## *Section 5: Project Description*

**1. *Project Objectives:***

The goal of the project is to restore and enhance wetlands in Martis Valley, an important Sierra Nevada Meadow. We have separated objectives into those related to Greenhouse Gas reduction, research, and co-benefits.

**Greenhouse Gas (GHG) Reduction Objectives.** Through completing restoration, GHG emissions are predicted to be reduced from the project area. Specific objectives include:

- Increase carbon storage in up to 37 acres of degraded wet meadow and 2 acres of riparian habitat through improving plant vigor;
- Increase soil organic content in up to 37 acres of degraded wet meadow and 2 acres of riparian habitat through extending the active plant growth season;
- Participate in Sierra Meadow Restoration Research Partnership, a Sierra-wide research project to assess effectiveness of restoration on GHG reduction.

**Research Objectives.** The overarching research objective of this project is to support development of methods for estimating net carbon (and CO2-equivalent) sequestration under pre- and post-restoration conditions for mountain meadows. The framework and methods employed in this project will be aligned with those proposed by other meadow restoration projects that represent a wide range of meadow conditions throughout the Sierra Nevada under the Sierra Meadow Restoration Research Partnership (SMRRP). Specific research objectives include:

- Determine potential contribution of GHG emissions to the overall carbon budget for project meadow and other meadows of same hydrogeomorphic type, geographic areas (climate, growing season), and parent material represented by this project area by measuring changes in soil carbon and peak GHG emissions under un-restored and restored conditions;
- Support development of parameters and proxy variables that will be used to build a model to estimate meadow carbon sequestration and GHG emissions by measuring soil organic carbon and GHG emissions along gradients expected to control GHG flux, such as depth and duration of saturation, soil texture and carbon content, plant community type, and length of growing season

**Co-Benefit Objectives.** Restoring function will improve meadow habitat, fish and wildlife habitat, and provide other co-benefits. Project objectives related to co-benefits include:

- Restore up to 10 acres of historic wetland and enhance 27 acres of existing wetlands;
- Restore one mile of historic intermittent channel;
- Improve fish passage/fish habitat in one mile of existing stream channel and restore associated 2 acres of riparian wetland;
- Eliminate damaging peak flows, improve late season base flow;
- Increase water storage in a degraded meadow system;
- Eliminate in-channel erosion;
- Improve avian habitat;
- Ameliorate impacts of climate change through reducing flooding caused by rain on snow events

## 2. ***Background and Conceptual Models:***

### Background

Prior to the construction of Brockway road (now Highway 267) in the 1800's, Middle Martis Creek formed an alluvial fan as it entered Martis Valley. The creek would have actively migrated among several stream channels on the fan. When the road was constructed, the creek was confined to a single channel, now on the south side of the highway (Figure 1). The confinement of Middle Martis Creek to a single channel has caused several significant problems including:

- Channel instability, erosion, and headcutting;
- Degradation of historic wetlands and riparian habitat;
- Water quality impacts from increased erosion;
- Even in moderate flows, flooding of Highway 267 and severe erosion of access roads and recreational trails.

The degradation caused by confinement of Middle Martis Creek is substantial and impacts properties owned by several different entities (Figure 2). TRWC completed a watershed assessment for the entire Martis Creek watershed (Balance Hydrologics, 2012), which included a stakeholder process. The Middle Martis project was identified in the assessment as a restoration opportunity. Prior to the assessment, individual property owners in the project area were developing plans to address degradation independent of one another. This piecemeal approach was unlikely to lead to sustainable solutions since the root cause of the impacts was not being addressed. The property owners agreed to work together on additional project feasibility analysis, project design, and implementation. The project stakeholders include the following organizations:

- Caltrans
- Northstar Community Services District
- Northstar Mountain Resort
- Truckee Donner Land Trust
- Truckee River Watershed Council
- Truckee Tahoe Airport District
- U.S. Army Corps of Engineers

**Existing Conditions**

Aquatic habitat surveys conducted in 2014 documented headcuts in the existing channel of Middle Martis Creek and extensive fine sediment deposition (Figure 2). No fish were observed in Middle Martis Creek through the project reach; however fish were present in the mainstem of Martis Creek at the confluence. The aquatic surveys were conducted as part of a Sierra-wide meadow study led by American Rivers. Raw data are available from TRWC and the report will be finalized in early 2015.

TRWC implemented a hydrologic monitoring program in 2013 (Balance Hydrologics, 2013). Data from shallow groundwater wells located through the project area show that groundwater levels drop fairly quickly in the spring. During the growing season, the groundwater level is below the rooting zone of plants in most of the project area. Figure 3 shows the locations of the wells and Figure 4 shows groundwater data from Water Year 2013.

We established vegetation transects throughout the project area in several different habitat types (Figure 5; Dudek, 2014). We also completed a wetland delineation (Figure 6; Dudek 2013). The meadow area to be restored on the north side of the project area ("wet meadow" habitat - Figure 6) is presently dominated by plants with a "Facultative Wetland" status (FACW) with limited amounts of plants with "Obligate" status – approximately 10% of all plant species.
Avian surveys show that bird species richness is lower in the area to be restored as compared to existing riparian zones upstream of the project area along Middle Martis Creek (TINS,

2014).

**Conceptual model – Greenhouse Gas Reduction**

We have developed a narrative conceptual model for how restoration is linked to reducing GHG emissions.

The distribution of vegetation types in mountain meadows reflects seasonal differences in ground water levels and litter decomposition (Allen-Diaz 1991, Merrill et al. 2006, Loheide and Gorelick 2007). Thus, hydrologically degraded Sierra meadows experience a radical change in plant community type distribution and overall plant biomass after restoration. In many cases, sparse cover of sagebrush, annual grasses, and forbs is replaced with dense thatch of sedge and willow species with similarly dense rooting structures (Chambers and Miller 2004, Lindquist and Wilcox 2000). In restored wet or very moist meadows, this change in meadow plant community structure co-occurs with an increase in net primary productivity and a decrease in aerobic decomposition rates of fine roots and above ground litter. These two changes (high NPP rates and slow decomposition) result in increased soil organic matter content representing carbon sequestration. Preliminary measurements of soil carbon in restored versus unrestored meadows in the Feather River watershed show that restoring meadows could provide a one-time increase in below ground C stores by 110 to 220 CO2-equivalent tons per acre over a 2 to 10 year post-restoration period (Wilcox et al. unpublished project results 2009). During the initial post-restoration years, these C sequestration numbers are very large and comparable to estimated rates of CO2equivalent sequestration reported for Delta fresh water wetlands and redwood forests (Miller et al. 2008, Miller et al. 2011, Knox et al. 2014).

Despite a paucity of existing data, the limited knowledge we have in these restored ecosystems is highly encouraging from a C-sequestration perspective. However, the net change in greenhouse gas (GHG) emissions from mountain meadows that occurs with restoration needs to be expanded to include fluxes of the greenhouse gases methane and nitrous oxide as well as soil carbon and carbon dioxide. The common unit, CO2-equivalents, is used to combine the radiative forcing effects of all greenhouse gases into a single value for any source, such as a wetland, forest, or manufacturing plant. Thus, net CO2-equivalents sequestered from a meadow take into account carbon dioxide uptake through photosynthesis and release to the atmosphere through respiration, as well as methane and nitrous oxide uptake and release to atmosphere. Net methane and nitrous oxide emissions from soils and sediment are critical because these gases, known to be important parts of the GHG budgets in other wetland types, have 25 and 298 times the radiative forcing of carbon dioxide, respectively, per mole of gas (over a 100-yr time horizon; Forster and others 2007).

Unfortunately, the few studies that measured methane and nitrous oxide emissions from meadows covered only a narrow range of meadow types (Mosier et al. 1993, Blankinship and Hart 2014). In addition to being a potent greenhouse gas, nitrous oxide has other impacts on the biosphere: it is known to degrade ozone, but it also removes nitrogen from streams and standing water where this limiting nutrient can reach such high levels it becomes a pollutant.
In soils and sediments, nitrous oxide emissions typically occur as a result of two processes: nitrification and denitrification.

Nitrification is an aerobic, oxidative process that converts ammonium to nitrate. Nitrous oxide is produced by nitrification during the incomplete oxidation of ammonium to nitrate. On the other hand, denitrification is a reductive process, meaning it occurs in anaerobic environments by which nitrate is reduced to nitrous oxide and eventually to dinitrogen gas. The nitrous oxide produced by nitrification may be significant, but it is typically much less than the nitrous oxide produced in adjacent, anaerobic sites where denitrification is dominant. Thus, restoration from a very dry and well drained meadow to a moist and more productive meadow could introduce increased nitrification rates and associated nitrous oxide emissions. Areas of a hydrologically restored meadow where soil saturation remains high and organic matter is biologically available could support denitrification and associated nitrous oxide emissions. Similarly, in anaerobic conditions, decomposition of organic matter by soil microbes produces methane (methanogenesis). Therefore, with any increase in soil carbon accumulation due to restoration one must also carefully consider the production of methane and nitrous oxide to the environment. We do not mean to suggest that methane or nitrous oxide production are likely to cause restoration to be a net source of GHGs (measured in carbon dioxide equivalents to the atmosphere); however nitrous oxide and/or methane emissions could be a significant part of the overall GHG budget. Therefore the importance of their contribution needs to be determined and if needed, included in any predictive models used to assess carbon credits gained through mountain meadow restoration.

Through this research, we will test the hypothesis that: re-establishing the hydrological connectivity between the stream and the surrounding meadow will increase net carbon sequestration, taking into account net GHG emissions, compared to non-restored conditions. To test this over-arching hypothesis, we will measure net carbon sequestration in the Middle Martis project area under pre and post-restoration conditions and at the same time measure net carbon sequestration in a similar degraded and unrestored meadow, completing a before-after-control-impact experimental design. We will assume that the change in net carbon sequestration in the project area as compared to change in the unrestored meadow is due to restoration.

We will develop and apply the science to measure GHG (carbon, methane, and nitrous oxide) gains from restoration of Middle Martis Creek wetlands. The same protocol will be applied to partner meadow-restoration projects in 2015 across the Sierras, and to type-matched degraded control meadows to clearly demonstrate effects of restoration on net sequestration. Other meadows will be added in subsequent years to include a full range of meadow types. Peer reviewed findings will be shared at an annual conference, developing a protocol to measure GHG dynamics and quantify the impact of restoration strategies on GHG capture in Sierra meadows.

**Conceptual model – Project Success**

TRWC follows a conceptual model outlined in Figure 7 for all our large scale restoration projects. The basics steps are:

- Assessment
- Feasibility Study
- Pre-Project Monitoring
- Project Design and Environmental Compliance
- Implementation
- Post-Project Monitoring
- Adaptive Management

We place an emphasis on process-based restoration – by understanding the underlying hydrologic, geomorphic, and biological conditions, restoration projects are designed to complement existing processes and success is much more likely. The Middle Martis Restoration project is designed to mimic the alluvial fan function that was lost when Brockway road was constructed and the creek confined to a single thread channel. Following the steps in our model prevented a piecemeal approach to treating current conditions along Middle Martis Creek.

**Climate change considerations**

Building resiliency in mountain meadow systems will help to alleviate impacts of climate change. We expect to see more rain on snow events and higher snow levels in the Sierra Nevada, leading to more flooding. The Middle Martis Creek Wetlands Restoration project (Middle Martis project) directly addresses flooding impacts in addition to GHG emissions. At present, extreme high flows are confined to a single, undersized channel. When flooding occurs, flows jump out of the channel and cause additional erosion in the existing channel and the adjacent meadow, resulting in loss of meadow habitat.

Splitting high flows to the historic wetlands north of Highway 267 will eliminate impacts in the existing channel of Middle Martis Creek and prevent future wetland loss on the south side of the highway. The flows will be able to spread over a vast meadow area and infiltrate instead of being concentrated. This will restore and enhance a significant area of wet meadow on the north side of the highway.

**Linkages with other activities**

The Middle Martis project is included in the Sierra Meadows Restoration Research Project for analyzing greenhouse gas reductions. Other meadows included in the study are shown in Table 1. The data gained from this meadow will inform research and restoration activities throughout the Sierra Nevada.

The Middle Martis project is specifically referenced in several plans: The Martis Watershed Assessment (Balance Hydrologics 2012), the Martis Creek Lake and Dam Master Plan Update (U.S. Army Corps of Engineers, 2015), and Coordinated Watershed Management Strategy (TRWC 2010).

## 3. ***Detailed project description, including all tasks to be performed:***

### Project Tasks

The Middle Martis project consists of the following work tasks:

### 1.0 Greenhouse gas reduction research project

Participate in Sierra Meadow Restoration Research Project (SMRRP, described in more detail under the "Project Approach" and "Research Component" sections below). Two types of research protocols are involved in the SMRRP; Middle Martis will be included as a "state factor" meadow, which is subject to less intense monitoring. The two types of research protocol are described in more detail under "Research Approach".

The SMRRP will follow a "Before-After-Control-Impact" (BACI) study design; focus meadows will be sampled pre- and post-restoration (the "Before" and "After") and will be paired with a similar, degraded meadow (the "Control"), which will be sampled during the same time periods as the restoration focus meadow (the "Impact"). Measurements will begin in degraded control and restoration meadows prior to restoration in 2015, and continue at both sites throughout 2015 and into the spring of 2016. Although restoration activities, described under Task 3, will begin in fall 2015, changes in groundwater level and plant community composition are not expected to occur until the following spring and summer when the large influx of water from winter snow melt recharges local groundwater levels and occupies the restored channel.

Spring 2016 sampling will effectively represent “pre-project” conditions.

1.1 Identify control meadow and establish transects

Control meadows, with the same hydrogeomorphic class and in close proximity to the target restoration meadow, will be selected in the spring of 2015 for each restoration meadow. Three to four transects will be established across each meadow perpendicular to the dominant slope and to the degree possible, aligned with existing ground water well transects and positioned to capture the vegetation types covering the greatest surface area of the meadow.

1.2 GHG measurements

GHG fluxes will be measured by static chamber methodology (Hutchinson and Mosier 1981). Soil fluxes of carbon dioxide, methane, and nitrous oxide production will be measured as part of a complete soil GHG flux estimate. Ancillary data on ground water level, soil temperature, and water filled pore space will also be collected with the gas samples.

1.3 Soil carbon and biomass production analysis

Soil carbon and biomass samples will be collected along transects established across the meadow (Task 1.1). Samples will be analyzed at a lab for vegetative carbon, soil carbon, and nitrogen.

1.4 Incorporation of ancillary data

Hydrologic data (specifically shallow groundwater data) and vegetation data (Tasks 2.1 and 2.2) will be used to inform the results of the GHG measurements. Shallow groundwater wells (piezometers) and vegetation transects will be established in the control meadow to mimic transects already in place for the “impact” or restoration target meadow.

1.5 Data analysis and reporting

The data collected for the Middle Martis project will be reported after each collection season to the SMRRP team and reviewed by a Technical Advisory Committee formed through the SMRRP and led by CalTrout, a SMRRP participant.

**2.0 Pre-project monitoring**

Pre-project monitoring consists of several elements, only hydrologic monitoring and vegetation monitoring will take place under the DFW funded portion of the project. Pre-project monitoring results will be summarized in an annual monitoring memo, submitted by the end of 2015.

2.1 Pre-project Hydrologic Monitoring

A surface and groundwater level monitoring program was put in place for the Middle Martis project in March, 2013. The project area is outfitted with six shallow groundwater wells (piezometers) and a stream gage upstream of the project area (Figure 3). We will continue pre-project monitoring through 2015, and post-project monitoring through Water Year 2017 (at a minimum). Hydrologic data will be incorporated into Task 1 (GHG reduction research project) as noted in Task 1.4.

2.2 Pre-project vegetation monitoring

Six permanent vegetation transects have been established in the project area (Figure 5). We will repeat pre-project monitoring during the growing season of 2015. Vegetation data will be incorporated into Task 1 (GHG reduction research project) as noted in Task 1.4.

2.3 Pre-project photo-monitoring

We have established a series of photo-points throughout the project area. We will repeat pre-project photo-monitoring in 2015.

**3.0 Project Construction**

100% Design plans are completed for the Middle Martis project and are attached to this grant application (Attachment 1). Different project elements are described briefly below.

3.1 Modify culvert intake and stream channel at existing culvert

A plate will be bolted to the culvert intake to limit flows passing through the culvert (Att. 1, Sheets 3.3, 4.1). The remainder of the flow will be directed to the north side of the highway towards historic wetlands. The proposed modifications will allow a base flow of 3 cubic feet per second (cfs) to remain in the existing channel on the south side of the highway, with up to 15 cfs peak flows. The remaining flows will be diverted to the north side of the highway, rewatering up to 37 acres of existing and historic wetlands.

3.2 Construct new channel downstream of diversion

Immediately downstream of the diversion structure, we will construct a channel to ensure that flows are contained in the steeper upstream reach on the north side of the project site (Att. 1, Sheets 3.3, 4.5). A road – Martis Estates Access Road – crosses the channel. At present, periodic high flows spill out of the existing channel and erode the road. The road will be reconfigured with a culvert to pass approximately 10-year flows, and a low water crossing that will pass higher flows (Att. 1, Sheet 4.0).

3.3 Place flow dispersal logs in restored meadow area

Further downstream, flows will be encouraged to spread across the meadows where there is sufficient space for infiltration. Flow dispersal logs and buried rock weirs will be placed to help direct the water. The logs and weirs will be planted with willows, and over time the logs will decompose. The willows will then provide the flow direction needed (Att. 1, Sheet 3.4, 4.3).

3.4 Remove existing flow constrictions on north side of highway

An old railroad grade crosses the proposed new flow path on the north side of the highway. We will breach the grade in selected locations to allow flow to pass through (Att. 1, Sheet 3.4). Downstream, an access road bisects the flow paths (Waddle Ranch Access Road). The road will be redesigned to incorporate low flow crossings to eliminate ponding and erosion caused by the current road configuration (Att. 1, 3.7, 3.8, 4.1).

3.5 Create stable confluence with existing Martis Creek

Below the road crossing, on the north side of the highway, the restored Middle Martis channels reconnect with the Mainstem of Martis Creek. There is a series of headcuts in the Middle Martis Creek channel. These will be stabilized with boulder riffles and willows (Att. 1, Sheet 3.6, 4.4). Beaver activity is significant downstream of the project area – the riffles will be designed to allow for beaver dam development.

3.6 Restore headcuts in existing channel

On the south side of the project area in the existing stream channel, the majority of the work will take place in the upstream end near the culvert outflow. A series of log check dams, log headcut repairs, and constructed breakout channels will help to direct flows back towards the Middle Martis Creek channel (Att. 1, Sheets 3.1, 3.2, 4.2, 4.3).

3.7 Revegetation

All disturbed areas will be reseeded or planted with native plants. Sheets 5.0 – 5.6 of Attachment 1 contain the revegetation mixes and planting plan. Some revegetation work will be completed by volunteers on an annual work day in October, 2015.

**4.0 Post-project monitoring**

Post-project monitoring includes several elements. Results will be reported annually in a monitoring memo.

4.1 Post-project GHG emissions monitoring

The GHG and soil carbon measurements described under Task 1 will be repeated at both the “impact” meadow – Middle Martis, and the “control” meadow. Repeat sampling will take place in 2017.

4.2 Post-project hydrologic monitoring

We will install a stream gage in the newly created channel immediately after construction. We will continue to operate the stream gage upstream of the project site as well. We will continue to record groundwater level data from our piezometers.

4.3 Post-project vegetation monitoring

We will continue annual vegetation monitoring through the grant period to assess post-project vegetation response.

4.4 Post-project avian monitoring

We will repeat avian monitoring after project implementation. Pre-project avian monitoring consisted of seven point count stations in the project area and twenty-one stations adjacent to the project area. Point count surveys were conducted three times during the breeding season of 2013 and will be repeated in 2015 prior to construction.

4.5 Post-project aquatic habitat and fish population monitoring

Aquatic habitat data were collected in 2014. Electroshock surveys of the project reach will take place in 2015. We will repeat these surveys once after the project is implemented.

4.6 Post-project photo-monitoring

We will continue annual photo-monitoring of the project area after project implementation.

## 5.0 Adaptive management

We will monitor the site for stability after construction. If any problems arise, we will develop a plan for corrective actions and implement them. Corrective actions may include additional heavy equipment work or additional revegetation. Data collected during post-project monitoring will also inform adaptive management actions.

## 6.0 Stakeholder coordination and project management

The Middle Martis project includes several property owners and stakeholders. The stakeholder group has been actively involved in project design and will be involved through implementation and post-project monitoring. Stakeholder coordination includes regular quarterly meetings and supplemental meetings as needed.

Project administration consists of managing subcontractors, reviewing reports and data, participating in construction observation, invoicing, and preparing reports.

## Project approach and project objectives

The Sierra Meadow Restoration Research Partnership (SMRRP) works from the premise that re-establishing hydrological connectivity between the stream and surrounding meadow will increase plant biomass above and below ground, increase soil organic matter, and thereby improve soil capacity to sequester GHGs from the atmosphere.

The SMRRP leverages the considerable experience and expertise of academic and consulting scientists, practitioners and resource agencies to:

- Establish the scientific foundation for what drives variation in GHG emissions and net carbon sequestration across a range of Sierra meadow types;
- Standardize field sampling, lab methodologies, and data analysis procedures for GHG measurements;
- Develop a predictive model for net carbon sequestration in Sierra meadows and an associated quantification protocol.

The SMRRP also leverages a wide range of meadow types, locations, and conditions that will provide a ‘gold mine’ of information on the range of variability and associated controls on GHG emissions in the Sierras (Table 1). Information on GHG emissions and factors that control emissions from micro-site conditions to plant community scales will be collected at these sites and used to develop a predictive model for meadow carbon sequestration that is robust for the entire Sierra region. Finally and very importantly, through the process of implementing this project, the partnership will build regional and local capacity to monitor (and predict, using quantitative models) carbon sequestration and GHG emissions in meadows across the Sierras.

We have high confidence in the success of the Middle Martis project because the design comes from a watershed-process based background. We have put significant effort into project feasibility analysis (Balance Hydrologics, 2012b), hydraulic analysis (Balance Hydrologics, 2014), and project design (Attachment 1). Re-watering historic wetlands will result in increase plant vigor (and therefore increased GHG uptake), reduce flooding and erosion, and improve fish and wildlife habitat.

Our project implementation conceptual model allows us to specify project objectives through assessment and pre-project studies and then document whether or not our objectives were met through post-project monitoring. We have established baseline data for key parameters relating to expected project benefits.

**Research component**

Participation in the SMRRP. The SMRRP was formed to provide a robust and coordinated regional response to the historic opportunity that AB 32 presents. The SMRRP is composed of a wide variety of agencies, organizations, and academic institutions (listed below) and represents a potential research sample of approximately 20 Sierra meadows in 2015. The SMRRP will work together to advance our understanding of GHG dynamics in Sierra Nevada meadows and address the meadow restoration needs prioritized in the CA State Water Action Plan.

The SMRRP will leverage data from a wide range of member meadow types, locations, conditions, and predictive variables for a robust assessment of variability on GHG emissions in the Sierra Nevada. The SMRRP will provide members with peer reviewed and standardized field sampling protocols, lab methodologies, and data analysis procedures for GHG measurements, allowing for a comparative analysis of meadows across the Sierra Nevada.

To coordinate the efforts of the SMRRP, CalTrout will facilitate the quarterly meeting of a technical advisory committee (TAC) comprised of Consulting Scientists and SMRRP partners to coordinate projects, develop methodologies, integrate and analyze data, train regional practitioners in sampling procedures, and develop a predictive model to be submitted for approval by CAR, ACR and VCS.

SMRRP partners include: American Rivers, California Trout, Plumas Corporation, Sierra Foothill Conservancy, Spatial Informatics Group – Natural Assets Laboratory, South Yuba River Citizens League, Stillwater Sciences, Truckee River Watershed Council, University of Nevada at Reno, University of California at Merced, University of California at Davis, Tahoe National Forest, Sequoia National Forest, and others.

Research approach. The proposed research will address the basic question: How does restoration of mountain meadows alter carbon sequestration in these ecosystems? We will address this broad question by collecting two sets of data at complimentary temporal and spatial scales. The first data set will be applied to **state factor meadows**, and will address the question of how state factors (Jenny 1994), including climate (elevation and latitude), parent material, topography (slope and aspect), vegetation zone, and time since disturbance, affect carbon sequestration and GHG emissions. Effects of these state factors will be addressed by measuring GHG emissions and associated field characteristics at coarse temporal yet fine spatial scales in SMRRP meadows representative of the range meadows across the Sierra Nevada. The second data set will be collected in **focus meadows** in order to (a) build robust annual GHG emission budgets that will inform annual estimates for other sites, and (b) to characterize key fine-scale hydrologic, geomorphic, vegetative, and biogeochemical parameters that relate to soil GHG fluxes. Information gained from this two-pronged approach will be used in order to create an empirically based model that can accurately predict the effect of restoration on soil GHG fluxes and carbon sequestration in meadows throughout the Sierra Nevada. Data from the proposed project will be made available to the entire SMRRP team to support development of the predictive model for meadow carbon sequestration.

Data from the state factor and focus meadows will be combined to establish quantitative relationships between readily measured proxy variables and carbon sequestration and between proxy variables and GHG emissions in Sierra meadows. These relationships will be used to build a model that estimates carbon sequestration and GHG emissions from un-restored and restored meadows in different parts of the Sierra Nevada. This draft model will be validated using emissions and sequestration data collected at a subset (at least one meadow complex) of the state factor meadows that will not be included in the development of model parameters. The quantitative model will build into a proposed carbon credit protocol for meadow restoration through the SMRRP. CalTrout will work with the California Air Resources Board to certify the protocol once it is developed through the meadow restoration projects implemented by SMRRP members.

**Personnel**

The project director is Beth Christman. Beth is responsible for participating in the SMRRP greenhouse gas project, overseeing monitoring activities, completing project permitting, contractor selection, managing project implementation, and overseeing post-project monitoring.

Beth was the project lead for the Martis Watershed Assessment, Project Feasibility Study, and Project Design. She has also overseen all the monitoring activities for the project. Beth has extensive experience implementing restoration projects and working with stakeholder groups. Beth was the project lead at TRWC for the following restoration projects: Johnson Canyon, Coldstream Canyon Floodplain, Perazzo Meadows Restoration – Upper Meadow and Middle Meadow, and Merrill Davies Restoration (all phases).

Lisa Wallace is the Executive Director of TRWC. She will be responsible for contracting, financial oversight, and managerial oversight for all project tasks. Lisa has provided project oversight for all the restoration projects mentioned above.

Bonnie Riley is the bookkeeper for TRWC. She will manage project invoicing and bookkeeping.

Kathy Whitlow is the Office Manager for TRWC. She will assist with public outreach, including press releases, newsletter articles, and website updates for the project.

## 4. ***Timeline:***

| Project Task | Start Date | Completion Date |
|---|---|---|
| 1.0 Greenhouse Gas Reduction Research project | June 1, 2015 | June 1, 2018 |
| 2.0 Pre-Project Monitoring | June 1, 2015 | December 31, 2015 |
| 3.0 Implementation | August 15, 2015 | October 31, 2015 |
| 4.0 Post-project monitoring | October 1, 2015 | June 1, 2018 |
| 5.0 Adaptive Management | June 1, 2016 | June 1, 2018 |
| 6.0 Stakeholder Coordination/Project Management | June 1, 2015 | June 1, 2018 |

## 5. ***Deliverables:***

1.0. Final Report for Greenhouse Gas Reduction Research project

2.0 Pre-Project Monitoring Report

3.0 Construction documentation including pre-, during and post-construction photographs

4.0 Annual Post-Project Monitoring Reports

5.0 Photo-documentation of any adaptive management actions

6.0 Final Project Report

Any water quality data that can be accepted by CEDEN will be submitted to CEDEN.

Data and reports from this project and the SMRRP will be uploaded to the Sierra Meadows Data Clearing House (http://meadows.ucdavis.edu/), hosted at U.C. Davis.

Other reports produced including data collected will be posted to the TRWC website.

## 6. ***Expected quantitative results (project summary):***

As noted in the PSN issued by CDFW for this grant program, very little research on greenhouse gas reduction in mountain meadows has been completed. One study of soil carbon uptake was completed in the Feather River watershed (Feather River CRM, 2010) which clearly demonstrated increased carbon uptake in restored meadow as compared to non-restored meadows. On average, carbon sequestration in restored meadow was 40 metric tons per acre higher than carbon sequestration in degraded meadows. We may expect similar reductions for the Middle Martis project.

The research component proposed by the SMRRP aims to build on the Feather River CRM study and will include other greenhouse gases other than carbon. At this point in time we do not have enough background data to predict total reductions. Our conceptual model, described in Section 5.2 outlines the process by which restoration will lead to a net decrease in greenhouse gas emissions from the project area.

## 7. ***Protocols:***

### Protocols for measuring GHG reduction

Work tasks for measuring GHG reduction are listed in Section 5.3, Task 1. The tasks are repeated here with more detail on the protocols to be followed.

1.1 Identify control meadow and establish transects

Paired control sites will be selected as meadows that have experienced hydrologic alteration and degradation similar to the target restoration meadow. There are several meadow sites within Martis Valley that are likely to be appropriate. Pairing control degraded meadows with treatment meadows (i.e., restoration sites) will also provide controls on interannual variability that could confound effects of restoration. Restoration and control degraded meadows will be stratified according to hydrogeomorphic type as described in Weixelman et al. 2011 and then by dominant vegetation type (Sawyer et al. 2009). Three to four transects will be established across each meadow perpendicular to the dominant slope and to the degree possible, aligned with existing ground water well transects and positioned to capture the vegetation types covering the greatest surface area of the meadow.

1.2 GHG measurements

Within each meadow included in the SMRRP (Table 1), up to three hydrogeomorphic/ vegetation types will be monitored for soil carbon, net primary production, and peak GHG emissions. Peak emissions are expected to occur during three periods: (1) directly following spring snow-melt; (2) during mid-summer with peak vegetative growth; and (3) during early fall rains following senescence, when the ground-water table is high and anaerobic conditions are optimal for methane and nitrous oxide production.

GHG emissions during spring snow melt have been reported to be highly variable, but nitrous oxide emissions during this period can be important parts of the annual GHG budget. To capture these peak fluxes, GHG emissions will be measured over 3 to 4 days during the end of spring snow melt at each site. Summer GHG emissions are also expected to be high relative to other times of the year, but less variable throughout the summer. Therefore, mid-summer emissions will be sampled from sites during a single mid-day sampling effort. Because a third peak in annual GHG emissions is expected in early fall with new litter input, reduced evapotransporation and the onset of fall rains, GHG emissions will be sampled during this period as well. Finally, to establish a baseline for non-peak periods, GHG emissions will be measured during a one-day data collection effort during the snow-free non-growing season, when fluxes are expected to be low. The pulse-driven nature of soil GHG emissions (particularly CH4 and N2O production), means that much of the annual CH4 and N2O flux could occur during relatively short, but important, periods of the year. Therefore, our experimental design in these state-factor sites seeks to characterize these peaks, so as to capture the most dynamic and significant fluxes of the year in meadow ecosystems.

This monitoring approach is intended to (1) specifically quantify the most important temporal and spatial variation in GHG emissions in each target meadow before and after restoration, and in each control meadow during the same time period; (2) contribute to development of coarse annual GHG emission and net carbon sequestration estimates for each restoration and control site; and (3) provide data on GHG emissions from meadows representative of the state factors to support development of a quantitative model for estimating net carbon sequestration in Sierra meadows. Information gained from the more intensive focus meadows will be used to help inform annual GHG emission estimates for the state factor meadows.

GHG fluxes will be measured using the static chamber methodology (Hutchinson and Mosier 1981). This method has been used by others to measure GHG emissions in mountain meadows in the Sierra Nevada and Intermountain West, including SMRRP participants Sullivan (UNR) and Hart (UC Merced) in various ecosystem types (Sullivan et al. 2008, Blankinship and Hart 2014). Boardwalks will be erected each year along these transects in wet areas to avoid trampling meadow soils and to minimize methane ebullition (bubbling) into the chambers during incubation measurements (Megonigal et al. 2004, Teh et al. 2011). Use of chambers vs. the eddy covariance method (Hutchinson and Mosier 1981; Baldocchi et al. 1988) will enable us to measure both nitrous oxide and methane emissions, and to link emission differences to sub-meadow scale variation in site conditions. Chambers will be constructed of polyvinyl chloride (PVC) tubing and be approximately 30 cm in diameter to reduce the inherent spatial variability associated with soil gas fluxes (Sullivan et al., 2010). In the field, the vented static chambers will rest on PVC collars that are permanently installed 2-3 cm deep in the soil to reduce soil disturbance and plant root mortality associated with repeated chamber-based flux sampling. Collars will be installed at least one month prior to the first measurement to allow stabilization of the surrounding soil and vegetation. Collars will be beveled on the soil-facing edge to minimize soil disturbance during installation. Soil fluxes of carbon dioxide, methane, and nitrous oxide production will be measured as part of a complete soil GHG flux estimate. Ancillary data on ground water level, soil temperature, and water filled pore space will also be collected with the gas samples.

UNR (Sullivan) and UCM (Hart) will work with Stillwater Sciences in order to refine chamber sampling techniques and protocols for measuring GHG emissions. Stillwater, with assistance from UNR (Sullivan) if needed, will train Plumas Corp field personnel in GHG sample collection. Both Stillwater and Plumas Corp will collect GHG samples from the state factor meadows. GHG gas samples generated in this effort will be sent to and analyzed by the Sullivan lab at UNR and the Hart lab at UC Merced using gas chromatography.

1.3 Soil carbon and biomass production analysis

Soil carbon and biomass samples are collected along transects established across the meadow, as described above. Four one-foot square plots will be chosen along each transect, with each plot representing a soil/vegetation type. In the un-restored meadows, it will be necessary to ensure that plot locations do not interfere with potential design features where earth movement activities are planned. Within these parameters, sample plot locations are randomly selected. The best representation of all vegetation/soil types is sampled in each meadow; however, not all types may be sampled and some may be sampled more than once. In an effort to make between-meadow comparisons, attempts to duplicate soil/vegetation types among similar meadows will be made.

Samples are removed within the one-foot square plot in the following pre-determined, definable layers: 1. All above-surface biomass material within the square is clipped to ground level. Soil surface is defined as the top of the O horizon. Material is removed, bagged and labeled by plot number for the entire square foot area. Documentation of meadow use, i.e. grazed or un-grazed is made, and percentage of utilization is estimated. 2. In wet sites, a 4" auger-size sample of the O horizon is taken. In dry sites, the O horizon of the entire square foot is taken. O horizon material consists of duff, litter and residual live plant material, down to a bare, mineral soil surface. Material is removed, bagged and labeled, including a notation of whether the wet or dry site method is used. 3. In the center of the square, an auger is used to sample the top three feet of soil. A representative sample of each foot of depth is collected. Approximately 20% of the soil in the auger is removed for analysis, with an attempt made to collect material from the upper, middle and lower portion of the core. 4. During augering, a representative bulk density sample (Blake, G.R., and K.H. Hartge, 1986) is collected for each foot of depth. Bulk density samples are collected at 9", 18" and 27". Soil cores are collected using an Oakfield 3-ft. Model B 36" Soil Sampler (mud augers worked best in wet sites). Bulk density samples are collected with a 0200 soil core sampler manufactured by Soilmoisture

Equipment Corp. All samples are stored in plastic bags, and labeled with meadow, plot number, depth, and date.

All samples are processed and tested at the Soil, Water and Forage Analytical Lab at Oklahoma State University (OSU) in Stillwater, OK. Processing entails grinding vegetation samples, and sieving soil samples using an ASTM#10 (2mm) 8" brass sieve. Vegetation carbon and soil carbon and nitrogen are all determined using a LECO TruSpec Carbon and Nitrogen Analyzer. Large organic material sieved and removed from the soil samples are tested with the vegetation sample. At least 0.5 pounds of soil per sample is needed for processing and testing. Bulk density samples are dried at 105$^{o}$C and dry weight determined from a digital scale to a resolution of one gram. All lab samples are shipped in bags provided by OSU. The lab at OSU has strict QA/QC protocols in place.

1.4 Incorporation of ancillary data

Piezometers and vegetation transects are already established in the restoration meadow. We will establish a monitoring program in the control meadow in June 2015.

Ground water levels will be recorded during each GHG measurement period. We will measure expected site-scale predictor variables from piezometers in each meadow, soil chemical and physical analyses (including soil pore water and soil temperature), vegetative productivity, soil carbon, and plant community composition.

1.5 Data analysis and reporting

Data analyzed and reported will include GHG emissions, biomass production, groundwater levels, soil carbon and water content, and soil temperatures for each GHG sampling date. Emissions will be summarized by vegetation/hydrogeomorphic type for the meadow as a whole, and by season (sample date). If feasible, emissions will be estimated to the full year. Statistical comparisons of the pre vs. post restoration GHG emissions and net carbon sequestration will be made using the control site data as controls for inter-annual variation in climate.

**Performance evaluation of co-benefits**

Our monitoring plan will allow us to document project benefits as related to our objectives:

- Restore up to 10 acres of historic wetland and enhance 27 acres of existing wetlands;
- Restore one mile of historic intermittent channel;
- Improve fish passage/fish habitat in one mile of existing stream channel and restore associated 2 acres of riparian wetland;
- Eliminate damaging peak flows, improve late season base flow;

- Increase water storage in a degraded meadow system;
- Eliminate in-channel erosion;
- Improve avian habitat;
- Ameliorate impacts of climate change through reducing flooding caused by rain on snow events

Restore and enhance wetlands. Our vegetation monitoring plan will allow us to document shifts in wetland vegetation throughout the project area. We will continue to repeat monitoring to document changes. Our hydrologic monitoring program will verify that wetland hydrology has been restored or improved through the project area.

Restore one mile of historic intermittent channel. Through photo-monitoring we will be able to demonstrate restored flow paths on the north side of the highway.
Improve fish passage/fish habitat in one mile of existing stream channel. We will repeat aquatic habitat surveys that documented pre-project degraded conditions.

Restore associated 2 acres of riparian habitat. We will document improved riparian habitat condition along the existing channel of Middle Martis Creek through vegetation and photo-monitoring.

Eliminate damaging peak flows, improve late season base flow. We have established a stream gage upstream of the project area. We will instrument the new channel as soon as it is constructed. A stream stage gage is located in the existing channel of Middle Martis Creek in the project area. Flow data from these stations will allow us to measure base flow. At present, even moderate flows cause flooding and erosion. After storm events, we will monitor the project area visually for evidence of flood impacts.

Increase water storage. Our groundwater monitoring program will allow us to document current water storage and post-project water storage in the meadow system. We predict that groundwater levels will remain high longer in the season.

Eliminate in-channel erosion. Aquatic habitat surveys will allow us to document shifts in grain size in the project reach. As of now, the substrate is dominated by sands and fine sediment. We predict this will change as erosion decreases. Photo-monitoring will also document erosion patterns along the stream channel.

Improve avian habitat. We have conducted pre-project bird monitoring. We will conduct post-project monitoring, however the avian response may take longer to detect. Pre-project surveys showed that bird diversity and numbers respond most strongly to willow, aspen, and cottonwood habitat in the project vicinity. These habitats take several years to develop, so significant change may not be observed during the grant period.

Ameliorate impacts of climate change. Within the time frame of this grant we will not be able to detect any response to climate change. However, we may be able to document reduced impact from flooding through our hydrologic monitoring program and photo-monitoring.

## 8. ***Literature Cited:***

### Project Reports and Technical Report


Balance Hydrologics, 2012a. Martis Watershed Assessment. Prepared for Truckee River Watershed Council, Truckee CA.

Balance Hydrologics, 2012b. Feasibility Assessment and Limited Design Basis for Restoration and Drainage Enhancement Alternatives on Middle Martis Creek at State Highway 267, Placer County, California. Prepared for Truckee River Watershed Council, Truckee CA.

Balance Hydrologics, 2013. Year 1 Baseline surface and groundwater monitoring for the Middle Martis Creek Wetland Restoration Project, Placer County, California. Prepared for Truckee River Watershed Council, Truckee CA.

Balance Hydrologics, 2014. Hydraulic Calculations and Modeling to Support the Middle Martis Creek Wetlands Restoration Project in Placer County, California. Prepared for Truckee River Watershed Council, Truckee CA.

Dudek, 2013. Jurisdictional Determination for the Middle Martis Creek Wetland Restoration Project, Placer County, California. Prepared for Truckee River Watershed Council, Truckee CA.

Dudek, 2014. Middle Martis Creek Restoration Project, Pre-construction Vegetation Monitoring Report. Prepared for Truckee River Watershed Council, Truckee CA.

Feather River Coordinated Resource Management. Quantification of Carbon Sequestration Benefits of Restoring Degraded Montane Meadows- Technical Report (2010).

Lahontan Regional Water Quality Control Board, 1995 (with amendments). Basin Plan. South Lake Tahoe, CA.

Lindquist, S., and J. Wilcox. 2000. New concepts for meadow restoration in the northern Sierra Nevada. Unpublished technical report.

National Fish & Wildlife Foundation, 2010. Sierra Nevada Meadows Restoration Business Plan. Washington, D.C.

Tahoe Institute for Natural Science (TINS), 2014. Middle Fork Martis Creek Restoration Project Avian Monitoring – 2013 Pre-treatment Results

Truckee Donner Public Utilities District, 2011. 2010 Urban Water Management Plan, Adopted June 1, 2011.

Truckee Donner Public Utilities District, 2014a. Revised Section 2010 Urban Water Management Plan.

Truckee Donner Public Utilities District, 2014b Revised Emergency Water Conservation Ordinance.

Truckee River Watershed Council, 2010. Coordinated Watershed Management Strategy, Truckee, CA.

U.S. Army Corps of Engineers, 2015. Martis Creek Lake and Dam Master Plan Update.
Weixelman, Dave. A., Barry Hill, David J. Cooper, Eric L. Berlow, Joshua H. Viers, Sabra E. Purdy, Amy G. Merrill, and Shana E. Gross. 2011. Meadow Hydrogeomorphic Types for the Sierra Nevada and Southern Cascade Ranges in California – A Field Key. US Department of Agriculture, R5-TP-034.

**Peer Reviewed Journal Articles**

Allen-Diaz, B. H. 1991. Water table and plant species relationships in Sierra Nevada meadows. American Midland Naturalist 126: 30–43.

Baldocchi, D. D., B. B. Hincks, and T. P. Meyers 1988. Measuring Biosphere-Atmosphere Exchanges of Biologically Related Gases with Micrometeorological Methods. Ecology 69:1331–1340.

Blake, G.R., and K.H. Hartge. 1986a. Bulk Density. In A. Klute (ed.) Methods of Soil Analysis. Part 1 - Physical and Mineralogical Methods Second Edition. American Society of Agronomy, Madison WI.

Blankinship, J. C. and S. C. Hart. 2014. Hydrological Control of Greenhouse Gas Fluxes in a Sierra Nevada Subalpine Meadow. Arctic, Antarctic, and Alpine Research, Vol. 46, No. 2, 2014, pp. 355–364.

Chambers, J. C., and J. R. Miller, editors. 2004b. Great Basin riparian ecosystems ecology, management, and restoration. Island Press, Covelo, California.

Forster, P., Ramaswamy, V., Artaxo, P., Berntsen, T., Betts, R., Fahey, D.W., Haywood, J., Lean, J., Lowe, D.C., Myhre, G., Nganga, J., Prinn, R., Raga, G., M., S., Van Dorland, R., 2007. Changes in Atmospheric Constituents and in Radiative Forcing. In: S. Solomon et al. (Editors), Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, U.K.

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:doi 10.1111/gcb.12745.

Loheide, S. P., II, and S. M. Gorelick. 2007. Riparian hydroecology: a coupled model of the observed interactions between groundwater flow and meadow vegetation patterning, Water Resources Research 43: W07414, doi:10.1029/2006WR005233

Miller, R.L., Fram, M.S., Wheeler, G., Fujii, R., 2008. Subsidence reversal in a re-established wetland in the Sacramento-San Joaquin Delta, California, USA. San Francisco Estuary and Watershed Science, 6(3): 1-24.

Miller, R. L., 2011 Carbon Gas Fluxes in Re-Established Wetlands on Organic Soils Differ Relative to Plant Community and Hydrology, Wetlands DOI 10.1007/s13157-011-0215-2

Megonigal, J.P., M.E. Hines, and P.T. Visscher. 2004. Anaerobic Metabolism: linkages to trace gases and anaerobic processes. Pages 317-424 in Schlesinger, W.H. (Editor). Biogeochemistry. Elsevier-Pergamon, Oxford, U.K.

Merrill, A. G., T. L. Benning, and J. Fites-Kaufmann. 2006. Factors controlling structural and floristic variation of riparian zones in a mountainous landscape of Western U.S.A. Western North American Naturalist 66: 137-154.

Mosier, A.R., L. K. Klemedtsson, R. A. Sommerfeld, and R. C. Musselman. 1993. Methane and nitrous oxide flux in a Wyoming subalpine meadow. Global Biogeochemical Cycles 7: 771-784.

Sawyer, J., T. Keeler-Wolf, and J. Evens. 2009. A Manual of California Vegetation, 2nd Edition. California Native Plant Society. Sacramento, CA.

Teh, Y. A., W. L. Silver, O. Sonnentag, M. Detto, M. Kelly, and D. D. Baldocchi. 2011. Large Greenhouse Gas Emissions from a Temperate Peatland Pasture. Ecosystems (2011) 14: 311–325.