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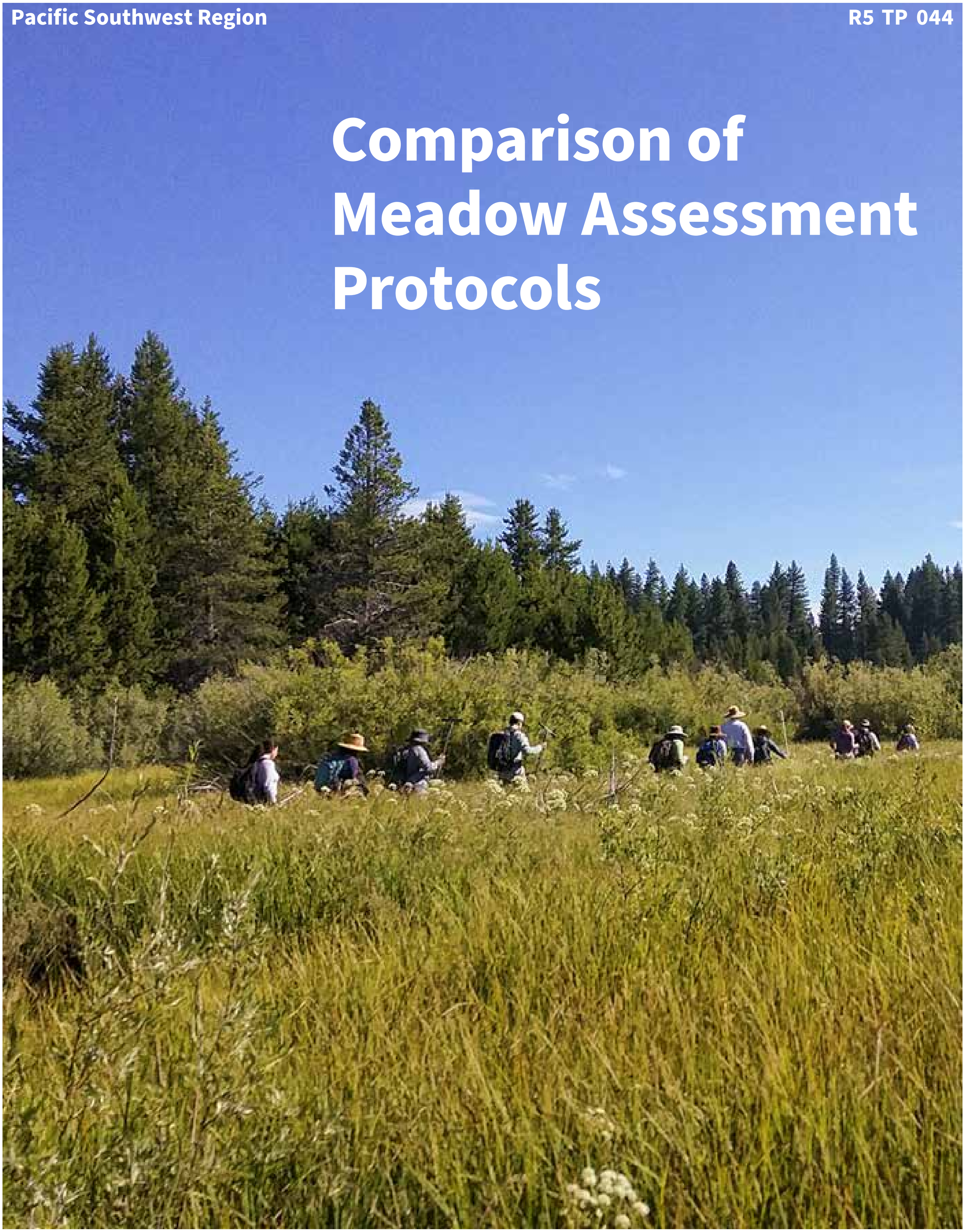
Comparison of Meadow Assessment Protocols



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Cover Photo

Meadow practitioners at Alder Creek Meadow.

Abstract

This document compares 11 different protocols that can be used to assess meadow condition in California. Although these protocols could be used in meadows across a broader geographic area, only some of them have been tested outside of California. Multiple assessment methodologies are available to evaluate meadow condition, but land managers are often unfamiliar with the suite of protocols available, and not sure which protocol will best answer their specific management questions. In this report we present detailed summaries of each of these 11 protocols and make comparisons between them. Our goal is to provide a resource for land managers and others to choose the most appropriate assessment protocol to evaluate the condition of meadows that they manage.

The protocols we review vary in a number of key attributes, including the specific objectives of the assessment, type of data collected (quantitative or qualitative), time and resources needed, skillsets required of the practitioners, type of meadow addressed, spatial extent and location of sampling, indicators and metrics evaluated, and the format and management applicability of the results. The amount of time required to collect and interpret data ranges from one hour to several days, and the sampling area ranges from 200m^2 (0.05 acres) to the entire valley surrounding the individual meadow. Some methodologies provide results in the form of maps and other spatial outputs, while others rely primarily on narrative descriptions to convey their findings. Finally, some of the protocols make explicit management recommendations, while others depend on users to infer the management implications.

We tested the protocols in a common set of three meadows and developed a standardized rating system to compare protocol findings. We found that the same meadow could be considered to be in Excellent, Good, Fair, or Poor condition depending on which protocol was used. Differences in how protocols rated meadow condition were primarily a result of differences in the metrics used, the spatial extent and location of the area sampled, and the specific objectives of the protocol. However, there were no consistent trends in how protocol characteristics affected meadow condition ratings. For example, protocols that rely on smaller assessment areas produced better, similar, or worse condition ratings than protocols that sampled the entire meadow depending on where the smaller sampling area was located.

We did not identify any single protocol as being better than others. Instead, we identified multiple factors that influence protocol ratings. These factors must be considered before choosing a meadow assessment protocol, because they will affect the results. Based on our findings, we emphasize that it is important to clarify the specific objectives and focus of an assessment prior to choosing a protocol for meadow evaluation. The best protocol for any given meadow will depend on the specific goals of the assessment and the ecological context of the meadow. A single protocol will not be appropriate for all meadows, and in some cases, it may be advisable to carry out several protocols in a single meadow. While this report focuses mostly on assessment protocols, it is important to recognize that monitoring is critical for adaptive management. After determining an appropriate protocol to assess meadow condition, we strongly encourage land managers to pursue longer-term monitoring efforts to evaluate trends in meadow condition over time.

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1. Introduction

Meadows are broadly defined as groundwater-dependent ecosystems composed of one or more herbaceous plant communities, where woody vegetation is often present but not dominant (Weixelman et al. 2011). Meadows are classified based on multiple environmental factors that include hydrology, vegetation, soil characteristics, geomorphology, physiography, altitude, and range type (Klikoff 1965, Benedict and Major 1982, Ratliff 1982, Ratliff 1985, Weixelman et al. 2011). Meadows develop in areas where there is a shallow water table and an accumulation of fine-textured soils, often with rich organic layers that are needed to draw water to shallow-rooted meadow plants by capillary rise (Wood 1975, Ratliff 1985, Weixelman et al. 2011). Meadows include wetland areas; however not all meadows are wetlands (Weixelman et al. 2011). Meadows fall along a hydrologic gradient of wet to dry. Peatlands are at the wettest end of this hydrologic spectrum. Dry meadows occur in the most arid topographic positions (Klikoff 1965).

Although meadows make up a small proportion of California landscapes, they play a large role in maintaining ecosystem function and biodiversity (Fryjoff-Hung and Viers 2012). Meadows are heterogeneous systems where underlying hydrologic and geomorphic variation influences patterns of vegetation composition and structure (Loheide and Gorelick 2007, Loheide et al. 2009, Lowry et al. 2011). This variation creates meadow complexes, hereafter referred to as meadows. Ecosystem services provided by meadows include attenuating peak flows after storms and reducing downstream flooding, recharging groundwater supplies, slowly releasing surface water throughout summer and fall, protecting streambanks and shorelines, filtering out pollutants and sediment, promoting nutrient uptake and storage through a complex food chain, improving water quality, supporting high levels of biodiversity and productivity, sequestering carbon, producing wildlife and livestock forage, and providing aesthetic, recreational, economic and cultural values (Ratliff 1982, Knopf and Samson 1994, Kattelmann and Embury 1996, Norton et al. 2011, Weixelman et al. 2011).

As a result of current and historical land uses, many meadows in California and throughout the western United States have become degraded and no longer provide many of these critical ecosystem services (Ratliff 1985). Meadows can be degraded by a wide range of activities, including poorly designed road and trail construction, off-road vehicle use, hydrologic alteration caused by ditching, damming, pumping, diversion of water and stream incision, inadequate livestock grazing management, noxious weed invasion, altered fire regimes, loss of native herbivores, and climate change (McKelvey and Johnston 1992, Kattelmann and Embury 1996, Chambers and Miller 2011).

Growing recognition of the importance of meadow ecosystems has led several federal, state, local, and private non-profit organizations to prioritize conservation and restoration of meadow ecosystems.

Practitioners who tested protocols in the field.

For example in 2015, the Sierra Meadows Partnership (https://www.sierrameadows.org/) was formed to increase the pace, scale, and efficacy of meadow restoration in the Sierra Nevada and Southern Cascades regions of California, with an ambitious goal of restoring and/or protecting 12,141 ha (30,000 acres) of meadows by 2030.

Developing effective management and restoration programs for meadow ecosystems requires that land managers understand the current condition of the meadows they manage to identify those most in need of restoration, and to understand what factors are contributing to degradation. Multiple assessment methodologies currently exist to evaluate meadow condition, but land managers are often unaware of what protocols are available to them, and unsure which protocol to use. Different assessment methods measure different attributes of the meadow ecosystem. Some focus on hydrology and geomorphology, while others are based solely on vegetation. Some protocols apply only to specific types of meadows, such as the protocol, "Assessing Proper Functioning Condition for Fen Areas," which is designed to be used exclusively in fens, while others are not specific to a particular meadow type. Each assessment protocol has different strengths and limitations.

The goals of this document are to: 1) summarize 11 protocols that can be used to assess meadow condition; 2) compare the results of the data collected using the protocols in a common set of three meadows; and 3) synthesize the written summaries and field based results from goals 1 and 2 to help meadow practitioners select the appropriate protocol for their specific needs and objectives. We achieve goal 1 by summarizing the objectives, attributes, and metrics and indicators of each protocol in Section 3.1 below. The results of data collection in the field are described in Section 3.2 to address goal 2. Goal 3 is described in Sections 4 and 5 which synthesize our findings and provide recommendations for protocol selection. We provide additional supporting information, including a worksheet in Section 6 which helps practitioners select the most appropriate protocol for their objectives. Examples of how to use the worksheet are provided in Appendices B through E. In Section 7 we provide detailed information about each of the 11 protocols. This section identifies the purpose, key questions, strengths and limitations, indicators and metrics, how to interpret results, and additional information for each protocol. Appendix A provides the results for each individual protocol collected during field work at the three meadows.

2. Methods

To conduct this review, we first identified 11 protocols used to assess meadow condition (Table 1). Our evaluation is focused on protocols that can assess meadow condition at a single point in time. Protocols designed primarily to map or classify meadows, such as the "Meadow Hydrogeomorphic Types for the Sierra Nevada and Southern Cascade Ranges in California: A Field Key" (Weixelman et al. 2011) were omitted. Methodologies intended to help guide long-term monitoring of meadows, such as the "Nevada Rangeland Monitoring Handbook" (Swanson et al. 2018) were also excluded in this evaluation. Many of the assessment methods we reviewed also contain a monitoring component, however we did not focus on the monitoring (i.e., repeated measurement) aspect of these protocols. While not included in this review, the Bureau of Land Management's "Assessment, Inventory, and Monitoring" (AIM) protocol is currently being tested to evaluate wetland or lentic resource condition and should be considered for meadow assessment in the future. Once it is finalized, the AIM protocol can be used for both systematic random sampling and targeted use-based monitoring.

Table 1. List of protocols included in this review. This table includes full title, shortened title or acronym used to refer to the protocol in this document, primary agency or organization that produced the protocol, web link to online version of the document, and page number for individual protocol summary that provides additional information for each protocol, including relevant citations.

Protocol Full Title	Protocol Short Title	Primary Agency or Organization[1]	URL	Protocol Summary
Climate Engine	Climate Engine	Desert Research Institute	https://app.climateengine.org	Page 35
California Rapid Assessment Method – Slope Wetlands	CRAM	California Rapid Assessment Method/ California Wetland Monitoring Workgroup	https://www.cramwetlands.org/documents	Page 37
Ecological Approach for Designing and Assessing Montane Meadow Restoration in California	EDA	USDA Forest Service, USDI Fish and Wildlife Service, USDI National Oceanic and Atmospheric Administration	https://academic.oup.com/bioscience/advance-article/doi/10.1093/biosci/biab065/6307424?login=true	Page 39
Groundwater Dependent Systems	GDE	USDA Forest Service	https://go.usa.gov/xFV8p	Page 42
American Rivers Meadow Condition Scorecard	Meadow Scorecard	American Rivers	http://s3.amazonaws.com/american-rivers-website/wp-content/uploads/2016/06/21173432/MeadowsScorecard-08.25.2014.pdf	Page 45
Multiple Indicator Monitoring	MIM	USDI Bureau of Land Management	https://go.usa.gov/xFV86	Page 47
The National Riparian Core Protocol	NRCP	USDA Forest Service	https://go.usa.gov/xFV9c	Page 49
Assessing Proper Functioning Condition for Fen Areas	PFC Fens	USDA Forest Service	https://go.usa.gov/xFAN2	Page 51
A User Guide to Assessing Proper Functioning Condition and the Supporting Science for Lentic Areas	PFC Lentic	USDI Bureau of Land Management, USDA Forest Service, USDA Natural Resources Conservation Service	https://go.usa.gov/xFV9r	Page 53
Proper Functioning Condition Assessment for Lotic Areas	PFC Lotic	USDI Bureau of Land Management, USDA Forest Service, USDA Natural Resources Conservation Service	https://go.usa.gov/xFV99	Page 56
Condition Assessment Using Rooted Frequency and Soil Measurements in Meadows	Rooted Frequency	USDA Forest Service	https://go.usa.gov/xFANN	Page 58

[1]This table only recognizes the primary agency/organization that developed or maintains the protocol, however many of these protocols involve numerous collaborators. See the original protocol for information about additional collaborators/contributors. Identification of the primary agency does not imply exclusive use of the protocol by that agency. Multiple agencies and organizations use a variety of protocols to assess meadow condition.

After identifying a number of assessment protocols to evaluate, we asked the primary author (or a practitioner with extensive experience) of the methodology to summarize the protocol according to a suite of attributes, including target system, scale, time and resources needed, key questions, whether the protocol includes a monitoring component or focuses on assessment only, and what kinds of data are collected. We also asked the contributors to determine the quantitative level of the protocol according to the following three categories: Level 1 – coarse landscape assessment based on resource inventories and maps; Level 2 – rapid assessment of stream/meadow condition which provides a single rating or score; or Level 3 – intensive site assessment of specific ecosystem functions (e.g., using metrics such as vegetation species identification, water column chemistry, aquatic toxicity, or benthic macroinvertebrate community). These levels are defined in "Elements of a State Water Monitoring and Assessment Program" (U.S. Environmental Protection Agency 2003).

To evaluate the kinds of data collected by each protocol, we grouped the individual protocol metrics into eight indicators based on the general data type and purpose in order to apply a consistent terminology across protocols. For the purpose of this comparison, metrics are the specific data collected to evaluate condition, while indicators are general categories of data the metrics are intended to describe. For example, species diversity is one metric that can be used as a Vegetation indicator. The eight indicators we grouped metrics into were: Climate, Cultural, Geomorphology, Hydrology, Landscape Context, Soil, Vegetation, and Wildlife (Table 2). Some indicators contain many metrics, while others have relatively few. A complete list of the metrics collected by each protocol is provided in Section 7. In some cases, a metric was assigned to an indicator that was different from what was described in the original protocol. For example, we assigned the stream channel substrate metric collected as part of the MIM protocol to the Geomorphology indicator because it is related to geomorphic processes, even though it could also have been identified as a Soil indicator. The goal for this exercise was to consistently assign the same metric to the same indicator across all protocols. This allowed us to compare the indicators each protocol addressed, and to determine if different protocols focused on different indicators.

Table 2. Examples of protocol metrics included in each of the eight indicators.

Indicator	Example Metrics (All metrics can be found in Section 7)
Climate	precipitation, temperature, flood and drought resilience
Cultural	archeological, paleontological, cultural, or historic sites/use
Geomorphology	channel cross-section, length of gullies and ditches, bank stability, presence of rocks and/or woody material
Hydrology	floodplain inundation, water quality, depth to groundwater, presence of wetland indicator species
Landscape Context	upstream hydrologic alteration, extent of riparian area, buffer condition
Soil	percent bare ground cover, soil texture, depth to mineral layer
Vegetation	age class distribution, stubble height of forage species, green line plant species composition, conifer encroachment, invasive species presence/absence
Wildlife	presence of aquatic and terrestrial animals, drought refugia habitat, animal effects disturbance

Finally, we convened the protocol authors and other experienced practitioners to conduct each protocol in three common meadows in the field. These three meadows are on the Tahoe National Forest, located north of Truckee, California along State Route 89, and are named Alder Creek Meadow, Kyburz Flat Meadow, and Sagehen/Kiln Meadow (Figure 1). The Alder Creek Meadow is located in Nevada County just north of Truckee and was selected because it is a candidate for restoration due to extensive channel incision in the lower portion of the meadow. Alder Creek Meadow is 43 ha (106 acres) and located adjacent to Prosser Creek Reservoir.

The meadow contains multiple spring-fed channels that flow into the reservoir and contains one fen identified during the field assessment. The Kyburz Flat Meadow is located in Sierra County and was selected because it is part of an active sheep-grazing allotment. Kyburz Flat is an approximately 200 ha (500 acre) meadow bisected by a road, containing multiple spring fed channels. Kyburz Marsh, a 105 ha (260 acre) wetland, is located at the south end of the meadow and was sampled by some of the protocols. The Sagehen/Kiln Meadow is an 18 ha (46 acres) meadow located in Nevada County and was selected because it has fens present.

Within each meadow, the practitioners determined the aTppropriate sampling area based on the specifications of their protocol, although sampling was broadly constrained to a common area to allow for comparison of results. Four of the 11 protocols require a channel to evaluate condition, therefore we focused on meadows with stream channels during our field work so that the protocols could be compared. The three assessment sites were all located in low-gradient (0-2%) riparian areas with large meadow systems adjacent to a stream channel. Among other factors, the total size of the meadow ecosystems and the degree of channel incision varied among the three sites. We tried to select three meadows that had a range of conditions, because some protocols cannot detect small differences if the meadow is in good condition (e.g., Meadow Scorecard).

Representative photos of the three meadows are provided in the individual protocol summaries (Section 7). Appendix A includes maps and the summarized results of each protocol for each of the three meadows. At each meadow, each group of practitioners conducted their sampling independently from the other protocols being conducted. Not all of the protocols were conducted at each meadow because of the absence of particular meadow features (e.g., fens) and/or time constraints (Table 3). While the NRCP protocol was conducted at all three meadows, results were not compiled because the Riparian Technical Guide, which will include methods for data analysis, has not yet been finalized. Therefore, we were not able to include this protocol in our comparative analysis of meadow sampling results (Section 3.2).

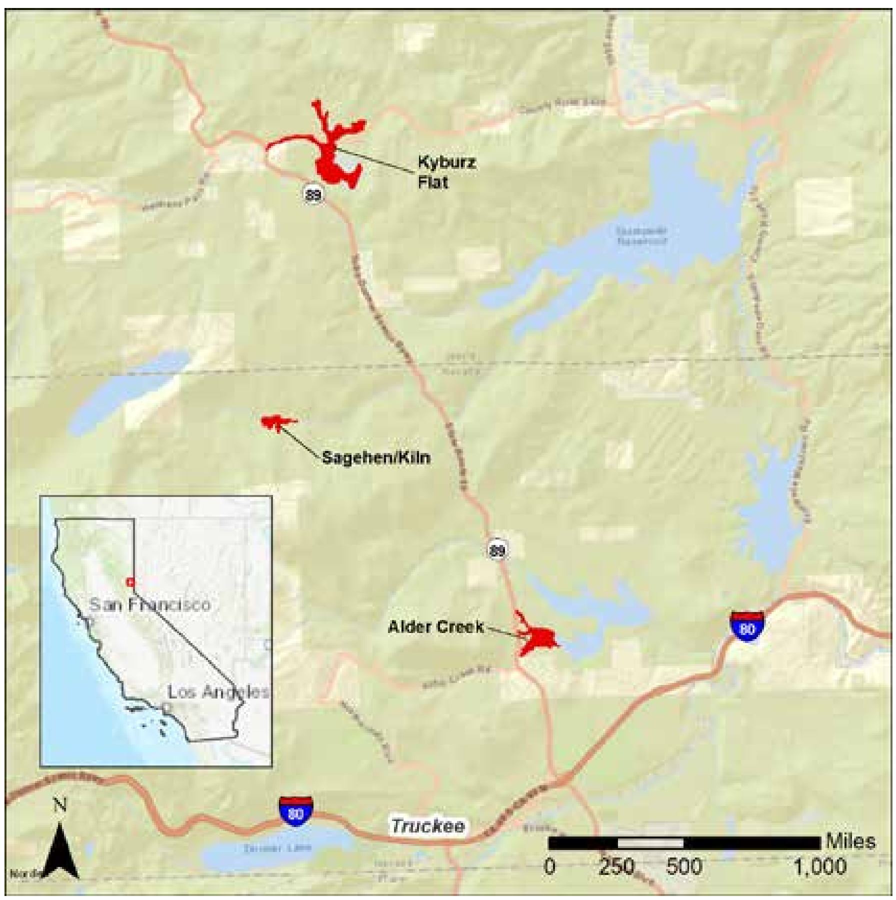

Figure 1. Meadows evaluated.

Table 3. Protocols conducted in each meadow.

Protocol	Alder Creek	Kyburz Flat	Sagehen/ Kiln
Climate Engine	x	x	x
CRAM	x	x	x
EDA		x	x
GDE	x	x	x
Meadow Scorecard	x	x	x
MIM	x	x	x
NRCP	x	x	x
PFC Fen			x*
PFC Lentic	x		
PFC Lotic	x	x	x
Rooted Frequency	x	x	x

*Two fens were sampled at Sagehen/Kiln and rated separately.

Alder Creek Meadow

To compare the results of the different protocols, we developed a system to rate each meadow according to the following categories for condition: Excellent, Good, Fair, or Poor. Although several protocols evaluate condition, they do not assign a single rating or category of meadow condition; we still felt it was important to standardize and assign these categorical ratings to compare methodologies. This rating system was used only to facilitate comparisons among the 11 protocols, and we recommend neither for nor against using such a rating system in meadow assessment in general. To assign comparable ratings to protocols with different outputs, each contributor helped develop the following rulesets to translate the results of their protocol to a broad four category rating system (Table 4). We then converted the categories into a numeric score where Excellent = 4, Good = 3, Fair = 2, and Poor = 1 so that we could calculate the average condition score given by each protocol.

Table 4. Individual protocol rule set assigned to rate each meadow as Excellent, Good, Fair, or Poor.

Protocol	Information Used to Assign Trend	Excellent	Good	Fair	Poor
Climate Engine	Trend and sensitivity to potential water deficit	Upward trend	No trend/ slight downward trend and no/ low sensitivity	Moderate downward trend and sensitivity	Strong downward trend and sensitivity
CRAM	CRAM numeric ratings	90-100	80-89	70-79	<69
EDA	Ratio between current and potential condition	≥95%	<95% and ≥75%	<75% and ≥ 50%	< 50%
GDE	Number of negative effect variables and of false management indicators	0 variables negative or false	1 variable negative or false	2-3 variables negative or false	>3 variables negative or false
Meadow Scorecard	Proportion of total points to possible points	0.85-1	0.75-0.85	0.50-0.75	<0.50

Protocol	Information Used to Assign Trend	Excellent	Good	Fair	Poor
MIM	Ecological Status Rating (ESR) and Winward Greenline Stability (WGS)	ESR = Potential Natural Community and WGS = High	ESR = Late Seral or Mid Seral and WGS = High	ESR = Mid Seral or Early Seral and WGS = Mid	ESR = Early Seral or Very Early Seral and WGS = Low
PFC protocols (i.e., lentic, lotic, and fen)	Narrative description and thermometer rating	Properly Functioning Condition	Functional at Risk with ≤4 non-functional variables; thermometer = high	Functional at Risk with >4 non-functional variables; thermometer = low	Non-Functional
Rooted Frequency	Ratliff (1985) Ecological Status Rating	>75	50-75	25-49	<24

3. Results

3.1. Summary of Protocols Used to Assess Meadow Condition

To achieve our first goal of summarizing information about the 11 protocols, we asked the following questions: 1) Why am I doing the assessment? 2) How am I going to do the assessment? 3) What data am I collecting for the assessment? and 4) What is the format and applicability of the assessment results? The answers to these questions provide an overview of the assessment protocols as described below.

3.1.1. Protocol Objectives—Why am I doing the assessment?

While all 11 protocols evaluated can be used to assess meadow condition, the specific objectives of each protocol differ (Table 5). It is important to understand the objective of the assessment protocol in order to properly interpret the results. The objective of some protocols is to evaluate the overall condition of the meadow, while others are designed to evaluate the condition of specific resources (e.g., vegetation). In addition, some protocols identify specific impacts and stressors that are affecting the meadow condition, while others go further to identify specific actions to improve condition. The objectives of each protocol are achieved by addressing key questions (Section 7) that are informed by collecting data on a variety of metrics and indicators (Section 3.1.3). While these protocols can be used in any meadow, most were developed for specific types of meadows (target system). This document focuses on comparing assessment protocols, six of which can also be used for monitoring (Table 5).

Table 5. Brief description of protocol objectives, target system, and if the protocol is designed only for assessment or if it can be used for monitoring as well.

Protocol	Objective	Target System	Applicability
Climate Engine	Uses remote sensing and spatial (GIS) climatic information to assess change within the study area that is related to climate, management, or other factors.	Any	Assessment and monitoring
CRAM	Designed to assess the overall ecological condition of a wetland and some common stressors that affect wetlands and riparian areas.	Meadows, wetlands, seeps, and springs	Assessment and monitoring
EDA	Characterizes sources of meadow degradation and develops actions to address them.	Meadows	Assessment only

Protocol	Objective	Target System	Applicability
GDE	Describes the major physical and biological characteristics of GDEs, including factors related to management.	Wetlands and springs	Assessment and monitoring
Meadow Scorecard	A preliminary screening tool intended to identify meadows with hydrologic restoration potential.	Meadows	Assessment only
MIM	Assesses streambanks, stream channels, and streamside riparian vegetation primarily to evaluate impacts of livestock and other large herbivores on wadable streams.	Low gradient streams	Assessment and monitoring
NRCP	Collects riparian vegetation composition and structure data for stream reach characterization and monitoring.	Streams and associated floodplains	Assessment and monitoring
PFC Fens	Assesses the condition of fens through consideration of hydrology, vegetation, and soil/landform attributes and evaluates apparent trend.	Fens	Assessment only
PFC Lentic	Determines a lentic riparian wetland area's physical function using hydrology, vegetation, and erosion/deposition attributes in relation to site potential and evaluates apparent trend.	Lentic wetlands	Assessment only
PFC Lotic	Assesses the function of perennial and intermittent streams and their associated riparian areas using hydrology, vegetation, and geomorphology attributes in relation to site potential and evaluates apparent trend.	Lotic wetlands	Assessment only
Rooted Frequency	Assess herbaceous plant species composition and selected soil attributes to evaluate meadow condition in grazed and ungrazed meadows.	Meadows	Assessment and monitoring

3.1.2. Protocol Attributes—How am I going to do the assessment?

The protocols we evaluated differ in a number of key attributes, some of which are summarized in Table 6. For example, four of the protocols subsample the meadow, while the remaining seven protocols focus on the entire relevant unit to determine the extent of sampling (e.g., entire meadow, entire fen). Four of the 11 protocols require the presence of a stream channel. Three of the protocols use a checklist for data collection that includes a series of questions with yes or no responses. Six of the protocols do not include collection of quantitative data during the preliminary assessment phase, although some of these recommend additional quantitative data collection if warranted. Most of the quantitative protocols require at least three hours to complete, except for Climate Engine which can be completed in an hour and does not require field work. Qualitative protocols generally require less than three hours to complete. These examples and Table 6 highlight a few of the various attributes of each protocol, but do not address all of the attributes of every protocol. A more complete description of the attributes of each protocol is provided in Section 7.

Table 6. Primary, but not all, attributes of meadow assessment protocols.

Protocol	Scale[1]	Requires channel[2]	Checklist style[3]	Quantitative[4]	Output is a score	Field time needed	Office time needed
Climate Engine	Entire relevant unit	no	no	yes	no	0-1 hours	1 hour
CRAM	Subsample	no	no	no	yes	2-3 hours	1-2 hours
EDA	Entire relevant unit	no	no	no	no	1+ days	1+ days
GDE	Entire relevant unit	no	no	no	no	1-2 hours	0-4 hours
Meadow Scorecard	Entire relevant unit	yes	no	no	yes	1-3 hours	1-2 hours
MIM	Subsample	yes	no	yes	no	3-6 hours	<1 hour
NRCP	Subsample	yes	no	yes	no	4+ hours	unknown
PFC Fens	Entire relevant unit	no	yes	no	no	1 hour-1 day	1 hour
PFC Lentic	Entire relevant unit	no	yes	no	no	1 hour-1 day	Varies
PFC Lotic	Entire relevant unit	yes	yes	no	no	1 hour-1 day	Varies
Rooted Frequency	Subsample	no	no	yes	no	2-4 hours	1+ hours

[1]Entire relevant unit may be a subsample of the larger meadow.
[2]If used in meadows without a stream channel it reduces the total number of indicators being evaluated.
[3]PFC protocols require a narrative rationale for yes/no/not applicable (NA) responses as well as a description of potential, condition rating, and trend rating.
[4]A no answer means the basic form of the protocol does not include quantitative data collection. However, some protocols include a more complex set of quantitative metrics that can be used when warranted.

3.1.3. Protocol Metrics and Indicators—What data am I collecting for the assessment?

Depending on your objectives, a single protocol might not be able to answer every question you might have about meadow condition. However, understanding what types of data are collected as part of each protocol can help you determine if the protocol will meet some, or most, of your needs. The type and number of indicators addressed varies greatly by protocol (Table 7, Section 7). For example, only Climate Engine and EDA include metrics directly related to the Climate indicator, and GDE is the only protocol to include metrics related to the Cultural indicator. If you have questions about meadow condition that include Climate or Cultural indicators, one of these protocols might be appropriate.

In addition to evaluating the general indicators addressed by each protocol, it is also important to think about how these indicators are measured by considering the individual metrics used. Choosing the appropriate metrics should be based on the objectives and individual project needs for the assessment. For example, while all the protocols collect metrics on the Vegetation indicator, four of these protocols do not identify plants to species (Table 7). If species composition is of interest, these protocols may not meet your needs. Similarly, only four protocols specifically evaluate metrics relative to grazing, measured by evaluating vegetation stubble height or trampling and bank erosion from hoof action as part of Vegetation, Geomorphology, or Hydrology indicators (Table 7). Three other protocols (CRAM, Meadow Scorecard, and NRCP) assess grazing impacts indirectly by allowing practitioners to note these effects as part of additional disturbance or stressor checklists. Identifying the protocols that include grazing metrics will be helpful if evaluating grazing effects is important to you.

The number of metrics used for each indicator also varies greatly across protocols (Table 7). It is as important to choose the right metrics as it is to choose the correct number of metrics. Relying on too few metrics can lead to data and knowledge gaps, whereas utilizing too many metrics may be costly and inefficient. For example, five of the 11 protocols include metrics related to the Soil indicator, but most of these rely on only one or two soil metrics. The GDE protocol, on the other hand, includes eight metrics related to Soil.

For all protocols, regardless of the level of intensity, it is important to engage personnel with the relevant and requisite experience and training. Meadows and riparian areas are complex systems, driven by a large suite of physical and biological factors. The specific expertise of individual team members will likely have a large influence on the results, particularly when protocol metrics are qualitative. Some protocols include metrics that require specialized skills, such as the botanical skills required for plant identification. For this evaluation, protocol experts collected the data.

Table 7. Number of metrics, grouped by indicator, addressed by each protocol.

Indicator[1]	Climate Engine	CRAM	EDA	GDE	Meadow Scorecard	MIM	NRCP	PFC Fen	PFC Lentic	PFC Lotic	Rooted Freq.	Total Protocols
Climate	3		1									2
Cultural				2								1
Geomorphology		3	13	3	3	6†	5	1	2	9		9
Hydrology		2	13	12				2†	9†	2	2	7
Landscape Context		5	1	3				2	2	2		6
Soil				8	1			1	2		2	5
Vegetation	2	5*	4	5	2	5*†	6*	4*	5*	6*	3*	11
Wildlife			5	3†								2
Total metrics	5	15	37	36	6	11	11	10	20	19	7	

[1]The number of metrics and groupings shown here may be slightly different than as described in each protocol. Metric totals are based on the primary metrics of each protocol and do not capture optional metrics.

*Includes collection of plant identification to species level.

†Includes metrics related to livestock grazing.

3.1.4. Protocol Output—What is the format and applicability of the assessment results?

The format and applicability of the assessment results is important to consider. Protocols not only vary in how they evaluate condition, but also in how the results are presented and interpreted. Some methodologies summarize findings in the form of maps and other spatial data, while some provide detailed tables to display results (Table 8, Section 7). The results of other protocols are conveyed primarily in a narrative form, and some protocols include a standardized format for reporting meadow condition, such as the graphic of a thermometer used by the PFC protocols. All the protocols we evaluated also have a notes section that allows the user to include information that was not necessarily captured in the standardized results or output. Notes are important, yet they can be difficult to summarize and rank across multiple sites.

Some assessments directly identify the management concern or need, while others require more interpretation (Table 8). Six of the protocols require interpretation to determine what the results mean in relation to management, while four protocols clearly identify management issues (e.g., the identification of a specific road that is constricting flow), and one protocol suggests specific actions needed to address management issues. It is important to consider how the meadow condition will translate into on-the-ground restoration actions. In some cases, the primary cause of meadow degradation may not be something that the manager can or wants to restore due to the scale of disturbance and resources needed for restoration (e.g., a road crosses the stream at the top of the meadow constricting flows through a culvert onto the meadow surface). However, in some cases the manager may decide it important to restore the meadow, regardless of the scale of degradation or the resources required.

Table 8. Brief description of how protocol outputs are formatted and how output translates to management.

Protocol	Format of Output	Translation to Management
Climate Engine	GIS outputs (maps), graphs, narrative descriptions of patterns observed.	Requires interpretation
CRAM	Standardized report with overall index score, attribute and metric scores, stressor checklist (not metricized), and a short narrative description of the meadow.	Requires interpretation
EDA	Annotated maps and narrative descriptions identifying sources of hydrologic disconnection and opportunities for restoration; includes maps of soils, vegetation types, and potential restoration conditions.	Suggests potential management actions
GDE	Standardized report including narrative description and detailed list of factors and management indicators that affect the site.	Identifies potential management issues
Meadow Scorecard	Scorecards including six metric scores, photographs, and a list of observations (e.g. aspen observed or culverts present).	Requires interpretation
MIM	Summary analysis with numeric outputs and statistical significance in both tabular and graphic format. Includes short narrative summary.	Requires interpretation
PFC Fens	Assessment form includes short description of site potential, yes/no/not applicable answers and notes for indicator items, summary determination of condition, and estimate of trend when functional at risk.	Identifies potential management issues
PFC Lentic	Assessment form includes short description of site potential, yes/no/not applicable answers and notes for indicator items, summary determination of condition, and estimate of trend when functional at risk.	Identifies potential management issues
PFC Lotic	Assessment form includes short description of site potential, yes/no/not applicable answers and notes for indicator items, summary determination of condition, and estimate of trend when functional at risk.	Identifies potential management issues
Rooted Frequency	Detailed species list, ground cover data, and summary of successional stage and ecological rating in a spreadsheet format.	Requires interpretation

3.2. Comparison of Meadow Assessment Results from Field Sampling

To achieve our second goal, we compared the results of data collected using each of the protocols in a common set of three meadows. The data collected are described in Appendix A, and the results are summarized below.

There was some general agreement among how protocols rated meadow condition. More than half of the protocols rated Alder Creek Meadow as being in Fair condition (62%), Kyburz Flat Meadow as being in Good condition (56%), and Sagehen/Kiln Meadow as being in Excellent condition (64%). However, the condition ratings given by the remaining protocols at each meadow differed greatly (Figure 2). In fact, all three meadows received all of the ratings, Excellent, Good, Fair, and Poor, except for Alder Creek, which did not receive any Poor ratings. These results emphasize that protocols differ in the way they assess meadow condition.

Figure 2. Condition ratings for each meadow using our standardized categories.

While individual meadows received a range of condition ratings (Figure 2), individual protocols also exhibited some general agreement in how they rated meadows (Figure 3). Some protocols assessed condition as Excellent at all meadows evaluated (i.e., MIM), while others consistently rated each meadow as being in worse condition (i.e., Poor or Fair) than other protocols (i.e., GDE). Differences in condition ratings were a result of differences in the objectives, the spatial extent and location of the area sampled, and the indicators and metrics used, as described in the following sections.

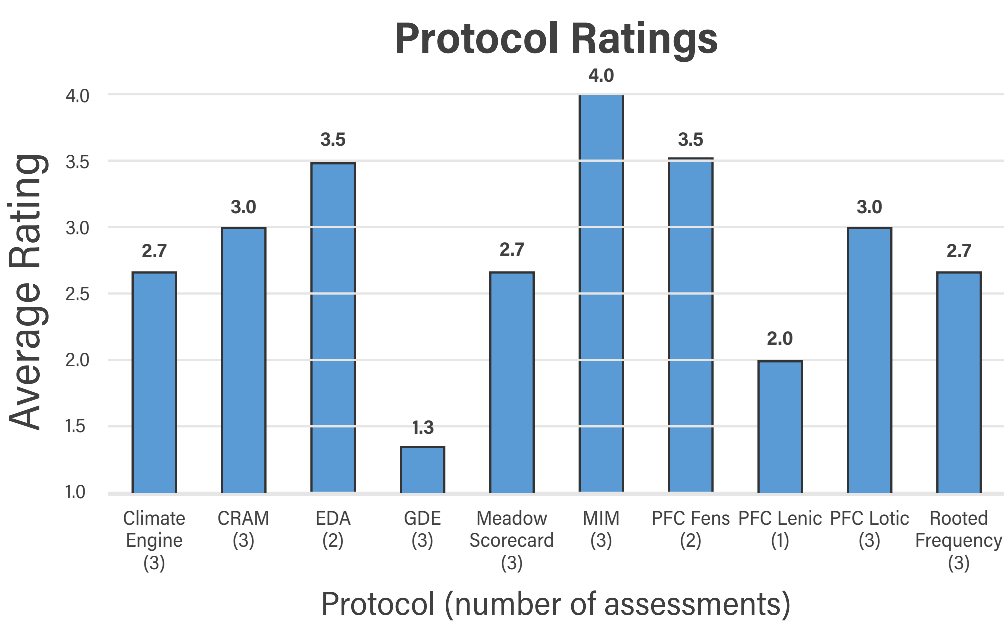

Figure 3. Average condition ratings for each protocol according to our standardized categories. Average rating is identified above each bar on a scale from 1 to 4 where 4=Excellent and 1=Poor. The total number of meadows contributing to the average rating is noted in parentheses after the protocol name.

3.2.1. Protocol Objectives

It is important to consider protocol objectives when selecting an assessment. Although all of the protocols we reviewed were designed to evaluate meadow condition, many of them differ in their specific objectives (Table 1). For example, the objective of the MIM protocol is to evaluate impacts of livestock and other large herbivores along the streambank. Two of the meadows we evaluated are not actively grazed by livestock, and therefore the MIM protocol did not find any grazing-related impacts to these meadows. The results of the MIM protocol indicated that all three meadows evaluated were in Excellent condition, leading to an average condition score of 4.0 for MIM (Figure 3). On the other hand, the GDE protocol rated two of the three meadows as being in Poor condition, and the third as being in Fair condition according to our system, leading to an average condition score of 1.3 for GDE. The objective of this protocol includes identifying factors that are related to management (e.g., recreational effects), and these factors contributed to lower meadow ratings compared with the ratings given by other protocols for the meadows we evaluated. However, this does not mean that protocol objectives will always produce a consistent type of condition rating (i.e., always Excellent or always Poor). The GDE protocol may have consistently determined that meadows were in Excellent condition if we had conducted this review in a remote, unmanaged wilderness area. The MIM protocol may have assigned all meadows a Poor rating if our study sites were all heavily grazed. Instead, our results demonstrate that protocol objectives should be considered in the context of the characteristics of the meadows to be evaluated, including issues related to management.

3.2.2. Spatial Extent and Location

The spatial extent and location of the area sampled may also explain why different protocols assigned different condition ratings to the same meadow (Figure 2). For example, protocols that sampled the entire relevant unit of the meadow at Alder Creek Meadow rated meadow condition as Fair, while most protocols that sub-sampled the meadow, especially near the channel, rated the condition as Good or Excellent (Figure 4). On the other hand, at Sagehen/Kiln Meadow, this pattern was reversed. Protocols that sampled the entire relevant unit of the meadow rated the condition as Excellent, while protocols that sub-sampled the meadow assigned various condition ratings (Figure 5). This result further emphasizes that while spatial extent matters, larger extents do not consistently produce better ratings than smaller ones, or vice versa.

Small subsamples may produce better ratings if they are located in areas that are less degraded. Larger sampling extents may produce better ratings if they reduce the importance of small, localized areas that are degraded. In general, the more heterogenous the meadow, the more sampling extent and location will influence the assessment outcome. For example, at Alder Creek protocols with a smaller sampling size (e.g., MIM) may have had lower ratings if sampling had been conducted on the incised portion of the channel closer to reservoir. However, MIM rated the meadow as Excellent based on a sampling location further upstream. Similarly, the Lotic PFC at Alder Creek may have given the meadow a lower condition rating if the sampling area had been limited to the lower portion of the channel, rather than encompassing the entire channel reach.

Alder Creek Meadow

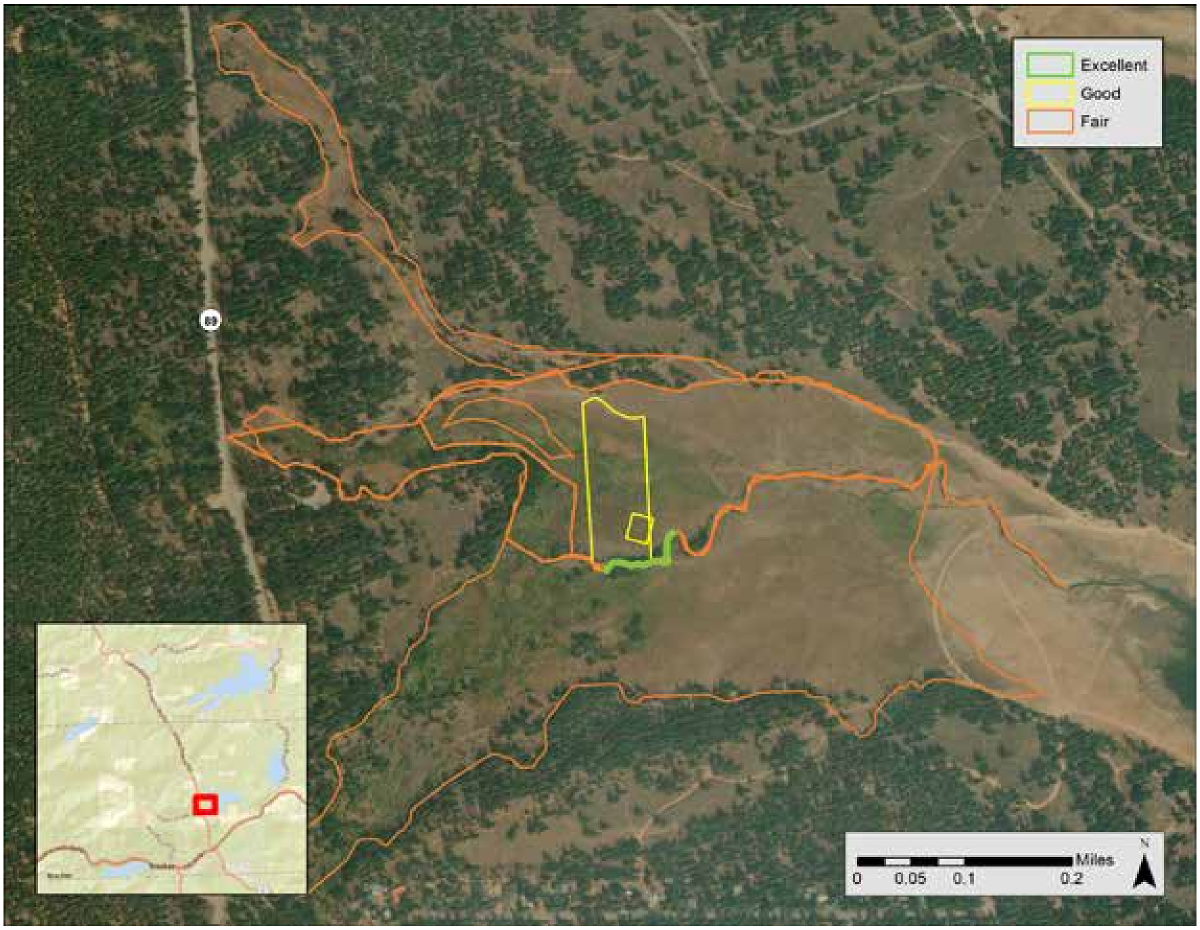

Figure 4. Spatial extent of sampling by standardized rating at Alder Creek Meadow.

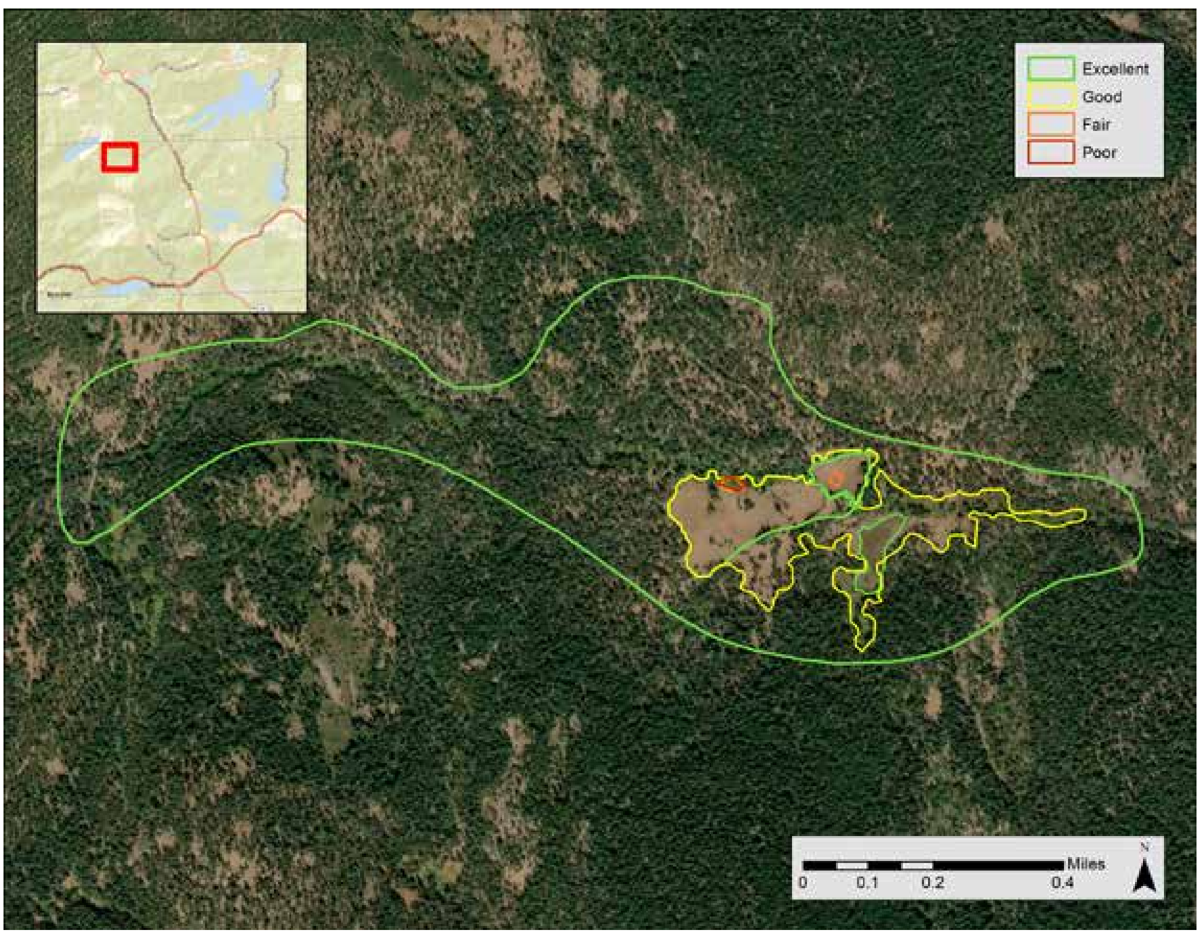

Figure 5. Spatial extent of sampling by standardized rating at Sagehen/Kiln Meadow.

These results emphasize that it is important to consider both the extent and location of samples when assessing meadow condition. Meadows that have high heterogeneity in condition or that support a range of biophysical attributes, such as different hydrogeomorphic land types, may need multiple subsamples to draw similar conclusions or may be more suited to a protocol that assesses the entire meadow. Prior to sampling it is important to walk around the entire site to determine the general condition and ecological context of the meadow or other relevant unit (e.g., is there a stream or fen present, are there multiple hydrogeomorphic land types that make up the meadow), and to consider what spatial extent and location of sampling will most accurately capture meadow condition.

3.2.3. Indicators and Metrics Used

The number and type of indicators and metrics evaluated also explain why the same meadow was given different condition ratings by different protocols (Figure 2). For example, the Rooted Frequency protocol collects several very detailed Vegetation metrics, including results about vegetative succession. Based on these metrics, the Rooted Frequency protocol rated the condition of Sagehen/Kiln Meadow as Fair. On the other hand, protocols that collected data related to other indicators such as Hydrology and Soil, and included fewer metrics related to the Vegetation indicator, rated Sagehen/Kiln Meadow as Good or Excellent. However, protocols that rely on detailed metrics about Vegetation did not consistently produce lower condition ratings than those that weight other indicators, such as Hydrology and Soil, more heavily (Figure 3). The Rooted Frequency protocol found that Alder Creek Meadow was in Good condition, while most other protocols rated the condition of Alder Creek as Fair. This result suggests that while indicators and metrics matter, whether their influence is positive or negative will depend on the specific characteristics of the meadow in which they are used.

3.3. Recommendations

Based on our summary of assessment methodologies (goal 1-Section 3.1) and our field-based data collection (goal 2-Section 3.2), we developed the following recommendations that are not captured elsewhere in this document. These recommendations will help practitioners assess meadow condition and provide recommendations for future efforts associated with improving meadow assessment tools.

Recommendations for assessing meadow condition

- All meadow assessments should use personnel with enough training and experience to conduct the selected protocol accurately and correctly with repeatability.
- When selecting a protocol there may be instances where multiple assessment protocols would be considered depending on the target system. For instance, a protocol associated with streams might be selected for meadows when a stream is present, while a different protocol might be considered for meadows without streams, or areas of the meadow that do not include a stream.
- A common reason to assess meadow condition is to prioritize meadows for restoration. While some of the protocols reviewed here provide a single output score (Table 6) which naturally lend themselves to prioritization, all of the protocols can be used to prioritize meadows for restoration. However, in order to prioritize meadows for restoration, a framework specific to project objectives needs to be developed to achieve a prioritization process, even for protocols that provide single output scores.
- In addition to assessing meadow condition, we strongly encourage land managers to pursue longer-term monitoring efforts to evaluate changes in meadow condition over time. Monitoring is critical for adaptive management and to identify trends. A single snapshot in time may identify that a site is in a degraded condition but leave the land manager unable to determine whether the site is in an upward trend and

could recover naturally. Even when a meadow is identified to be in good condition, it is beneficial to evaluate condition over time to determine if the site is stable or in an upward or downward trend. Monitoring meadow condition over time is also essential to determine if restoration efforts have been effective.

Recommendations for future work to improve meadow assessment tools

- Future efforts to review meadow assessment methodologies could develop a standardized checklist from the notes sections of the protocols to allow for comparison across meadows and protocols. The results we have compiled as part of this comparison could form the basis of such a checklist (Appendix A). However, it is important to note that due to the complexity and variability of meadow systems, a checklist may still miss information that can only be addressed by an unstructured narrative description.
- Additional work may be needed to develop metrics associated with Climate, Cultural, and/or Wildlife indicators. Of the 11 protocols, these indicator groups were only evaluated by one or two protocols. Climate metrics may be especially important as changes in climate continue and there is interest in identifying climate refugia locations.

4. Discussion

This section summarizes information from goals 1 (Section 3.1) and 2 (Section 3.2) to help meadow practitioners select the appropriate protocol for their specific needs (goal 3).

We found that meadow condition ratings varied both among meadows and across protocols. Surprisingly, the same meadow was considered to be in all categories of Excellent, Good, Fair, and Poor condition depending on the protocol used. Some protocols determined that all the meadows evaluated were in Excellent condition, while others determined that all meadows were mostly in Poor condition. Differences in how the protocols rated meadow condition were primarily a result of differences in the objectives of the protocol, indicators and metrics evaluated, and the spatial extent and location of the area sampled. For example, protocols that sub-sampled small portions of the meadow produced different condition ratings than those that sampled or described the entire meadow ecosystem or surrounding watershed. However, there were no consistent trends in how protocol assessment characteristics affected meadow condition ratings. For example, protocols that rely on smaller samples produced either better or worse condition ratings than protocols that sampled the entire meadow or other relevant unit, depending on where the smaller sampling area was located. Although specific protocol objectives, indicators and metrics, and spatial location and extent mattered, the effect of these variables on assessment outcomes (i.e., either positive or negative condition ratings) depended on the specific characteristics of the meadow being evaluated.

In most cases, a single protocol will not be appropriate for all meadows. The best assessment protocol for any given meadow will depend on the type of meadow, the objectives of the assessment, the indicator groups and metrics of interest, the time and resources available, and the skillsets of the practitioners. For example, some practitioners may be primarily interested in evaluating the effect of livestock use on soil and vegetation characteristics associated with a stream channel within a meadow, while others may want to evaluate how climate variables influence landscape-scale vegetation characteristics of meadows and adjacent vegetation types. Site pre-work can help inform the protocol selection process by identifying key aspects of the site, such as the presence of a stream or a fen, or by determining if the site is grazed. Additionally, while all the protocols identify factors that might be contributing to meadow degradation, some protocols make more direct links to potential management actions than others (Table 8).

To fully evaluate the condition of a meadow, a combination of protocols may be warranted to answer different questions, or to evaluate different spatial scales. For example, a qualitative interdisciplinary assessment across a large area can be a good way to start the evaluation process by helping to identify objectives, landscape context, spatial extent, and metrics of interest. This qualitative assessment can then be followed by a more focused quantitative assessment.

5. Choosing an Assessment

All of the protocols presented here can be used to assess the condition of a specific meadow or suite of meadows. We did not identify any single protocol as being better than others and we do not recommend any particular protocol for widespread assessment of meadow condition. Instead, we identified three factors that influence protocol ratings. These are: 1) protocol objectives, 2) spatial extent and location of sampling, and 3) metrics and indicators evaluated. These factors must be considered before choosing a meadow assessment protocol, because they will affect the results. We created a worksheet (Section 6) to help practitioners review important aspects of the assessment protocols presented here. The worksheet asks practitioners to answer a series of questions to help identify a protocol that will work best for their assessment goals as follows: Step 1. Why am I doing this assessment? (i.e., what is the primary objective?) Step 2. What data do I want to collect? (i.e., what indicators and metrics am I interested in?) Step 3. How am I going to do the assessment? (i.e., what scale and resources do I have?) Step 4. What is the format and applicability of the assessment results? And Step 5. Protocol selection and summary. Finally, users must consider other factors, such as if they have the resources and expertise necessary to implement the protocol and evaluate the results. By completing each of these steps, it will be possible to determine which protocol is best suited for a particular meadow assessment project.

We also provide four examples of how to use the worksheet in Appendix B through E. The examples specifically look at hypothetical situations, however the findings of these situations may differ from your specific situation and therefore it is important to walk through the worksheet whenever you begin a new project. The examples we provide are:

Appendix B

You want to evaluate the condition of six pre-identified meadows to prioritize the meadows specifically for stream channel restoration.

Appendix C

You are doing an analysis of grazing effects to meadows in general, and you are particularly interested in evaluating streambanks and channels.

Appendix D

You want to understand the condition of meadows across an entire National Forest.

Appendix E

You want to evaluate the effect of climate on a few meadows where you conducted restoration projects several years ago, but never collected any data.

6. Worksheet for Protocol Screening

The following worksheet is designed to assist you with the process of choosing an assessment. Although there is no one best assessment, filling out this worksheet may help you identify a protocol that will work best for your goals. This worksheet is designed to walk you through five steps that may help you choose an assessment protocol.

Step 1. Why am I doing this assessment?

Step 2. What data do I want to collect?

Step 3. How am I going to do the assessment?

Step 4. What is the format and applicability of the assessment results?

Step 5. Final Summary

With each step, you will identify the protocol(s) that will meet your needs and eliminate others that do not. Sometimes it may be easy to identify these protocols, but sometimes it may be less clear, and you may want to keep some on your list as alternate choices. Consider ranking protocols or using color coding to keep track. Make sure to take clear notes at the end of each step to document your logic. At the beginning of each subsequent step, it may be helpful to cross off the protocols that you have already eliminated. By Step 5, you may still have several protocols to choose from. In that case, you should consider which protocol characteristics are most important to you. Alternatively, you may have one or two protocols identified before you complete all five steps of this worksheet. In this case, you can use the remaining steps to double check that these protocols are suitable for your specific needs.

Step 1. Why am I doing this assessment?

1A) My objective:

1B) Indicate which protocols match your objective as defined in 1A. Writing a short description of why a protocol will or will not meet your needs may also be helpful. Some protocols may fit better than others, so you should also note those which could possibly fit your needs.

Protocol	Objective	Consistent with my objective?
Climate Engine	Assess change within the study area that is related to climate, management, or other factors, using remote sensing and spatial (GIS) climatic information.	
CRAM	Designed to assess the overall ecological condition of a wetland and some common stressors that affect wetlands and wildlife.	
EDA	Characterizes sources of meadow system degradation and develops actions to recover the meadow ecosystem.	
GDE	Describes the major physical and biological characteristics of GDEs, including factors related to management.	
Meadow Scorecard	A preliminary screening tool intended to identify meadows with hydrologic restoration potential.	
MIM	Assesses streambanks, stream channels, and streamside riparian vegetation primarily to evaluate impacts of livestock and other large herbivores on wadable streams.	
NRCP	Collects riparian vegetation composition and structure data for stream reach characterization and monitoring.	
PFC Fens	Assesses the condition of fens through consideration of hydrology, vegetation, and soil/landform attributes and evaluates apparent trend.	
PFC Lentic	Determines a lentic riparian wetland area's physical functioning using hydrology, vegetation, and erosion/deposition attributes in relation to site potential and evaluates apparent trend.	
PFC Lotic	Assesses the function of perennial and intermittent streams and their associated riparian areas using hydrology, vegetation, and geomorphology attributes in relation to site potential and evaluates apparent trend.	
Rooted Frequency	Assess herbaceous plant species composition and selected soil attributes to evaluate meadow condition in grazed and un-grazed meadows.	

1C) What is the result of Step 1B? Which protocols will be considered moving forward and why?

Step 2. What data do I want to collect for the assessment?

2A) What indicator groups are important to you? Note the indicators you want information about for your meadows. You might rank them in order of importance. Some may be critical, some may be optional, or you may only need one of several indicators that are important to you. Also consider if you have the capacity to collect these data. See Table 2 in Section 2 for a summary of the types of metrics included in each indicator.

Indicators	Important to me?
Climate	
Cultural	
Geomorphology	
Hydrology	
Landscape Context	
Soil	
Vegetation	
Wildlife	

2B) Review this table of indicators included in each protocol. Considering only the protocols you identified in Step 1C, use the bottom row of the table to identify protocols which address the indicators you selected in 2A. You may want to note the number of indicators provided versus the number you need in this row. You can also review Section 7 in the main document to get an idea of how intensively each indicator is measured based on the number of metrics collected.

Indicator	Climate Engine	CRAM	EDA	GDE	Meadow Scorecard	MIM	NRCP	PFC Fen	PFC Lentic	PFC Lotic	Rooted Frequency
Climate	3		1								
Cultural				2							
Geomorphology		3	13	3	3	6†	5	1	2	9	
Hydrology		2	13	12				2†	9†	2	2
Landscape Context		5	1	3				2	2	2	
Soil				8	1			1	2		2
Vegetation	2	5*	4	5	2	5*†	6*	4*	5*	6*	3*
Wildlife			5	3†							
Total metrics	5	15	37	36	6	11	11	10	20	19	7
Does the protocol adequately address enough of the indicators identified in step 2A to meet my needs?											

The number of metrics and groupings shown here may be slightly different than as described in each protocol. Metric totals are based on the primary metrics of each protocol and do not capture optional metrics.
*Includes collection of plant identification to species level.
†Includes metrics related to livestock grazing.

2C) What is the result? Which protocols will be considered moving forward and why?

Step 3. How am I going to do the assessment?

Using the protocols identified in Step 2C, work through each of the following questions. Some questions may be more important to you than others. Even if a protocol clearly emerges as your top choice after the first or second question, consider completing the rest of the questions as confirmation of this choice.

3A) Do you need to sample the entire relevant unit, or can you subsample? The entire relevant unit could be the entire meadow, fen, or other sampling area such as both the meadow and surrounding watershed. Use the table to note the protocols which meet your sampling needs.

Protocol	Scale	Meets Needs?
Climate Engine	Relevant unit	
CRAM	Sub-sample	
EDA	Relevant unit	
GDE	Relevant unit	
Meadow Scorecard	Relevant unit	
MIM	Sub-sample	
NRCP	Sub-sample	
PFC Fens	Relevant unit	
PFC Lentic	Relevant unit	
PFC Lotic	Relevant unit	
Rooted Frequency	Sub-sample	

3B) Is there a channel in your meadow(s)? If you believe you may be sampling meadows where there are no channels, then the protocols which require a channel will not meet your needs. Use the table to indicate the protocols which meet your sampling needs. If you have meadows with and without a channel, you may consider using one protocol for the area with a channel and another protocol for areas without channels.

Protocol	Requires Channel	Meets Needs?
Climate Engine	no	
CRAM	no	
EDA	no	
GDE	no	
Meadow Scorecard	yes[1]	
MIM	yes	
NRCP	yes	
PFC Fens	no	
PFC Lentic	no	
PFC Lotic	yes	
Rooted Frequency	no	

[1] If used in meadows without a stream channel it reduces the total number of indicators being evaluated.

3C) Do you need quantitative data? If you do not need quantitative results, then any of the protocols can work. Identify the protocols which meet your sampling needs.

Protocol	Quantitative	Meets Needs?
Climate Engine	yes	
CRAM	no	
EDA	no	
GDE	no	
Meadow Scorecard	no	
MIM	yes	
NRCP	yes	
PFC Fens	no	
PFC Lentic	no	
PFC Lotic	no	
Rooted Frequency	yes	

3D) How much total time do you have to do the assessment? Based on the amount of field and office time required for each protocol, indicate which protocols you can potentially use to sample in the amount of time you have available (note field time ranges are for actual time on the ground and does not include travel time).

Protocol	Field Time	Office Time	Meets Needs?
Climate Engine	0+1 hours	1 hour	
CRAM	2-3 hours	1-2 hours	
EDA	1+ days	1+ days	
GDE	1-2 hours	0-4 hours	
Meadow Scorecard	1-2 hours	1-2 hours	
MIM	3-6 hours	<1 hour	
NRCP	4+ hours	unknown	
PFC Fens	1 hour – 1 day	1 hour	
PFC Lentic	1 hour – 1 day	Varies	
PFC Lotic	1 hour – 1 day	Varies	
Rooted Frequency	2-4 hours	1+ hours	

3E) Do you prefer to have a checklist style data sheet that will allow for yes/no answers? This type of data collection can be quicker and easier for some people to collect. Indicate which protocols meet your sampling needs.

Protocol	Checklist Style	Meets Needs?
Climate Engine	no	
CRAM	no	
EDA	no	
GDE	no	
Meadow Scorecard	no	
MIM	no	
NRCP	no	
PFC Fens	yes	
PFC Lentic	yes	
PFC Lotic	yes	
Rooted Frequency	no	

3F) Considering all of the questions evaluated in Step 3 (A-E), what is the result? Which protocols will be considered moving forward and why?

Step 4. What is the format and applicability of the assessment results?

4A) Consider what outputs you need and how you will use this information for future management or monitoring. Do you want results in the form of a numeric score as a first step in prioritization? Are you trying to communicate results to stakeholders where maps might be helpful? Do you want to use this assessment as a basis for future monitoring? Are you interested in developing specific management actions based on the results of this assessment? Using only the protocols identified in Step 3F, note the protocols whose results are provided in a format that meets your needs.

Protocol	Format of Output	Translation to Management	Monitoring Applicability	Meets Needs?
Climate Engine	GIS outputs (maps), graphs, narrative descriptions of patterns observed.	Requires interpretation	Assessment and Monitoring	
CRAM	Standardized report with overall index score, attribute and metric scores, stressor checklist (not metricized), and a short narrative description of the meadow.	Requires interpretation	Assessment and Monitoring	

Protocol	Format of Output	Translation to Management	Monitoring Applicability	Meets Needs?
EDA	Annotated maps and narrative descriptions identifying sources of hydrologic disconnection and opportunities for restoration; includes maps of soils, vegetation types, and potential restoration conditions.	Suggests Management Actions	Assessment Only	
GDE	Standardized report including narrative description and detailed list of factors and management indicators that affect the site.	Identifies potential management issues	Assessment and Monitoring	
Meadow Scorecard	Scorecards including six metric scores, photographs, and a list of observations (e.g. aspen observed or culverts present).	Requires interpretation	Assessment Only	
MIM	Summary analysis with numeric outputs and statistical significance in both tabular and graphic format. Includes short narrative summary.	Requires interpretation	Assessment and Monitoring	
NRCP	(under development)	(under development)	Assessment and Monitoring	
PFC Fens	Assessment form includes short site description of potential, yes/no/not applicable (NA) answers and notes for indicator items, summary determination of condition, and estimate of trend when functional at risk.	Identifies potential management issues	Assessment Only	
PFC Lentic	Assessment form includes short site description of potential, yes/no/NA answers and notes for indicator items, summary determination of condition, and estimate of trend when functional at risk.	Identifies potential management issues	Assessment Only	
PFC Lotic	Assessment form includes short site description of potential, yes/no/NA answers and notes for indicator items, summary determination of condition, and estimate of trend when functional at risk.	Identifies potential management issues	Assessment Only	
Rooted Frequency	Detailed species list, ground cover data, and summary of successional stage and ecological rating in a spreadsheet format.	Requires interpretation	Assessment and Monitoring	

4B) What is the result? Which protocols will be considered moving forward and why?

Step 5. Final Summary

Discuss why you ended up choosing one protocol over the others.

If you still have several candidate protocols remaining by step 4B, it may be useful for you to review the summaries of the candidate protocols provided in Section 7 to get more information about them. Verify that you have the expertise, time and resources required to conduct your chosen protocol. Reviewing the complete protocol from the original source would then be the final step in determining if the protocol will meet your needs.

7. Individual Protocol Summaries

7.1. Climate Engine

https://app.climateengine.org/climateEngine

Objectives

What is the purpose of the protocol?

This tool uses remote sensing and spatial (GIS) climatic information to assess change within the study area that is related to climate, management, or other factors. Specifically, the tool identifies changes in meadow greenness using the Normalized Difference Vegetation Index (NDVI), as well as wetness, using the Normalized Difference Water Index (NDWI).

Key Questions

- Has vegetation vigor (as measured by greenness and wetness) in the meadow changed through time, and is this variation related to disturbance, climate, and/or management?
- Has restoration proven to be successful? Is there an increase in vegetation vigor after restoration that is statistically significant and independent of climate?

Attributes

Assessment or Monitoring

Both

Target System

Any ecosystem

Channel Required

No

Scale

Entire meadow, minimum size 0.1-0.2 hectares (0.25-0.5 acres) or 1-2 30 m (98 ft) pixels

Office Time

1 hour

Field Time

Additional time for field verification

Personnel

1 person

Quantitative Level

Level 1: resource inventories and maps

Figure 6. Climate Engine practitioners in Kyburz Flat Meadow.

Indicators and Metrics

Indicator	Metric
Climate	Precipitation
	Temperature
	Evaporative demand
Vegetation	Normalized differential water index (NDWI)
Vegetation	Normalized differential vegetation index (NDVI)

Assessment Strengths

- Very quick and easy tool to use.
- Based on non-biased, objective satellite data.
- Can be easily tied to climate histories to separate out climate effects from other impacts.
- Can be applied to any study area of interest going back to 1984.

Assessment Limitations

- Field validation would be very useful, but not necessarily required. There is not currently a protocol for field validation.
- Prior knowledge of the site history is very useful, but not necessarily required.
- Just looking at NDVI and NDWI alone can be hard to interpret when climate and site history are not put into context.

Interpreting Results

Results are provided as GIS outputs (maps), graphs, and narrative descriptions of patterns observed. While there is no protocol that identifies how to interpret results, there is some guidance developed with examples for meadow analyses. Interpretation of results can be improved and clarified with more information about the background of the study location (e.g., restoration history, management history, etc.), and with field validation. Data can be summarized over any range of time (e.g., month, year, etc.) going back to 1984. The metrics can also be evaluated as change or patterns over time. In addition, there are opportunities to evaluate statistical significance of observed changes.

Additional Information

This is both an assessment and monitoring tool but may be more useful for monitoring. Hausner et al. (2018) and Huntington et al. (2017) discuss the use of the tool with statistics. The most useful products within the application are based on the use of Landsat and Sentinel satellite imagery, the computation of NDVI and NDWI, and anomalies of these vegetation indices. Both maps and time series can be computed for specific areas of interest. Although the quantitative level of this tool is level 1 for resource inventories and maps, the data used and results produced by this tool are very quantitative, but at a coarse scale. The Sierra Meadows Partnership Annual Meeting workshop material and guidebook provides background information on remote sensing and drought index, and also includes information about how to apply Climate Engine to meadow areas: https://climate.northwestknowledge.net/CLIMATEENGINE/UserManual_ClimateEngine.pdf. Additionally, the Sierra Meadows Partnership is developing a methodology for assessing restoration effectiveness using this as a monitoring tool.

7.2. CRAM (California Rapid Assessment Method)

https://www.cramwetlands.org/documents#Field%20Books%20

Objectives

What is the purpose of the protocol?

This protocol is a field-based method that uses indicators of physical and biological complexity and structure to assess the overall ecological condition of a wetland and the stressors that affect that wetland (California Rapid Assessment Method 2017).

CRAM can provide condition data for individual wetlands, or populations of wetlands, that can be compared temporally or spatially. It also allows for monitoring and assessment at the project, watershed, eco-region, or statewide scale. CRAM is not intended to replace any existing tools or approaches to monitoring or assessment, but rather to compliment other Level 1 (inventory) and Level 3 (intensive monitoring) data.

There are currently ten different CRAM modules available for different wetland ecosystems, this summary focuses specifically on the slope wetland module.

Key Questions

- What is the current overall ecological condition of the wetland?
- What disturbances and stressors are present that are negatively affecting wetland condition?

Attributes

Assessment or Monitoring
Both

Target System
Meadows, Wetlands, Seeps, Springs, Fens

Channel Required
No

Scale
Varies by wetland type, recommended about 1 ha (2.47 acres) for most

Office Time
1 to 2 hours

Field Time
2 to 3 hours

Personnel
2 to 3 people

Quantitative Level
Level 2: rapid assessment of stream/meadow condition

Figure 7. CRAM practitioner next to scour pool in Kyburz Flat Meadow.

Indicators and Metrics

Indicator	Metric
Geomorphology	Hydrologic connectivity: bank height ratio
Geomorphology	Structural patch richness
Geomorphology	Topographic complexity
Hydrology	Hydrologic connectivity: percent dewatered
Hydrology	Hydroperiod
Landscape context	Aquatic area abundance
Landscape context	Buffer: average buffer width
Landscape context	Buffer: buffer condition
Landscape context	Buffer: percent of assessment area with buffer
Landscape context	Water source
Vegetation	Horizontal interspersion
Vegetation	*Plant community composition: number of co-dominant species
Vegetation	Plant community composition: number of plant layers
Vegetation	*Plant community composition: percent invasive species
Vegetation	Plant life forms

* Includes collection of plant identification to species level.

Assessment Strengths

- Is applicable to any wetland type and can be used anywhere in California.
- Can be applied by trained practitioners from a variety of organizations, companies, or agencies, and serve as the common method of data collection between them.
- Allows for temporal or spatial comparisons between individual wetlands or populations of wetlands.

Assessment Limitations

- Practitioners must be trained.
- CRAM assessments provide a snapshot of wetland condition. They do not provide information about function; CRAM infers that wetlands that are in good condition are providing the suite of functions that are expected for that wetland type.
- Data must be collected during the growing season of plants- in the Sierra Nevada that typically means May/June to September.

Interpreting Results

A CRAM assessment provides a standardized report with an overall Index Score, Attribute and metric scores, and a short description of the meadow. The numerical overall Index Score is the average of four Attribute Scores (Buffer and Landscape Context, Hydrology, Physical Structure, and Biotic Structure). The Index Score is a useful summary, but users are encouraged to also consider the more detailed Attribute scores, and even the Metric scores, to better understand the wetland condition.

Additional Information

The CRAM numerical scores can be used in a number of ways, including for assessment of condition in an area of interest, monitoring of wetlands, monitoring of pre- and post-project conditions, evaluation of impacts, assessment of mitigation performance or success, assessment of compliance, comparison of proposed alternatives, or assisting in the development of mitigation ratios.

7.3. EDA (Ecological Approach for Designing and Assessing Montane Meadow Restoration in California)

Objectives

What is the purpose of the protocol?

The EDA protocol is used to develop actions that restore or work with natural processes to recover the meadow ecosystem. The aim of this assessment is to characterize sources of meadow system degradation and sediment system connectivity as the basis for identifying restoration actions.

Key Questions

The underlying principles of the approach are to: (1) Characterize the natural or pre-development meadow landscape and processes; (2) Delineate the human infrastructure and management actions that constrain and disconnect the pre-development meadow landscape; (3) Identify indicators of meadow system recovery and system degradation; (4) Develop actions to remove or modify human infrastructure and management constraints to the meadow ecosystem; and (5) Develop actions to accelerate and expand existing system recovery process.

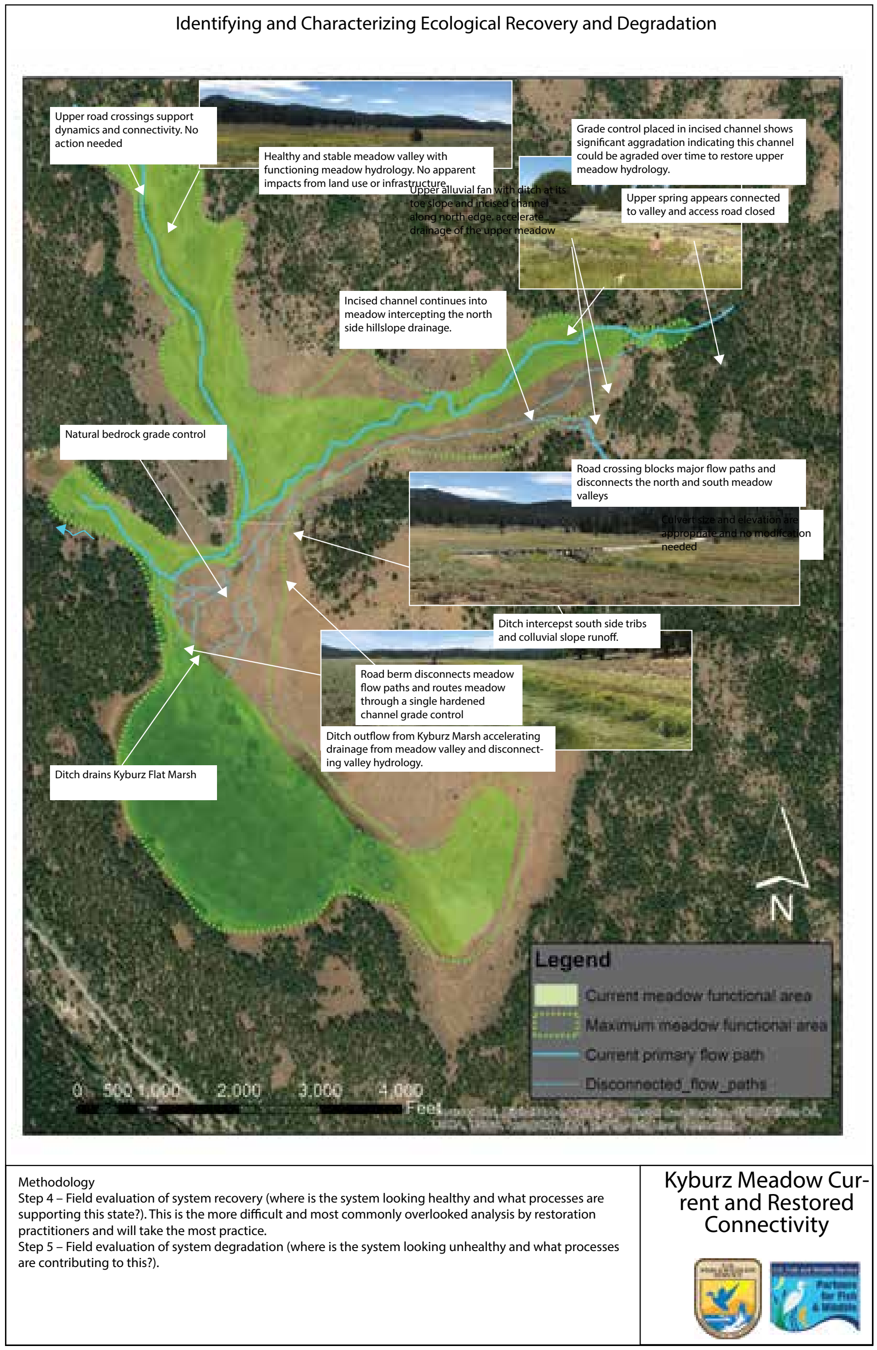

Figure 8. Identifying and characterizing ecological recovery and degradation for Kyburz Flat Meadow.

Attributes

Assessment or Monitoring

Assessment Only

Target System

Meadows

Channel Required

No

Scale

Valley

Office Time

1+ day

Field Time

1+ day

Personnel

1 to 4 people, multi-disciplinary team

Quantitative Level

Level 1: resource inventories and maps, and

Level 2: rapid assessment of stream/meadow condition

Indicators and Metrics

Indicator	Metric
Climate	Resilience: flood and drought
Geomorphology	Channel and floodplain features: bedform and bars
Geomorphology	Channel and floodplain features: islands
Geomorphology	Channel and floodplain features: local confluence/diffluences
Geomorphology	Channel and floodplain features: riparian margins
Geomorphology	Channel and floodplain features: river cliffs
Geomorphology	Channel and floodplain features: sediment storage
Geomorphology	Channel and floodplain features: side channels
Geomorphology	Channel and floodplain features: stable banks
Geomorphology	Habitat: exposed tree roots
Geomorphology	Physical channel dimensions: shoreline length and complexity
Geomorphology	Physical channel dimensions: wetted area relative to flow
Geomorphology	Substrate: substrate patchiness
Geomorphology	Substrate: substrate sorting
Hydrology	Channel and floodplain features: connected wetlands
Hydrology	Channel and floodplain features: floodplain extent and connectivity
Hydrology	Hydraulics: hydraulic diversity
Hydrology	Hydraulics: marginal deadwater
Hydrology	Hydrological regime: base flow
Hydrology	Hydrological regime: flood attenuation
Hydrology	Hydrological regime: flood pulse
Hydrology	Hydrological regime: hyporheic connectivity
Hydrology	Vegetation: aquatic plants
Hydrology	Vegetation: emergent plants
Hydrology	Water quality: clarity
Hydrology	Water quality: nutrient cycling
Hydrology	Water quality: temperature amelioration (shade and hyporeic flow)
Landscape context	Resilience: disturbance
Vegetation	Vegetation: floodplain plants
Vegetation	Vegetation: leaf litter
Vegetation	Vegetation: riparian plants
Vegetation	Vegetation: woody debris
Wildlife	Biota: 1st and 2nd order productivity
Wildlife	Biota: biodiversity (species richness and trophic diversity)
Wildlife	Biota: proportion of native biota
Wildlife	Habitat: drought refugia
Wildlife	Habitat: flood refugia

*This table is based on Tables IV and V in Cluer and Thorne (2013).

Assessment Strengths

- Identifies sources of meadow system degradation and key ecological process at the stream reach and valley scales.
- Identifies actions that promote stewardship.
- Based on ecological engineering principles aimed at reducing anthropogenic impediments and working with ecosystem recovery process.

Assessment Limitations

- Characterizing meadow and stream processes at multiple spatial scales requires training and experience in multiple disciplines. A multidisciplinary team is preferable.
- Assessment may not be applicable to projects aimed at hardening meadow stream channels, reconstructing meadow valleys or constructing specific novel habitats.

Interpreting Results

The output of this analysis includes annotated maps identifying sources of meadow system degradation and sediment and hydrologic system connectivity as the basis for specific restoration actions. Additional results can include a more detailed written or oral communication to stakeholders characterizing important processes influencing meadow recovery and actions that remove impediments to processes and work with existing. Common actions in Sierra Nevada meadows include upgrading road crossings, livestock management and constructing wood jams to accelerate depositional process in incised stream channels. A results summary describes specific potential restoration actions aimed at restoring ecosystem recovery processes in a meadow. These results may be used by managers to set restoration targets, prioritize implementation actions, develop metrics for gauging progress, and develop an adaptive management plan for the meadow restoration.

Additional Information

This protocol is based on Cluer and Thorne (2013) and Pope et al. (2018). The US Fish and Wildlife Service and US Forest Service are further developing the protocol for publication and are available to provide training in this methodology in California and Nevada. More information about this protocol is available at: https://academic.oup.com/bioscience/advance-article/doi/10.1093/biosci/biab065/6307424?login=true

7.4. GDE (Ground Water Dependent Ecosystems)

https://www.fs.fed.us/geology/GDE_Level_I_FG_final_March2012_rev1_s.pdf

Objectives

What is the purpose of the protocol?

This protocol describes the major physical and biological characteristics of GDEs, including factors related to management (U.S. Department of Agriculture 2012). Data collected allow the user to describe a site, its general condition, monitor major changes over time, and to make comparisons among sites of a certain type or within a certain region. This protocol can be used to characterize an individual GDE, inform the site selection process to characterize the GDEs within an area, or to collect baseline information about a particular GDE or a defined group of GDEs.

Key Questions

- Are ecological systems functioning and disturbance processes operating within the natural or desired range of variation?
- Are human pressures or changes in ecological systems inducing changes to the ecological context in which species reside?
- Are habitat relationships or ecological factors affected by management creating risk to species persistence?
- Are projects and activities being implemented as designed?
- Are mitigation measures, best practices and design features effective in mitigating anticipated impacts?
- Are conservation actions achieving desired outcomes?

Figure 9. GDE practitioners sampling soil in Sagehen/Kiln Meadow.

Attributes

Assessment or Monitoring

Both

Target System

Springs, wetlands, fens

Channel Required

No

Scale

N/A

Office Time

0 to 4 hours

Field Time

Level 1: <2 hours

Level 2: 3 to 6 hours

Personnel

Level 1: 2 to 3 people

Level 2: 3 to 5 people

Quantitative Level

Level 1: resource inventories and maps, and

Level 2: rapid assessment of stream/meadow condition

Indicators and Metrics

Indicator	Metric
Cultural	Disturbance: archeological, paleontological, cultural, or historic sites / use
Cultural	Disturbance: recreational effects
Geomorphology	Disturbance: structures
Geomorphology	Flow and Spring Channel: Length of outflow stream
Geomorphology	Flow and Spring Channel: What happens to stream outflow
Hydrology	Disturbance: hydrologic alteration
Hydrology	Flow and spring channel: flow patterns for site
Hydrology	Flow and spring channel: hydroperiod
Hydrology	Flow and spring channel: site flow measurements/estimate
Hydrology	Flow and spring channel: surface water
Hydrology	Water quality: dissolved oxygen
Hydrology	Water quality: oxidation-reduction potential
Hydrology	Water quality: specific conductance
Hydrology	Water quality: temperature
Hydrology	Water quality: water ph
Hydrology	Water table: water table depth
Hydrology	Water table: water table type
Landscape Context	Disturbance: miscellaneous
Landscape Context	Fen characteristics
Landscape Context	Vegetation: surrounding vegetation
Soil	Disturbance: soil alteration
Soil	Soil: color of mineral soil
Soil	Soil: depth of peat, mucky peat, and muck
Soil	Soil: depth to mineral layer
Soil	Soil: hydrogen sulfide odor
Soil	Soil: reaction to dilute hcl
Soil	Soil: redoximorphic features and depths
Soil	Soil: texture of mineral layer
Vegetation	Species of interest (plants); rare or target special interest species
Vegetation	Species of interest (plants); invasive species
Vegetation	Vegetation: bryophyte abundance
Soil	Soil: reaction to dilute hcl
Soil	Soil: redoximorphic features and depths
Soil	Soil: texture of mineral layer
Vegetation	Species of interest (plants); rare or target special interest species
Vegetation	Species of interest (plants); invasive species
Vegetation	Vegetation: bryophyte abundance
Vegetation	Vegetation: lifeform dominant species
Vegetation	Vegetation: lifeform rank
Wildlife	Disturbance: animal effects[†]
Wildlife	Fauna: presence of aquatic and terrestrial animals
Wildlife	Fauna: species of interest

[†]Includes metrics related to livestock grazing.

Assessment Strengths

- Practitioners can pick and choose which attributes are most relevant to their project, including a large number of management indicators.
- Results are integrated into the interagency, collaborative Springs OnLine database.

Assessment Limitations

- Level 2 monitoring requires a much more robust, targeted, and time intensive approach.
- Designed for springs and wetlands in a variety of ecosystems. Not tested in a wet meadow environment, but most of the basic hydrology, soils and vegetation data would be relevant.

Interpreting Results

Level 1 GDE protocol results are descriptive. Level 2 results include a detailed list of factors and management indicators that affect the site. These are generated by the Management Indicator Tool, which includes a series of questions to evaluate if management actions are needed. Data can be entered into the Springs OnLine database maintained by the Springs Stewardship Institute. The database has a wide range of export products, including a geodatabase and reports.

7.5. Meadow Scorecard (American Rivers)

https://www.americanrivers.org/wp-content/uploads/2016/06/MeadowsScorecard-08.25.2014.pdf

Objectives

What is the purpose of the protocol?

The Meadow Scorecard is a preliminary screening tool (American Rivers n.d.). The purpose is to identify meadows with hydrologic restoration potential. The scorecard is qualitative in nature; however, the scoring is based on quantitative measurements, such as bank height, percent bare ground, and length of gullies.

Key Questions

- Are there severe impacts affecting meadow hydrology that restoration actions could improve?
- Is the meadow in good hydrologic condition?

Attributes

Assessment or Monitoring

Assessment Only

Target System

Meadows

Channel Required

Yes, although sometimes used in meadows without a channel, reducing the number of indicators and comparability in the total score among meadows with a channel.

Scale

Size of meadow

Office Time

1 to 2 hours

Field Time

1 to 3 hours

Personnel

1 to 2 people

Quantitative Level

Level 2: rapid assessment of stream/meadow condition

Figure 10. Photo from the Meadow Scorecard assessment of Alder Creek Meadow.

American Rivers

Indicators and Metrics

Indicator	Metric
Geomorphology	Bank height
Geomorphology	Bank stability
Geomorphology	Length of gullies and ditches
Soil	Bare ground
Vegetation	Conifer or upland shrub encroachment
Vegetation	Vegetation cover (graminoid/ forb ratio)

Assessment Strengths

- Assessment requires minimal time or specialized knowledge.
- The data collection is easy to calibrate between observers.
- There is an existing database to enter and store results (https://meadows.ucdavis.edu/).
- The protocol is focused on screening and prioritizing sites for restoration.

Assessment Limitations

- This protocol is not a monitoring tool.
- There are no criteria for defining meadow edge, so determining encroachment can be ambiguous.
- Bank height can be a misleading measure of incision in large streams.
- Entrenched channels with well-established inset banks may be difficult to determine.
- If all meadows are in good condition it can be hard to detect small differences.

Interpreting Results

Scorecards include six numbers, photographs, and a list of observations (e.g. aspen observed or culverts present). There is an existing database to manage scorecard assessment results. Interpretation is straightforward if there are severe impacts or minimal impacts (extremes) and inconclusive where impacts are intermediate. Practitioners are discouraged from relying on a single score because a deeply entrenched meadow with no encroachment is a much better candidate for restoration than a slightly entrenched meadow with slight entrenchment, even though the averages of all six attributes might be the same. American Rivers (2012) provides an example report demonstrating how to evaluate and prioritize meadows for restoration.

Additional Information

In addition to the quantitative metrics described above, a checklist is used to record anecdotal observations such as past restoration efforts, roads in or adjacent to the meadow, grazing observations, evidence of beavers, and the amount of gopher disturbance.

7.6. MIM (Multiple Indicator Monitoring)

https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fseprd558332.pdf

Objectives

What is the purpose of the protocol?

The MIM protocol is designed to monitor streambanks, stream channels, and streamside riparian vegetation (Burton et al. 2011). Indicators and procedures in this protocol were selected and developed primarily to monitor impacts of livestock and other large herbivores on wadable streams (usually less than 10 m [33 feet] wide). A number of metrics in MIM focus on the "greenline" or streamside vegetation that is capable of stabilizing streambanks. For low gradient streams, this metric is an important indicator of condition.

Key Questions

- Is the current season's livestock grazing meeting grazing use criteria?
- Does grazing explain changes in riparian vegetation and channel conditions over time?
- What is the current condition and trend of streambanks, channels, and streamside vegetation?
- Are local livestock grazing management strategies and other land management actions making progress toward achieving the long-term goals and objectives for streamside riparian vegetation and aquatic resources?

Attributes

Assessment or Monitoring

Both

Target System

Low gradient (<4%) streams

Channel Required

Yes

Scale

110 meters (361 feet), with more than 80 20 x 50 cm (8 x 20 in) quadrat

Office Time

Less than 1 hour

Field Time

3 to 6 hours

Personnel

Interdisciplinary team with strong botanical, soil, and hydrology skills

Quantitative Level

Level 3: intensive site assessment

Figure 11. MIM practitioner in Alder Creek Meadow.

Indicators and Metrics

Indicator	Metric
Geomorphology	Greenline-to-greenline width
Geomorphology	Mean residual pool depth
Geomorphology	Pool frequency
Geomorphology	Stream channel substrate
Geomorphology	†Streambank alteration (livestock hoof prints)
Geomorphology	Streambank stability and cover
Vegetation	*Green line plant species composition
Vegetation	†Stubble height of forage species
Vegetation	Woody species age class
Vegetation	†Woody species browsing use
Vegetation	Woody species height class

* Includes collection of plant identification to species level.
†Includes metrics related to livestock grazing.


Kyburz Flat Meadow

Assessment Strengths

- Useful for answering questions about impacts to the near stream environment.
- Protocol is quantitative and statistically rigorous.
- The MIM publication is very detailed and easy to follow.
- The protocol is designed to measure the effects of livestock grazing on streams and streamside vegetation but can also be used to measure the effects of other activities in streamside zones.

Assessment Limitations

- Does not sample the entire meadow or riparian area, instead the protocol focuses on the greenline area.
- The protocol is limited to streams less than 4% gradient and generally less than 10 meters in width.
- Some training and practice are necessary to recognize the greenline feature along the stream channel.
- Does not directly measure channel incision of the floodplain.

Interpreting Results

Protocol results include a summary analysis with numeric outputs in both tabular and graphic format, as well as a short narrative summary. Metrics are classified into "good," "low," or "medium" condition classes to help with interpretation. Summarized metrics can also be compared with objectives and strategies or standards and guidelines in planning documents to aid in interpretation.

Additional Information

The MIM protocol is designed to: 1) address multiple short and long-term indicators; 2) measure the most important indicators relevant to detecting change; 3) use existing procedures to the extent possible; 4) improve efficiency through the use of electronic data collection; 5) yield statistically acceptable results within realistic time constraints; and 6) provide useful data to inform management decisions.

7.7. NRCP (National Riparian Core)

https://www.fs.fed.us/rm/pubs_series/rmrs/gtr/rmrs_gtr367.pdf

Objectives

What is the purpose of the protocol?

The NRCP is a site intensive protocol designed for sampling ecologically important characteristics of riparian areas, including: 1) plant species composition, 2) vertical structure of vegetation, 3) size-class structure of trees, and 4) physical channel characteristics (Merritt et al. 2017). The NRCP is intended to guide land managers in gathering riparian data to make comparisons among multiple reaches or track the trajectory of reaches' vegetation composition and structure over time.

Key Questions

- How does riparian vegetation change across hydrologic gradients and fluvial landforms along a given stream reach?
- How does natural (insect, herbivory, disease), fluvial (stream-related), or human-caused disturbance shape vegetation composition over time?
- What is the effectiveness of stream or riparian restoration in recovering desirable attributes of riparian vegetation, including composition, structure, habitat value, and individual tree fitness?

Attributes

Assessment or Monitoring
Both

Target System
Streams and associated floodplains

Channel Required
Yes

Scale
Channel Reach

Office Time
Unknown

Field Time
4+ hours

Personnel
Botanical skills required

Quantitative Level
Level 3: intensive site assessment

Figure 12. NRCP practitioners in Kyburz Flat Meadow.

Indicators and Metrics

Indicator	Metric
Geomorphology	Active channel width
Geomorphology	Channel cross-section
Geomorphology	Geomorphic classification of fluvial surfaces; including channel, bank, and floodplain features
Geomorphology	Ground cover
Geomorphology	Reach longitudinal profile
Vegetation	*Presence of woody and herbaceous vegetation
Vegetation	Tree basal area and diameter at breast height
Vegetation	Tree canopy condition category
Vegetation	Tree canopy potential
Vegetation	Tree stem density
Vegetation	Vegetation height category

* Includes collection of plant identification to species level.

Sagehen/Kiln Meadow

Assessment Strengths

- The protocol provides a simple, flexible framework for collecting riparian vegetation composition and structure for reach characterization, and can serve as the foundation of a long-term monitoring program.
- The methods can be used on a wide variety of stream types and within a variety of valley settings.
- The number of transects, spacing of transects and/or points per transect, and specific sampling techniques can be modified for specific projects.

Assessment Limitations

- In large valley bottom riparian settings, the protocol can be time intensive.
- A possible limitation is that the greenline or channel bank area is not sampled intensively. This may or may not be a consideration depending on the objectives of the survey.

Interpreting Results

Site attributes are quantitatively summarized and the protocol can be used to track changes over time or to compare multiple sites. Reaches along a segment may be used to track large-scale changes in a stream segment over time. Sites may be evaluated and compared using a variety of metrics and summary statistics. Data entry, quality control and assurance, and data summary and analysis techniques will be detailed in Chapter 8 of the Riparian Technical Guide, which is currently under development. Therefore, we were not able to evaluate protocol results as part of this review.

7.8. PFC Fens (Assessing Proper Functioning Condition for Fen Areas)

https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5385279.pdf

Objectives

What is the purpose of the protocol?

The purpose of the fen PFC is to assess the condition of fens in the Sierra Nevada and Southern Cascades of California through consideration of hydrology, vegetation, and soil/landform attributes (Weixelman et al. 2009).

Key Questions

- Is the fen functioning properly based on the condition of hydrology, vegetation, and soil attributes?
- What are the primary factors that are contributing to fen degradation when present, including hydrology, vegetation, and soils?

Attributes

Assessment or Monitoring

Assessment Only

Target System

Fens

Channel Required

No

Scale

Size of fen

Office Time

1 hour

Field Time

1 hour to 1 day

Personnel

Requires interdisciplinary team with expertise in botany, range, and soils or hydrology

Quantitative Level

Level 2: rapid assessment of stream/meadow condition

Figure 13. Large Fen at Sagehen/Kiln Meadow.

Figure 14. Presence of surface water in the Sagehen/Kiln fen site.

Indicators and Metrics

Indicator	Metric
Geomorphology	Erosion/deposition
Hydrology	Depth to water table
Hydrology	Surface and subsurface flow patterns†
Landscape Context	Conditions adjacent to fen
Landscape Context	Hydrologic alteration
Soil	Bare soil/exposed peat
Vegetation	Conifers and upland shrubs
Vegetation	Vegetation species composition: Presence of non-wetland plant species
Vegetation	Vegetation species composition: Presence of peat forming species*
Vegetation	Vegetation species composition: Presence of wetland indicator species*

* Includes collection of plant identification to species level.
†Includes metrics related to livestock grazing.

Assessment Strengths

- The fen PFC assessment requires specialists with different expertise to work together in the field to agree upon the condition of the fen. By addressing hydrology, vegetation, and soils, the assessment provides an integrated overview of fen condition including a range of important variables.
- The protocol concentrates on problem areas first, thereby increasing efficiency.

Assessment Limitations

- Depending on the experience of the assessment team, some of the questions can be subjective.
- The utility of the assessment varies with the experience of the interdisciplinary (ID) team.

Interpreting Results

The standardized assessment form for the fen PFC includes a short site description, yes/no/not applicable (NA) answers and notes for checklist questions, and a summary determination of condition in one of the following categories: 1) proper functioning condition; 2) functional at-risk with an upward or downward trend; and 3) non-functional. The final summary rating provided by the fen PFC is easy to interpret and can be used to prioritize fens for restoration.

Additional Information

The fen PFC User Guide is often used as a source of background information for understanding fen ecosystems. It provides an overview of fens, how they form, different types of fens, factors that threaten fens, and species that are associated with fens. Prior to conducting the fen PFC, the fen should have been inventoried and basic descriptive data such as water chemistry should have been collected.

7.9. PFC Lentic (A User Guide to Assessing Proper Functioning Condition and the Supporting Science for Lentic Areas)

https://sagebrusheco.nv.gov/uploadedFiles/sagebrusheconvgov/content/CCS/4.1%20Field%20CCS%20Forms%20-%20Lentic%20PFC%20User%20Guide%20(Credit%20Projects).pdf

Objectives

What is the purpose of the protocol?

The lentic PFC provides guidance for assessing the condition of any riparian wetland area other than a lotic (riverine) area (Prichard et al. 2003). The assessment considers hydrology, vegetation, and erosion/deposition attributes using a checklist and additional notes to determine a lentic riparian wetland area's health.

Remote sensing and other GIS data can be used to locate, classify, and stratify lentic riparian areas to select those most representative or in need of assessment. Management and climate records, and existing monitoring information, can also contribute to the PFC.

The assessment defines PFC as a state of resiliency that will allow a lentic riparian wetland area to remain stable during wind and wave action events or overland flow events with a high degree of reliability. This resiliency allows an area to then produce desired values, such as water quality and storage, wildlife habitat, and forage over time. Riparian wetland areas that are not functioning properly cannot sustain these values.

Key Questions

- How well are the physical processes of the lentic riparian area functioning?
- Is the lentic system at risk of degradation or nonfunctional?
- What is the trend in the condition of the lentic area?

Attributes

Assessment or Monitoring
Assessment Only

Target System
Lentic wetlands

Channel Required
No

Scale
Size of lentic riparian wetland

Office Time
Varies

Field Time
1 hour to 1 day

Personnel
Requires interdisciplinary team with expertise in botany, range, and soils or hydrology

Quantitative Level
Level 2: rapid assessment of stream/meadow condition

Figure 15. PFC Lentic practitioner in Alder Creek Meadow.

Indicators and Metrics

Indicator	Metric
Geomorphology	Water and sediment being supplied by the watershed (i.e., no excessive erosion or deposition)
Geomorphology	Islands and shoreline characteristics
Hydrology	Riparian-wetland area is saturated at or near the surface or inundated in "relatively frequent" events
Hydrology	Fluctuation of water levels
Hydrology	Water quality supports riparian-wetland plant species
Hydrology	†Natural surface or subsurface flow patterns are not altered by disturbance (i.e., hoof action, dams, dikes, trails, roads, rills, gullies, drilling activities)
Hydrology	Structure accommodates safe passage of flows (e.g., no headcut affecting dam or spillway)
Hydrology	Species present indicate maintenance of riparian-wetland soil moisture characteristics
Hydrology	Microsite condition (woody material, water temperature, etc.)
Hydrology	Accumulation of chemicals affecting plant productivity/composition
Hydrology	Saturation of soils (i.e., ponding, flooding frequency, and duration) is sufficient to compose and maintain hydric soils
Landscape Context	Riparian-wetland area is enlarging or has achieved potential extent
Landscape Context	Upland watershed is not contributing to riparian-wetland degradation
Soil	Hydrologic heaving (from frost or other)
Soil	Underlying geologic structure/soil material/ permafrost
Vegetation	Age-class distribution of riparian-wetland vegetation
Vegetation	*Composition of riparian-wetland vegetation
Vegetation	Vegetation is comprised of those plants or plant communities that have root masses capable of withstanding wind events, wave flow events, or overland flows
Vegetation	Riparian-wetland plants vigor
Vegetation	Riparian-wetland vegetative cover is present to protect shoreline/soil surface and dissipate energy

* Includes collection of plant identification to species level.
†Includes metrics related to livestock grazing.

Assessment Strengths

This relatively simple protocol can reduce the frequency and sometimes the extent of more data and labor intensive inventories. The lentic PFC can also reduce time and cost by concentrating efforts on the most significant problem areas and problematic attributes first, increasing efficiency.

Assessment Limitations

The lentic PFC does not replace or eliminate the need for more intensive inventory and monitoring protocols. Instead, this protocol is meant to complement more detailed methods by providing a way to synthesize data and communicate results.

Interpreting Results

The lentic PFC provides results in the form of a short site description, yes/no/not applicable (NA) answers and notes for the checklist questions, and a summary determination of condition. The assessment is intended to be performed by a trained and experienced interdisciplinary (ID) team, who must review the answers on the checklist and collectively agree on a rating of proper functioning condition, functional at risk, or nonfunctional. If an ID team agrees on a functional at risk rating, a determination of trend is made when possible.

Additional Information

Quantitative techniques are available to support the lentic PFC checklist and should be used in conjunction with this assessment for individual calibration, where answers are uncertain, or where experience is limited. The lentic PFC is also an appropriate starting point for determining and prioritizing the type and location of additional quantitative inventory or monitoring as necessary.

7.10. PFC Lotic (Proper Functioning Condition Assessment for Lotic Areas)

https://efotg.sc.egov.usda.gov/references/public/CO/TR_1737-15.pdf

Objectives

What is the purpose of the protocol?

The lotic PFC is designed to assess the function of perennial and intermittent streams and their associated riparian areas (Dickard et al. 2015). Remote sensing and other GIS data can be used to delineate reaches with similar hydrology, geomorphology, and vegetation.

Properly functioning condition is defined as, "when adequate vegetation, landform, or woody material is present to: 1) Dissipate stream energy associated with high water flow, thereby reducing erosion and improving water quality; 2) Capture sediment, and aid floodplain development; 3) Improve floodwater retention and ground-water recharge; 4) Develop root masses that stabilize streambanks against erosion; and 5) Maintain channel characteristics." A properly functioning lotic riparian area will, in turn, provide associated values, such as wildlife habitat or recreation opportunities.

Key Questions

- How well are physical processes of the lotic riparian area functioning?
- Is the lotic system at risk of degradation or nonfunctional?
- What is the trend in condition for those areas determined to be functional at risk?

Attributes

Assessment or Monitoring

Assessment Only

Target System

Lotic wetlands

Channel Required

Yes

Scale

Stream Reach

Office Time

Varies

Field Time

1 hour to 1 day

Personnel

Requires interdisciplinary team with expertise in botany, range, and soils or hydrology

Quantitative Level

Level 2: rapid assessment of stream/meadow condition

Figure 16. PFC Lotic assessment area in Alder Creek Meadow.

Indicators and Metrics

Indicator	Metric
Geomorphology	Beaver dams are stable
Geomorphology	Channel dimensions in balance with the landscape setting: width/depth ratio
Geomorphology	Channel dimensions in balance with the landscape setting: channel gradient
Geomorphology	Channel dimensions in balance with the landscape setting: channel sinuosity
Geomorphology	Floodplain and channel characteristics (i.e., rocks, woody material, vegetation, floodplain size, overflow channels)
Geomorphology	Point bars are revegetating with stabilizing riparian plants
Geomorphology	Streambanks are laterally stable
Geomorphology	Stream system is vertically stable (not incising)
Geomorphology	Stream is in balance with the water and sediment that is being supplied by the drainage basin (i.e., no excessive erosion or deposition)
Hydrology	Floodplain inundation
Hydrology	Species composition—indicate maintenance of riparian soil-moisture characteristics
Landscape Context	Riparian area is expanding or has achieved potential extent
Landscape Context	Riparian impairment from the upstream or upland watershed
Vegetation	*Diversity of stabilizing riparian vegetation
Vegetation	Age-class distribution of riparian vegetation
Vegetation	*Species composition— stabilizing plant communities
Vegetation	Riparian plants vigor
Vegetation	Stabilizing riparian vegetation is present to protect banks and dissipate energy
Vegetation	Plant communities are an adequate source of woody material

* Includes collection of plant identification to species level.
†Includes metrics related to livestock grazing.

Assessment Strengths

- The lotic PFC provides a consistent approach for assessing the physical function of lotic riparian areas.
- The assessment can help establish and prioritize management, monitoring, and restoration activities, and communicate fundamental riparian concepts to a wide variety of audiences.

Assessment Limitations

- Utility of the assessment varies with the quality of the interdisciplinary (ID) team.
- The assessment is not designed to assess the condition of ephemeral streams, or to monitor resource conditions and trends.

Interpreting Results

The lotic PFC provides results in the form of a short site description, yes/no/not applicable (NA) answers and notes for the checklist questions, and a summary determination of condition. The ID team must review the yes and no answers on the checklist and their respective comments about the nature and severity of the situation, then collectively agree on a rating of proper functioning condition, functional at risk, or nonfunctional. If an ID team agrees on a functional at risk rating, a determination of trend is made when possible.

Additional Information

The lotic PFC is designed to be used on most stream and river systems, regardless of size, provided that the ID team fully understands the attributes and processes influencing the function of that system. The lotic PFC assessment has been used as the basis for standards and guidelines developed by both the Bureau of Land Management and the Forest Service for management of lotic riparian areas.

7.11. Rooted Frequency (Condition Assessment Using Rooted Frequency and Soil Measurements in Meadows)

https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fseprd558321.pdf

Objectives

What is the purpose of the protocol?

The purpose of the protocol is to monitor changes in herbaceous vegetation, including wetland plant species and woody vegetation (Weixelmann et al. 2014).

Key Questions

- What is the condition and trend of the meadow (based primarily on plant community composition and soil cover)?
- What are the trends in individual plant species or groups of species (for example plant functional types or wetland species)?

Attributes

Assessment or Monitoring

Both

Target System

Meadows

Channel Required

No

Scale

25 x 10 meter (32 X 82 feet) plot; can include multiple plots in larger meadows

Office Time

1+ hours

Field Time

2 to 4 hours

Personnel

Botanical skills are needed

Quantitative Level

Level 3: intensive site assessment

Figure 17. Rooted Frequency practitioners in Kyburz Flat Meadow.

Indicators and Metrics

Indicator	Metric
Hydrology	Depth to mottles
Hydrology	Soil saturation
Soil	Ground cover summary; vegetation, litter, bare
Soil	Soil texture at 25 cm (10 in)
Vegetation	*Plant species
Vegetation	Rooting depth for common, fine and very fine roots
Vegetation	Species similarity to potential natural community

* Includes collection of plant identification to species level.

Assessment Strengths

- This is a simple, repeatable method for monitoring changes in plant species composition.
- Results include detailed species lists, with complete floristic data for each plot.
- Because the rooted frequency method only records the presence or absence of species rooted in the plot, sites can be grazed, and results are still comparable to ungrazed readings.
- The methods track frequency of woody species using the presence or absence of a canopy above the quadrat.
- The protocol is adaptable to most herbaceous plant communities.
- Soil measurements can be used to determine depth to saturation, soil texture, and rooting characteristics.

Assessment Limitations

- This method uses the presence or absence of plant species, not cover. This can limit the interpretation of data because rooted frequency does not always equate to dominance in terms of cover.
- This method is best used for a targeted assessment for a portion of a meadow. The method samples only a 10 X 25 meter (32 X 82 feet) portion of a meadow. It does not sample large portions of a meadow, although multiple plots can be established in a single meadow to increase sampling intensity.

Interpreting Results

The Rooted Frequency protocol results include a detailed species list, ground cover data, and a summary of successional stage and ecological rating in a spreadsheet format. There is an existing ACCESS database for entering data. Plant frequency data can be summarized using the Ratliff condition class scorecard and the plant successional ratings in the publication, "Plant Guide for Resource Managers" (Lorenzana et al. 2017). The Ratliff condition scorecard estimates the condition class (either Excellent, Good, Fair, or Poor) for the site sampled. The data can also be used to conduct additional statistical analyses.

Additional Information

This protocol is the foundation of large-scale, regional range monitoring efforts conducted by the Forest Service. The plots should be located in a relatively homogenous portion of the meadow in terms of hydrology and landform to allow for easier interpretation of trends. For trend measurements, transects should be permanently marked, for example, with sunken rebar stakes.

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Appendix A

Meadow Assessment Results from Field Sampling

This appendix includes the results from all the protocols sampled at Alder Creek, Kyburz Flat, and Sagehen/Kiln meadows. Sampling location is presented for each protocol (Figure 19, Figure 21, Figure 23). Results are also visualized by the standardized rating of Excellent, Good, Fair or Poor (Figure 4, Figure 5, and Figure 22) and as tables that include information on the assessment output, the standardized rating used for this comparison, and the factors identified that contributed to the rating (Table 9, Table 10, Table 11).

The original field results can be found at the Sierra Nevada Meadows Data Clearinghouse hosted by UC Davis the Center for Watershed Sciences and the Information Center for the Environment. Each meadow has a unique meadow page where all results from this field work, as well as other field work, can be reviewed to understand what the raw and summarized data looks like.

Data for each protocol collected at Alder Creek Meadow can be found at:
https://meadows.ucdavis.edu/meadows/ucdsnm014565

Data for each protocol collected at Kyburz Flat Meadow can be found at:
https://meadows.ucdavis.edu/meadows/ucdsnm014791

Data for each protocol collected at Sagehen/Kiln Meadow can be found at:
https://meadows.ucdavis.edu/meadows/ucdsnm014662

Alder Creek Meadow

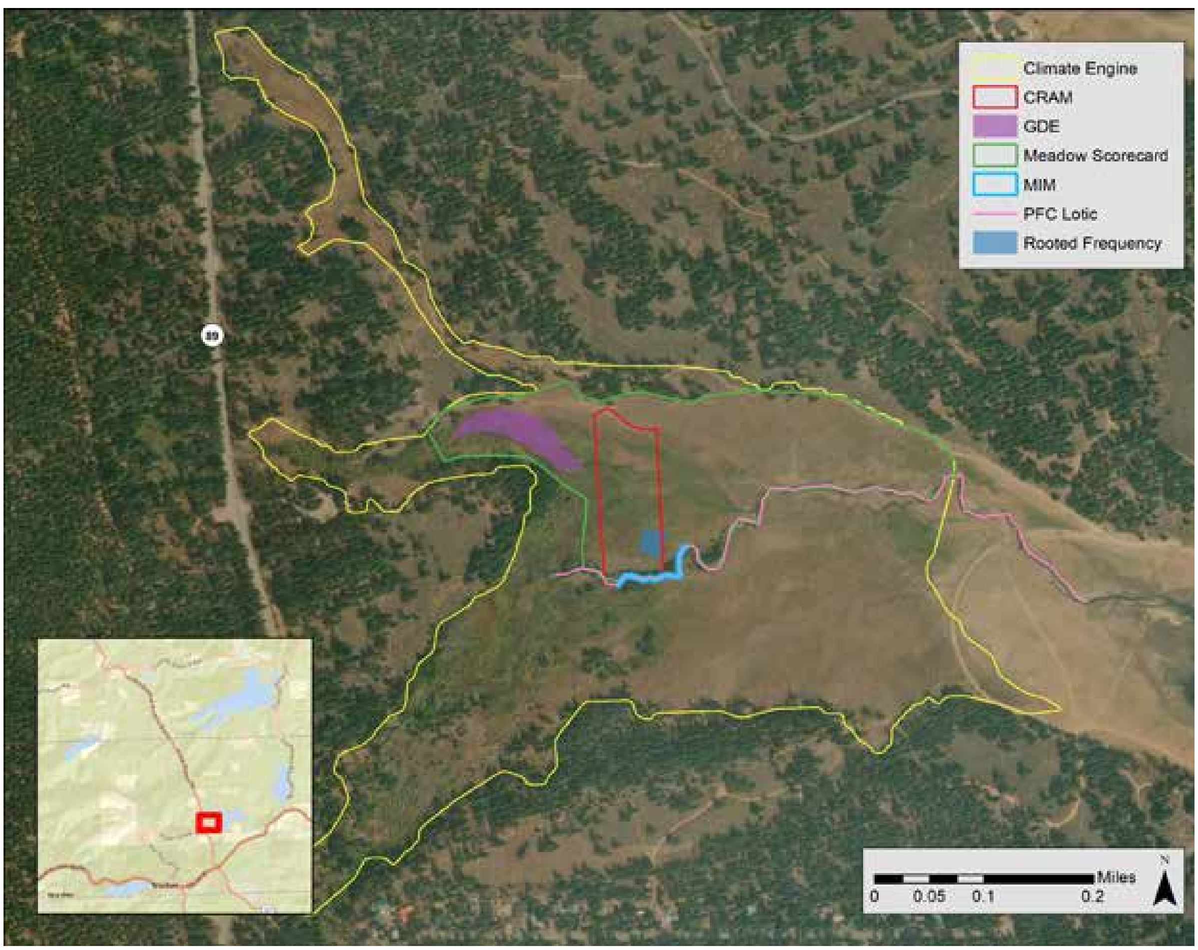

Figure 18. Spatial extent and location of the eight protocols sampled during meadow field work at Alder Creek.

Table 9. Assessment results for the eight protocols sampled during field work at Alder Creek. The table provides information on the assessment output, the standardized rating, and factors identified that contributed to the standardized rating.

Protocol	Assessment Output	Standardized Rating	Factors Identified
Climate Engine	Downward trend and sensitivity to potential water deficit	Fair	Drying, extensive downcutting, declining vegetative cover in small area
CRAM	84/100	Good	Incised channel, otherwise good condition
GDE	2 negative effects identified, no False Management Indicators	Fair	Fen dewatering due to channelized flow
Meadow Scorecard	18/32 = 56%	Fair	Headcuts, channel incision, drying
MIM	Greenline Ecological Status Rating = 92.7 (PNC); Winward Greenline Stability Rating = 7.73 (High)	Excellent	Robust stream channel with no signs of erosion, no streambank alteration
PFC Lentic	Functional at Risk, with 8 variables identified as non-functional	Fair	Incision, headcutting, drying of meadow at downstream end
PFC Lotic	Functional at Risk, with 8 variables identified as non-functional	Fair	Incision, headcutting, fluctuation of water levels, lack of stabilizing vegetation at downstream end
Rooted Frequency	Ecological status rating of 63	Good	43% competitor/decreaser species

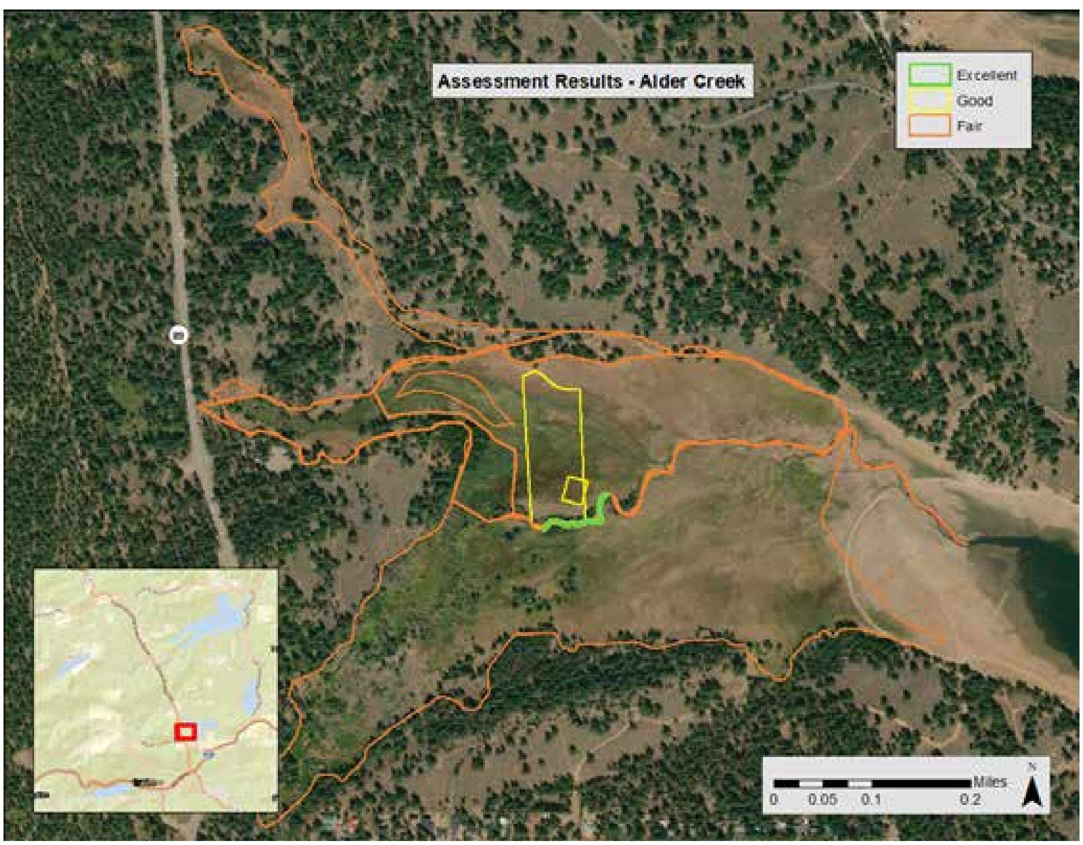

Figure 19. Spatial extent of sampling by standardized rating at Alder Creek Meadow.

Kyburz Flat Meadow

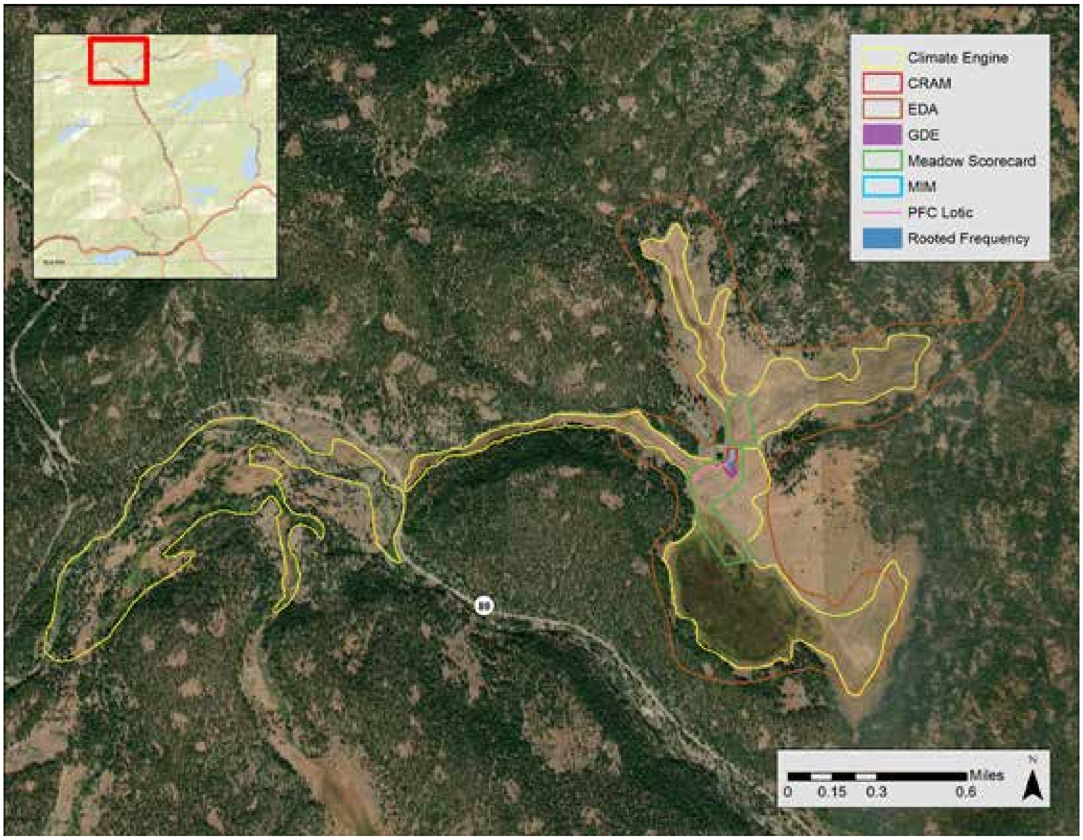

Figure 20. Spatial extent and location of the eight protocols sampled during field work at Kyburz Flat Meadow.

Table 10. Assessment results for the eight protocols sampled during field work at Kyburz Flat Meadow. The table provides information on the assessment output, the standardized rating, and factors identified that contributed to the standardized rating.

Protocol	Assessment Output	Standardized Rating	Factors Identified
Climate Engine	Mostly no trend and low sensitivity to potential water deficit	Good	Potentially some drying and conifer encroachment
CRAM	72/100	Fair	Hydrologic and physical structure attributes - dikes, levees, culverts, channel incision, drying
EDA	Current (357 acres) / potential meadow area (464 acres) = about 77%.	Good	Partially recovered but locked in current state. Current infrastructure disconnects hydrology
GDE	5 negative effects identified, 3 False Management Indicators	Poor	Channel incision, erosion, altered hydrology
Meadow Scorecard	14/24=58%	Fair	Bare ground, conifer encroachment
MIM	Greenline Ecological Status Rating = 100 (PNC); Winward Greenline Stability Rating = 7.94 (High)	Excellent	No streambank alteration along the greenline
PFC Lotic	Functional at Risk, with 4 variables identified as not-functional	Good	Culvert, road, concentrated flood flows, channel incision, erosion
Rooted Frequency	Ecological status rating of 51	Good	31% competitor/decreaser species

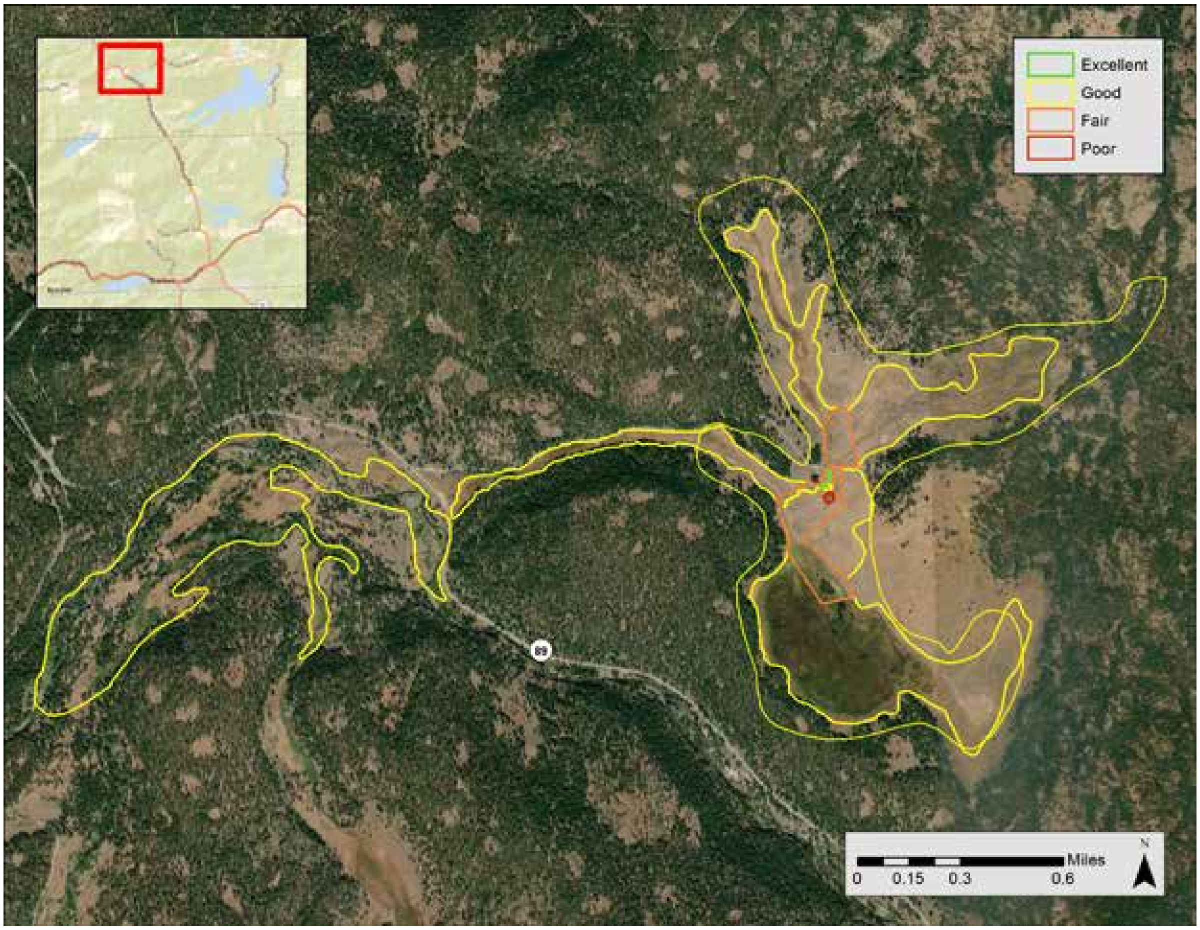

Figure 21. Spatial extent of sampling by standardized rating at Kyburz Flat Meadow.

Sagehen/Kiln Meadow

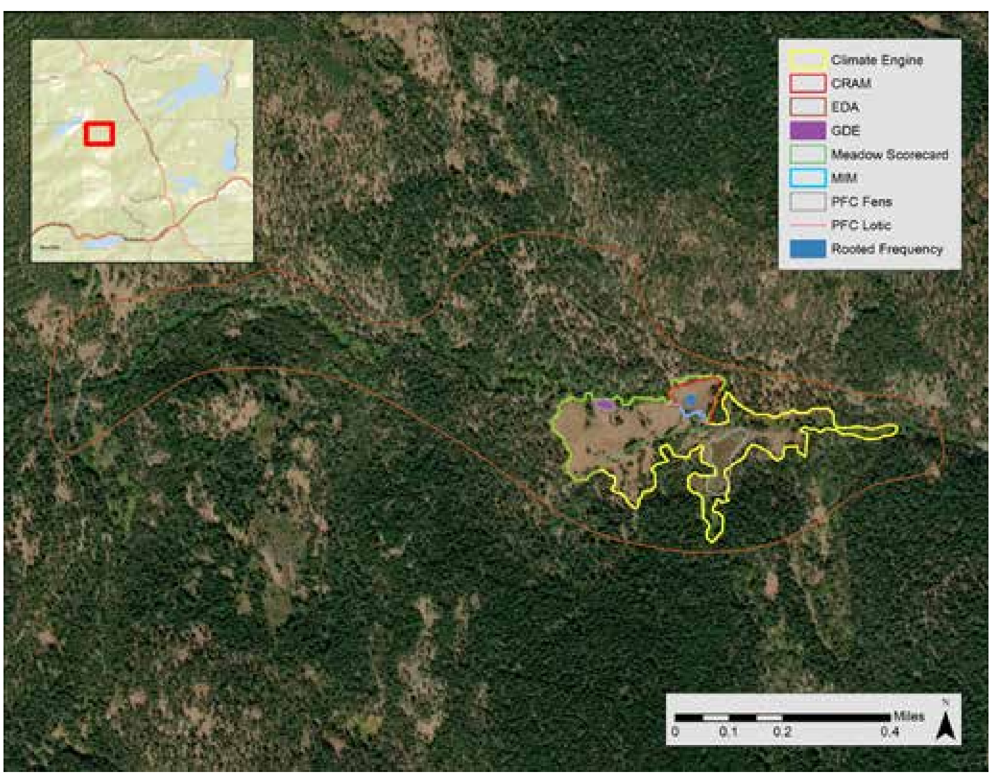

Figure 22. Spatial extent and location of the nine protocols sampled during field work at Sagehen/Kiln Meadow.

Table 11. Assessment results for the eight protocols sampled during field work at Sagehen/Kiln Meadow. The table provides information on the assessment output, the standardized rating, and factors identified that contributed to the standardized rating.

Protocol	Assessment Output	Standardized Rating	Factors Identified
Climate Engine	Slight downward trend and some sensitivity to potential water deficit	Good	Drying, possibly declining vegetative cover in small area near fen
CRAM	90/100	Excellent	Could be used as reference site
EDA	Current and potential meadow area roughly equal.	Excellent	High level of function. Healthy hydrology. Did not see indicators of disconnectivity in material/sediment supply to the meadow. One culvert with localized effects, otherwise this site could be used as a reference.
GDE	3 negative effects identified, 1 false management indicator	Poor	Channel potentially dewatering fen, some upland species
Meadow Scorecard	28/32 = 87.5%	Excellent	Slight impacts to bank stability and vegetative cover - small areas of incision/erosion
MIM	Greenline Ecological Status Rating = 100 (PNC); Winward Greenline Stability Rating = 8.44 (High)	Excellent	No streambank alteration, no uncovered or eroding banks
PFC Fens	Proper Functioning Condition, with 2 variables identified as not-functional	Excellent	Channels present, conifer species encroachment
PFC Fens	Functional at Risk, with 3 variables identified as not-functional	Good	Channel dewatering fen, conifer and upland species encroachment
PFC Lotic	1 variable not functional, PFC	Excellent	Some areas may not experience frequent flooding
Rooted Frequency	Ecological status rating of 36	Fair	21% competitor/decreaser species

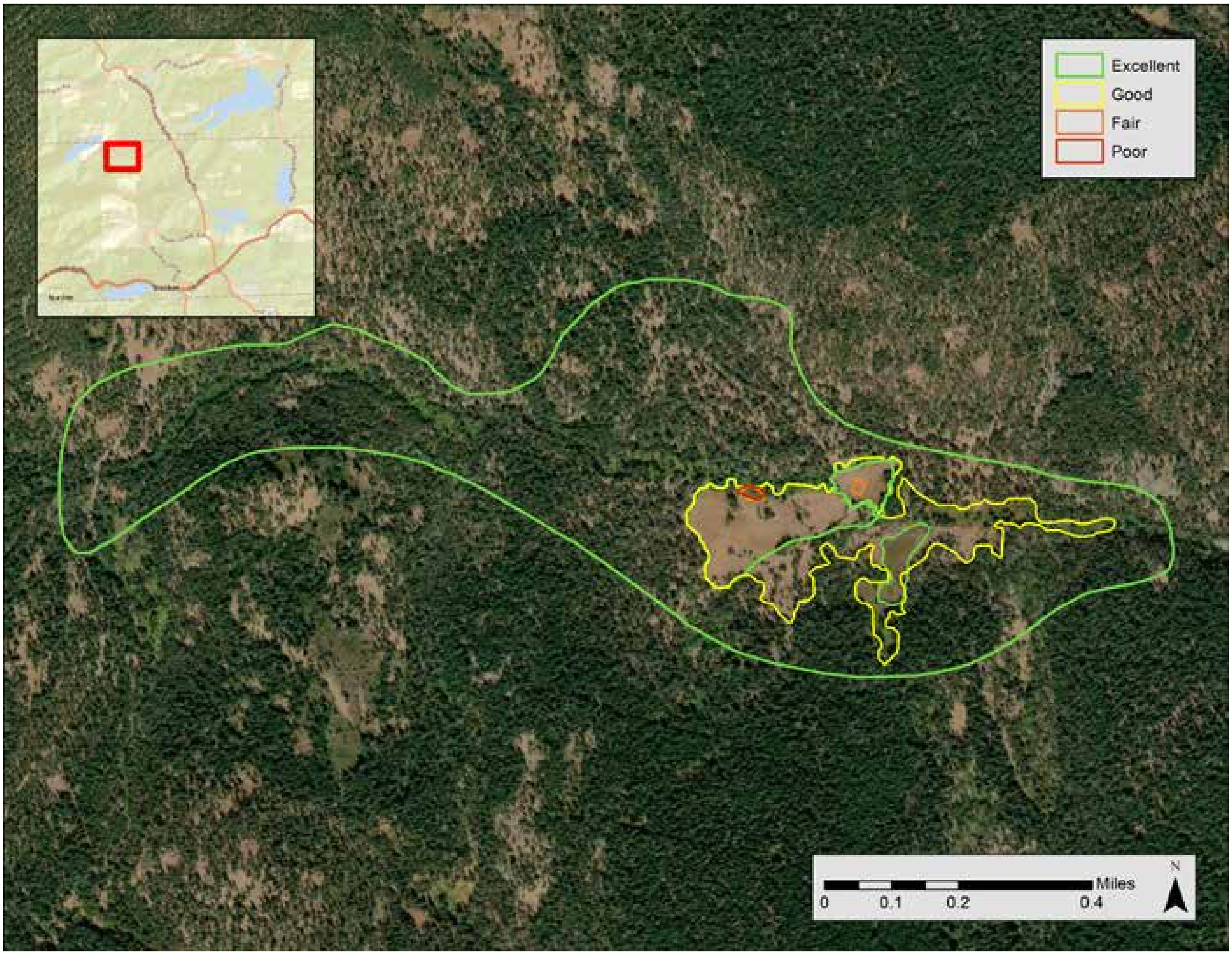

Figure 23. Spatial extent of sampling by standardized rating at Sagehen/Kiln Meadow.

Appendix B

Example 1: Worksheet to prioritize six pre-identified meadows for stream channel restoration

The examples specifically look at hypothetical situations, however the findings of these situations may differ from your specific situation and therefore it is important to walk through the worksheet whenever you begin a new project.

Step 1) Why am I doing this assessment?

1A) My objective:

Is to evaluate the condition of six pre-identified meadows to prioritize specifically for stream channel restoration.

1B) Indicate which protocols match your objective as defined in 1A.

Writing a short description of why a protocol will or will not meet your needs may also be helpful. Some protocols may fit better than others, so you should also note those which could possibly fit your needs.

Protocol	Objective	Consistent with my objective?
Climate Engine	Assess change within the study area that is related to climate, management, or other factors, using remote sensing and spatial (GIS) climatic information.	X
CRAM	Designed to assess the overall ecological condition of a wetland and some common stressors that affect wetlands and wildlife.	X
EDA	Characterizes sources of meadow system degradation and develops actions to recover the meadow ecosystem.	X
GDE	Describes the major physical and biological characteristics of GDEs, including factors related to management.	X
Meadow Scorecard	A preliminary screening tool intended to identify meadows with hydrologic restoration potential.	X
MIM	Assesses streambanks, stream channels, and streamside riparian vegetation primarily to evaluate impacts of livestock and other large herbivores on wadable streams.	X
NRCP	Collects riparian vegetation composition and structure data for stream reach characterization and monitoring.	X
PFC Fens	Assesses the condition of fens through consideration of hydrology, vegetation, and soil/landform attributes and evaluates apparent trend.	No
PFC Lentic	Determines a lentic riparian wetland area's physical functioning using hydrology, vegetation, and erosion/deposition attributes in relation to site potential and evaluates apparent trend.	No
PFC Lotic	Assesses the function of perennial and intermittent streams and their associated riparian areas using hydrology, vegetation, and geomorphology attributes in relation to site potential and evaluates apparent trend.	X
Rooted Frequency	Assess herbaceous plant species composition and selected soil attributes to evaluate meadow condition in grazed and un-grazed meadows.	X

1C) What is the result of Step 1B? Which protocols will be considered moving forward and why?

All of the protocol objectives match the objective of this assessment, except for PFC Fens and PFC Lentic which are focused on the non-stream components of the meadow

Step 2) What data do I want to collect for the assessment?

2A)

What indicator groups are important to you? Note the indicators you want information about for your meadows. You might rank them in order of importance. Some may be critical, some may be optional, or you may only need one of several indicators that are important to you. Also consider if you have the capacity to collect these data. See Table 2in Section 2 for a summary of the types of metrics included in each indicator.

Indicators	Important to me?
Climate	
Cultural	
Geomorphology	X
Hydrology	X
Landscape Context	
Soil	
Vegetation	
Wildlife	

2B)

Review this table of indicators included in each protocol. Considering only the protocols you identified in Step 1C, use the bottom row of the table to identify protocols which address the indicators you selected in 2A. You may want to note the number of indicators provided versus the number you need in this row. You can also review Section 7 in the main document to get an idea of how intensively each indicator is measured based on the number of metrics collected.

Indicator	Climate Engine	CRAM	EDA	GDE	Meadow Scorecard	MIM	NRCP	PFC Lotic	Rooted Frequency
Climate	3		1						
Cultural				2					
Geomorphology		3	13	3	3	6†	5	9	
Hydrology		2	13	12				2	2
Landscape Context		5	1	3				2	
Soil				8	1				2
Vegetation	2	5*	4	5	2	5*†	6*	6*	3*
Wildlife			5	3†					
Total metrics	**5**	**15**	**37**	**36**	**6**	**11**	**11**	**19**	**7**
Identify protocols that address enough of the indicators identified in step 2A to meet my needs?	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

The number of metrics and groupings shown here may be slightly different than as described in each protocol. Metric totals are based on the primary metrics of each protocol and do not capture optional metrics.
*Includes collection of plant identification to species level.
†Includes metrics related to livestock grazing.

2C) What is the result? Which protocols will be considered moving forward and why?

Geomorphology and hydrology are intricately connected therefore we want to focus on protocols that evaluate at least one of these indicators. At this step Climate Engine will no longer be brought forward.

Step 3) How am I going to do the assessment?

Using the protocols identified in Step 2C, work through each of the following questions. Some questions may be more important to you than others. Even if a protocol clearly emerges as your top choice after the first or second question, consider completing the rest of the questions as confirmation of this choice.

3A)

Do you need to sample the entire relevant unit, or can you subsample? The entire relevant unit could be the entire meadow, fen, or other sampling area such as both the meadow and surrounding watershed. Use the table to note the protocols which meet your sampling needs.

Our preference is to evaluate the entire meadow to really understand restoration need, however if the sub-samples are representative of channel condition then a sub-sample would be okay. In order to capture this, we identified samples at the entire relevant unit as a priority 1 and sub-sampling protocols as priority 2.

Protocol	Scale	Meets Needs?
CRAM	Sub-sample	Priority 2
EDA	Relevant unit	Priority 1
GDE	Relevant unit	Priority 1
Meadow Scorecard	Relevant unit	Priority 1
MIM	Sub-sample	Priority 2
NRCP	Sub-sample	Priority 2
PFC Lotic	Relevant unit	Priority 1
Rooted Frequency	Sub-sample	Priority 2

3B)

Is there a channel in your meadow(s)? If you believe you may be sampling meadows where there are no channels, then the protocols which require a channel will not meet your needs. Use the table to indicate the protocols which meet your sampling needs. If you have meadows with and without a channel, you may consider using one protocol for the area with a channel and another protocol for areas without channels.

There are channels in all of the meadows and the objective of this project is to focus on channel restoration.

Protocol	Requires Channel	Meets Needs?
CRAM	no	
EDA	no	X
GDE	no	X
Meadow Scorecard	yes1	X
MIM	yes	X
NRCP	yes	X
PFC Lotic	yes	X
Rooted Frequency	no	X

1If used in meadows without a stream channel it reduces the total number of indicators being evaluated.

3C)

Do you need quantitative data? If you do not need quantitative results, then any of the protocols can work. Identify the protocols which meet your sampling needs.

No.

Protocol	Quantitative	Meets Needs?
CRAM	no	X
EDA	no	X
GDE	no	X
Meadow Scorecard	no	X
MIM	yes	X
NRCP	yes	X
PFC Lotic	no	X
Rooted Frequency	yes	X

3D)

How much total time do you have to do the assessment? Based on the amount of field and office time required for each protocol, indicate which protocols you can potentially use to sample in the amount of time you have available (note field time ranges are for actual time on the ground and does not include travel time).

We have six meadows and up to two days available per meadow.

Protocol	Field Time	Office Time	Meets Needs?
CRAM	2-3 hours	1-2 hours	X
EDA	1+ days	1+ days	X
GDE	1-2 hours	0-4 hours	X
Meadow Scorecard	1-2 hours	1-2 hours	X
MIM	3-6 hours	<1 hour	X
NRCP	4+ hours	unknown	X
PFC Lotic	1 hour – 1 day	Varies	X
Rooted Frequency	2-4 hours	1+ hours	X

3E)

Do you prefer to have a checklist style data sheet that will allow for yes/no answers? This type of data collection can be quicker and easier for some people to collect. Indicate which protocols meet your sampling needs.

Not necessarily.

Protocol	Checklist Style	Meets Needs?
CRAM	no	X
EDA	no	X
GDE	no	X
Meadow Scorecard	no	X
MIM	no	X
PFC Lentic	yes	X
PFC Lotic	yes	X
Rooted Frequency	no	X

3F)

Considering all of the questions evaluated in Step 3 (A-E), what is the result? Which protocols will be considered moving forward and why?

Step 3 did not further reduce the total number of protocols, but it did identify priority 1 and priority 2 protocols.

Our priority 1 protocols include: EDA, GDE, Meadow Scorecard, and PFC Lotic.

Our priority 2 protocols include: MIM, NRCP, and Rooted Frequency

Step 4) What is the format and applicability of the assessment results?

4A)

Consider what outputs you need and how you will use this information for future management or monitoring. Do you want results in the form of a numeric score as a first step in prioritization? Are you trying to communicate results to stakeholders where maps might be helpful? Do you want to use this assessment as a basis for future monitoring? Are you interested in developing specific management actions based on the results of this assessment? Using only the protocols identified in Step 3F, note the protocols whose results are provided in a format that meets your needs.

The goal of this project is to prioritize meadows for restoration and therefore it is important for the results to translate to management.

Protocol	Format of Output	Translation to Management	Monitoring Applicability	Meets Needs?
CRAM	Standardized report with overall index score, attribute and metric scores, stressor checklist (not metricized), and a short narrative description of the meadow.	Requires interpretation	Assessment and Monitoring	No
EDA	Annotated maps and narrative descriptions identifying sources of hydrologic disconnection and opportunities for restoration; includes maps of soils, vegetation types, and potential restoration conditions.	Suggests Management Actions	Assessment Only	Yes
GDE	Standardized report including narrative description and detailed list of factors and management indicators that affect the site.	Identifies potential management issues	Assessment and Monitoring	Yes
Meadow Scorecard	Scorecards including six metric scores, photographs, and a list of observations (e.g. aspen observed or culverts present).	Requires interpretation	Assessment Only	No
MIM	Summary analysis with numeric outputs and statistical significance in both tabular and graphic format. Includes short narrative summary.	Requires interpretation	Assessment and Monitoring	No
NRCP	(under development)	(under development)	Assessment and Monitoring	No
PFC Lotic	Assessment form includes short site description of potential, yes/no/NA answers and notes for indicator items, summary determination of condition, and estimate of trend when functional at risk.	Identifies potential management issues	Assessment Only	Yes
Rooted Frequency	Detailed species list, ground cover data, and summary of successional stage and ecological rating in a spreadsheet format.	Requires interpretation	Assessment and Monitoring	No

4B) What is the result? Which protocols will be considered moving forward and why?

At this step all of the protocols identified are priority 1 protocols from step 3, these are: EDA, GDE, and PFC Lotic.

Step 5) Final Summary

Discuss why you ended up choosing one protocol over the others.

If you still have several candidate protocols remaining by step 4B, it may be useful for you to review the summaries of the candidate protocols provided in Section 7 to get more information about them. Verify that you have the expertise, time and resources required to conduct your chosen protocol. Reviewing the complete protocol from the original source would then be the final step in determining if the protocol will meet your needs.

All three protocols collect data on a large number of indicators and metrics. EDA includes 37 metrics and 6 indicators and GDE includes 36 metrics and 7 indicators. Both of these protocols collect data on a greater number of indicator groups and metrics than the PFC Lentic protocol, which includes 20 metrics and 4 indicators. All three protocols collect information on both hydrology and geomorphology indicators.

EDA could be a priority because it collects data at a larger scale. It collects data on the valley scale, versus GDE which targets the groundwater component of the meadow and PFC Lentic which focuses on the channel within the meadow. Collecting data at a larger scale could lead to a better understanding of the entire system.

EDA suggests management actions rather than just identifying management concerns, which could help with prioritizing the meadows for restoration.

One reason to consider GDE or PFC Lentic over EDA would be related to training. Currently the full protocol for EDA is under development whereas both the GDE and the PFC protocol are well developed. It may make sense to use GDE or PFC Lentic to prioritize meadows for restoration need and then to do a more thorough design related to project actions for top priority meadow using EDA.

Appendix C

Example 2: Worksheet to evaluate condition relative to grazing effects in meadows

Step 1) Why am I doing this assessment?

The examples specifically look at hypothetical situations, however the findings of these situations may differ from your specific situation and therefore it is important to walk through the worksheet whenever you begin a new project.

1A) My objective:

Is to assess grazing effects to meadows.

1B)

Indicate which protocols match your objective as defined in 1A. Writing a short description of why a protocol will or will not meet your needs may also be helpful. Some protocols may fit better than others, so you should also note those which could possibly fit your needs.

Protocol	Objective	Consistent with my objective?
Climate Engine	Assess change within the study area that is related to climate, management, or other factors, using remote sensing and spatial (GIS) climatic information.	X
CRAM	Designed to assess the overall ecological condition of a wetland and some common stressors that affect wetlands and wildlife.	X
EDA	Characterizes sources of meadow system degradation and develops actions to recover the meadow ecosystem.	X
GDE	Describes the major physical and biological characteristics of GDEs, including factors related to management.	X
Meadow Scorecard	A preliminary screening tool intended to identify meadows with hydrologic restoration potential.	X
MIM	Assesses streambanks, stream channels, and streamside riparian vegetation primarily to evaluate impacts of livestock and other large herbivores on wadable streams.	X
NRCP	Collects riparian vegetation composition and structure data for stream reach characterization and monitoring.	X
PFC Fens	Assesses the condition of fens through consideration of hydrology, vegetation, and soil/landform attributes and evaluates apparent trend.	X
PFC Lentic	Determines a lentic riparian wetland area's physical functioning using hydrology, vegetation, and erosion/deposition attributes in relation to site potential and evaluates apparent trend.	X
PFC Lotic	Assesses the function of perennial and intermittent streams and their associated riparian areas using hydrology, vegetation, and geomorphology attributes in relation to site potential and evaluates apparent trend.	X
Rooted Frequency	Assess herbaceous plant species composition and selected soil attributes to evaluate meadow condition in grazed and un-grazed meadows.	X

1C) What is the result of Step 1B? Which protocols will be considered moving forward and why?

All of the protocols can likely meet our objectives. MIM and Rooted Frequency might rank higher than other protocols because they explicitly mention grazing.

Step 2) What data do I want to collect for the assessment?

2A)

What indicator groups are important to you? Note the indicators you want information about for your meadows. You might rank them in order of importance. Some may be critical, some may be optional, or you may only need one of several indicators that are important to you. Also consider if you have the capacity to collect these data. See Table 2 in Section 2 for a summary of the types of metrics included in each indicator.

Indicators	Important to me?
Climate	
Cultural	
Geomorphology	
Hydrology	X
Landscape Context	
Soil	X
Vegetation	X
Wildlife	

2B)

Review this table of indicators included in each protocol. Considering only the protocols you identified in Step 1C, use the bottom row of the table to identify protocols which address the indicators you selected in 2A. You may want to note the number of indicators provided versus the number you need in this row. You can also review Section 7 in the main document to get an idea of how intensively each indicator is measured based on the number of metrics collected.

Indicator	Climate Engine	CRAM	EDA	GDE	Meadow Scorecard	MIM	NRCP	PFC Fen	PFC Lentic	PFC Lotic	Rooted Frequency
Climate	3		1								
Cultural				2							
Geomorphology		3	13	3	3	6†	5	1	2	9	
Hydrology		2	13	12				2†	9†	2	2
Landscape Context		5	1	3				2	2	2	
Soil				8	1			1	2		2
Vegetation	2	5*	4	5	2	5*†	6*	4*	5*	6*	3*
Wildlife			5	3†							
Total metrics	5	15	37	36	6	11	11	10	20	19	7
Identify protocols that address enough of the indicators identified in step 2A to meet my needs?	No	P2	P2	P1	P2	P1	No	P1	P1	P2	P1

The number of metrics and groupings shown here may be slightly different than as described in each protocol. Metric totals are based on the primary metrics of each protocol and do not capture optional metrics.
*Includes collection of plant identification to species level.
†Includes metrics related to livestock grazing.

2C) What is the result? Which protocols will be considered moving forward and why?

All of the protocols address at least one of our three target indicators. At this step we decided to drop any of the protocols that only addressed one of the three indicators, unless it specifically includes information relevant to grazing. This caused us to drop Climate Engine and NRCP.

We identified both priority 1 (P1) and priority 2 (P2) protocols. At this point we will only move P1 protocols forward. If we determine in the following steps that one of these is not suitable, we will return to this step and evaluate P2 protocols. P1 protocols are any protocol that specifically evaluated information relative to grazing or addresses all 3 indicators.

Priority 1 protocols being moved forward are GDE, MIM, PFC Fen, PFC Lentic, and Rooted Frequency (note Rooted Frequency does not specifically have indicators address grazing, however the overall objective is associated with grazing and therefore it is being moved forward).

Priority 2 protocols: CRAM, EDA, Meadow Scorecard, PFC Lotic

Step 3) How am I going to do the assessment?

Using the protocols identified in Step 2C, work through each of the following questions. Some questions may be more important to you than others. Even if a protocol clearly emerges as your top choice after the first or second question, consider completing the rest of the questions as confirmation of this choice.

3A)

Do you need to sample the entire relevant unit, or can you subsample? The entire relevant unit could be the entire meadow, fen, or other sampling area such as both the meadow and surrounding watershed. Use the table to note the protocols which meet your sampling needs.

For our objectives, scale is not as relevant as being able to detect grazing impacts. Sub-sampling protocols could work if the data is collected specifically in grazed areas.

Protocol	Scale	Meets Needs?
GDE	Relevant unit	X
MIM	Sub-sample	X
PFC Fens	Relevant unit	X
PFC Lentic	Relevant unit	X
Rooted Frequency	Sub-sample	X

3B)

Is there a channel in your meadow(s)? If you believe you may be sampling meadows where there are no channels, then the protocols which require a channel will not meet your needs. Use the table to indicate the protocols which meet your sampling needs. If you have meadows with and without a channel, you may consider using one protocol for the area with a channel and another protocol for areas without channels.

Yes, all meadows have some sort of channel.

Protocol	Requires Channel	Meets Needs?
GDE	no	X
MIM	yes	X
PFC Fens	no	X
PFC Lentic	no	X
Rooted Frequency	no	X

3C)

Do you need quantitative data? If you do not need quantitative results, then any of the protocols can work. Identify the protocols which meet your sampling needs.

Quantitative data is important because changes in grazing effects can be subject to litigation. However, data that is not quantitative could still be informative if it is repeatable. Therefore, we are prioritizing quantitative data as priority 1, but will revisit protocols using qualitative data if needed.

Protocol	Quantitative	Meets Needs?
GDE	no	P2
MIM	yes	P1
PFC Fens	no	P2
PFC Lentic	no	P2
Rooted Frequency	yes	P1

3D)

How much total time do you have to do the assessment? Based on the amount of field and office time required for each protocol, indicate which protocols you can potentially use to sample in the amount of time you have available (note field time ranges are for actual time on the ground and does not include travel time).

Time is not a constraint. Meeting our objectives is our primary goal.

Protocol	Field Time	Office Time	Meets Needs?
GDE	1-2 hours	0-4 hours	X
MIM	3-6 hours	<1 hour	X
PFC Fens	1 hour to 1 day	1 hour	X
PFC Lentic	1 hour to 1 day	Varies	X
Rooted Frequency	2-4 hours	1+ hours	X

3E)

Do you prefer to have a checklist style data sheet that will allow for yes/no answers? This type of data collection can be quicker and easier for some people to collect. Indicate which protocols meet your sampling needs.

Does not matter.

Protocol	Checklist Style	Meets Needs?
GDE	no	X
MIM	no	X
PFC Fens	yes	X
PFC Lentic	yes	X
Rooted Frequency	no	X

3F)

Considering all of the questions evaluated in Step 3 (A-E), what is the result? Which protocols will be considered moving forward and why?

We prefer a quantitative assessment for this assessment; however, it is not 100% required. Therefore, we are moving quantitative protocols forward as priority 1: MIM and Rooted Frequency. However, if these protocols do not fit the objective of the assessment, we will revisit qualitative protocols: GDE, PFC Fen, and PFC Lentic.

Step 4) What is the format and applicability of the assessment results?

4A)

Consider what outputs you need and how you will use this information for future management or monitoring. Do you want results in the form of a numeric score as a first step in prioritization? Are you trying to communicate results to stakeholders where maps might be helpful? Do you want to use this assessment as a basis for future monitoring? Are you interested in developing specific management actions based on the results of this assessment? Using only the protocols identified in Step 3F, note the protocols whose results are provided in a format that meets your needs.

Results that provide a direct application to management would be nice but are not necessary. Additionally, being able to monitor grazing over time after the assessment is complete would be preferable.

Protocol	Format of Output	Translation to Management	Monitoring Applicability	Meets Needs?
MIM	Summary analysis with numeric outputs and statistical significance in both tabular and graphic format. Includes short narrative summary.	Requires interpretation	Assessment and Monitoring	X
Rooted Frequency	Detailed species list, ground cover data, and summary of successional stage and ecological rating in a spreadsheet format.	Requires interpretation	Assessment and Monitoring	x

4B) What is the result? Which protocols will be considered moving forward and why?

Both MIM and Rooted Frequency still meet the needs of this assessment.

Step 5) Final Summary

Discuss why you ended up choosing one protocol over the others.

If you still have several candidate protocols remaining by step 4B, it may be useful for you to review the summaries of the candidate protocols provided in Section 7 to get more information about them. Verify that you have the expertise, time and resources required to conduct your chosen protocol. Reviewing the complete protocol from the original source would then be the final step in determining if the protocol will meet your needs.

MIM and Rooted Frequency have both been used to assess grazing impacts in meadows and they both can be used for longer term monitoring if desired.

MIM monitors the impacts of grazing specifically along the greenline surrounding the channel, whereas Rooted Frequency subsamples within the meadow away from the channel.

MIM captures data on 11 metrics and two indicators, one of which is a target for this assessment. Rooted Frequency collects data on 7 metrics and three indicators, all of which are targets for this objective.

Both protocols require interpretation to understand what the assessment data means

Appendix D

Example 3: Worksheet to understand the condition of meadows across an entire National Forest

The examples specifically look at hypothetical situations, however the findings of these situations may differ from your specific situation and therefore it is important to walk through the worksheet whenever you begin a new project.

Step 1) Why am I doing this assessment?

1A) My objective:

Is to understand the conditions of meadows across the Eldorado National Forest (ENF).

1B)

Indicate which protocols match your objective as defined in 1A. Writing a short description of why a protocol will or will not meet your needs may also be helpful. Some protocols may fit better than others, so you should also note those which could possibly fit your needs.

Protocol	Objective	Consistent with my objective?
Climate Engine	Assess change within the study area that is related to climate, management, or other factors, using remote sensing and spatial (GIS) climatic information.	X
CRAM	Designed to assess the overall ecological condition of a wetland and some common stressors that affect wetlands and wildlife.	X
EDA	Characterizes sources of meadow system degradation and develops actions to recover the meadow ecosystem.	X
GDE	Describes the major physical and biological characteristics of GDEs, including factors related to management.	X
Meadow Scorecard	A preliminary screening tool intended to identify meadows with hydrologic restoration potential.	X
MIM	Assesses streambanks, stream channels, and streamside riparian vegetation primarily to evaluate impacts of livestock and other large herbivores on wadable streams.	No, a channel is not present in all meadows.
NRCP	Collects riparian vegetation composition and structure data for stream reach characterization and monitoring.	No, a channel is not present in all meadows.
PFC Fens	Assesses the condition of fens through consideration of hydrology, vegetation, and soil/landform attributes and evaluates apparent trend.	No, many of the meadows being considered are not fens
PFC Lentic	Determines a lentic riparian wetland area's physical functioning using hydrology, vegetation, and erosion/deposition attributes in relation to site potential and evaluates apparent trend.	X
PFC Lotic	Assesses the function of perennial and intermittent streams and their associated riparian areas using hydrology, vegetation, and geomorphology attributes in relation to site potential and evaluates apparent trend.	No, a channel is not present in all meadows.
Rooted Frequency	Assess herbaceous plant species composition and selected soil attributes to evaluate meadow condition in grazed and un-grazed meadows.	X

1C) What is the result of Step 1B? Which protocols will be considered moving forward and why?

Seven protocols will be brought forward: Climate Engine, CRAM, EDA, GDE, Meadow Scorecard, PFC Lentic, and Rooted Frequency.

Protocols that did not meet our objectives were those that have specific features of meadows to sample (fens, streams), and some meadows on the forest may not contain these features.

Step 2) What data do I want to collect for the assessment?

2A) What indicator groups are important to you?

Note the indicators you want information about for your meadows. You might rank them in order of importance. Some may be critical, some may be optional, or you may only need one of several indicators that are important to you. Also consider if you have the capacity to collect these data. See Table 2 in Section 2 document for a summary of the types of metrics included in each indicator.

Indicators	Important to me?
Climate	
Cultural	
Geomorphology	X
Hydrology	X
Landscape Context	
Soil	
Vegetation	X
Wildlife	

2B)

Review this table of indicators included in each protocol. Considering only the protocols you identified in Step 1C, use the bottom row of the table to identify protocols which address the indicators you selected in 2A. You may want to note the number of indicators provided versus the number you need in this row. You can also review Section 7 in the main document to get an idea of how intensively each indicator is measured based on the number of metrics collected.

Indicator	Climate Engine	CRAM	EDA	GDE	Meadow Scorecard	PFC Lentic	Rooted Frequency
Climate	3		1				
Cultural				2			
Geomorphology		3	13	3	3	2	
Hydrology		2	13	12		9†	2
Landscape Context		5	1	3		2	
Soil				8	1	2	2
Vegetation	2	5*	4	5	2	5*	3*
Wildlife			5	3†			
Total metrics	**5**	**15**	**37**	**36**	**6**	**20**	**7**
Identify protocols that address enough of the indicators identified in step 2A to meet my needs?	No - 1	3	3	3	2	3	2

* Requires plant identification to species level.
† Indicator includes information relevant to grazing.

2C) What is the result? Which protocols will be considered moving forward and why?

We will continue considering CRAM, EDA, GDE, Meadow Scorecard, PFC Lentic, and Rooted Frequency, because all of these protocols address at least 2 of our 3 target indicators.

We will drop Climate Engine from further consideration because it only evaluates vegetation.

Step 3) How am I going to do the assessment?

Using the protocols identified in Step 2C, work through each of the following questions. Some questions may be more important to you than others. Even if a protocol clearly emerges as your top choice after the first or second question, consider completing the rest of the questions as confirmation of this choice.

3A)

Do you need to sample the entire relevant unit, or can you subsample? The entire relevant unit could be the entire meadow, fen, or other sampling area such as both the meadow and surrounding watershed. Use the table to note the protocols which meet your sampling needs.

Our preference is to evaluate the entire meadow, however if the sub-samples are representative of condition then a sub-sample would be okay.

Protocol	Scale	Meets Needs?
CRAM	Sub-sample	x
EDA	Relevant unit	x
GDE	Relevant unit	x
Meadow Scorecard	Relevant unit	x
PFC Lentic	Relevant unit	x
Rooted Frequency	Sub-sample	x

3B)

Is there a channel in your meadow(s)? If you believe you may be sampling meadows where there are no channels, then the protocols which require a channel will not meet your needs. Use the table to indicate the protocols which meet your sampling needs. If you have meadows with and without a channel, you may consider using one protocol for the area with a channel and another protocol for areas without channels.

Some meadows have a channel, while others do not.

Protocol	Requires Channel	Meets Needs?
CRAM	no	x
EDA	no	x
GDE	no	x
Meadow Scorecard	yes1	x
PFC Lentic	no	x
Rooted Frequency	no	x

1If used in meadows without a stream channel it reduces the total number of indicators being evaluated.

3C)

Do you need quantitative data? If you do not need quantitative results, then any of the protocols can work. Identify the protocols which meet your sampling needs.

Given the nature of sampling a large number of meadows, quantitative data is not required.

Protocol	Quantitative	Meets Needs?
CRAM	no	x
EDA	no	x
GDE	no	x
Meadow Scorecard	no	x
PFC Lentic	no	x
Rooted Frequency	yes	x

3D)

How much total time do you have to do the assessment? Based on the amount of field and office time required for each protocol, indicate which protocols you can potentially use to sample in the amount of time you have available (note field time ranges are for actual time on the ground and does not include travel time).

There are a large number of meadows that have been mapped on the ENF (1,403), therefore a protocol that is relatively quick and easy is important.

Protocol	Field Time	Office Time	Meets Needs?
CRAM	2-3 hours	1-2 hours	X
EDA	1+ days	1+ days	No
GDE	1-2 hours	0-4 hours	X
Meadow Scorecard	1-2 hours	1-2 hours	X
PFC Lentic	1 hour to 1 day	Varies	No
Rooted Frequency	2-4 hours	1+ hours	No

3E)

Do you prefer to have a checklist style data sheet that will allow for yes/no answers? This type of data collection can be quicker and easier for some people to collect. Indicate which protocols meet your sampling needs.

Not necessarily.

Protocol	Checklist Style	Meets Needs?
CRAM	no	X
EDA	no	X
GDE	no	X
Meadow Scorecard	no	X
PFC Lentic	yes	X
Rooted Frequency	no	X

3F)

Considering all of the questions evaluated in Step 3 (A-E), what is the result? Which protocols will be considered moving forward and why?

We dropped all protocols that took longer than 3 hours on the upper end of time commitment to complete. At this step we have three protocols moving forward: CRAM, GDE, and Meadow Scorecard.

Step 4) What is the format and applicability of the assessment results?

4A)

Consider what outputs you need and how you will use this information for future management or monitoring. Do you want results in the form of a numeric score as a first step in prioritization? Are you trying to communicate results to stakeholders where maps might be helpful? Do you want to use this assessment as a basis for future monitoring? Are you interested in developing specific management actions based on the results of this assessment? Using only the protocols identified in Step 3F, note the protocols whose results are provided in a format that meets your needs.

Due to the large number of meadows we wish to sample, we will likely need to develop a method to compare meadows. For this reason we decided to select protocols that either identify potential management issues, or have an output score. All of our remaining protocols do so.

Protocol	Format of Output	Translation to Management	Monitoring Applicability	Meets Needs?
CRAM	Standardized report with overall index score, attribute and metric scores, stressor checklist (not metricized), and a short narrative description of the meadow.	Requires interpretation	Assessment and Monitoring	X
GDE	Standardized report including narrative description and detailed list of factors and management indicators that affect the site.	Identifies potential management issues	Assessment and Monitoring	X
Meadow Scorecard	Scorecards including six metric scores, photographs, and a list of observations (e.g. aspen observed or culverts present).	Requires interpretation	Assessment Only	X

4B) What is the result? Which protocols will be considered moving forward and why?

We have three protocols remaining: CRAM, GDE, and Meadow Scorecard.

Step 5) Final Summary

Discuss why you ended up choosing one protocol over the others.

If you still have several candidate protocols remaining by step 4B, it may be useful for you to review the summaries of the candidate protocols provided in Section 7 to get more information about them. Verify that you have the expertise, time and resources required to conduct your chosen protocol. Reviewing the complete protocol from the original source would then be the final step in determining if the protocol will meet your needs.

Both CRAM and GDE collect information on all three of the target indicators for this assessment, while the Meadow Scorecard does not collect information on the hydrology indicator. GDE (36 metrics and 7 indicators) collects the most metric and indicator data, followed by CRAM (15 metrics and 4 indicators), and then the Meadow Scorecard (6 metrics and 3 indicators).

The Meadow Scorecard samples the entire meadow, whereas CRAM subsamples the meadow and GDE samples the entire relevant unit of the ground water dependent system, which might not be the entire meadow.

Both the Meadow Scorecard and CRAM provide meadow condition scores that could be developed into a ranking system for the project. GDE provides a standardized report, which could also be translated into a ranking system.

While the Meadow Scorecard can be used in meadows without a channel, it limits the total number of indicators and impacts the ability to compare results with channeled meadows

Appendix E

Example 4: Worksheet to evaluate the effect of climate on a few meadows where restoration was completed in the past, but data was never collected

The examples specifically look at hypothetical situations, however the findings of these situations may differ from your specific situation and therefore it is important to walk through the worksheet whenever you begin a new project.

Step 1) Why am I doing this assessment?

1A) My objective:

I conducted restoration projects in four meadows in 2017. I was not able to collect field data prior to the restoration. I am interested in evaluating the success of my restoration efforts by assessing the current condition of these meadows.

1B)

Indicate which protocols match your objective as defined in 1A. Writing a short description of why a protocol will or will not meet your needs may also be helpful. Some protocols may fit better than others, so you should also note those which could possibly fit your needs.

Protocol	Objective	Consistent with my objective?
Climate Engine	Assess change within the study area that is related to climate, management, or other factors, using remote sensing and spatial (GIS) climatic information.	YES
CRAM	Designed to assess the overall ecological condition of a wetland and some common stressors that affect wetlands and wildlife.	YES
EDA	Characterizes sources of meadow system degradation and develops actions to recover the meadow ecosystem.	Restoration actions have already been completed.
GDE	Describes the major physical and biological characteristics of GDEs, including factors related to management.	YES
Meadow Scorecard	A preliminary screening tool intended to identify meadows with hydrologic restoration potential.	Restoration actions have already been completed.
MIM	Assesses streambanks, stream channels, and streamside riparian vegetation primarily to evaluate impacts of livestock and other large herbivores on wadable streams.	We are more interested in evaluating the entire meadow.

Protocol	Objective	Consistent with my objective?
NRCP	Collects riparian vegetation composition and structure data for stream reach characterization and monitoring.	We are more interested in evaluating the entire meadow.
PFC Fens	Assesses the condition of fens through consideration of hydrology, vegetation, and soil/landform attributes and evaluates apparent trend.	
We did not work on fens.		
PFC Lentic	Determines a lentic riparian wetland area's physical functioning using hydrology, vegetation, and erosion/ deposition attributes in relation to site potential and evaluates apparent trend.	Since our restoration efforts including channel work, this might not work as well.
PFC Lotic	Assesses the function of perennial and intermittent streams and their associated riparian areas using hydrology, vegetation, and geomorphology attributes in relation to site potential and evaluates apparent trend.	Might work, but we are also interested in areas of the meadow around the channel.
Rooted Frequency	Assess herbaceous plant species composition and selected soil attributes to evaluate meadow condition in grazed and un-grazed meadows.	YES

1C) What is the result of Step 1B? Which protocols will be considered moving forward and why?

Protocols whose objectives are consistent with mine include: Climate Engine, CRAM, GDE and Rooted Frequency.

Step 2) What data do I want to collect for the assessment?

2A)

What indicator groups are important to you? Note the indicators you want information about for your meadows. You might rank them in order of importance. Some may be critical, some may be optional, or you may only need one of several indicators that are important to you. Also consider if you have the capacity to collect these data. See Table 2 in Section 2 for a summary of the types of metrics included in each indicator.

Indicators	Important to me?
Climate	YES
Cultural	
Geomorphology	
Hydrology	YES
Landscape Context	YES
Soil	YES
Vegetation	YES
Wildlife	

2B)

Review this table of indicators included in each protocol. Considering only the protocols you identified in Step 1C, use the bottom row of the table to identify protocols which address the indicators you selected in 2A. You may want to note the number of indicators provided versus the number you need in this row. You can also review Section 7 in the main document to get an idea of how intensively each indicator is measured based on the number of metrics collected.

Indicator	Climate Engine	CRAM	GDE	Rooted Frequency
Climate	3			
Cultural			2	
Geomorphology		3	3	
Hydrology		2	12	2
Landscape Context		5	3	
Soil			8	2
Vegetation	2	5*	5	3*
Wildlife			3†	
Total metrics	5	15	36	7
Does the protocol adequately address enough of the indicators identified in step 2A to meet my needs?	Yes (2/5)	Yes (3/5)	Yes (4/5)	Yes (2/5)

The number of metrics and groupings shown here may be slightly different than as described in each protocol. Metric totals are based on the primary metrics of each protocol and do not capture optional metrics.
*Includes collection of plant identification to species level.
†Includes metrics related to livestock grazing.

2C) What is the result? Which protocols will be considered moving forward and why?

All of the remaining protocols include at least 2 out of the 5 indicators of interest. GDE addresses these. However, Climate Engine is the only protocol to address climate, which is of particular interest to me.

Step 3) How am I going to do the assessment?

Using the protocols identified in Step 2C, work through each of the following questions. Some questions may be more important to you than others. Even if a protocol clearly emerges as your top choice after the first or second question, consider completing the rest of the questions as confirmation of this choice.

3A) Do you need to sample the entire relevant unit, or can you subsample?

The entire relevant unit could be the entire meadow, fen, or other sampling area such as both the meadow and surrounding watershed. Use the table to note the protocols which meet your sampling needs.

I am interested in sampling the entire meadow, and potentially the surrounding watershed, to provide a more comprehensive evaluation of our restoration projects.

Protocol	Scale	Meets Needs?
Climate Engine	Relevant unit	YES
CRAM	Sub-sample	NO
GDE	Relevant unit	YES
Rooted Frequency	Sub-sample	NO

3B) Is there a channel in your meadow(s)?

If you believe you may be sampling meadows where there are no channels, then the protocols which require a channel will not meet your needs. Use the table to indicate the protocols which meet your sampling needs. If you have meadows with and without a channel, you may consider using one protocol for the area with a channel and another protocol for areas without channels.

Yes there are channels in our meadows.

Protocol	Requires Channel	Meets Needs?
Climate Engine	no	YES
CRAM	no	YES
GDE	no	YES
Rooted Frequency	no	YES

1If used in meadows without a stream channel it reduces the total number of indicators being evaluated.

3C) Do you need quantitative data?

If you do not need quantitative results, then any of the protocols can work. Identify the protocols which meet your sampling needs.

Quantitative data would be preferable.

Protocol	Quantitative	Meets Needs?
Climate Engine	yes	YES
CRAM	no	Maybe
GDE	no	Maybe
Rooted Frequency	yes	YES

3D) How much total time do you have to do the assessment?

Based on the amount of field and office time required for each protocol, indicate which protocols you can potentially use to sample in the amount of time you have available (note field time ranges are for actual time on the ground and does not include travel time).

This project is a priority for me and I am willing to spend a significant amount of time on it.

Protocol	Field Time	Office Time	Meets Needs?
Climate Engine	0-1 hours	1 hour	YES
CRAM	2-3 hours	1-2 hours	YES
GDE	1-2 hours	0-4 hours	YES
Rooted Frequency	2-4 hours	1+ hours	YES

3E) Do you prefer to have a checklist style data sheet that will allow for yes/no answers?

This type of data collection can be quicker and easier for some people to collect. Indicate which protocols meet your sampling needs.

No. This question is not relevant to my selected protocols.

Protocol	Checklist Style	Meets Needs?
Climate Engine	no	YES
CRAM	no	YES
GDE	no	YES
Rooted Frequency	no	YES

3F) Considering all of the questions evaluated in Step 3 (A-E), what is the result? Which protocols will be considered moving forward and why?

Question 3A eliminated CRAM and Rooted Frequency from consideration because I do not want to subsample my meadows. Question 3C eliminated GDE because I prefer to collect quantitative data. This leaves only Climate Engine for me to consider to assess the condition of my restored meadows.

Step 4) What is the format and applicability of the assessment results?

4A)

Consider what outputs you need and how you will use this information for future management or monitoring. Do you want results in the form of a numeric score as a first step in prioritization? Are you trying to communicate results to stakeholders where maps might be helpful? Do you want to use this assessment as a basis for future monitoring? Are you interested in developing specific management actions based on the results of this assessment? Using only the protocols identified in Step 3F, note the protocols whose results are provided in a format that meets your needs.

I would like to have quantitative results that can detect trends. Maps and spatial outputs would also be helpful.

Protocol	Format of Output	Translation to Management	Monitoring Applicability	Meets Needs?
Climate Engine	GIS outputs (maps), graphs, narrative descriptions of patterns observed.	Requires interpretation	Assessment and Monitoring	YES

4B) What is the result? Which protocols will be considered moving forward and why?

The format of the outputs produced by Climate Engine are compatible with my needs, so I will continue to consider this protocol for my meadow condition assessment.

Step 5) Final Summary

Discuss why you ended up choosing one protocol over the others.

If you still have several candidate protocols remaining by step 4B, it may be useful for you to review the summaries of the candidate protocols provided in Section 7 to get more information about them. Verify that you have the expertise, time and resources required to conduct your chosen protocol. Reviewing the complete protocol from the original source would then be the final step in determining if the protocol will meet your needs.

After reviewing the summary of Climate Engine provided in Section 7, I am convinced that this is the right protocol for me. The questions this protocol was designed to answer include: 1) Has vegetation vigor (as measured by greenness and wetness) in the meadow changed through time, and is this variation related to disturbance, climate, and/or management? and 2) Has restoration proven to be successful? Is there an increase in vegetation vigor after restoration that is statistically significant and independent of climate?

These are my study questions. I am looking forward to using Climate Engine to answer them and to evaluate the effectiveness of my restoration projects.

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