The Sierra Meadows Partnership
Collaborative meadow restoration and protection

SM-WRAMP
3-year Work Plan

(updated summer 2018)

Executive Summary

The proposed Sierra Meadow Wetland and Riparian Area Monitoring Plan (SM-WRAMP) is being developed by the Sierra Meadows Partnership WRAMP Advisory Committee (SM-WAC). Two over-arching goals of this effort are to track progress in meadow restoration and conservation and to provide critical information for adaptive management of the Sierra Meadow Strategy. These monitoring protocols will address a goal set out in the Sierra Meadow Strategy under Approach 1: “Restore and/or protect meadows to achieve desired conditions.” By developing a common set of protocols with instructions on field methods and reporting and with guidance on how to apply the methods for a particular meadow, a body of comparable data will be created from all restored and protected meadows in the greater Sierra Nevada. With this large body of comparable data, critical questions that span multiple meadows within a watershed, or across regional and program areas can be addressed.

The SM-WRAMP is designed to help answer programmatic or administrative questions such as (1) Is the Sierra Meadow Partnership (SMP) on track to achieve its goal of 30,000 acres of restored and/or protected meadows by 2030? (2) How do the restoration and/or protection activities differ geographically and across land tenure types? (3) How much is this costing initially and for on-going maintenance and repairs? A large fraction of the WRAMP data to be collected also will help address questions on restoration success, such as (4) Are the restoration projects achieving their stated goals for changes in conditions and/or function? Specific questions on targeted changes in condition and function (desired conditions) will trigger collection of appropriate, specific types of monitoring data so that the changes in a targeted condition are measured and reported consistently among meadows sharing the same type of targeted change. Another set of questions will address the efficacy of different restoration techniques to answer the broad question of what types of restoration techniques are demonstrated to be most effective, and under what conditions?

The SM-WRAMP structure is nested, with levels and tiers within those levels of monitoring specificity. At the first level and first tier (1A) all monitoring protocols are required since these protocols focus on programmatic attributes such as meadow size, action type (active restoration, conservation), location, action date, etc. At the second level and first tier (2A), key attributes as required for regulatory compliance for most active meadow restoration activities are reported. And at the third level and first tier (3A), targeted changes in desired conditions determine which sets of protocols must be applied. The second tier of Level 3 (3B) is not required but offers a more in-depth set of protocols for targeted desired conditions. The required monitoring for Levels 1-3, Tier A could also be adopted for meadows identified for conservation and/or new land acquisitions.

An important task in development of the SM-WRAMP is gaining agreement from participants in the SMP to consistently apply these protocols on all meadow restoration and conservation projects. These guidelines and protocols will streamline monitoring for project managers by providing information to help budget and plan field and data management efforts, as well as to train field crew to consistently collect and report monitoring data before and after meadow restoration and/or protection. By having a collaborative partnership collect data across multiple project and meadow types, the power of more data, more experiences, and better understanding can be leveraged to rapidly build upon and improve the current art and science of meadow restoration.

Site assessment to inform restoration or conservation actions differs from implementation and effectiveness monitoring because the primary intent of site assessment is to evaluate where restoration actions are needed, not to evaluate effectiveness of a project. However, some overlap in on the ground data collection might occur and an important aspect of developing the SM-WRAMP is to clearly identify where and under what circumstances those overlaps might occur and to maximize the information gain from such overlap. Thus, communication and coordination with the Design Team is part of the process of developing the SM-WRAMP.

Like restoration techniques, this document is not intended to be static, but to be adaptively managed. The following document presents additional specifics on SM-WRAMP goals, structure, hypotheses-driven monitoring protocols, the timeline for completing monitoring planning and testing for Level 1A, 2A, 3A, and 3B (anticipated to be fully completed by fall of 2020). The document does not include steps associated with developing Level 3C focused research questions and long-term general monitoring.

Lastly the group has identified the need for long-term monitoring of both healthy and degraded meadows in a monitoring network across the SMP area (Level 3C) to better understand meadow functions and to track changes in meadow health and condition due to natural processes and climate change. This information is critical for evaluating meadow restoration success at a range of both temporal and spatial scales; however, the SM-WRAMP workplan does not currently include the development of this monitoring.

Introduction

The proposed Sierra Meadow Wetland and Riparian Area Monitoring Plan (SM-WRAMP) has been developed by the Sierra Meadows Partnership WRAMP Advisory Committee (SM-WAC) with the intent of creating a framework to assess pre- and post-restoration conditions specific to mountain meadows within the greater Sierra Nevada. The two primary objectives associated with development of the SM-WRAMP are to:

1. Serve as a robust, replicable and cost-efficient monitoring plan to track and understand the extent and effectiveness of meadow restoration and conservation actions by employing protocols pre- and post-restoration and/or conservation. Establishing a Sierra Meadows specific WRAMP provides the basis for determining the efficacy of meadow restoration at the project site-level and for improving our scientific understanding of cause and effect relationships among key meadow functions and restoration actions. This system of consistent monitoring protocols also will generate data on meadow restoration and conservation that can be compared with other management and regulatory programs at regional and statewide scales.

2. Serve as a short, medium and long-term approach to monitoring implementation of the Sierra Meadows Strategy (Strategy) completed in the fall of 2016. The intention of the Strategy is to guide all aspects of restoring and maintaining the health of meadows, including assessments, prioritization, project design, permitting, implementation and post-implementation monitoring. The overarching goal of the strategy is to increase the pace, scale and efficacy of meadow restoration, targeting 30,000 acres of restored and/or protected meadows by the year 2030. In addition to the SM-WRAMP providing site-level information, data derived from its implementation will serve as a framework for evaluating overall success of the Strategy through short, medium and long-term outcomes. More specifically, data derived from the application of the SM-WRAMP will provide the foundation necessary to determine advances in terms of: (a) the abundance, in number and acreage, of meadows protected and/or restored, (b) the diversity and distribution of meadows restored/ protected, (c) overall condition of meadows reported, and (d) information on important meadow attributes, such as water storage, soil carbon storage, biological abundance and diversity such as the distribution, abundance and diversity of plants, fish, birds, amphibians, and mammals.

The final deliverables of the SM-WRAMP work plan will include the materials, outreach and training, and integration of the SM-WRAMP generated data into an accessible database that can be used by multiple stakeholders and program administrators to manage and accelerate meadow protection and restoration with high quality and sufficient information. Through collaboration and coordination among participants, the SMP will provide a much larger, more coherent, and more consistent data set than would multiple entities working independently. Moreover, through the SMP, data collection methods and protocols will incorporate existing institutional knowledge which will foster broader acceptance and adoption. Familiarity, training, and adoption of data collection and reporting protocols will be made broadly available through in person trainings, databases, and the U.C. Davis Meadows Clearinghouse; dissemination also will be reinforced through word of mouth across the large network of SMP participants.

Direct Ties to Sierra Nevada Meadow Partnership Strategy

The SM-WRAMP will inform the primary goal of the Sierra Meadow Strategy, to restore and protect 30,000 acres of meadow by 2030. Information reported through the SM-WRAMP will enable institutions and the public to track the progress of meadow restoration/ protection in the greater Sierra Nevada through time, and to gain insight on the distribution, success, and costs of restoration. This data will inform program level responses and corrections to ensure the Strategy stays on track to achieve the stated goal. Moreover, as a direct link to Approach 1, "Restore and/or protect meadows to achieve desired conditions", the SM-WRAMP will provide feedback to project managers and program administrators on the degree to which specific projects or programs are achieving desired conditions. The need for consistent monitoring is illustrated in the Strategy flow chart for developing and using SMART objectives to achieve desired conditions (see Strategy, Figure 3 on page 24). Pre-restoration monitoring is performed to understand existing versus desired conditions. Post-restoration monitoring is employed to direct adaptive management to ensure that desired conditions are achieved. This process is applicable for a single meadow as well as for a set of meadows to achieve desired conditions. Employment of a consistent and effective set of monitoring protocols is critical for providing managers and program administrators with relevant and reliable information.

SM-WAC members (Table 1) will develop the protocols for the SM-WRAMP based upon a common structure, as agreed upon by the SM-WAC in Spring 2018. The proposed SM-WRAMP structure has been developed based on the identification of information considered essential to effectively asses and monitor meadows pre and post-restoration in a robust, replicable and cost-efficient manner. It has also been developed with the intent of meeting requirements of funding programs requiring assessments and monitoring activities.

The SM-WAC was assembled for the following purposes:

1. To guide the overall development, implementation and revision (as needed) to the SM-WRAMP.
2. To develop topically focused groups within the SM-WAC based on SM-WAC members fields of expertise. These groups currently include, fish and wildlife, soils, hydrology, geomorphology, and vegetation. Each of the topical groups will have a designated lead responsible for ensuring all data collected based on the application of the SM-WRAMP is complete, of sufficient quality and that is uploaded and managed in the SM-WRAMP database. The designee also will lead the coordination of uploading appropriate data to relevant regional datasets.
3. Designated leads, working with the coordinator will spearhead potential revisions to the SM-WRAMP once applied, based on review of data.
4. Assure integration with other groups in the SMP, particularly the Restoration Design Group and the Prioritization Group.

Table 1. The Sierra Meadows WRAMP advisory committee (SM-WAC) includes the listed members; topical leads are indicated by blue highlight.

Name	Institution	Role and/or Area of Expertise
Amy Merrill	Stillwater	SM-WAC Lead, Soils Topical Lead, Veg
Christian Braudrick	Stillwater	Geomorphology – Topical Lead
Brent Campos	Point Blue	Wildlife-Topical Lead
Janet Hatfield	Caltrout	SM-WAC liaison, Project Design Group

Nina Hemphill	**USFS**	**Aquatic ecology – Topical Lead**
Carrie Monahan	**Sierra Fund**	**Hydrology- Topical Lead**
Shana Gross	**USFS**	**Vegetation – Topical Lead**
Beth Christman	Truckee River Watershed Council	Restoration and Permitting
Judy Drexler	USGS	Soils and Hydrology
Rachel Hutchinson	SYRCL	Vegetation
Karen Pope	USFS Research	Wildlife
Terri Rust	Plumas Corporation	Hydrology
Natalie Stauffer-Olson	Trout Unlimited	Fish/Wildlife
Sheli Wingo	USFWS	Vegetation
Evan Wolfe	Private Consultant	Soils, Vegetation
Sarah Yarnell	U.C. Davis	Fish/Wildlife, Hydrology

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The sections below outline three levels of monitoring: program and landscape assessment (Level 1), rapid assessment (Level 2), and more intensive site assessment data (Level 3). In addition, as part of the SM-WRAMP, all participating meadows would be required to report project goals and desired conditions, types of degradation to be addressed through the project, and hypothesized sources of degradation (such as undersized culvert, recent or legacy intensive grazing, channel re-alignment, etc.). How the project proponent reports on these important linkages between project goals and desired conditions, types and hypothesized source(s) of degradation, intended actions to address those sources, and degree of success in removing or alleviating those sources of degradation, will be further developed in the SM-WRAMP during coming year, once funding becomes available.

The proposed SM-WRAMP reflects the EPA National Wetlands Monitoring Workgroup structure by having three levels of data: program and landscape assessment (Level 1), rapid assessment (Level 2), and more intensive site assessment data (Level 3) (see Table 2). Further, the SM-WAC determined that using tiers nested within these levels was also important for guiding data collection: data to be required for all funded projects, depending on targeted desired conditions (Tier A), data necessary to meet specific project objectives such as species level information (Tier B), and data relevant for scientific research that would likely be pursued and applied at "sentinel" or long-term research meadows (Tier C). Levels 1 and 2 of the SM-WRAMP contain only Tier A data. Level 3 includes Tiers A, B and C data.

Table 2. SM-WRAMP Levels and Tiers

Level	Description	Tier A	Tier B	Tier C
Level 1.	Landscape Assessment			
Level 2.	Rapid Assessment			
Level 3.	Intensive Site Assessment			

As of summer 2018, the first draft of the SM-WRAMP protocols is not complete. Here we outline a series of steps necessary to develop a SM-WRAMP that will meet the goals described above.

Spring 2019: Complete Full Draft of SM-WRAMP Protocols

As a next step, the SM-WAC will finalize attributes to be measured for Levels 1A and 2A for programmatic tracking and for Level 3A by linking each attribute to specific desired conditions for tracking restoration or conservation outcomes. As of summer 2018, the exact field protocols and metrics for measuring, analyzing and reporting on these attributes have yet to be drafted. We further assume, that with pilot applications and external peer review, additional refinements in these data collection and management methods will occur. The attributes and metrics listed in Tables 3 through 6 below are based upon current best estimates of attributes and associated field data collection methods.

2019 onwards: Training Materials and Training Sessions

The protocols themselves will be communicated in several formats, including written and video. A pilot training session will be held in spring 2019 and materials and methods used during the pilot training will be refined and improved based on trainee feedback. These updated materials and methods will be applied during up to three training sessions located in different locations in the Sierra Nevada during spring of 2020. A video will be developed and revised as part of this training to increase access of the training materials to a broader audience.

Summer 2019: Pilot Draft Protocol and Solicit Expert Review

Once applied to a first set of pilot meadows, the SM-WAC will review and analyze the data collected with the goal of applying these types of data to additional meadows in the future. These data will be intended to help determine trends in meadow conditions across varied geographical settings and subject to varied restoration techniques. The initial piloting of the SM-WRAMP will include questions for field crews to solicit critical feedback on the structure and content of the protocols and clarity of the field guidance documents. At the same time, outside experts will review the draft protocols and will provide feedback to the SM-WAC by the end of the field season.

Fall 2019: Refine Draft Protocols and Produce Final Version

The SM-WAC will collate, review, and integrate field crew and expert reviewer comments and suggestions on the first draft of the protocol in the final draft. The final protocols will include written brief background information on each set of attributes and measurement methods, and instructions for preparing materials for data collection. This set of documents will be paired with the Protocol Guidelines described below. The SM-WRAMP will be applied as a tool to compare pre-restoration conditions of hydrologic, physical and biological attributes of target meadows. Additionally, the intent is to apply the SM-WRAMP post-restoration (post-restoration time frame might vary by metric) to enable quantification of changes in meadow conditions as a function of restoration activities. It might be critical to monitor metrics at a longer time scale than funding cycles allow to adequate address if the project was effective at different temporal scales.

Spring 2020: Guidance on Protocol Application and Data Analysis

Written protocols will include a “Guidance” document with an explanation of how the protocols can be applied at a site or set of sites. Thus, this document will provide overall guidance on control site selection, setting up data collection locations within a meadow (e.g., spatial distribution and density), and data collection timing and frequency. Other guidance on co-location of different data collection types, potential pitfalls and/or technical advice will also be provided. Because methods for statistical analysis should be part of the initial data collection plans, guidance on potential methods for data analysis to address the hypothesis driving each Level 3A attribute will also be part of this Guidance document. Finally, this document will include information on field equipment and recommendations on equipment construction or purchasing, as appropriate.

A much briefer field instructions document will be developed to accompany the Guidance document. These detailed instructions on how to collect and report field measurements will ensure that all data are collected the same and can be directly compared to one another across projects.

2020: Develop Guidance on Protocol Management

As a future step, the SM-WAC will evaluate the efficacy of the proposed SM-WRAMP and potentially revise it based on analysis of its implementation, and its ability to be scaled back for time and cost-efficiency - while ensuring data collected provides robust and necessary information to evaluate efficacy of restoration activities over time at site-specific and programmatic scales.

2020: Data management, analysis and adaptive approach to proposed SM-WRAMP

In addition to the SM-WRAMP development, the SM-WAC intends to provide guidance on management and analysis of data derived from the implementation of the SM-WRAMP. This will include guidance on QA/QC of SM-WRAMP specific data and ultimately ensuring data is structured in a manner appropriate for submittals to the Sierra Meadows Clearinghouse. During this phase of SM-WRAMP development, the SM-WAC will investigate opportunities to integrate and or link SM-WRAMP data with other current data from the UC Davis Meadows clearinghouse, to ensure longevity, accessibility and a user-friendly platform. In this scenario, for all database submittals, all meadow data will be tagged with a unique Meadow ID, to enable queries across multiple databases that include or are outside of the Meadow data clearing house (e.g., CEDEN, eCRAM, etc.).

Throughout: Engage Agencies and Other Users

Multiple institutions will need to adopt the SM-WRAMP protocols to ensure wide use and population of a truly representative database for restoration and management of Sierra Meadows. An incomplete list of these institutions includes the public land management agencies such as the US Forest Service, the National Park Service, the Bureau of Land Management, California Tahoe Conservancy, and California State Parks. Other stakeholders and practitioners include Water Boards, Environmental Protection Agency, Plumas Corporation, Sierra Nevada Conservancy, American Rivers, CalTrout, The Nature Conservancy, the Foothill Conservancy and other Land Trusts and Conservancies. Agencies involved in regulatory compliance as well as private and public funding agencies and organizations will also have a strong interest in ensuring that the SM-WRAMP protocols are well constructed and broadly applied. Monitoring will be clearly articulated to current organization requirements and needs.

Proposed SM-WRAMP Attributes, Levels 1-3

Level 1: Maps and Spatial Information

Level 1 data are required for all participating meadows. This Level 1 information is primarily directed towards tracking the number and distribution of planning vs. implementation meadow restoration projects in the Program Area. Other basic information on land ownership and project partners is also reported at this level (Table 3). Level 1 includes landscape context variables that could be used to stratify meadows within the program area, such as underlying parent material (granitic, volcanic, etc.), elevation, county, start and end date, target desired conditions (proposed drop-down list), and restoration method (proposed drop-down list). Thus, Level 1 data can be used to facilitate analysis of distribution and diversity of meadow restoration and conservation projects, and to explore relationships between meadow restoration projects and landscape scale characteristics, such as land use and tenure, climate change patterns, as well as fundamental differences in geology, growing season length, fire frequency, etc.

Table 3. Proposed Level 1 data for SM-WRAMP

Data Attribute	Tier
Project name	A
UCD Unique Meadow ID	A
Project partners	A
Meadow name	A
Meadow site characteristics: Meadow HGM type(s), size (ac), past land use practices	A
Restoration Project Characteristics: project goals and objectives, restoration methods (select from list), target desired conditions (select from list), expected impact area (ac)	A
Meadow landscape context: underlying parent material, elevation, site location (lat/long)	A
County	A
HUC 12	A
National Forest Land (Y/N)	A
If Yes, Specific Ranger District	A
If No, Specify Land Ownership	A
Project activity type (assessment, planning, restoration-implementation etc.)	A
Project schedule: Implementation start and expected end dates	A

Level 2: Information Collected for Regulatory Compliance

Level 2 data are data that are reported for SM-WRAMP only if collection is required for regulatory compliance. These reporting protocols are a means of 'harvesting' this data for use in assessing changes in wetland extent and distribution and plant species composition. Project specific information is reported here from the California Rapid Assessment Method CRAM report on meadow vegetation, hydrologic regime, water source, presence of peat soils, extent of section 404 wetland delineated area (Table 4).

Table 4. Proposed Level 2 data for SM-WRAMP

Methodology	Tier
CRAM	A*
Wetland delineation	A*

*Wetland delineation and CRAM may be required prior to restoration implementation, regardless of project type. However, it is not considered required for every project. For example, if a proposed project is to install plantings with no earthwork, a wetland delineation might not be required and so the information reporting is not required as part of the SM-WRAMP protocol. The information for Tier3A vegetation monitoring was identified so that it can pair with or serve in lieu of wetland delineation information if necessary.

Level 3: Specific condition information

Within the Level 3 data, we propose having three Tiers of information. Level 3, Tier A (3A) would be required of all participating meadow restoration projects, with monitoring of some attributes only required if triggered by potential effects of proposed actions. Level 3, Tier B (3B) data would not be required; but would support more thorough monitoring for targeted desired conditions or other potential outcomes. Level 3, Tier C (3C) data would support greater understanding of underlying processes that support healthy and resilient meadows in the face of climate change and in response to restoration actions and would be implemented in a subset of meadows selected to represent the diversity of meadows in the program area. These 3C protocols would require the greatest level of scientific rigor. Level 3C is recognized as needed; however, is not being developed at this time as part of this request.

Level 3, Tier A

The intent of these Level 3A data are to provide more detailed landscape and site-specific information on meadow conditions and processes. While some of these attributes will be required for all participating meadows, such as photo-monitoring and response to climatic stress, others are only required if restoration or conservation is intended to address a relevant class of problems, based on a decision tree (to be developed). Such a decision tree for Level 3 Tier A would be structured around project goals and types of degradation. For example, types of degradation could include an incised channel, conifer encroachment, or loss of native plant cover to invasive species. Actions to address incised channels would trigger monitoring attributes related to channel structure, ground and surface water. Actions to address conifer encroachment can also trigger monitoring for groundwater response but would not require monitoring and reporting on channel structure or surface water. Additional monitoring would be welcome but not required unless 'triggered' by the protocol. Thus, information from 3A could be used to track condition or target population changes in individual meadows as well as changes in overall site conditions for meadows at a programmatic scale. All these data types are screened to provide 'effective, easy, and affordable' information. As part of this data set, all participating meadows would be required to establish permanent photo-points from which photographs are taken during July prior to restoration and for years 1, 3, and 5 post-restoration (specific photo-monitoring and reporting protocol will be included). Each attribute is intended to address a particular hypothesis, as indicated in Table 5

Tables 5 and 6 reflect a draft set of triggering conditions ("when required"), hypotheses, quantifiable attributes, methodologies and rationales, subject to refinement in Spring 2019.

Table 5. Proposed Level 3, Tier A variables for SM-WRAMP

When Required	Hypotheses	Quantifiable Attribute	Methodology	Rationale
Required for all	Restoration and protection of meadows will occur at a steady pace and with even spatial and land tenure type distribution across the greater Sierra Nevada between now and 2030 to achieve a total of 30,000 acres of restored and/or protected meadows.	Measure of restoration success based on stated goals (specifics tbd); maintenance required (including restoration amendments or corrections), year, cost	Photos and simple data questions	This provides an opportunity to track efficacy of the design and tie the results to ecological outcomes being investigated. If project is continually maintained, then it may not be achieving desired conditions as far as returning meadow to disturbance adapted system.
	Some restoration methods are more costly and less effective than others.	Cost per acre to implement, cost per acre and year for maintenance. [need to combine with effectiveness or success attribute]	Reporting	This provides an opportunity to track efficacy of the design and tie the results to ecological outcomes being investigated. If project is continually maintained, then it may not be achieving desired conditions as far as returning meadow to disturbance adapted system.
	Compared to unrestored degraded meadows, restored degraded meadows will have more resistance/ resilience to climatic perturbations. On a shorter time-scale and per meadow, climate will affect near-term restoration response. Response variables tbd from this table.	Climatic conditions as explanatory variables: Total precipitation over water year; growing season temperature – average, maximum, minimum.	Climate Engine: http://app.climateengine.org/	Climate influences meadows directly through the timing and amount of precipitation and evapotranspiration, which modifies the position of the water table. Therefore, restoration response is influenced by climate.

When Required	Hypotheses	Quantifiable Attribute	Methodology	Rationale
Where channel structure is altered to address incision, widened and/or straightened channel	Channel planform and sediment transport properties will change: higher sinuosity, increased bed patchiness, decreased channel incision, increased bar-pool morphology	Sinuosity, migration rate, sediment transport and deposition, Upstream and downstream hydrologic effects	Geomorphic Mapping and Grain Size Analysis	Geomorphic maps and grain size analysis can be used to assess meadow condition before and after restoration; experienced geomorphologists required.
	Channel form will change with restoration: decreased channel slope, decreased grain size, increased width-depth ratio, channel width and slope will become quasi stable once the channel adjusts	Channel morphology	Cross sections and Long profile	Channels can adjust to changes in sediment supply via adjustments in channel dimensions, slope, and surface grain size. This protocol will provide data to quantify these changes in functionally relevant ways.
	A more extensive area will become inundated at lower discharge events following restoration compared to before restoration.	Floodplain connectivity	Relevant indicators from USFS Stream Condition Inventory and/or other scientifically accepted protocols	Fundamental expected restoration effect that supports multiple other changes in site conditions, including aquatic habitat
Where losses from shallow groundwater are reduced or inputs increased	Following restoration, depth to shallow groundwater decreases during the growing season overall, and/or depth is less for greater portion of growing season. Change in depth to groundwater brings groundwater to or higher within the plant rooting zone.	Depth to shallow groundwater table	Shallow groundwater well transects established and monitored at least monthly during the growing season; where relevant, linked to elevation transects established during design phase	Fundamental expected restoration effect that supports multiple other changes in site conditions for terrestrial habitat. Linkage to Design Group to use design data for pre-restoration monitoring. Minimum of 3 wells per meadow (further detail to come).
	Following restoration, shallow groundwater inputs to surface water will increase	Specific conductance	Growing season measures using YSI meter or field titration kit	Reflects dissolved solids such as salts, minerals, and can be used indicator of pollution and/or source water

When Required	Hypotheses	Quantifiable Attribute	Methodology	Rationale
	With greater plant production and longer periods of soil saturation at or near the surface, soil carbon content will increase, more within the first 15 cm than in deeper soils	Surface soil carbon content	Soil cores, to 45 cm depth; See SMRRP protocol	Core samples for C bulk density in 15 cm depth intervals, C and N content
Where losses from shallow groundwater are reduced or inputs increased	With restoration that reduces depth to groundwater during the growing season, net soil carbon loss will decrease	Soil carbon loss rate	TBD	Net soil carbon loss rate should decrease rapidly with hydrologic restoration as more carbon is added from increased production and less old soil C is lost via aerobic decomposition
	Longer spring flows, higher baseflows, reduced annual peak flow, greater lateral and more frequent inundation extent per flow level will occur with restoration.	Surface Water Hydrology	Hydrograph analysis: base flow duration, slope of rising limb, peak flow entering and existing	Hydrograph data for summer base flow (duration), rising limb slope (connectivity/ wet up), and peak flow entering and existing meadow (attenuation)
	Stream water temperatures are cooler for a longer period of the growing season with restoration	Water temperature	Deploy and manage data from temperature loggers within meadow	Reflects multiple interactions: ground/surface water contributions, channel shade, duration of snow melt
	Vegetation production and growth increases with greater access to surface or groundwater with restoration.	Change in vegetation vigor	Normalized Difference Vegetation Index (NDVI)	Indicator of vegetation vigor. This is a good, simple monitoring tool for restoration effectiveness which can visually display if after restoration vegetation vigor increases despite drought conditions.
	Restoration increases plant access to water and decreases plant water stress at the beginning, middle, and end of the growing season. The degree of change in water stress with restoration varies with changes in vegetation type and extent.	Change in water stress	Normalized Difference Water Index	Indicator of plant water content and a good proxy for plant water stress.

When Required	Hypotheses	Quantifiable Attribute	Methodology	Rationale
	Restoration increases extent of water dependent plant community types	Acres by vegetation community type	Acres by community type as mapped by a rapid assessment method per CNPS - CalVeg mapping to alliance level.	Changes in vegetation community type expected to be a fundamental response to most restoration actions. This can be complimentary to data reported under Level 2.
Where invasive plants removed	Reduced competition with invasive plant species supports increased native plant diversity	Plant species composition and cover	Cover or rooted density (tbd) by species in quadrats along transects	Removal of invasive species, including conifers, changes availability of light, water, and nutrients and will favor a different set of species. If all invasives are addressed, natives will increase in cover

Level 3, Tier B

Level 3B attributes are not required for all meadows but will be standardized so that meadow restoration proponents choosing to track more in-depth and/or more specific meadow condition responses to restoration actions can report changes using the same method protocols. This will support tracking and adaptive management on a meadow-specific basis, as well as meta-analysis of meadow response and restoration 'success' at broader spatial scales, or within stratified sets of meadows (e.g., classified by parent material, elevation, ownership, or restoration methods) (Table 6).

Table 6. Proposed Level 3, Tier B variables for SM-WRAMP

When suggested	Hypothesis	Quantifiable Attribute (*performance outcomes*)	Methodology	Rationale
Manage to affect depth to groundwater	Impact on change in depth to groundwater due to restoration varies across full meadow area	Acres by depth to shallow groundwater; depth bins will be included in protocol	Use transect groundwater and surface topography data to develop spatial data of depth to groundwater; create depth bins and report acreage per bin	Reporting change by area will increase resolution of data on efficacy of restoration action(s).

When suggested	Hypothesis	Quantifiable Attribute (*performance outcomes*)	Methodology	Rationale
Changes in surface water hydrology	Changes in stream flow hydrograph varies from top to mid to bottom of meadow channel due to restoration	Stream channel discharge above and below meadow	Establish and collect data from multiple field gages, perform hydrologic modeling	Track change in amount and duration of summer baseflow, a potential benefit of meadow restoration
Changes in groundwater inputs and/or losses	Restoration results in an overall increase in alluvial groundwater storage that can be quantified	Alluvium storage capacity	Measure alluvium surface area, depth, porosity, and 'shape factor' per Cornwell and Brown 2008	Track change in total volume of groundwater storage in meadow
		Depth to water table	Establish and monitor groundwater wells (see above)	
Changes in ground and surface water inputs and flow	With restoration, expected improvements in water quality will be reflected in benthic invertebrate community characteristics	Benthic invertebrates	Direct surveys: community structure: diversity, richness, tolerance	Reflects spatial and temporal integration of water quality conditions (DO, temperature, etc.); also characterizes base of aquatic food web
	Bank erosion will decrease with restoration	Bank stability pre- and post-restoration	Multiple Indicator Monitoring of Stream Channels and Streamside Vegetation	Reflects aquatic and streamside habitat condition
	Turbidity will decrease with restoration	Turbidity	Turbidity meter during range of conditions, with focus on peak storm events; timing, spatial density and frequency of measurement tbd	Turbidity reflects water transparency, due to suspended solids and dissolved organic matter; it affects aquatic habitat quality
	Suspended sediment concentration will decrease with restoration	Suspended sediment concentration	<2mm filtered, dried and weighted water samples; timing, spatial density and frequency of measurement tbd	Increased filtration is an expected benefit of many meadow restoration efforts. Suspended solid concentration reflects part

When suggested	Hypothesis	Quantifiable Attribute (*performance outcomes*)	Methodology	Rationale
				of sediment transport load as well as water quality condition
	Dissolved oxygen will increase with restoration	Dissolved oxygen	DO meter, timing, spatial density and frequency of measurement tbd	Direct measurement of important water quality attribute that directly affects aquatic plants and animals
Changes in habitat conditions for plant species	The species and populations of rare plant species will change, depending on the species needs in relation to effects of restoration on habitat conditions, such as water and shade availability	Rare plant survey	CNDDB protocol; using databases from CDFW (CNDDB) and CNPS (rare plants database)	Likely already required for NEPA or CEQA compliance and monitored to reflect progress towards restoration goal(s).
	The species and populations of invasive species will change, depending on species needs in relation to effects of restoration on habitat conditions and eradication actions	Invasive Species	Mapped level of data for invasive species	If invasive species are found then this would be an indicator to track how restoration project influenced invasion
	Plant community composition, diversity, and distribution of functional groups will change with restoration	Plant rooted frequency, root depth, groundcover, plant species richness and diversity	R5 Rangeland monitoring protocol	Valuable because data would align with existing long-term monitoring database; include call-out for invasive species
	Conifer encroachment will decrease with treatment	Conifer encroachment	USFS R5 protocols for conifer encroachment	Conifer encroachment is an issue in many meadows so this would

When suggested	Hypothesis	Quantifiable Attribute (*performance outcomes*)	Methodology	Rationale
				provide direct measure of intended benefit
Changes in Soil Conditions	Increased flood frequency and extent will increase delivery of mineral soils, with grain size decreasing with water energy in deposition area	Soil texture distribution	Sand/silt/clay analysis, SOM content (sampling distribution and density tbd)	Provides information fundamental to interpreting C sequestration, surface erosion, plant community composition, water holding capacity
	Soil carbon content will increase with restoration to 1 m depth (greater increase in shallow than deep soils)	Soil carbon content to 1 m: Core samples for bulk density, C and N content in 15 cm depth intervals	Measure to 100 cm depth	Changes in carbon content to 1 m vs. 45 cm depth provide more information on long term soil C storage – although small changes likely to occur over 1 to 5 years in deeper soils
	Rate of net soil carbon loss will decrease with restoration	Grams of C per acre per year	tbd	Changes in rates of soil carbon loss = shorter time-scale information on meadow response to restoration
Aquatic, terrestrial species richness, habitat diversity	Aquatic and terrestrial species that are appropriate to the site (as determined by wildlife and/or fisheries biologists and past monitoring information) will increase in abundance and diversity in restored meadows	Abundance, species richness, diversity, community structure/age class, recruitment, presence/absence, expansion of spawning area (change in substrate type and temperature), habitat connectivity	Fish, bird, amphibian, and mammal surveys, habitat surveys	Direct measure of expected benefit of restoration to determine changes in aquatic and terrestrial species richness and habitat diversity