Section 5: Project Description

1. **Project Objectives:**

The Sherman Island Wetland Restoration Project (Project) is composed of two phases. The first phase includes constructing a 700 acre wetland restoration area on the west side of the Antioch Bridge and the second phase includes constructing a 1000 acre wetland restoration area on the northeast side of the Antioch Bridge. This Project also incorporates elements of uplands and riparian forest, on the perimeter and on upland areas, including berms and islands.

There are no aspects of this project that are required by law or permit condition, thus this project is truly "Additional". Furthermore, since Sherman Island is significantly subsided, with land elevations between 10 and 25 feet below sea level, all sequestered GHG will be "Permanent". Subsided Delta islands are like bowls and if tule wetlands are constructed and permanently flooded, these bowls over time will fill up with rhizome root material (or Carbon). And if these lands are flooded permanently, and agricultural activities do not subject the peat material to oxygen or fertilizers, the underlying peat will not continue to emit GHG into the atmosphere and allow subsidence. Some potential risks to "Permanence" would include fire and land management changes that would convert these wetlands back into agricultural fields. However, fire risk is greatly diminished since these projects will be permanently flooded and since DWR owns this property, the likelihood of returning these lands to agriculture is remote. Lastly, the flood risk on Sherman Island is significant but if this were to occur, the carbon sequestered would be under water and essentially capped, with very little GHG release. Additionally, it would be likely that the Island would be reclaimed because of both the assets and significance to water quality. Once reclaimed, these wetlands would be restored and continue to operate as wetland habitat restoration facilities.

The first phase of this project, otherwise known as the "Whale's Mouth Wetland" has been designed and currently has all necessary environmental permits. The second phase of this project (Belly Wetland), will likely be designed during the summer of 2015 and all environmental permits obtained prior to summer 2016. If funded phase 1 will initiate construction in May 2015 and phase 2 will likely initiate construction summer 2016. Once mature, these projects together will likely sequester approximately 20,000 metric tons of CO_2-eq per year based upon the most recent research conducted by UCB on Sherman and Twitchell Islands. Specific project Objectives are described below.

Objective 1: Restore and Enhance Wetlands by constructing approximately 1700 acres of new wetlands on Sherman Island

As discussed above, this phased project will construct approximately 1700 acres of wetlands. The first phase of this project has been designed and permitted. Attachment 2 contains the final Plans as well as approved environmental permitting documents. Phase 2 of this project does not yet have detailed designs or environmental permits, but these activities can occur over the next year, allowing for construction to commence in either late summer 2016 or spring 2017. (See Attachment 1 - Boundary Layout)

Objective 2: Sequester GHG, approximately 20,000 metric tons CO_2-eq per year (CO_2 and CH_4 flux).

Baseline GHG (CO_2 and CH_4) has been collected over the last 7 years within the boundaries of phase 1. GHG emissions (CO_2 and CH_4) at this irrigated pasture site ranges between 5.7 to 6.6 metric tons CO_2-eq per acre per year. Additionally, analysis of mature wetland systems on Twitchell Island shows GHG (CO_2 and CH_4) sequestration rates for 2011 through 2014 to be between 5.2 and 4.2 metric tons CO_2-eq per acre per year. Based upon this data, it is expected that these wetlands (once mature) will have a net GHG sequestration rate of approximately 11.5 metric tons CO_2-eq per acre per year or approximately 20,000 metric tons of CO_2-eq per year.

Please note that while N_2O has not been thoroughly analyzed at this site, some N_2O data was collected in 2007-8, which showed emissions of 302 ± 168 g CO_2-eq m^{-2} y^{-1}. These values are up to an order of magnitude higher than managed peatlands in other regions (Jungkunst and Fiedler 2007; Langeveld and others 1997; Regina and others 2004; Schils and others 2006) and dominated the global warming potential for this site (Teh et al. 2011). While this data does not solely support Delta-wide N_2O emissions estimates for this baseline type, it does suggest that N_2O is quite possibly an extremely large contributor to GHG in the Delta. Furthermore, because wetlands are not a major contributor of N_2O, the potential GHG sequestration of this project is likely much greater than 20,000 metric tons CO_2-eq per year.

Objective 3: Conduct Delta-wide GHG monitoring for CO_2, N_2O, and CH_4

This Project will ensure continued data collection of CO_2 and CH_4 at 6 different sites on both Sherman and Twitchell Islands, as well as establish 3 new sites that will collect *CO_2, N_2O, and CH_4* data. The scope of work for this testing is contained in Attachment 3 and all services for the GHG data accumulation and analysis will be conducted by UCB. Furthermore, this Project will also employ multiple modeling strategies to predict greenhouse gas fluxes across diverse soil and land use types in the Delta. All of these elements are necessary to further current activities being conducted by State agencies to develop a GHG Protocol for the California Air Resources Board's Cap and Trade Program. Additionally, quantification of GHG flux rates for Delta agricultural activities (including corn, alfalfa, irrigated pasture, rice, and constructed wetlands) will enable others within the Delta to grow wetland crops in the Delta and sell Carbon Credits on the newly formed Cap and Trade markets.

Objective 4: Reverse land subsidence on Sherman Island

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

Since 1997, DWR has constructed and studied two large scale wetlands in the West Delta by monitoring the effects of growing tules, including land surface elevation changes and recently carbon sequestration. The data show that surface elevation changes due to accretion ranges from 1.3–2.2 inches each year and sequesters greenhouse gases. In comparison, the areas used for agricultural purposes lose up to 2 inches of soil per year, mainly from the oxidation of peat soils. This oxidation results in the emission of greenhouse gases. The land surface net gain for growing tules on peat soils can result in up to 4 inches per year

Objective 5: Restore and enhance connectivity to associated wetlands and upland natural communities within the west delta

This Project is located directly adjacent to a 6200 foot habitat setback levee, which incorporates native species on the waterside to ensure connectivity between the waterside and landside habitat regimes. This Project is also located directly adjacent to a 300 acre wetland that was constructed in 2010 (Mayberry Farms) and an 11 acre riparian forest that was constructed in the late 1990s for mitigation purposes. The Sherman Island Wildlife Management Plan (WMP) developed in 1990, lays out a conceptual plan to develop significant acreage into wildlife habitat, including wetlands, uplands, and riparian forests.

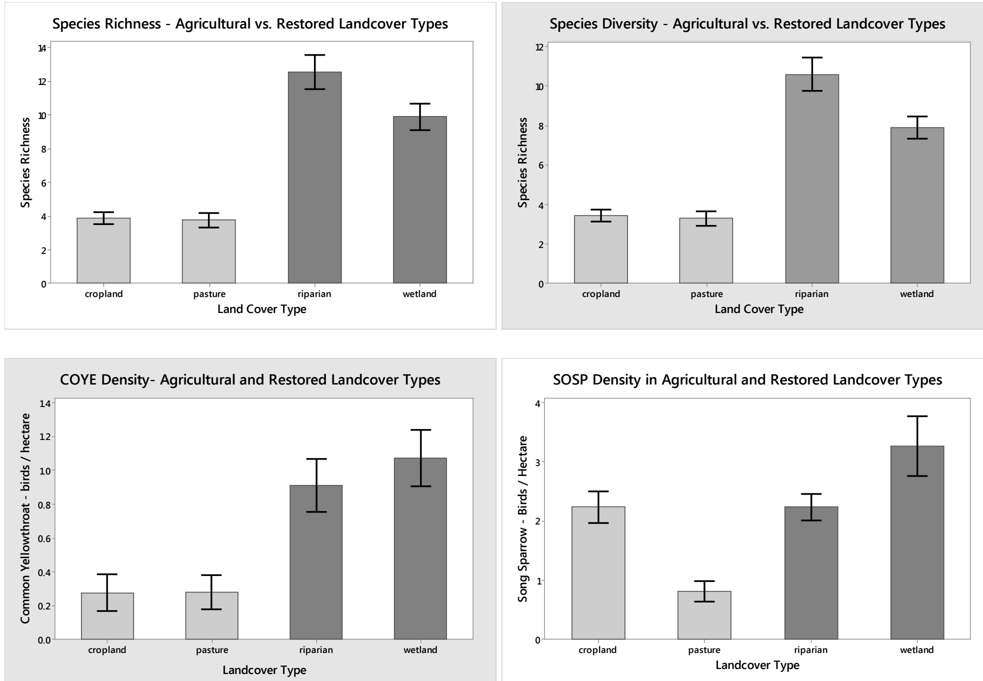
Over the past several years, DWR has partnered with local Reclamation Districts (mainly Sherman and Twitchell Islands) to develop significant habitat regimes within the west delta. Approximately 30,000 lineal feet of habitat setback levees along the San Joaquin River on Twitchell Island is in the final design and permitting phase. Construction initiation of approximately 7,000 feet of this setback levee will commence in 2016, with additional sections to follow. This builds upon approximately 2500 feet of setback levee that was built in the early 2000s, as well as 1600 acres of wetland habitat and 45 acres of riparian habitat that has been constructed on Twitchell Island over the last 10 years. Additional projects, including a 75 acre tidal wetland on the southwestern tip, as well as 150 acres of uplands and riparian forest, on the northern section of Twitchell Island are also currently in the planning phase.

The Sherman Island Wetland Restoration Project will not only build upon the projects listed above, but also tie in well with other projects in the Delta, including tidal restoration proposed on Dutch Slough, Meins Landing, McCormick Williamson and other habitat sites on Bradford and Jersey Islands.

Objective 6: Restore and enhance nesting, roosting, foraging, and cover habitats for native wildlife species

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

RHJV (Riparian Habitat Joint Venture). 2004. The riparian bird conservation plan: a strategy for reversing the decline of riparian associated birds in California. California Partners in Flight. http://www.prbo.org/calpif/pdfs/riparian_v-2.pdf



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

Objective 7&8: Improve flood protection and reduce risk of significant water quality impacts

All of Sherman Island is protected by levees as the landside elevations are generally 15 to 30 feet below the mean high tide elevation of both the Sacramento and San Joaquin rivers. Constructing wetlands on the peat soils provides a long-term solution for levee stability by immediately reducing the void by approximately 2.5 feet, thus reducing the hydrostatic pressure on the levees. Secondly, USGS studies on Twitchell Island have shown that wetland tules accrete approximately 5 cm of organic material annually. In fact, the Twitchell Wetland accreted approximately 20 inches of organic matter over a 14 year period. This accretion is in lieu of a continual subsidence rate between 3.5 to 7.5 cm per year (depending upon groundwater surface elevation and organic content of soil). As a result of these studies, the Delta Stewardship Council has recommended in their EIR, that State owned lands in the Delta be converted from agriculture to Wetland crops as funding becomes available. Continual monitoring of subsidence reversal rates will be measured at pre identified stations.

As a result of the subsidence reversal aspects of this project, both levee stability and flood protection are greatly enhanced. Additionally, because Sherman Island is located at the confluence of the Sacramento and San Joaquin Rivers and the Suisun Marsh, where water salinity is at the steepest gradient, Sherman Island acts as a buffer to ensure water quality within the entire Delta. If Sherman Island were to flood, brackish water intrusion would inundate the Delta, increasing salinity throughout and greatly impacting the Delta's ecosystem and California's water supply. Recent hydraulic modeling performed by the Department of Water Resources and its consultants shows that a levee breach on Sherman Island would increase salinity levels at the Clifton Court Forebay by 26% (on average depending upon tides, river flow rates, and reservoir capacity to flush the Delta system). This proposed project will protect significant Statewide interests including the Delta ecosystem.

Objective 9: Protect climate reugia

Climate change and the associated changes to sea levels are expected to affect terrestrial biodiversity at all system levels, including species-level reductions in range size and abundance, exposing many taxa to increased risk of extinction. In the Delta, the specter of sea level rise and its impact upon terrestrial habitats is particularly taxing due to the continuing subsidence of the Delta. As sea level rise increases pressure upon levees, the subsiding land elevations increase the stress upon the levees. In the case of levee failure and flooding, land will be under ever increasing depths of water and completely non-viable for terrestrial mammals, reptiles or birds. Through the subsidence reversal projects on Sherman and Twitchell Islands, rising land elevations will provide marsh habitats that will be at less risk in the case of levee failure. Not only do these projects increase land elevations and the subsequent decrease of future flood risk, they also provide sustainable freshwater tule marsh, once prevalent throughout the historical Delta but now extremely rare. The freshwater marsh created will have increasing elevations that will stay ahead of sea level rise and provide viable habitat in the present and refugia well into the future.

Objective 10: Increase diversity and relative cover of native plan species and minimize the establishment and growth of non-native, invasive plant species

Lastly, the proposed construction sites for both phases of this project are currently managed as irrigated pasture but have significant infestation of pepper weed and Himalayan Blackberry. By permanently flooding significant acreages of land we will eliminate the aforementioned invasive species by growing native tule/cattails. Additionally, both phases consist of restoring native plants on the upland berms, islands, and surrounding areas. Selected upland species including grasses, shrubs, and trees will be planted at the appropriate elevations to ensure survival. The "Whale's Mouth" plan sheets include a proposed planting plan and species palette, which will be typical for all restoration projects.

2. *Background and Conceptual Models:*

The Sacramento-San Joaquin Delta region is ¾ of a million acres in size and is replete in marshes, wetlands and agricultural peatlands. Over the past 150 years, the Delta region has undergone considerable land use change. The region was an extensive wetland before the Gold Rush era (circa 1849); it formed during the Holocene epoch as sea levels slowly rose, with the melting ice age, and inundated wetland vegetation growing at the confluence of the Sacramento and San Joaquin

Rivers. Centuries of plant growth and decay created rich organic peat soil. After the Gold Rush, much of this region was reclaimed and drained for agriculture by building a network of 'islands' surrounded by levees.

Over the years, agriculture has flourished because of the rich organic soils and abundant water sources. Unfortunately, the deep organic peat soils are highly susceptible to subsidence under current agricultural practices. The exposure of organic peat soil to air has caused the peat soil to oxidize and soil to subside [*S.J. Deverel and Rojstaczer*, 1996]. Subsidence is caused by the oxidation of peat soils and eventually results in the sinking of island interiors, which then requires construction of ever-larger levees to prevent flooding. Eventually, failure and flooding threatens Delta water quality (including water export to various areas throughout California), life and property, public and private assets (including highways, bridges, electrical power supplies, gas lines, etc…), as well as a delicate ecosystem and natural habitat.

Today, a combination of oxidation, subsidence, erosion, and compaction has caused many 'islands' to be 10 m below sea level [*Drexler et al.*, 2009; *Mount and Twiss*, 2005]. From scientific, ecological, and societal viewpoints, the Sacramento-San Joaquin Delta is a vulnerable to additional degradation and eventual collapse [*Mount and Twiss*, 2005]. The continuing oxidation/subsidence of the Delta peatlands is threatening long-term agricultural use of these lands by pushing the soil level further and further below sea-level. These levees are especially vulnerable to breaching by a major earthquake, winter storms, high tides, natural seepage, invasion by burrowing animals and rising sea-level [*BlueRibbonTaskForce*, 2008; *Mount and Twiss*, 2005]. Any flooding of the Delta islands will cause an intrusion of salt water from the San Francisco Bay estuary, which will have a dire impact on over 20 million Californians, who rely on high quality water flowing through the Delta for irrigation, commerce and drinking [*R L Miller et al.*, 2000].

While the future of Delta is very uncertain and a subject to great debate, it is clear that current land use practices in the Delta are not sustainable. Fortunately, ecological solutions to this subsidence problem are possible. High rates of carbon sequestration and net primary productivity are expected from marshes in the Sacramento-San Joaquin River Delta because the region experiences a long and warm growing season with ample sunlight and water [*Brinson et al.*, 1981; *L G Miller et al.*, 2001; *Zhao et al.*, 2009]. On the other hand, high CH_4 effluxes [*Teh et al.*, 2011b] may occur because the flooded landscape overlay C-rich and anaerobic soils [*Drexler et al.*, 2009].

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

Since 1997, DWR has constructed and studied three large scale wetlands in the West Delta including a 15-acre pilot wetland and 750-acre full scale wetland on Twitchell Island, as well as a 300-acre wetland on Sherman Island. By monitoring the effects of growing tules, including land surface elevation changes and GHG flux, we have shown that surface elevation changes due to accretion ranges from 1.3–2.2 inches each year and the net rate of GHG sequestration is between 9 and 14 metric tons CO_2-eq per acre per year. In comparison, the areas used for agricultural purposes lose up to 2 inches of soil per year, mainly from the oxidation of peat soils. This oxidation results in the emission of greenhouse gases. The land surface net gain for growing tules on peat soils can result in up to 4 inches per year.

In addition to the three large scale wetlands, DWR and its research partners constructed and continues to research a 600-acre Rice Research Project on Twitchell Island to research the effect of growing rice in the Delta. The initial research data from rice crops in 2009 through 2014 shows rice production has stopped subsidence, achieved small amounts of accretion, sequestered atmospheric carbon dioxide (CO_2), and acted as a sink for pesticides and herbicides [*Hatala et al.*, 2012b; *Knox et al.*, 2014].

However, one significant question that has not yet been investigated is the amount of nitrous oxide (N_2O) emissions avoided via wetland restoration. Nitrous oxide is a potent GHG with a global warming potential approximately 268 time of CO_2 over 20 years and 298 times that of CO_2 over a 100-year period. Previous work on drained peatland pastures showed high N_2O emissions. Flooding decreases N_2O emissions and thus wetland restoration may result in significant GHG savings.

Delta Ecosystems can also be a large source of N_2O [*Hatala et al.*, 2012a; *Teh et al.*, 2011a]. Because N_2O is such a potent GHG, understanding the factors regulating the emission of N_2O from different land uses in the Delta is an important step for developing a GHG protocol. Soil surface N_2O emissions are difficult to predict because they are the net result of multiple biological and physical processes. N_2O is produced as an intermediate during nitrification and denitrification. N_2O is primarily derived from nitrification at low to moderate soil moistures and denitrification at higher soil moistures due to decreased soil O_2 availability [*Firestone et al.*, 1989]. However, soil moisture also influences the diffusion of N_2O through the soil column, thereby influencing soil surface fluxes. Beyond soil moisture and O_2, N_2O emissions are known to be regulated by temperature, soil C availability, crop type, tillage, soil pH, soil texture, re-wetting of dry soil, and fertilizer application [*Stehfest and Bouwman*, 2006]. Fertilization and re-wetting events are especially important for N_2O budgets, where a single pulse event can account for >50% of the annual N_2O budget [*Wagner-Riddle et al.*, 1997], emphasizing the importance of continuous measurement strategies. Finally, across a given agricultural field, hot spots are known to occur where high N_2O emissions are observed in association with certain plant species or soil substrate availability such as Pepperweed invasions in the Delta (Yang et al. in prep). Hot spots are best addressed by measuring fluxes across the landscape, including all microsite types.

Flooding during wetland restoration can lower soil O_2 availability, thus decreasing the production of nitrate, an important precursor to N_2O production (McNicol and Silver 2014). Flooding of C-rich soils can also stimulate complete denitrification resulting in the production of the inert dinitrogen (N_2) gas in place of N_2O (Yang et al. 2012). Thus wetland restoration has the potential to offset significant N_2O emissions from agricultural land uses in the Delta.

Efforts are underway to restore these drained peatlands to their native state with the reintroduction of wetland vegetation. While pilot studies show that ecological restoration is successful in sequestering carbon and building peat soils, it also produces methane (CH_4) at enhanced rates [*Hatala et al.*, 2012b; *Knox et al.*, 2014;

R L Miller et al., 2008]. Furthermore, more data are needed on continuous N_2O emissions to determine potential offsets. Hence, baseline information on CO_2, N_2O, water vapor and CH_4 fluxes from drained peatlands, both high and low in organic carbon [*Steven J. Deverel and Leighton*, 2010], are needed to advise how CO_2, N_2O, and CH_4 fluxes may change if peatland pastures and farmland are restored to native vegetation and wetlands.

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

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

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

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

We propose to continue measuring the dominant greenhouse gas (N_2O, CH_4, CO_2 and H_2O) fluxes across a suite of sites in the delta that represent current agricultural practices, restored wetlands and rice production, which is an alternative to wetlands. With this proposed funding, and by leveraging funds from the USDA-AFRI and US DOE, we will establish a network of 9 continuous greenhouse gas measurements sites across the Delta. This network will include a current set of sites (6) and will establish 3 new sites. We will continue measuring greenhouse gas fluxes over a rice paddy on Twitchell Island, on a restored (established fall 2010) a tule/cattail wetland near Mayberry Slough, on the 17 year old, 15-acre pilot wetland restoration project on Twitchell Island, an alfalfa field on Twitchell Island and on the newest restored wetland (fall, 2013) on Twitchell Island. These sites are on the western portion of the delta and lay on more mineral and lower organic content soil (< 20%). With newer funding we intend to establish 3 new greenhouse gas flux measurements sites in the Delta, with a focus on the high organic content soils (> 40%) in the Central Delta [*Steven J. Deverel and Leighton*, 2010].

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

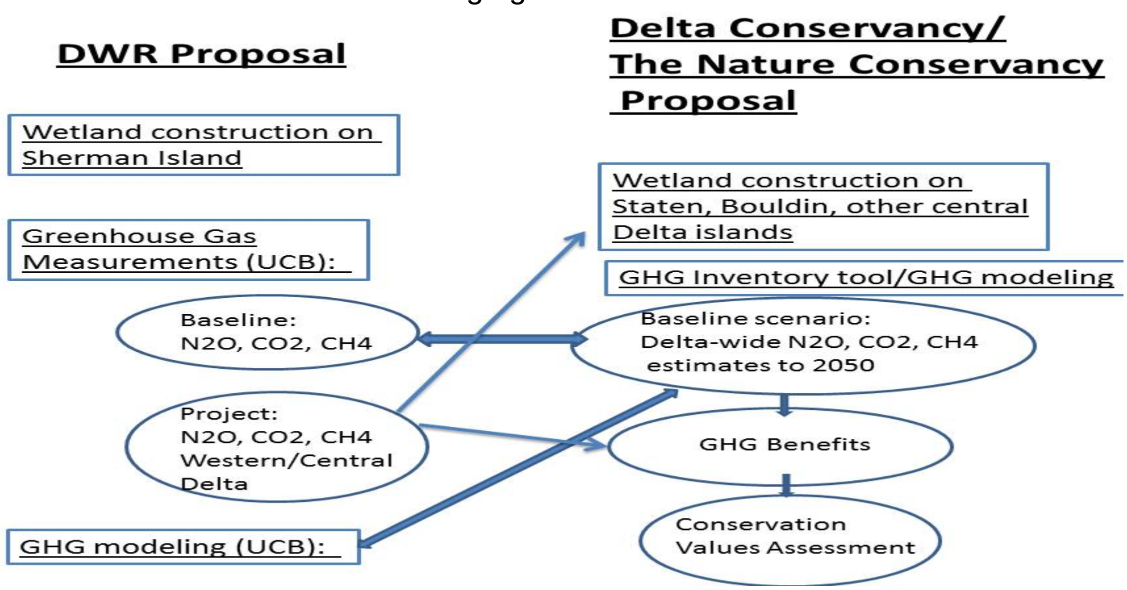


Figure 1. Relation between DWR and Delta Conservancy/The Nature Conservancy proposals.

This Project will allow DWR to partner with UCB to develop GHG Emissions Reduction and Carbon Sequestration Protocols to place Delta landowners in a position to be able to capitalize on the emerging carbon market if they elect to change from growing crops to growing carbon.

The site for phase 1 is currently managed as a flood irrigated pasture, which includes a regular and extensive disturbance regime associated with field prepping and grazing. This site has an extensive amount of pepper weed and Himalayan Blackberry. As a result of more than 130 years of farming practices and subsequent oxidation of the peat soils, land elevations are more than 20 ft below the water levels in both the Sacramento and San Joaquin Rivers. Phase 2 is currently managed as flood irrigated agricultural fields, where farmers grow corn, alfalfa, and hay. Similar to the phase 1 site, there is significant amounts of invasive plant species; however, ground elevations in this area are as much as 35 feet below the water levels of adjacent rivers.

DWR is also currently working with a number of other public agencies (including the Delta and Coastal Conservancies) to develop a GHG Protocol, which will ultimately be considered by the California Air Resources Board (CARB) for adoption as an Offset Protocol for the Cap and Trade Program. This Protocol will likely be considered for adoption by the American Carbon Registry for use in the voluntary carbon market in early 2015, and then by CARB sometime in late 2015 or early 2016. Once adopted, it is expected that DWR will be able to use these credits to subsidize operational and maintenance costs or as offsets for energy consumption for the State Water Project.

3. ***Detailed project description, including all tasks to be performed:***
There are two aspects to this project including the development of approximately 1700 acres of wetlands and uplands, as well as developing a Delta-wide GHG monitoring program. The following is an overview of all activities associated with Project.

Phase 1
Several key components associated with the construction of Phase 1 include: constructing approximatey 700 acres of wetlands, planting native species on uplands within and surrounding the restoration area, and operating and maintaining the facilities. All planning, permitting, and design activities have been completed for the entire project. A list of the following are provided in Appendix 2 including:

- 401 Clean Water Act WQC WDID#5B34CR00057 from RWQCB dated August 28, 2014
- Certification of Consistency C20141 from Delta Stewardship Council dated August 6, 2014
- Complete Final Plan Set for Sherman Island Whale's Mouth Wetland Restoration US-CA-437-3 dated September 6, 2014
- 404 Certification from USACE Corps File SPK-2013-01084 dated August 19, 2014
- BO from NFWS/USACE Corps File SPK-2013-01084 dated August 11, 2014
- USFWS BO
- Complete Notification of Lake or Streambed Alteration 1600-2014-0104-R3 from CDFW dated May 28, 2014
- CEQA Notice of Completion from State Clearing House.
- Preliminary Jurisdictional Determination Form from USACE Corps File SPK-2013-01084 dated February 24, 2014
- Resolution from RD 341 adopting MND CEQA for Whales Mouth dated November 12, 2013
- State Clearing House Form dated September 10, 2013
- Notice of Determination with Sacramento County dated November 14, 2013
- Bid Abstract from RD 341 for Whale's Mouth Project dated October 15, 2014

The Project focuses on the restoration of palustrine emergent wetlands, complemented with upland riparian forest, scrub shrub, and grassland to add diversity of structure and habitat to the site. Restoration of wetlands will be accomplished by upgrading existing water management infrastructure and installing new infrastructure such as water control structures and water conveyance channels. In addition, the height of some existing berms will be increased and the Project will create habitat loafing islands. When the Project is completed, water will be maintained on the Project Site year-round, effectively creating a permanent wetland. Restoring permanent wetlands on Delta islands has been shown to halt and reverse subsidence. This Project will combine the wildlife benefits of wetland restoration with the importance of reversing Delta island subsidence. Upland vegetation will be planted on a higher elevation area adjacent to the wetland. Site preparation will begin in Summer 2015. All construction activities in 2015 will be completed by October. If work is not completed in 2015, it will commence again in May 2016. All work will be performed on-site.

During construction of the Project, perimeter ditches, perimeter berms, interior berms, interior water conveyance channels and water control structures will be installed or improved. In addition, loafing islands will be constructed.

It is anticipated that the Project will excavate approximately 550,000 cubic yards from various locations within the Project Site and relocate that material in different areas to build the necessary project features. No material will be exported and a cut fill balance will be achieved where possible. Details of planned improvements to water management infrastructure and construction of additional infrastructure required to manage the Site as emergent wetlands are described below. Fill may be imported by truck or barge as needed.

A new 3 foot high perimeter berm will be constructed around the western, eastern, southern and northern boundary of the site to ensure water levels can be maintained at the required elevation. The berm height is based on the results of an extensive topographic survey that indicates the elevation of the site ranges from 7.5 to 16 ft below sea level. The perimeter berm will have at least 3.0 ft of freeboard and a 12-ft top width. Berm height above existing ground will vary depending on existing topography (Figure 4). Materials to create the perimeter berm will be obtained onsite from the creation of swales and other open water areas.

Development of perimeter and transition berms will allow water levels to be increased to restore and maintain permanently flooded emergent wetland on-site. The top of the improved perimeter berm elevation will vary; however, the typical height will be approximately 8-10 ft below sea level.

Approximately 27 water control structures will be installed. The interior of the site will be divided up into 9 managed wetland units, separated by 47,000 lineal feet of proposed interior berms, and crossed with conveyance swales, in order to facilitate appropriate water and vegetation management capabilities. Water levels in each unit will be managed independently to restore the desired emergent wetland conditions throughout the site. When the Project is completed, water is proposed to be maintained in the project area year-round, effectively creating a permanent wetland.

Water will be conveyed within the wetland system via gravity flow from the higher elevation units to the lower elevation units until it finally makes its way back to the District's drainage canal, to the east of the project boundary. The ultimate outcome of the Project will be approximately 600 acres of freshwater emergent wetlands. Each wetland unit will be a mosaic of open water channels and emergent vegetation comprised predominantly of species such as California bulrush (*Schoenoplectus californicus*) and narrow leaved cattails (*Typha angustifolia*). Other native plant restoration components will include installation of native trees and shrubs compatible with their respective hydrologic regime as well as a substantial amount of upland transitional area, all of which will provide great diversity and increased habitat opportunity for wildlife.

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

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

Conveyance channels will have an approximately 15-ft wide bottom with gradual, 5:1 side slopes. Most of the existing agricultural drainage ditches on Sherman Island have rectangular configurations. A gradual channel side slope will allow for easy wildlife movement across the channels while reducing channel erosion by encouraging vegetation growth along the channel's edges. Depth of channel excavation will vary depending on existing topography.

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

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

Water to the site will be delivered by existing gravity siphons along the San Joaquin River Levee. At this time it is anticipated that siphons 1, 2, 3 and 4 (as shown in plan set) will be utilized as the primary source of water. Siphon 1 is a 14 inch pipe that is capable of discharging approximately 3000-3500 gallons per minute. Siphon 2 is a 12 inch pipe that is capable of discharging approximately 2500-3000 gallons per minute. Siphon 3 is a 12 inch pipe that is capable of discharging approximately 2500-3000 gallons per minute. Siphon 4 is a 10 inch pipe that is capable of discharging approximately 1750-2200 gallons per minute. Water will be conveyed within the wetland system via gravity flow from the higher elevation units to the lower elevation units until it finally makes its way back to the District's drainage canal at the eastern boundary of the Project.

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

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

Construction activities will be performed during the summer months of 2015 through October 2015, and if necessary between May 2016 and October 2016. Earth moving activities will be performed by a licensed contractor and will use agricultural scrapers to transport soils during the excavation of swales and open water areas to construct the Site's interior and perimeter berms as well as loafing islands. Excavators will be used to create ditches and install piping.

Construction will require that the water table be as low as possible. Initial site preparation includes the dewatering of ditches in order to dry soils for construction, where feasible. This will be accomplished by ensuring that the interior agricultural ditches are clean and flowing freely to the District's drainage canal. The District's main discharge pump may also need to be adjusted to keep the main drainage ditch water level lower than normal.

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

The Project Site is completely enclosed by a perimeter berm that will prevent any discharge of storm runoff. Construction staging will take place on the southeast end of the Project Site, on the upland area adjacent to the dredge spoil site. Best management practices (BMPs) for erosion control and hazardous materials handling will be implemented during construction. Any spills of hazardous materials will be cleaned up immediately and reported to the responsible resource agencies within 24 hours. Any such spills, and the success of the cleanup efforts, shall also be reported in post-construction compliance reports. Measures will be taken to minimize windborne transport of fine particles to adjacent areas.

Phase 2

While the planning and design for this phase has yet to be completed, the steps are very similar to Phase 1, including:

Activity	Time Line
Initial Topographic Survey	Summer 2015
Conceptual Design (10%)	Summer 2015
60% Design	Fall 2015
CEQA Document Development (IS/MND)	Summer 2015-Spring 2016
Wetland Delineation & Report	Summer-Fall 2015
BA and Rare Plant Surveys (1)	Fall 2015-Spring 2016
Habitat Management Plan (2)	Fall 2015
Air Quality/GHG	Fall 2015
Water Management Plan	Fall 2015
404 Permit (NWP) (3)	Fall 2015-Spring 2016
ESA - CESA Compliance (BA - USFWS/NOAA/CDFW)	Spring 2016
Section 106	Winter 2015
401 Certification (4)	Spring 2016
1600 Application	Spring 2016
SWPPP Construction Gen. Permit	Summer 2016
Delta Stewardship Council Consistency Determination	Spring 2016
Preparation Bid Documents	Spring 2016
Pre-construction Survey	Summer 2016
Construction	Summer 2016 or Summer 2017
Construction Management	Summer 2016 or Summer 2017
Operations and Maintenance	Ongoing

All detailed construction activities above will likely be required for this phase as well, and generally include:

- Digging perimeter ditches;
- Constructing perimeter and interior berms;
- Developing exterior/interior water conveyance channels and water control structures;
- Constructing loafing islands;
- Planting native species on all restoration areas; and
- Maintaining facilities.

Greenhouse Gas Monitoring

As described in the conceptual model section of this application, GHG monitoring is a significant element that will be performed as part of this project, and will occur Delta-wide. In addition to the data collection, mathematical models will be developed and calibrated for both baseline land use regimes, as well as treatment regimes, including tule wetlands and growing rice. Specific methods will be described in the Protocols section below.

4. ***Timeline:***

Construction activities for Phase 1 will be performed during the summer of 2015 and if necessary between May 2016 and October 15, 2016. Planning activities for Phase 2 will be completed consistently with the timelines stated above. GHG monitoring will be funded by DWR, with current activities continuing and new sites added during the summer of 2015. All data accumulation and modeling documents and reports, as well as final invoices will be submitted to the Department of Fish and Wildlife prior to March 2020.

5. ***Protocols:***

There are two significant protocol considerations for this Project, including Wetland Management Protocols and GHG Data Collection and Modeling Protocols. Both of these Protocols are discussed below.

Management of the Site will have two goals: to maintain permanently flooded emergent wetlands to reverse subsidence, sequester GHG, and to provide permanent wetland and upland habitat for a diverse range of wildlife. The Habitat and Water Management Plan is available upon request.

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

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

As discussed above, water to the site will be provided by four existing gravity siphons along the San Joaquin River/Mayberry Slough Levee to the south of the Project Site that have fish screens maintained by DWR. Water will be conveyed within the wetland system via gravity flow from the higher elevation units to the lower elevation units until it finally makes its way back to the District’s drainage canal located to the east of the Project Site.

A Habitat and Water Management Plan (available upon request) was prepared and includes complete water budgets. As water levels will remain fairly constant throughout the year, the Site is expected to divert less water from the San Joaquin River on an annual basis than the existing irrigated agricultural uses. It is anticipated that drainage water will be used during the winter to slowly fill the wetlands until an initial average operating level of approximately 1.5 feet is achieved. This initial water level will be maintained during the first full year to ensure that bank erosion due to wave wash does not occur prior to emergent vegetation establishment. Water will then slowly be added over the following late winter and early spring, again from District drainage, to increase the average operating level to approximately 2.0 feet, which will be the optimal average operating water level.

Maintenance of water levels throughout the year will require only minimal water withdraws from the San Joaquin River to balance evapotranspiration. Summertime flow rates during the hottest times of the year may require daily application flows of approximately 5000 - 7000 gpm, while winter time flows will require minimal if any water application.

GHG Data Collection and Modeling Protocols will be implemented by UCB, whom shall provide analytical services for the following:

A. Carbon Dioxide, Methane, Nitrous Oxide, Water Vapor, and Energy Exchange Measurement and Modeling
    1. Measurement of CO_2, CH_4, N_2O, water vapor, and energy exchange will be measured at a variety of sites determined by DWR staff, sampled on a quasi-continuous basis. Fluxes of greenhouse gases will be produced on an hourly basis and summed to produce daily and annual fluxes. Copies of validated data and analysis provided by UCB will be transmitted to DWR on a bi-annual basis.
    2. Construct and operate automated chambers and eddy covariance flux measurement systems that continually collect samples and are based on cavity ring down spectroscopy (chambers) and open-path, non-dispersive infrared spectrometer, open-path CH_4 sensor (eddy flux), and other components of active flux towers by UCB.
    3. Modeling will be conducted by UCB using a data-model assimilation approach and will be closely coordinated with efforts proposed by the Delta Conservancy/The Nature Conservancy GHG Inventory.

Analytical services to be provided by:
University of California, Berkeley
Prof. Dennis D. Baldocchi, PhD and Prof. Whendee Silver
Ecosystem Science Division
Department of Environmental Science, Policy and Management

Baseline eddy covariance greenhouse gas fluxes (CO_2 and CH_4) will be measured over several existing drained, peatland sites as listed below. Additionally, Whendee Silver's lab will make surface flux CO_2, CH_4, and N_2O measurements at 3 selected sites in the Delta.

Figure 1 shows the location of active and proposed flux towers and Table 1 lists the locations and attributes of sites where we propose to measure the fluxes of a suite of greenhouse gases.

Site description	Location	GHGs measured
Baseline 1: Pasture	Sherman or Twitchell	CO_2, H_2O, N_2O, & CH_4
Baseline 2: corn	Sherman or Twitchell	CO_2, H_2O, N_2O, & CH_4
Baseline 3: Alfalfa	Twitchell Island	CO_2, H_2O, N_2O, & CH_4
Baseline 4: Alfalfa/Pasture	TBD	CO_2, H_2O, N_2O, & CH_4
Baseline 5: Corn	TBD	CO_2, H_2O, N_2O, & CH_4
Treatment 1: 5-year restored wetland	Sherman Island: Mayberry Slough	CO_2, H_2O, CH_4
Treatment 2: 17-year restored wetland	Twitchell Island	CO_2, H_2O, CH_4
Treatment 3: 1- year restored wetland	Twitchell	CO_2, H_2O, CH_4
Treatment 4: rice paddy	Twitchell Island	CO_2, H_2O, CH_4

Table 1. The land-use types measured in this study include 'status-quo' baseline characterization of typical drained land-uses as well as a range of flooded ecosystem treatments.

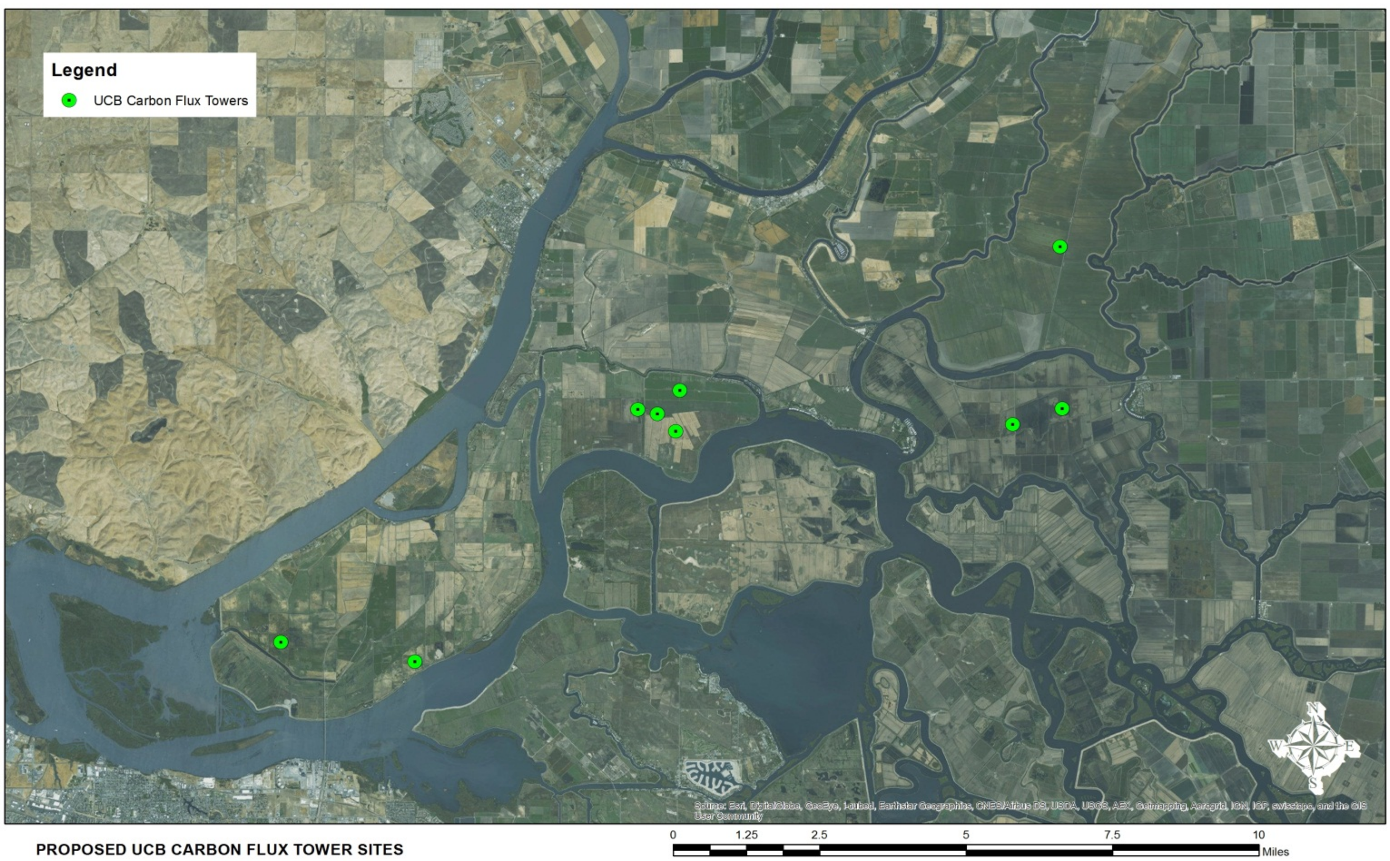


Figure 1 Current and proposed Location of eddy flux towers in the Sacramento-San Joaquin Delta.

The climate of the Delta region is Mediterranean, with wet cool winters and dry hot summers; mean annual rainfall is 325 mm and mean annual air temperature is 15.6 C. Predominant winds come from the west as they are channeled through the Carquinez Straight and flow into the Great Central Valley.

Carbon dioxide, water vapor and energy exchange will be measured at the baseline peatland pasture and corn field sites, which contain well-drained, aerobic soils that are not CH_4 sources. The restored and created wetland treatment sites are anaerobic, so we will measure CH_4 fluxes at those sites in addition to CO_2, water vapor and energy exchange. Surface flux measurements will be measured from the upland sites.

Trace gases will be measured using automated chambers plumbed to a cavity ring down spectrophotometer (Picarro G2508, Picarro Instruments, Santa Clara, CA). This instrument measures CO_2, N_2O, and CH_4 concentrations using a Telecom, near-Infrared (NIR) laser to quantify spectral features of gas phase molecules in an optical cavity. This approach yields high precision and sensitivity with a small footprint. Published precision for N_2O is < 10 ppb+/- 0.05 %, < 7 ppb +/- 0.05 % for CH_4, and < 300 ppb +/- 0.05 % for CO_2 with little or no interference among these gases. We will deploy 9 chambers per laser and supplement with static flux chambers if necessary to cover as much of the spatial heterogeneity as possible.

For the eddy flux system, CO_2 and water vapor concentrations will be measured with an open-path, non-dispersive infrared spectrometer (LI-7500a, LI-COR Biogeosciences, Lincoln NE USA). The path length of the sensor is 12.5 cm and it consumes 12 Watts during operation. The sensor noise at 10 Hz is 0.11 □mol mol^{-1} for CO_2 and it is 0.0047 mmol mol^{-1} for H_2O.

Methane concentrations will be measured with an open-path CH_4 sensor, based on wavelength modulation spectroscopy (LI-7700, LI-COR Biogeosciences, Lincoln NE USA). The laser beam traverses a 0.5 m physical path 60 times, for a total path of 30 m. The sensor has a nominal power consumption of 8 Watts. Sensor noise at 10 Hz is 5 ppb. Minimal detectable flux densities for water vapor, CO_2 and CH_4 are 0.035 mmol m^{-2} s^{-1}, 0.31 □mol m^{-2} s^{-1} and 3.78 nmol m^{-2} s^{-1} , respectively at a 95% confidence interval [*M. Detto et al.*, 2011]. The low power consumption of the gas analyzers used in this study will permit the sites to be entirely run from solar panels, eliminating the need for electrical generators.

We will sample the air at a height of 3 m above the drained peatland pasture, restored wetland and the rice paddy. A taller tower, up to 5 m, will be needed to sample air above the corn canopy and mature wetland.

Field calibrations will be performed on a regular interval (monthly) using a primary standard gas that was traceable to the NOAA ESRL laboratory in Boulder Colorado. A suite of meteorological variables will be measured in conjunction with the greenhouse gases. Mean wind velocity, turbulence vectors and virtual temperature fluctuations will be measured with a three-dimensional sonic anemometer (Gill Windmaster Pro). Air temperature and humidity will be measured with an aspirated and shielded thermistor and capacitance sensor (Vaisala HMP 45, Helsinki, Finland). Soil temperature will be measured with a profile of copper-constantan thermocouples. Soil moisture will be measured with a network of capacitance (ML2, Theta Probe, Delta-T Devices, Cambridge, UK) and time domain reflectometer sensors (Moisture point PRB-K probes, Environmental Sensors Inc., Sydney, BC, Canada). Soil O_2 sensors (SO 110, Apogee Instruments, Logan Utah) will be installed in surface soils (0-10 cm). Water table will be measured with a pressure sensor (PDCR 1830-8388, Druck Pressure Transducer, Campbell Scientific, Logan, UT) immersed in a well, next to each meteorological tower.

The greenhouse gas sensors will be integrated into an eddy covariance system to measure constituent fluxes [*Baldocchi*, 2003; *Detto et al.*, 2010; *M. Detto et al.*, 2011]. The instruments used to make eddy covariance flux measurements will be polled 10 times per second and 30 minute averages will be produced. Flux densities ($F_\chi = \overline{\rho_a}\ \overline{w'\chi'_{c,nat}}$) will be computed in terms of the covariance between vertical wind velocity (w) and mixing ratio (χ_c) fluctuations, times the density in dry air (ρ_a). These covariances will be corrected for density fluctuations due to water vapor (χ_q) using the methods of Webb et al [1980]. and Detto and Katul [2007]. We will also correct the covariances for time lags in the transport of air through the separation of the anemometer and spectrometer and spectral attenuation caused by the sampling volume.

We will subject the flux time series to a number of quality assurance checks [*Aubinet et al.*, 2000; *Foken and Wichura*, 1996]. First, we will filter and exclude data when the sensors are not working, if rain blocked the transmission of sound on the sonic anemometers or if the concentrations are below ambient background conditions or off scale. Greenhouse gas fluxes will be integrated over daily and annual time scales by applying well-vetted gap filling techniques [*Falge et al.*, 2001; *Papale et al.*, 2006].

To monitor field phenology and the presence or absence of cows at the pasture, we will install digital cameras at each site and point them towards the west, the prevailing wind direction [*Sonnentag et al.*, 2011]. The presence or absence of cows within the vicinity of the meteorological tower at the peatland pasture will be determined from the digital images through object-oriented image analysis.

We will monitor the seasonal evolution of leaf area index at each site with a variety of methods. We will make direct measurements of leaf area index by destructively sampling a known area of plants and measuring the area of leaf matter in a leaf area meter (Licor LI-3100C). We will also make indirect measurements of leaf area index, optically, with a LI-2000 or with digital cameras using GreenCropTracker software (http://www.flintbox.com/public/project/5470/).

At the wetland site, we will assess fluxes for different wind directions using remote sensing information, flux footprint models and state of art upscaling methods [*Chasmer et al.*, 2011; *Forbrich et al.*, 2011; *Hsieh et al.*, 2000].

To determine accretion of carbon in soils we will sample soil bulk density, texture, carbon content and nitrogen content at the beginning and end of the experimental period. Nitrogen mineralization will be measured during the growing season at each site. To evaluate the leakage of carbon from the wetland we will measure dissolved organic carbon content (DOC) of the water entering and leaving the wetland on a weekly to bi-weekly basis. Water chemistry will be analyzed on a Shimadzu TOC 5050a total organic carbon analyzer housed in Silver Lab at UC Berkeley.

Portable static chambers will be used to sample N_2O, CO_2 and CH_4 fluxes following the procedure of Teh et al. [2011b]. A set of static chamber flux measurements will be made on a monthly basis by enclosing a 0.05 m^2 area with an opaque, 2-component vented chamber for 30 minutes; headspace samples will be collected using a gas-tight syringe at 5 time points.

Gas samples will be stored in pre-evacuated 10 ml glass bottles sealed with Geo-Microbial Technologies septa (Geo-Microbial Technologies Inc., Ochelata, Oklahoma, USA), and analysed for CH_4, CO_2, and N_2O using a Shimadzu GC-14A gas chromatograph (Shimadzu Scientific Inc., Columbia, Maryland, USA), equipped with a Porapak-Q column, flame ionisation detector (FID), thermal conductivity detector (TCD), and electron capture detector (ECD). The global warming potential for CH_4 and N_2O will be converted to CO_2 equivalents by multiplying CH_4 and N_2O fluxes by 25 and 298, respectively; these scaling factors represent the global warming potential for CH_4 and N_2O over a 100 year time horizon.

Chamber-based CH_4, CO_2 and N_2O fluxes will be calculated by applying a linear least squares regression to the chamber headspace concentration of each gas plotted against time ($P<0.05$). Diffusion is assumed to be the dominant physical transport pathway in chambers showing a linear change in concentrations over time, and fluxes calculated using a linear least squares approach ($P<0.05$).

Multiple modeling strategies will be employed to predict greenhouse gas fluxes across diverse soil and land use types in the Delta. We have parameterized and validated a process-based model to predict CO_2 and CH_4 exchange in a mature restored wetland using a data-model assimilation approach. This model will be expanded to accommodate young and heterogeneous wetlands where open water and patches of vegetation strongly influence greenhouse gas production and exchange. N_2O emissions are known to be negligible in wetlands and are therefore conservatively excluded from wetland greenhouse gas model predictions.

In order to predict greenhouse gas exchange in drained peatland systems, we will use the soil subsidence Deverel model (Deverel and Leighton, 2010). This model which is proposed to be refined and recalibrated within the Delta Conservancy/The Nature Conservancy proposal (this solicitation) will be used to help guide baseline GHG measurements. We also plan to adapt and validate additional process-based models for the prediction of CH_4 and N_2O emissions from drained peatland systems including the Dual Arrhenius Michaelis-Menten kinetics model (DAMM) [Davidson et al., 2012] and the Daily Century model (DAYCENT). We will collaborate with Steven Deverel and the efforts proposed within the Delta Conservancy/The Nature Conservancy proposal for this solicitation. Baseline and wetland/rice models will provide essential input the proposed Delta-wide GHG inventory tool and quantification of GHG benefits. All modeling approaches will employ data assimilation techniques that use continuous flux measurements to parameterize and assess uncertainty in model structure and model predictions. 90% confidence intervals will be provided for all modeled greenhouse gas emissions as required by voluntary and mandatory carbon markets.

6. *Deliverables:*

Upon completion of this Project in 2020, approximately 1700 acres of wetland and additional acreage of surrounding uplands habitat restoration will be constructed and fully operational. In addition, UCB/DWR and their partners will provide published and peer reviewed data to support calibrated models that will estimate typical Delta agriculture GHG emissions for CO2, CH4, and N20, as well as provide estimates for treatment crops including tule wetlands and rice. Specifically, UCB will provide DWR with the following deliverables, which will be shared among all partners (including DFW).

The acceptable reporting and method detection limits shall be according to the Environmental Protection Agency (EPA) methods or a mutually agreed upon acceptable alternative. UCB shall submit all reports and copies of data to the project manager for review and approval by June 30th and December 31st of each project year. The project manager shall approve or deny all deliverables in writing within 45 days of receipt.

A. UCB shall be responsible for all work to be performed under this agreement. All quality control, certification and any other requirements of UCB are applicable to the subcontracting laboratory.
B. UCB shall comply with and follow the contents of their Quality Assurance manual in performing the analyses of this agreement. Specifically, UCB will ensure the adequacy of the laboratory facilities and qualifications of the staff, adequate laboratory internal quality control and standard operating procedures are performed.
C. UCB shall participate in any external quality assurance checks on performance arranged or conducted by DWR. DWR reserves the right to check on the performance of UCB by submittal of performance evaluation samples.
D. UCB shall be responsible for the collection and delivery of all samples for laboratory analysis. All samples will be labeled with identifying code and a chain of custody listing the analyses to be performed as required by UCB. UCB shall notify the DWR contact person and send the samples within the prescribed holding times unless other alternative arrangements have been made to the locations described under the Scope of Work.
E. Analytical results will be mailed or delivered to DWR electronically in Excel spreadsheet format showing the sample identification number, date of sample collection, and date of analysis. Discussion of analytical results and data package verifying method and Quality Control (QC) performance shall be provided in Word format. All Data analysis turnaround time for the sample data packages is not to exceed 90 days.

Dennis Baldocchi is principal investigator of this project. He will supervise and assist in data acquisition, processing, analysis and report writing. Joe Verfaillie is the laboratory technician. He will be responsible for installing and maintaining the eddy flux instruments, calibrating the sensors and writing programs to control the data loggers. Whendee Silver is the co-principal investigator and will supervise and assist in data acquisition, processing, and analysis of the surface flux measurements. We will hire a field technician for this project to assist with the quasi-continuous chamber measurements. We will hire two new postdocs to assist in the management, data collection, data processing and interpretation of data from the new field sites. A technician, postdoc and grad student are currently being deployed to service and maintain the other 6 sites in the delta. We also aim to add another graduate student to the project during the fall of 2015. A research scientist will also be hired to develop and test greenhouse gas models and integrate publically available model products into greenhouse gas protocols.

To ensure that the data are processed and inspected for quality on a regular manner, we plan to hire a postdoctoral scientist with expertise in wetland ecosystems. This junior scientist and graduate students will also be responsible for performing routine calculations of eddy fluxes from the sites, as well as collecting plant, soil and water metadata on a regular basis that will be used to interpret the flux data in addition to weather and climate data.

We will produce seasonal or annual sums of greenhouse gas fluxes from each of the treatments, with sampling and measurement uncertainties. We will use this information to inform and refine models and carbon sequestration protocols of wetland restoration for the state of California. This work will be conducted in conjunction with the research scientist/modeler. It is our hope that carbon sequestration credits that will be associated with wetlands can be used to offset carbon emissions via cap and trade activities, and meet the legislated goals of AB 32 to reduce greenhouse gas emissions from the state. We will also use our data to guide the design and development of future wetland restoration projects in the Delta. Data will be used to gauge the depth of water, salinity content and plant density and areal extent that maximize levels of carbon uptake and minimize levels of CH_4 production. Finally, these data will also contribute hourly flux and meteorological data to the national AmeriFlux and international FLUXNET databases.

7. ***Expected quantitative results (project summary):***
As described in various sections of this document, DWR has contracted with the UCB, over the last 4 years, to measure GHG (both CO_2 and CH_4) fluxes on Sherman and Twitchell Islands. One of the sites monitored includes the eastern portion of Phase 1. Data collected has shown GHG emissions between 5.7 and 6.6 tons CO_2-eq per acre per year at this site. Additionally, data collected at a mature wetland site on Twitchell Island over the past 3 years shows a GHG sequestration (CO_2 and CH_4 fluxes) between 5.21 and 4.18 tons CO_2-eq per acre per year, resulting in a probable GHG net sequestration of approximately 11.5 tons CO_2-eq per acre per year, once the wetland is mature (4 to 5 years old). Please note that these are metric tons per acre and these numbers do not include N_2O; however, N_2O will likely increase the GHG sequestration rates. Additionally, DWR and UCB are measuring baseline emissions on both corn and alfalfa fields located on Twitchell Island, as well as fluxes on rice and newly constructed wetland on both Sherman and Twtichell Islands (Mayberry Farms and Twitchell East End Project). This project will build upon the CO2 and CH4 data sets, as well as help develop N2O data sets for both baseline and treatment regimes.

Data accumulated by the above efforts have been used to begin developing and calibrating a mathematical model to help analyze and predict expected GHG sequestration rates in wetlands. Currently, the predictive model is matching up well with the data set for the mature wetland and in the coming year we will begin to apply model development techniques to both newly created wetlands as well as baseline crops. This project will help to further calibrate the predictive models developed by UCB and DWR.

Ultimately, this Project will yield more than 1700 acres of restored wetlands and surrounding habitat, and sequester approximately 20,000 metric tons CO_2-eq per year. Additionally, this project will develop a template for projects throughout the delta to use when converting agricultural lands to wetlands for participation in the Cap and Trade programs. In addition to GHG data and models, data containing habitat benefits, as well as subsidence reversal rates, will also be provided.

8. ***Literature Cited:***

a. Aubinet, M., et al. (2000), Estimates of the annual net carbon and water exchange of Europeran forests: the EUROFLUX methodology, *Advances in Ecological Research*, *30*, 113-175.

b. Baldocchi, D. D. (2003), Assessing the eddy covariance technique for evaluating carbon dioxide exchange rates of ecosystems:past, present and future., *Global Change Biol*, *9*, 479-492.

c. Baldocchi, D. D., M. Detto, O. Sonnentag, J. Verfaillie, Y. A. Teh, W. Silver, and N. M. Kelly (2012), The challenges of measuring methane fluxes and concentrations over a peatland pasture, *Agricultural and Forest Meteorology*, *153*, 177-187.

d. BlueRibbonTaskForce (2008), Our Vision of the California Delta*Rep.*

e. Brinson, M. M., A. E. Lugo, and S. Brown (1981), Primary Productivity, Decomposition and Consumer Activity in Fresh-Water Wetlands, *Annual Review of Ecology and Systematics*, *12*, 123-161.

f. Chasmer, L., N. Kljun, C. Hopkinson, S. Brown, T. Milne, K. Giroux, A. Barr, K. Devito, I. Creed, and R. Petrone (2011), Characterizing vegetation structural and topographic characteristics sampled by eddy covariance within two mature aspen stands using lidar and a flux footprint model: Scaling to MODIS, *J. Geophys. Res.*, *116*(G2), G02026.

g. Crooks, S., M. Orr, and D. Brew (2009), Greenhouse Gas Mitigation Typology Issues Paper

h. Tidal Wetlands Restoration*Rep. PWA REF. 1957*, 64 pp, Philip Williams & Associates, Ltd.

i. for California Climate Action Registry, San Francisco.

j. Davidson, E. A., S. Samanta, S. S. Caramori, and K. Savage (2012), The Dual Arrhenius and Michaelis–Menten kinetics model for decomposition of soil organic matter at hourly to seasonal time scales, *Global Change Biology*, *18*(1), 371-384.

k. Detto, M., and G. G. Katul (2007), Simplified expressions for adjusting higher-order turbulent statistics obtained from open path gas analyzers, *Boundary-Layer Meteorology*, *122*(1), 205-216.

l. Detto, M., D. Baldocchi, and G. G. Katul (2010), Scaling Properties of Biologically Active Scalar Concentration Fluctuations in the Atmospheric Surface Layer over a Managed Peatland, *Boundary-Layer Meteorology*, *136*(3), 407-430.

m. Detto, M., D. Baldocchi, F. Anderson, J. Verfaillie, and L. Xu (2011), Comparing laser-based open- and closed-path gas analyzers to measure methane fluxes using the eddy covariance method., *Agricultural and Forest Meteorology*, *submitted*.

n. Detto, M., J. Verfaillie, F. Anderson, L. Xu, and D. Baldocchi (2011), Comparing laser-based open- and closed-path gas analyzers to measure methane fluxes using the eddy covariance method, *Agricultural and Forest Meteorology*, *In Press, Corrected Proof*.

o. Deverel, S. J., and S. Rojstaczer (1996), Subsidence of agricultural lands in the Sacramento-San Joaquin Delta, California, role of aqueous and carbon fluxes, *Water Resour. Res.*, *32*, 2359-2367.

p. Deverel, S. J., and D. A. Leighton (2010), Historic, Recent, and Future Subsidence, Sacramento-San Joaquin Delta, California, USA, *San Francisco Estuary and Watershed Science*, *8*(2).

q. Drexler, J. Z., C. S. de Fontaine, and S. J. Deverel (2009), The Legacy of Wetland Drainage on the Remaining Peat in the Sacramento San Joaquin Delta, California, USA, *Wetlands*, *29*(1), 372-386.
r. Falge, E., et al. (2001), Gap filling strategies for defensible annual sums of net ecosystem exchange, *Agricultural and Forest Meteorology*, *107*, 43-69.
s. Firestone, M., E. Davidson, M. Andreae, and D. Schimel (1989), Microbiological basis of NO and N2O production and consumption in soil, *Exchange of trace gases between terrestrial ecosystems and the atmosphere.*, 7-21.
t. Foken, T., and B. Wichura (1996), Tools for quality assessment of surface-based flux measurements, *Agricultural and Forest Meteorology*, *78*(1-2), 83-105.
u. Forbrich, I., L. Kutzbach, C. Wille, T. Becker, J. Wu, and M. Wilmking (2011), Cross-evaluation of measurements of peatland methane emissions on microform and ecosystem scales using high-resolution landcover classification and source weight modelling, *Agricultural and Forest Meteorology*, *151*(7), 864-874.
v. Hatala, J. A., M. Detto, O. Sonnentag, S. J. Deverel, J. Verfaillie, and D. D. Baldocchi (2012a), Greenhouse gas (CO2, CH4, H2O) fluxes from drained and flooded agricultural peatlands in the Sacramento-San Joaquin Delta, *Agriculture, Ecosystems & Environment*, *150*(0), 1-18.
w. Hatala, J. A., M. Detto, O. Sonnentag, S. J. Deverel, J. Verfaillie, and D. D. Baldocchi (2012b), Greenhouse gas (CO2, CH4, H2O) fluxes from drained and flooded agricultural peatlands in the Sacramento-San Joaquin Delta, *Agriculture, Ecosystems & Environment*, *150*, 1-18.
x. Hsieh, C. I., G. Katul, and T. Chi (2000), An approximate analytical model for footprint estimation of scaler fluxes in thermally stratified atmospheric flows, *Advances in Water Resources*, *23*(7), 765-772.
y. Knox, S. H., C. Sturtevant, J. H. Matthes, L. Koteen, J. Verfaillie, and D. Baldocchi (2014), Agricultural peatland restoration: effects of land-use change on greenhouse gas (CO2 and CH4) fluxes in the Sacramento-San Joaquin Delta, *Global Change Biology*, n/a-n/a.
z. Miller, L. G., R. M. Kalin, S. E. McCauley, J. T. G. Hamilton, D. B. Harper, D. B. Millet, R. S. Oremland, and A. H. Goldstein (2001), Large carbon isotope fractionation associated with oxidation of methyl halides by methylotrophic bacteria, *Proc. Natl. Acad. Sci. U. S. A.*, *98*(10), 5833-5837.
aa. Miller, R. L., L. Hastings, and R. Fujii (2000), Hydrological treatments affect gaseous carbon losses from organic soils, Twitchell Island, California, October, 1995-December, 1997.*Rep. 00-4042*, U.S. Geological Survey.
bb. Miller, R. L., M. Fram, R. Fujii, and G. Wheeler (2008), Subsidence reversal in a re-established wetland in the Sacramento-San Joaquin Delta, CA, USA, *San Francisco Estuary and Watershed Science*, *6*.
cc. Mount, J., and R. Twiss (2005), Subsidence, seal level rise and seismicity in the Sacramento-San Joaquin Delta, *San Francisco Estuary and Watershed Science*, *3*.
dd. Papale, D., et al. (2006), Towards a standardized processing of Net Ecosystem Exchange measured with eddy covariance technique: algorithms and uncertainty estimation, *Biogeosciences*, *3*(4), 571-583.
ee. Simenstad, C., J. Toft, H. Higgins, J. Cordell, M. Orr, P. Williams, L. Grimaldo, Z. Hymanson, and D. Reed (2000), Sacramento/San Joaquin Delta Breached Levee Wetland Study*Rep.*, University of Washington, Seattle.
ff. Sonnentag, O., D. M, V. R, R. Y, R. BRK, K. M, and B. DD (2011), Tracking the structural and functional development of a perennial pepperweed (Lepidium

latifolium L.) infestation using a multi-year archive of webcam imagery and eddy covariance measurements, *Agricultural & Forest Meteorology*, *in press*.

gg. Stehfest, E., and L. Bouwman (2006), N2O and NO emission from agricultural fields and soils under natural vegetation: summarizing available measurement data and modeling of global annual emissions, *Nutrient Cycling in Agroecosystems*, *74*(3), 207-228.

hh. Teh, Y., W. Silver, O. Sonnentag, M. Detto, M. Kelly, and D. Baldocchi (2011a), Large Greenhouse Gas Emissions from a Temperate Peatland Pasture, *Ecosystems*, *14*(2), 311-325.

ii. Teh, Y., W. Silver, O. Sonnentag, M. Detto, M. Kelly, and D. Baldocchi (2011b), Large Greenhouse Gas Emissions from a Temperate Peatland Pasture, *Ecosystems*, *14*, 311-325.

jj. Wagner-Riddle, C., G. Thurtell, G. Kidd, E. Beauchamp, and R. Sweetman (1997), Estimates of nitrous oxide emissions from agricultural fields over 28 months, *Canadian Journal of Soil Science*, *77*(2), 135-144.

kk. Webb, E. K., G. I. Pearman, and R. Leuning (1980), Correction of Flux Measurements for Density Effects Due to Heat and Water-Vapor Transfer, *Q. J. R. Meteorol. Soc.*, *106*(447), 85-100.

ll. Zhao, C., A. E. Andrews, L. Bianco, J. Eluszkiewicz, A. Hirsch, C. MacDonald, T. Nehrkorn, and M. L. Fischer (2009), Atmospheric Inverse Estimates of Methane Emissions from Central California,, *Journal of Geophysical Research, Atmospheres*, *doi:10.1029/2008JD011671.*