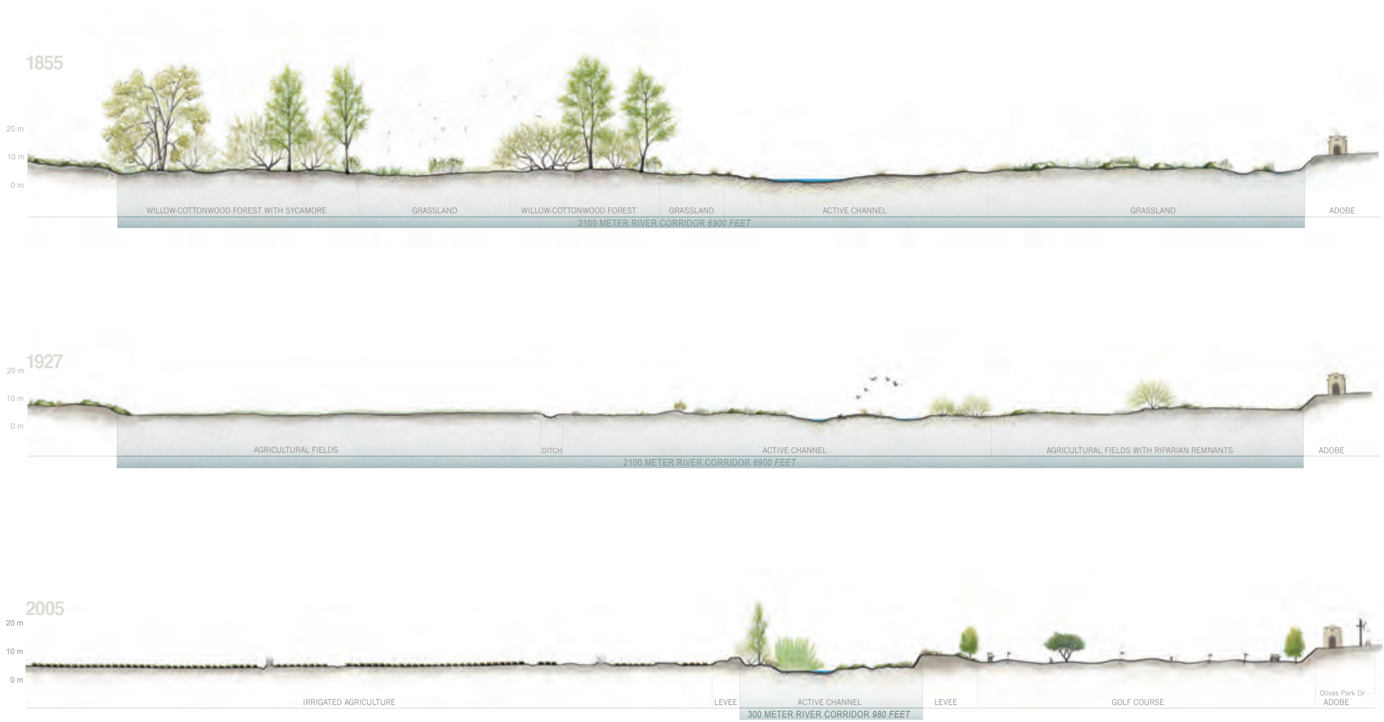
DAVID DIETHELM





Computer-based 3-D visualizations using GIS data. By David Diethelm (http://ise.uoregon.edu/staff/diethelm/diethelm.html).

JENNIFER NATALI



Contemporary (above) and historical (below) cross-sections for lower Santa Clara River. By Jennifer Natali (http://jennifernatali.com/index.html) based on ASC data for the forthcoming Ventura County Historical Ecology Study report.

Other websites with visualizations relevant to proposed project products:

Beyond Mannahatta, The Welikia Project: //welikia.org/

Oregon Historical Society Timeweb: //www.ohs.org/education/oregonhistory/timeweb/

Metropolitan Water District: //www.youtube.com/user/metropolitanwater?feature=mhum#p/a/u/0/vaFlCS9VsXQ

Appendix B: Qualifications of core team members

Aquatic Science Center staff

Robin Grossinger, is a Senior Scientist at ASC/SFEI, where he directs the Historical Ecology Program. A leading authority on historical California landscapes, he advises restoration projects throughout California and has nearly 20 years experience leading interdisciplinary applied research projects to support the restoration of wetland and riverine systems. Mr. Grossinger received his M.S. in Marine Sciences at the University of California at Santa Cruz, with research on the accuracy of early maps of the San Francisco Estuary and their use to determine the natural structure and function of tidal marsh systems. He has recently led the development of the *Napa Valley Historical Ecology Atlas*, to be published by the University of California Press, and the first analysis of Southern California historical wetland patterns, designed to inform restoration strategies for the region. As the Principal Investigator of ASC's current Delta Historical Ecology Study, he chaired the special session at the Bay-Delta Science Conference on *The Natural Delta: Pattern and Process before Modern Management*. Robin has also developed popular presentations of ecological history for museum exhibits and public art, and serves as an Advisor for the new Bay Observatory at the Exploratorium. The work of Robin and his colleagues to research and visualize landscape trajectories has received awards in the realms of map design and local education and has been featured widely, including in *The Living Landscape: An Ecological Approach to Landscape Planning*, the KQED TV science program QUEST, and the *Saving the Bay* documentary.

Letitia Grenier leads the Conservation Biology Program at ASC/SFEI. She is interested in the development of regional and landscape approaches to conserving wildlife, with an eye toward future changes in the Bay Area. Letitia has been working in the tidal marshes of the San Francisco Bay estuary since 1999. She received her Ph.D. from the Environmental Science, Policy and Management Department at UC Berkeley, focusing on vertebrate conservation biology and specializing in tidal marsh animal ecology. Her past research has included tidal marsh food web structure, differentiation and adaptations of tidal marsh vertebrates, and how the tidal gradient structures the ecology of marsh sparrows. Currently, she continues to study wetlands ecology and the bioaccumulation of contaminants in estuarine food webs, particularly methylmercury in tidal marsh animals.

Josh Collins is the Lead Scientist at ASC/SFEI. He oversees the development and integration of ASC/SFEI's scientific work. Josh is a landscape ecologist and regional ecological planner with special expertise in mapping and assessing stream and wetland ecosystems. He received his Doctorate in Entomological Sciences at the University of California at Berkeley and did post-doctoral work in Geography and Ecology at the UC Berkeley and UC Davis. As an ecologist in the public utilities industry, Josh assessed the impacts of power plants on marine, estuarine, and riverine ecosystems. As a consulting ecologist in private practice, he designed stream and wetland restoration projects and developed methods to assess their performance. Since joining ASC/SFEI, Josh has initiated continuing programs in wetland science, watershed science, historical ecology, and regional GIS. He is a leader for a variety of efforts in the West to set long range ecological goals and he has been instrumental in the development of wetland and stream monitoring and assessment methods for California and the nation. Among his many current advisory roles, Josh chairs the technical team supporting California's new wetland and riparian area protection policy.

Alison Whipple is an Associate Environmental Scientist with the Historical Ecology Program at ASC/SFEI. She is currently a science lead and project manager for the Delta Historical Ecology Study, performed in collaboration with DFG. She has presented this research at the 2010 Bay-Delta Science Conference, the 2010 IEP Annual Conference, and the 2009 Delta Science Program Large-Scale Restoration Workshop. She received her B.S. and M.S. in Earth Systems from Stanford University, where she studied watershed science, land use planning, hydrology, and the history and policy of California water resource management. During this time, she participated in interdisciplinary research on streams and agricultural water use, which led to her master's thesis research focused on low-flow characteristics of small tributary streams in Mediterranean watersheds.

Ruth Askevold is a Project Manager at ASC/SFEI and will work closely with the science leads to plan, execute, monitor, and provide quality assurance and project status communication during the life cycle of the project. She brings over 15 years of management experience on large and complex technical projects. She currently oversees project management for over one million dollars in contracts of ASC/SFEI. Previously, Ms. Askevold helped develop and implement project management methods at a natural resources consulting firm that provided GIS and remote sensing services to state and federal agencies. She has also been a technical analyst on several studies at ASC/SFEI, including historical ecology studies of Coyote Creek in Santa Clara County; Eastern Contra Costa County; and Alameda Creek. She received her B.A. and M.A. in Geography and Environmental Studies from San Francisco State University.

Meredith Williams is a Project Manager at ASC/SFEI where she leads the Environmental Data Information and Technology (EDIT) team. She comes to ASC/SFEI with more than fifteen years of experience at such companies as Applied Materials and 3M in semiconductor research, product development,and product management. She helped develop products ranging from photovoltaic solar cell materials to advanced transistor processing methods. Since joining ASC/SFEI she has managed a number of wetlands-related projects and led the implementation of several online data delivery products. She has also served as ASC/SFEI's Senior Project Manager. She holds a Ph.D. in physics from North Carolina State University and a bachelor's degree from Yale University.

Kristen Cayce is ASC/SFEI's GIS Manager. She received her B.A. in Geography and Human Environmental Studies from San Francisco State University and is currently finishing her M.A. in Natural Resource Management. Her studies emphasized geographic techniques, GIS, remote sensing and cartography, and their application to understanding the natural landscape. Before joining the ASC/SFEI team, Kristen worked with several resource management agencies including, the Romberg Tiburon Center, US Fish and Wildlife Service, and US Environmental Protection Agency. At ASC/SFEI, Kristen manages the GIS team that services the geospatial needs of the Institute. She also leads several landscape level projects including the BAARI effort, mapping of stream and wetland resources for the San Francisco Bay region, a multiyear project funded by the State. Kristen has also been involved in the development of USCS T-sheet products at ASC/SFEI including the South San Francisco Bay Area and Southern California Coast datasets (www.caltsheets.org).

Landscape Interpretation Team

The project draws upon a diverse team of scientific experts.

Michael Barbour is Professor Emeritus of Plant Ecology at the University of California, Davis. He received his Ph.D. in Botany/Plant Ecology from Duke University in 1967 and has been a faculty member at UC Davis since then, except for periods as an invited visiting professor. During his 40 year career he has taught plant biology, forest ecology, plant communities of California, fire ecology, and plant community ecology. His research focus has been on vegetation dynamics in many California ecosystems (salt marsh, coastal dunes, vernal pools, montane conifer forests, warm desert scrub). He is a co-author or co-editor of several botany and ecology textbooks, including the second edition of *Terrestrial Plant Ecology* and the recently published third edition of the *Terrestrial Vegetation of California*. In 1988, UC Davis recognized his abilities as an instructor by awarding him a Citation for Distinguished Teaching.

Brian Collins has a Ph.D. and M. S. in geomorphology from the University of Washington and a B.A. in biology from Oberlin College. He is currently a Research Scientist at the University of Washington with a focus on the geomorphology, historical ecology and environmental history of Puget Sound lowland rivers. His research includes: (1) linking geomorphology and historical ecology to understand the geological evolution, regional structure of, and mechanics of the physical landscape template and how the template influences and is influenced by ecosystems, (2) historical aquatic habitat change analyses, and (3) developing approaches to river restoration that link physical and ecological process in a river-valley or landscape-scale context.

Chris Enright is a Senior Water Resources Engineer at the Delta Science Program. He joined the program in 2010 after spending 21 years as a water resources engineer at DWR. For the last 15 years, Chris served as the chief of Suisun Marsh Planning in the Division of Environmental Services. His research interests include hydrodynamics and transport processes, estuarine landscape ecology, and wetland restoration. He holds a B.A. in Environmental Studies from UC Santa Barbara where he developed his interest in California water resources issues. He holds a B.S. in Environmental Resources

Engineering from Humboldt State University where he emphasized water resources planning and management by applying open channel hydraulics, numerical methods, and operations research methods to hydrological and water quality problems. He also holds a M.S. in Civil and Environmental Engineering from UC Davis where he applied operations research and numerical methods to problems in water resources planning and management.

Geoff Geupel has over 23 years of experience in ornithological monitoring and conservation research. Geoff has a B.S. in Biology from Lewis and Clark College and has authored over 30 publications, many of which have helped define bird-monitoring protocols throughout North America and Mexico. He has worked closely with private, state and federal agencies in California and other Western states to assess the impact of land management practices and restoration efforts on landbird populations. Geoff has taught numerous technical workshops on bird monitoring and conservation planning. He oversees 8 program areas including projects in The Great Valley, Eastern Sierra, Intermountain west shrub steppe, the Sierra Nevada, Latin America, and oak woodland and desert regions of California, that employ over 40 field biologists annually. He is currently co-Chair of California Partners in Flight, head of the Science Committee of the Riparian Habitat Joint Venture, member of the California State Steering Committee of the Intermountain West Joint Venture, technical committee member of the Central Valley Habitat Joint Venture, board member of the Sonora Joint Venture and member of the National Cowbird Advisory Council and International Important Bird Area Technical Committee.

Todd Keeler-Wolf is an ecologist who has worked in California for over 30 years. Currently he is the Senior Vegetation Ecologist at the California Department of Fish and Game and leads their Vegetation Classification and Mapping Program. He is also technical program advisor to the California Native Plant Society's Vegetation Program and is a member of the Executive Committee of the Ecological Society of America's Vegetation Panel. In addition to the two editions of the *Manual of California Vegetation*, he has co-authored several books and publications, including the revised UC Press *California Plant Life Natural History* guide, and the recently published third edition of the *Terrestrial Vegetation of California*. Todd is actively involved in inventorying and describing all the vegetation of the state using quantitative classification and mapping to focus conservation planning efforts. Along with colleague Diana Hickson, he was responsible for developing the quantitative classification and mapping of the vegetation of the Sacramento-San Joaquin River Delta in 2007. Todd has also been involved in work with the Oakland Museum of California on using current quantitative vegetation classification and mapping methods to more accurately interpret historic vegetation patterns in the East Bay Area. He received his undergraduate and graduate degrees at UCSC.

William Lidicker, Jr. is Professor Emeritus of integrative biology and curator of mammals at the Museum of Vertebrate Zoology, University of California at Berkeley. He is also an Adjunct Research Scientis for the Institute of Ecology at the University of Georgia. Bill has published extensively and written several books on mammalian ecology, landscape ecology, and conservation biology. He is co-author of the recently published *Corridor Ecology: The Science and Practice of Linking Landscapes for Biodiversity Conservation*. He holds editorial positions for several publications, is President of the International Federation of Mammalogists, and is a member of many professional societies, including the California Academy of Sciences, the International Association for Ecology, and the Society for Conservation Biology. Bill received his Ph.D. from the University of Illinois.

Jay Lund is a Professor of Civil and Environmental Engineering, and currently the Ray B. Krone Chair of Environmental Engineering. He is on the editorial board of several water resources publications, has been a member of the Advisory Committee for the 1998 and 2005 California Water Plan Updates, and has served as Convenor of the California Water and Environment Modeling Forum (CWEMF) and President of the Universities Council on Water Resources (UCOWR). His principal research interest is in the application of systems analysis, economic, and management methods to infrastructure and public works problems. He has led development and application of a large-scale optimization modeling for California's water supply, as well as various other modeling studies for the management of flood control and environmental purposes. He is co-author of several books and reports on the Sacramento-San Joaquin Delta, published by the Public Policy Institute of California and University of California Press. He co-authored an analysis of economical water supply alternatives to Hetch Hetchy Dam.

Peter Moyle has been studying the ecology and conservation of freshwater and estuarine fishes in California for over 40 years. He has documented the declining status of many native species in California as well as invasions of alien species. The interactions between native and alien species in environments with varying degrees of disturbance have provided a basis for his ecological studies. Peter is a professor of fish biology in the Department of Wildlife, Fish, and Conservation Biology and associate director of the Center for Watershed Sciences, University of California, Davis. He is part of the Delta Solutions Team with his colleagues at UC Davis and the Public Policy Institute of California, which is addressing diverse problems in the estuary (has produced two books on the subject). He is a member of the Technical Advisory Committee for restoration of the San Joaquin River, including restarting runs of Chinook salmon. Peter is author/coauthor/co-editor of over 180 peer-reviewed scientific papers, 8 books (including *Inland Fishes of California*), and many other publications. Most recently, he co-authored *Managing California's Water: from Conflict to Reconciliation* published in 2011 by PPIC.

Anke Mueller-Solger serves the Delta Stewardship Council as Lead Scientist for the Bay-Delta Interagency Ecological Program (IEP), a cooperative multi-agency ecological research and monitoring program. In her role as IEP Lead Scientist, Anke provides scientific leadership and coordination for the IEP agencies. Closely working with the Delta Science Program, she also works to tie IEP research and monitoring into the larger Bay-Delta scientific program and serves as a science conduit between the Delta Stewardship Council and the IEP agencies. She is the principal communicator of IEP-generated scientific information to the Delta Stewardship Council, the IEP agency Directors, and other policymakers with decision making authority over managing Bay-Delta resources. These efforts are critical to help the IEP meet its mission to provide ecological information and scientific leadership for use in managing the Bay-Delta system. Anke has degrees in biology from Goettingen University in Germany and a Ph.D. in Ecology from UC Davis. Her scientific research focuses on the ecology of lakes, rivers, floodplains and estuaries, and encompasses a variety of organisms, from algae and protists to invertebrates and fish. Anke's involvement with the IEP began in 1998 as a postdoctoral scientist working on a CALFED-funded project on carbon sources and sinks in the upper San Francisco Estuary.

Dave Zezulak currently manages the Department's Bay-Delta Ecosystem Restoration Program and also managed the Department's Bay-Delta Conservation Plan program when it began in 2006. Dave was the Department lead for several large scale Habitat Conservation Plan processes in the Sacramento Valley and Delta, including the Natomas Basin and San Joaquin County HCPs. He also served as Branch Chief for the Department's Wildlife Program Branch from 1998 to 2001. Dave was the Field Operations Supervisor at California Waterfowl Association and was a researcher at UC Davis, before working at DFG. He has a B.S. in Wildlife and Fisheries Biology and Ph.D. in Ecology, both from the University of California, Davis.

Section 7: Project Budget

1. **Detailed Project Budget** ***(Excel spreadsheets can be used)***

Budget			
Project Title			
			Totals
PERSONNEL SERVICES			
Staff Level	**Number of Hours**	**Hourly Rate**	
Sr Manager/Senior Scientist II	2000	$ 76.26	$ 152,520
Manager/Senior Scientist I	1250	$ 52.86	$ 66,075
Scientist II/III	335	$ 47.02	$ 15,752
Scientist I/Associate Scientist	2250	$ 35.13	$ 79,043
Project Manager	975	$ 36.94	$ 36,017
Sr Envir/IT/GIS Analyst	675	$ 28.05	$ 18,934
Envir/IT/GIS Analyst	0	$ 21.71	$ -
Administrative/IT Support Staff[1]	957	$ 33.90	$ 32,442
Intern	0	$ 19.68	$ -
Subtotal			$ 400,782
Staff Benefits @ 43.59%			$ 174,701
TOTAL PERSONNEL SERVICES			**$ 575,483**
OPERATING EXPENSES			
Description			
Subcontractor Costs			
Landscape visualization: Laura Cunningham			$ 7,500
Landscape visualization: Jennifer Natali			$ 4,500
Landscape visualization: David Diethelm			$ 17,495
Landscape Interpretation Team stipends and travel[2]			$ 67,400
Materials & Supplies:			
Software Licenses[3]			$ 3,495
Report Printing and Duplicating[4]			$ 12,375
Travel and Per Diem			$ 8,707
General Expenses[5]			$ 38,500
Lease Costs:			
Office Machines			$ 7,000
IT Infrastructure			$ 14,500
Building			$ 38,500
Total Operating Expenses			$ 219,972

SUBTOTAL			$	795,455
OVERHEAD @ 10% (Less Equipment)			$	79,545
GRAND TOTAL			**$**	**875,000**

[1] Administrative/IT Support Staff hours include, but are not limited to, accounting, human resources, office management, administrative tracking/reporting/management, and IT directly related to project implementation.

[2] The Landscape Interpretation Team members include Michael Barbour (UC Davis), Brian Collins (University of Washington), Chris Enright (Delta Science Program), Geoffrey Geupel (PRBO Conservation Science), Todd Keeler-Wolf (DFG), William Lidicker (UC Berkeley), Jay Lund (UC Davis), Peter Moyle (UC Davis), Anke Mueller-Solger (Bay-Delta Interagency Ecological Program), and Dave Zezulak (DFG). Travel and/or stipends will be covered for some, but not all, members.

[3] Software Licenses includes the purchase of one visualization software license (Maya).

[4] Report Printing and Duplicating includes printing drafts for reviewers and final report.

[5] General Expenses include, but are not limited to, general office supplies and printing directly attributable to the project.

2. Budget justification:

As a scientific synthesis and integration project, high-level scientific involvement is necessary by Senior Scientists, particularly related to the interaction with the Landscape Interpretation Team, which will occur throughout the period of the project. A license for the 3D visualization software, Maya, is included as it is a tool necessary to meet the objectives of Task 4 (Outreach and Communication). Travel and Per Diem is associated with meetings, data collection, and public presentations scoped in the project description. Other specified direct expenses include printing and publication of draft and final memos and reports, as well as the portion of materials and consumables used by the project team, such as office supplies, IT supplies and hardware, equipment, vehicle, computer and facilities lease costs that directly cover this project.

3. Administrative overhead:

The 10% overhead rate includes all other administration costs that cannot be directly associated with projects.