



Rocky Mountain Network Vegetation Composition Structure and Soils Monitoring Protocol

Small Park Grasslands, Shrublands, and Woodlands
Version 1.0

Natural Resource Report NPS/ROMN/NRR—2011/383



ON THE COVER

View of mountains west of Grant-Kohrs Ranch National Historic Site, Deer Lodge, MT
Photograph by: Donna Shorrock

Rocky Mountain Network Vegetation Composition Structure and Soils Monitoring Protocol

Small Park Grasslands, Shrublands, and Woodlands

Version 1.0

Natural Resource Report NPS/ROMN/NRR—2011/383

Daniel D. Manier

United States Geological Survey
Fort Collins Science Center
2150 Centre Ave, Bldg. C
Fort Collins, CO 80526

D. Shorrock, E.W. Schweiger, I. Ashton, B. Frakes, M. Britten, D. Pillmore, and J. Burke

National Park Service
1201 Oakridge Drive
Suite 200
Fort Collins, CO 80525

April 2011

U.S. Department of the Interior
National Park Service
Natural Resource Program Center
Fort Collins, Colorado

The National Park Service, Natural Resource Program Center publishes a range of reports that address natural resource topics of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

The Natural Resource Report Series is used to disseminate high-priority, current natural resource management information with managerial application. The series targets a general, diverse audience, and may contain NPS policy considerations or address sensitive issues of management applicability.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner.

This report received formal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data, and whose background and expertise put them on par technically and scientifically with the authors of the information.

Views, statements, findings, conclusions, recommendations, and data in this report do not necessarily reflect views and policies of the National Park Service, U.S. Department of the Interior. Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the U.S. Government.

This report is available from

<http://www1.nrintra.nps.gov/im/units/romn/ReportsPublications.cfm> and the Natural Resource Publications Management website (<http://www.nature.nps.gov/publications/nrpm/>). Please cite this publication as:

Manier, D., D. Shorrock, E. W. Schweiger, I. Ashton, B. Frakes, M. Britten, D. Pillmore, and J. Burke. 2011. Rocky Mountain Network vegetation composition structure and soils monitoring protocol: Small park grasslands, shrublands, and woodlands; Version 1.0. Natural Resource Report NPS/ROMN/NRR—2011/383. National Park Service, Fort Collins, Colorado.

Contents

	Page
List of Figures	ix
List of Tables	ix
List of Appendices	xi
List of Standard Operating Procedures (SOPs)	xiii
Executive Summary	xv
Acknowledgements	xvii
Background	1
The NPS Inventory and Monitoring Program	1
Overview	2
Rationale and justification	5
Importance of vital sign(s) in ROMN parks	5
Measurable objectives	11
Objectives	11
Reference conditions	12
Rationale for selected measures	12
Sample design	15
Introduction	15
Survey designs	15
Target populations	15
Sample population	16
Survey design sample frame	17
Membership design	21
Revisit design (sample size)	21

Contents (continued)

GRKO and other small park pilot studies.....	22
Power analysis	22
Summary of results	24
Final design.....	26
Sentinel design/sites.....	28
Field Methods	31
Introduction.....	31
Timing of sampling (index period).....	31
Establishing / relocating sites	31
Site layout and measurements	32
Standard Operating Procedures (SOPs).....	36
Managing a sampling season	39
Introduction.....	39
General timeline.....	39
Communication with parks' staffs.....	39
Data management (field preparation)	40
Data Management	41
Introduction.....	41
Sensitive Data Management	41
Analysis Overview	43
Introduction.....	43
Parameter estimation	43
More Complex Models	45
Comparisons to Thresholds; Reference Conditions	46

Contents (continued)

VCSS Reporting.....	47
Monitoring and Assessment Reports	47
Annual reports	48
Comprehensive synthesis and analysis reports.....	48
Protocol review reports.....	48
Data and information objectivity, utility and integrity and peer review.....	49
Administration and operations for VCSS monitoring	51
Introduction.....	51
Annual Work Planning	51
Budget.....	51
Compliance and Permitting	51
Field monitoring	52
Revising the Protocol.....	55
Protocol evaluation	55
Literature cited.....	57

List of Figures

	Page
Figure 1. Map of ROMN parks.....	2
Figure 2. Driver-component model.....	7
Figure 3. State and transition model.	8
Figure 4. GRKO ecological site based sample frame, sample design, and park unit boundary.	18
Figure 5. LIBI ecological site based sample frame, sample design, and park unit boundary.	19
Figure 6. FLFO ecological site based sample frame, sample design, and park unit boundary.	20
Figure 7. Examples of power analyses results.	28
Figure 8. Vegetation monitoring response design (field plot design).....	34
Figure 9. Example Data Flow Model for VCSS.....	41
Figure 10. Status of the mean canopy cover of the ten most abundant species found in 1m ² plots at Grant-Kohrs Ranch NHS in 2009.	44

List of Tables

	Page
Table 1. Summary of variance components and other parameters used in linear modeling from four GRKO pilot study representative response measures.	23
Table 2. Draft panel structure to be used in small park VCSS survey designs.....	27
Table 3. Average annual costs for VCSS monitoring in GRKO and LIBI utilizing student interns from 2006-2008.	51
Table 4. Mean annual survey sample events and sampling days required for VCSS sampling in ROMN parks from 2006-10.	52

List of Appendices

	Page
Appendix 1. Previous Park Monitoring and Mapping Efforts.....	65
Appendix 2. General Process for Field Sampling.....	67
Appendix 3. Power Analysis and Design Comparison Details.....	71
Appendix 4 Target Population Tables	89
Appendix 5 Soils Analysis Laboratory Methods.....	91
Appendix 6 VCSS Field Datasheets	93
Appendix 7. Standard Operating Procedures associated with this protocol	105

List of Standard Operating Procedures (SOPs)

Standard Operating Procedure (SOP): VCSS Site Suitability	107
Standard Operating Procedure (SOP): VCSS Moving and Replacing Sites.....	111
Standard Operating Procedure (SOP): VCSS Navigating to Sites	113
Standard Operating Procedure (SOP): VCSS Site Layout	115
Standard Operating Procedure (SOP): VCSS Completing <i>Site Description</i> Forms	121
Standard Operating Procedure (SOP): VCSS Photo Documentation	129
Standard Operating Procedure (SOP): VCSS Transect Methods	133
Standard Operating Procedure (SOP): VCSS Plot Methods.....	141
Standard Operating Procedure (SOP): VCSS Unknown Plant Species.....	151
Standard Operating Procedure (SOP): VCSS Soil Characterization	157
Standard Operating Procedure (SOP: VCSS Optional Relevé Plot.....	171
Standard Operating Procedure (SOP): VCSS Tree/ Shrub Plots	175
Standard Operating Procedure (SOP): VCSS Site Disturbance	187
Standard Operating Procedure (SOP): VCSS Post-Sampling Event Procedures	195
Standard Operating Procedure (SOP): VCSS Design-based Analysis	215
Standard Operating Procedure (SOP): VCSS Hypothesis Testing	217

Executive Summary

The Rocky Mountain Inventory & Monitoring Network (ROMN) includes a wide range of biophysical environments, ranging from mountain peaks (>4000m above sea level) down through evergreen and deciduous forests to western grasslands of the North American Great Plains (<1000m above sea level). Here, we present a protocol to monitor vegetation and surface soils within the three smaller units of the Network (Grant-Kohrs Ranch National Historic Site, Little Bighorn Battlefield National Monument, and Florissant Fossil Beds National Monument) that are characterized by grassland, shrubland, and woodland ecosystems.

The Vegetation Composition, Structure, and Soils (VCSS) protocol for small parks was developed through the integration and adaptation of the approaches of several other national inventory programs and through rigorous field testing. The primary objectives of the VCSS protocol are to:

1. Determine status and trend in vegetation structure, species composition, and diversity in grassland, shrubland, and woodland ecosystems* within Network small parks.
2. Determine status and trends in abundance of invasive/exotic plant taxa in these areas based on park-specific lists of likely and ecologically significant invaders at each park.
3. Determine the status and trend in soil condition in grassland, shrubland, and woodlands* of each park based on measures of 1) dynamic properties such as soil stability, extent of non-vegetated soils, and erosion and 2) inherent properties including physical texture, composition and soil chemistry.

*excluding high visitor use areas, developed infrastructure, culturally sensitive locations, and unsafe or inaccessible sites

A long-term goal of the Network is to develop quantitative methods to assess ecosystem integrity and health through the development of bioassessment models that will incorporate reference condition distributions and identify both temporal and spatial departures from these distributions within a park. While such methods are common in aquatic systems, this will be one of the first applications of these models in terrestrial vegetated systems and thus will only be developed after robust and long-term data sets from this protocol are in place.

To meet the VCSS objectives and to accurately describe the population of grassland, shrubland, and woodland systems within the three smaller parks, we use spatially balanced probabilistic surveys for our sample design. Sample frames are based on soil map units, implemented throughout the entire park, and a paneled structure is used to allow both status and trend estimates. Our monitoring targets (sample frames) systematically exclude primary management and visitor use areas, sensitive resource areas, and any infrastructure, such as roads, trails and buildings, associated with these activities. Therefore, our objectives and results are applicable to the expanse of “natural” ecosystems within each park.

The field methods at each sample location call for a combination of transects and plots to structure sampling of vegetation and soil within a 0.5 hectare (1.3 acres) circular sample area (site). We include systematic, repeated measurements of vegetation structure and composition (including trees when applicable), abundance of invasive species, dynamic soil surface properties

(including soil stability, sheet and gully erosion and mineral soil exposure), and less frequently sampled inherent soil properties (such as nutrient levels and texture) as indicators of ecological integrity. Most results are integrated across replicates within the response design.

In addition to the future development of bioassessment models, we use the data to describe baseline conditions, examine change over time, describe spatial variability within and across parks, and correlate changes in vegetation and soil with climate and landscape-level drivers (e.g., atmospheric nitrogen deposition and fire). The ROMN VCSS protocol provides robust methods for measuring change in grassland, shrubland, and woodland vegetation and soils in the parks and data that can be used in collaboration with other networks and programs to monitor grassland, shrubland and woodland vegetation and soils across the region.

Acknowledgements

The authors (Rocky Mountain Network) are indebted to monitoring efforts that were developed prior to this program. These include the USDA ARS (Agricultural Research Service) Jornada Field Station staff for developing and publishing the Monitoring Manual for Grassland, Shrubland and Savanna Ecosystems (Herrick et al. 2005) and to the USDA Forest Service FIA (Forest Inventory and Assessment) Program for developing and standardizing forested land monitoring methods and definitions. Further, we are indebted to the efforts of C. Elzinga, D. Salzer, and J. Willoughby who developed and published (BLM Technical Reference 1998) technical guidance and justification for Measuring & Monitoring Plant Populations. We are also indebted to at least 17 prior funded I&M networks; their protocols, research and development efforts and expertise have contributed in many ways to these protocols. Many others were integral in the process of developing this protocol. T. Seastedt and J. Herrick reviewed and helped shape our soil methods. Network Technical Committee representatives and ROMN parks' staffs, especially Tara Carolin, provided valuable input and logistical support for pilot work done at the parks. The Network worked closely with statisticians and ecologists at Colorado State University (S. Urquhart), the EPA (T. Olsen) and from several other I&M networks (notably, S. Garman at NCPN and L. Starcevich at SIEN) to develop our sample designs. We are grateful for the significant amount of (often gratis) advice and help these individuals have offered. Appreciation is also extended to the Intermountain Region's Program Manager, Bruce Bingham, for his insightful comments in the review process, and for coordinating the anonymous peer reviewers of the protocol. Greg Eckert of the Biological Resources Management Division, aided the development process in various ways, including expertise, fieldwork, and equipment. Lastly, the Network offers its gratitude to the peer reviewers for their time dedicated toward making this protocol a better document.

Background

The NPS Inventory and Monitoring Program

The purpose of the Inventory & Monitoring (I&M) Program is to develop and provide scientifically sound information on the current status and long-term trends in the composition, structure, and function of park ecosystems, and to determine how well current management practices are sustaining those ecosystems. As part of the National Park Service's effort to "improve park management through greater reliance on scientific knowledge," a primary role of the Inventory and Monitoring Program is to collect, organize, and make available natural resource data and to contribute to the Service's institutional knowledge by facilitating the transformation of data into information through analysis, synthesis, and modeling of specific key "vital signs." The Inventory & Monitoring Program defines the term "vital sign" as "a subset of physical, chemical, and biological elements and processes of park ecosystems that is selected to represent the overall health or condition of park resources, known or hypothesized effects of stressors, or elements that have important human values."

The five goals of the I&M Program are to (Fancy et al. 2009):

1. Inventory the natural resources and park ecosystems under National Park Service stewardship to determine their nature and status.
2. Monitor park ecosystems to better understand their dynamic nature and condition and to provide reference points for comparisons with other, altered environments.
3. Establish natural resource inventory and monitoring as a standard practice throughout the National Park system that transcends traditional program, activity, and funding boundaries.
4. Integrate natural resource inventory and monitoring information into National Park Service planning, management, and decision making.
5. Share National Park Service accomplishments and information with other natural resource organizations and form partnerships for attaining common goals and objectives.

These goals are accomplished through park-wide inventories and a long-term monitoring program. In establishing a service-wide natural resources inventory and monitoring program, the National Park Service (NPS) created networks of parks that are linked by geography and shared natural resource characteristics. Working within networks improves the efficiency of inventory and monitoring because parks are able to share budgets, staffing, and other resources to plan and implement an integrated program.

The Rocky Mountain Network (ROMN) is one of 32 vital signs monitoring networks across the NPS. The ROMN is comprised of six National Park Service units: Glacier National Park (GLAC), Grant-Kohrs Ranch National Historic Site (GRKO), and Little Bighorn Battlefield National Monument (LIBI), Montana; and Florissant Fossil Beds National Monument (FLFO), Great Sand Dunes National Park and Preserve (GRSA), and Rocky Mountain National Park (ROMO), Colorado (Figure1). The six ROMN parks are located in the central and southern Rocky Mountain Cordillera, roughly along a NNW–SSE axis that follows the Continental Divide. LIBI is the one exception; it lies about 300 km to the east of the Divide on the northern Great Plains.

The ROMN Vital Signs Monitoring Plan (Britten et al. 2007) is the foundation of the long-term ecological monitoring program for the Network's six parks, and describes the rationale and basis for the program. The plan was developed during a three-year planning effort that included parks' staffs and scientific partners from numerous organizations. The Plan identifies 12 high-priority ROMN vital signs including Vegetation Composition, Structure and Soils and Invasive/Exotic Plants. These two vital signs are addressed in this protocol for GRKO, LIBI and FLFO, the three small ROMN parks. Four other high priority ROMN vital signs are linked to this protocol: Landscape Dynamics, Weather and Climate, Wet and Dry Deposition and Focal Species-Elk.

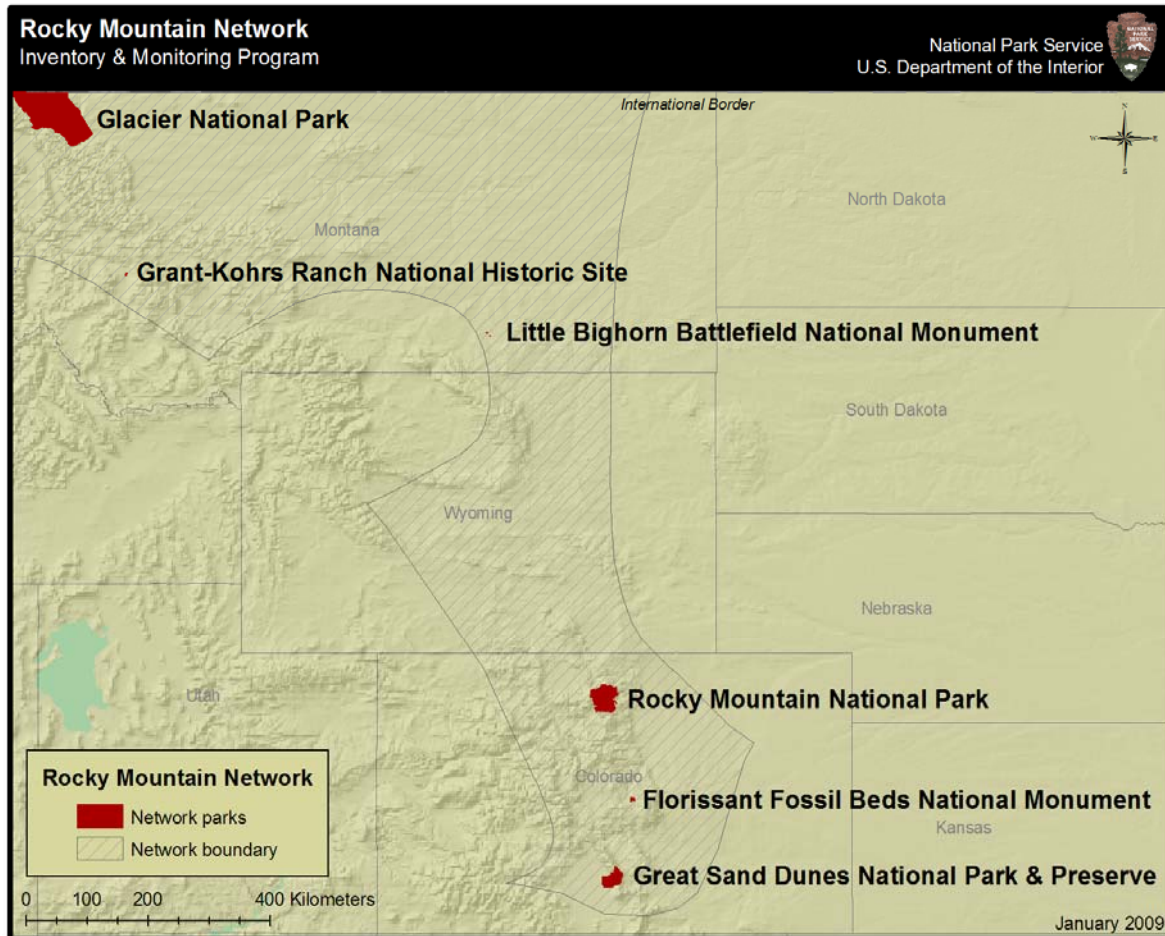


Figure 1. Map of ROMN parks

Overview

The ROMN Vegetation Composition, Structure and Soils (VCSS) protocol for small parks is designed to monitor grassland, shrubland, and woodland systems within our Network parks. Using this protocol, we monitor the status and trend in these ecosystems as they are affected by natural and anthropogenic disturbance over the long term. Using analyses integrated with other vital signs (e.g., weather and climate, landscape dynamics, wet and dry deposition), we expect to empirically link observed changes (or lack thereof) in vegetation structure and condition and soil

condition with the stressors or drivers potentially causing these changes. Important drivers of condition and trends in upland communities within ROMN parks include climate, atmospheric deposition (of nutrients and/or toxins), human land use (surrounding lands in addition to within parks), and species level effects and responses (such as non-native species introductions or invasions).

We chose to focus this protocol on the three small ROMN parks because vegetation composition and structure are extremely important components of the natural landscape and, especially for GRKO and LIBI, key components of the cultural landscapes these parks were established to protect. We are taking a park-wide survey approach in this protocol in order to characterize VCSS across the entirety of the parks. In part, this is because access is easy and affordable and we can monitor vegetation and soils at relatively fine scales, which we anticipate will provide information useful to managing park landscapes.

For the three much larger, mountainous, and ecologically heterogeneous parks, vegetation and soils are also very important, but implementing a park-wide monitoring program will be costly and logistically challenging. We will work with GLAC, GRSA and ROMO staffs and other collaborators to develop useful (to park management) objectives for vegetation and soils monitoring in the large parks and investigate affordable approaches.

In the process of developing the VCSS protocol, the ROMN considered an extensive list of potential features to monitor. A number of the community characteristics that were evaluated include: species composition, physical structure and pattern, rare population distributions and dynamics, soil type and chemistry, soil physical condition, surface soil erosion, primary production, soil biotic community composition, nitrogen availability and cycling rates, and soil carbon accumulation and turn-over rates (decomposition). Multiple constraints including financial, logistical, and resource protection restrict the capabilities of the Network; therefore, we are implementing a subset of these desired measures to balance efficiency, repeatability, and ecological significance. ROMN monitoring focuses on basic community structure attributes (vegetation, litter, and soil surface), plant species composition and diversity, and the physical and chemical characters of soils. Descriptions are based on transect and plot based estimates of vegetation (noting invasive species), substrate, and litter cover and frequency, extent of bare ground, soil characteristics, and surface conditions. Sampling in woodlands requires additional metrics beyond those used in grasslands and shrublands and are included as an optional component of the protocol.

Several common terrestrial vegetation types fall outside of the scope of this protocol including riparian habitat, forests, and alpine areas (above timberline). Riparian zones are considered separate ecosystems largely due to surface and ground water hydrology; they are included in the ROMN wetland and stream protocols (Schweiger et al., in preparation). Forests will be monitored primarily using the ROMN landscape dynamics protocol (Burke et al., in preparation) and only the three large parks within ROMN have extensive forested areas. The decision to monitor forests remotely was based upon cost, availability of data, and the scale needed to monitor forests to best inform management.

Rationale and justification

Importance of vital sign(s) in ROMN parks

All of the units with the ROMN contain grasslands, shrublands, and/ or woodlands; two of these units (GRKO and LIBI) are almost entirely shrub- and/or grasslands (including managed meadows and fields). FLFO includes shrub-, grass- and woodlands and mixed conifer forests.

GRKO was established to commemorate the Western cattle industry from its 1850s inception through recent times. The cultural landscape setting – one dominated by herbaceous vegetation is an important resource for the park to manage and protect (John Milner Assoc., Inc. 2004). Similarly, LIBI was established to commemorate the 1876 Battle of the Little Bighorn. Protected since 1876, and central to its mission, LIBI's mixed grass prairie has not been domestically grazed since 1891. FLFO was established in 1969 to protect the setting for a remarkably diverse paleoecological community preserved in the paper shales of the Florissant Formation.

Within the ROMN, these three ecosystem types represent important habitats and resources for wildlife as well as unique assemblages of local flora. Interactions between the natural or desired conditions and succession of vegetation, fire and fire suppression effects, human use and management patterns, as well as climate, pollutants, and invasive species result in immediate management challenges to preserving these communities. Integration of vegetation and soil patterns with environmental monitoring (e.g., temperature trends, especially related to timing of growing season start and end), management strategies, and external influences (such as atmospheric deposition) is important for interpretation of trend data.

The ROMN has identified twelve high priority vital signs of which the VCSS protocol directly addresses two: vegetation composition, structure and soils and invasive/exotic plants (Britten et al. 2007). Four other high priority vital signs are indirectly linked to vegetation condition including: Landscape Dynamics, Weather and Climate, Wet and Dry Deposition, and Focal Species – Elk.

Conceptual models

The ROMN conceptual model of terrestrial ecological systems identifies a well-known set of drivers and stressors of system condition and function (Figure 2). Geography and geology describe the regional template including continental position, geologic substrate (parent materials), and topography; these patterns are slow to change, but have strong and lasting determinant effects on the distribution of ecosystems. Atmospheric trends and cycles (primarily temperature and precipitation) couple with soil characteristics as primary determinants of vegetation structure and composition over short and long-term cycles. While nutrient deposition may currently be fairly localized in ROMN parks (with the exception of ROMO (Baron 2006)), increasingly intense human land-use across landscapes surrounding these parks can be expected to contribute to atmospheric deposition resulting in changes to soil nutrients and subsequently vegetation composition and structure. Disturbance cycles (e.g., drought, fire, and insect outbreaks) are a fundamental part of the long-term function and dynamics of all natural systems within ROMN, and they drive the dynamics in spatial patterns of vegetation structure and composition on the landscape. Our designs anticipate eventual and/or periodic modifications due to natural and anthropogenically driven events; we may not be able to research the details of any one event, but we will assess the role and cumulative effects across these NPS landscapes as they

occur. Landscape context is a critical driver of resource condition for parks because of the ability of humans to affect and even dominate the condition and function of very large areas. Combined with the wide-ranging needs of migratory species, wildlife population structures and dynamics, and the flow of energy and contaminants across landscapes, it is clear that issues faced by current land managers extend beyond their management units. Thus, while we are unable to monitor all possible ramifications of these drivers on the condition of park communities, we expect that data representing these drivers will have important statistical and explanatory power for interpretation of our monitoring data.

A more narrowly defined subset of the primary drivers identified below (Figure 2, items A, B, C, D), acts as an array of potential “stressors” that may influence future trends in vegetation structure and composition. For example, herbivory from wild and domestic species may have large effects on vegetation composition, structure, and soils. The grasslands of GRKO and FLFO (until 1975) have a long history of domestic herbivory (cattle). Most of LIBI has rarely, if ever, been grazed by domestic livestock. FLFO systems are affected from drought and fire suppression, and die-off from beetle infestation (conifers). Finally, all of the units within ROMN have concerns with invasive plant species, which have the potential to change not only species composition, but also nutrient cycling, disturbance regimes, and forage quality resulting in dramatic changes to ecosystem function (Ehrenfeld et al. 2001, D'Antonio et al. 1999, Mack and D'Antonio 1998).

A more detailed state and transition model (Figure 3) can also aid in our understanding and assessment of detected changes in vegetation structure. In this model, structural patterns created by the type and productivity of the vegetation distinguish distinct community types. Drivers of change in these systems generally reduce or dramatically change the type of vegetation (e.g., shrub to annual grass dominance) via exposing bare soil surfaces, changing soil microbial function resulting in changed nutrient availability and surface soil damage and loss. While most of the other transitions in the model may be natural, desirable, or tolerable, this type of major system change must be detectable early to be successfully addressed by management. Additional, detailed process models have been developed to support discussion and interpretation of the interactive roles of grazing, and ecosystem functions (see Britten et al. 2007, Appendix C: Conceptual Models); these will help inform interpretation and communication of monitoring results.

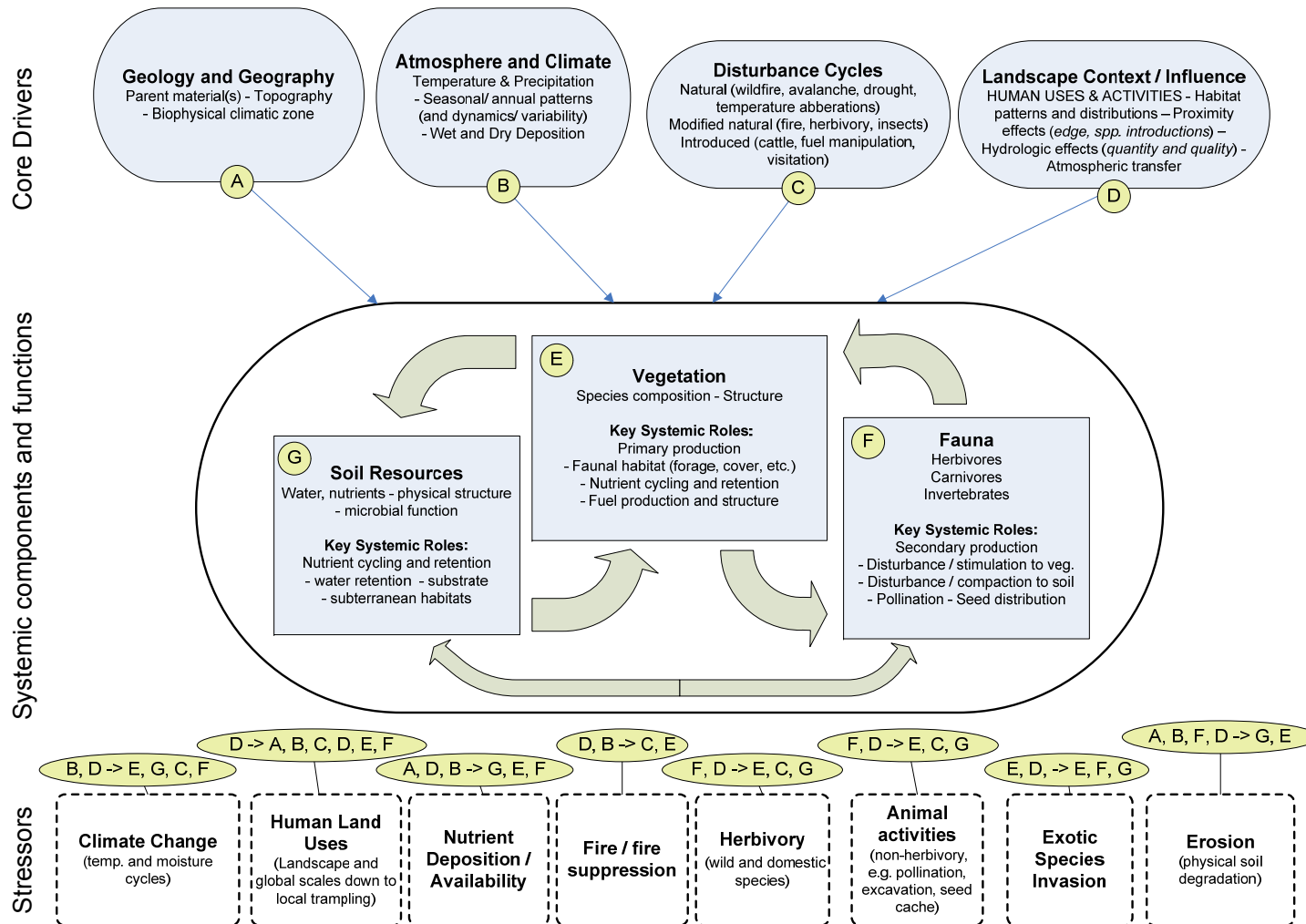


Figure 2. Driver-component model. Shows basic system components (center), the key factors of the larger environmental context that determine the state and function of the systems (top), and the key dynamic forces (stressors) that potentially affect trends in structure and function in the future (bottom).

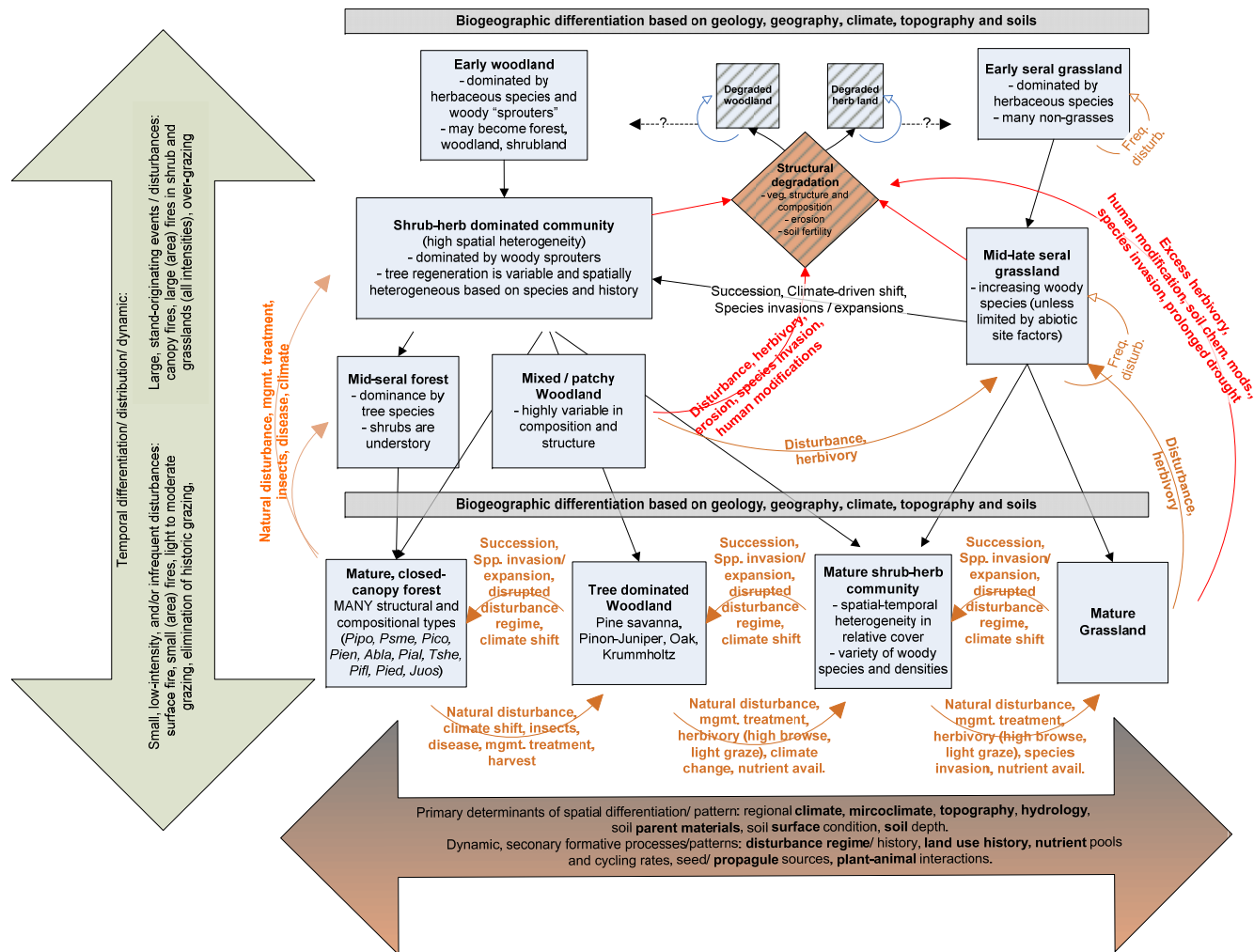


Figure 3. State and transition model. Shows simplified set of possible upland states discretely representing a continuum of structure and composition based on the dominant vegetation. Potential transitions (represented by orange and red arrows) are annotated with processes (especially drivers and stressors) that exert some level of control over the structure and composition of the vegetation.

In Figure 3, blue rectangles represent major community types. Differentiation mostly associated with biogeographic features generate horizontal distinctions in the model (i.e., patterns and processes that typically work across large areas and change slowly over a period of years such as aspect, soil type, elevation, and continental position). Dynamics in structure and composition associated with more rapid community and ecosystem dynamics (such as succession, disturbance, plant-animal interactions, species invasions, or expansions) are distinguished along vertical axes. Arrows represent transitions among these states (notated with examples of likely drivers). Details such as the role of herbivory in controlling plant production and composition or the role of herbivores and people in affecting surface stability and soil function are not explicit in this model, however they are identified as drivers of transitions (see arrow labels). Of most concern may be the red arrows leading to the “Structural degradation” state, which is of particular concern to successful management and conservation of natural areas.

Historical monitoring

Historical monitoring and inventory efforts complement the ROMN VCSS protocol. Most other relevant vegetation inventory and monitoring efforts surrounding (and including) ROMN parks have been part of regional-scale approaches by national programs including the Environmental Protection Agency (EPA) Environmental Monitoring and Assessment Program (EMAP), EPA Regional EMAP (very limited vegetation and soils work), the United States Department of Agriculture (USDA), the Forest Inventory Analysis (FIA) Program (widespread but focuses on forest structure), and statewide projects such as the Colorado Gap Analysis Project (Colorado Division of Wildlife) and the Montana Gap Analysis Project GAP (Montana Natural Heritage Program). Only the USDA FIA program (which now includes both historic FIA and Forest Health Monitoring programs) conducts detailed long-term monitoring, whereas the others are inventory projects (i.e., one time efforts, not continued monitoring). FIA reports status and trend in forest area and location, based on the species, size, and health of trees, total tree growth, mortality, and removals by harvest, wood production and utilization rates by various products. While several FIA plots fall in and near ROMN units, the spacing between plots is wide (1 plot per 6,000 acres, approximately 2 plots per 10 km²) resulting in few plots in each ROMN unit, and within park sampling intensity is low. The FIA does not provide adequate vegetation monitoring within parks, but can provide a regional context for interpreting changes to NPS woodlands and forests.

Park level monitoring of vegetation varies by unit within ROMN. None of the units has comprehensive, long-term vegetation monitoring programs. Conversely, all of the units have supported research on park vegetation at some time in the past. Refer to Appendix 1 for documentation of mapping and monitoring projects that have been undertaken at each park.

Measurable objectives

The objectives for conducting ecological monitoring of grasslands, shrublands, and woodland, within ROMN small units are two-fold: to quantify status and trend over the long term in select attributes of vegetation and soil, and to supply short-term feedback that will inform and aid managers with assessing strategies to maintain and restore rangeland communities.

All VCSS monitoring objectives focus on status, trend, and condition of grassland, shrubland, or woodland systems. *Status* is defined as some statistic (e.g., a mean or a proportion) of a vital sign or measure over all monitoring sites in a park (from one to many) within a single or well bounded temporal window (Britten et al. 2007). *Trend* is a non-cyclic, directional change in a response measure that can be with or without pattern and, if it exists, always has a linear component (Urquhart et al. 1998). Trend is the primary way in which the effect size or amount of relevant long-term change in a vital sign or target population is quantified across time. In this context, a trend of a given magnitude is synonymous with a minimum detectable change in a measure. *Condition* is synonymous with ecological integrity and is the capacity to support and maintain a balanced, integrated, and adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of natural habitats of the region (Karr 1986). Ecological integrity includes biotic (e.g., vegetation) and abiotic (e.g., soil chemistry) processes. The concept recognizes that the dynamics of ecological processes vary with the scale of description (Holling 1992) and is by definition explicitly linked to management objectives (De Leo and Levin 1997).

The following statements are specifically monitoring objectives. They are statements that provide focus about the purpose or desired outcome of VCSS monitoring. Other forms of objectives important within the ROMN monitoring framework include management, sampling, and analytical objectives (Britten et al. 2007, NPS 2006). Management objectives are typically presented in park General Management Plans and are not included here (but they motivate many ROMN monitoring objectives). Analytical and sampling objectives, while closely associated with monitoring objectives, will be used to guide the analysis, modeling and assessment (interpretation) of ROMN monitoring data.

Objectives

1. Determine status and trend in vegetation structure, species composition, and diversity in grassland, shrubland, and woodland ecosystems* within Network small parks.
2. Determine status and trends in abundance of invasive/exotic plant taxa in these areas based on park-specific lists of likely and ecologically significant invaders at each park.
3. Determine the status and trend in soil condition in grassland, shrubland, and woodlands* of each park based on measures of 1) dynamic properties such as soil stability, extent of non-vegetated soils, and erosion and 2) inherent properties including physical texture, composition and soil chemistry.

*excluding high visitor use areas, developed infrastructure, culturally sensitive locations, and unsafe or inaccessible sites

Our grassland, shrubland, and woodland monitoring is intended to strike a balance between increasing fundamental understanding of these systems and providing managers early warning of undesirable change. It documents the variability in these systems while providing information needed for resource management decisions. Addressing these two goals is accomplished partly through sampling design and data analysis. Importantly, our defined monitoring targets, and therefore our frame for making inferences about park conditions, exclude areas of focused human use, including visitors and management, as well as concentrated facilities and sensitive resource areas. Therefore, our objectives are to provide indications of status and trend in more natural systems.

Reference conditions

These monitoring objectives form the foundation upon which all VCSS monitoring and assessment (i.e., interpretation) are built. A secondary objective is to develop quantitative methods to assess ecosystem integrity and condition through the development of bioassessment models that will incorporate reference condition distributions and identify both temporal and spatial departures from these distributions within a park.

In time, in cooperation with partners (other networks, agencies, and academic institutions), and with a robust dataset in place, an explicit assessment component based upon reference conditions in vegetation and soil attributes will be developed. The Network will develop park and/or habitat based reference condition distributions (Stoddard et al. 2006) for key response variables using our survey design data, other monitoring program data, and related research. In ROMN small parks, reference conditions will likely be derived from across the surrounding landscape including other monitoring data sources. Once reference conditions are established, the Network can determine the relative context of trends in vegetation and soil condition based on comparison of park estimates to referenced conditions.

Rationale for selected measures

Monitoring plant species cover is fundamental to understanding changes in grassland, shrubland, and woodland ecosystems. Cover measurements recognize the contribution of small species, are directly related to the biomass of most plant functional types, and “are easily visualized and intuitive” (Elzinga et al. 1998, p. 178). Moreover, canopy (foliar) cover is often used as an indicator of changes in plant community composition, is a strong determinant of water erosion, directly correlates with primary productivity, and is linked to ecological processes such as carbon and nitrogen cycling (Herrick et al. 2005). Monitoring shifts in the ratio of vegetation cover to exposed ground surfaces over time provides information regarding biomass production and the extent of bare soil, indicating susceptibility to erosion. Finally, estimating cover remains one of the most common methods in vegetation studies allowing for comparisons between our work and other national and local inventories.

We also record frequency in our plots to complement canopy cover. Frequency is the percentage of total possible plots occupied by each species being measured and is a very repeatable measurement that performs equally well in a range of habitats featuring different growth forms. Because it is not as sensitive to annual biomass changes, frequency measurements are more

robust to annual and seasonal changes in plant individuals. Additionally, frequency measurements may be taken any time after germination; this consequent independence from peak phenology creates a larger sampling window (Elzinga et al. 2001).

Tree species characteristics are also important to measure, in part because of their influence on the understory herbaceous vegetation patterns, soils, and water balance. Structurally, trees are also important to numerous species of wildlife. As weather and climate changes in the west, vegetation patterns shift as well. Under drier conditions, we observe woody species encroaching into open grasslands. We also see reduction in forests and woodlands that are experiencing rapid and significant tree mortality due to the spread of various species of bark beetles. This protocol uses measures of tree density, biomass, canopy health, and regeneration to characterize the patterns of woodland decline and expansion, and describe overall condition of woody species and communities.

Another vegetative component of the VCSS protocol is exotic species. The NPS defines exotic species as "those that occur in a given place as a result of direct or indirect, deliberate, or accidental actions by humans." Many exotic species can arrive without major alterations to the current ecosystem, but significantly alter the biological (species dominance), chemical (via litter deposition), and physical (fuels and aesthetics) environments after establishment. NPS policy calls for park managers to manage or eliminate exotic species that threaten park resources or public health. We survey for and estimate exotic species cover to inform park managers of exotic species' presence and changes in their abundance over time.

In addition to vegetation measures, ROMN identified surface soils as an indicator of terrestrial ecosystem integrity. Soil conditions at each site are characterized to assess slow-changing, inherent properties as well as more dynamic properties including erosion and potential for erosion, compaction of top soils, water availability to plants, nutrient storage and cycling, and the potential for acidification of the soil from the deposition of pollutants. While we realize the value of characterizing the soil profile through the rooting zone, ROMN is restricted from excavating soil pits in our small parks, which feature cultural and paleontological resources and artifacts that could be compromised from this physical disturbance. Brief descriptions of the soil characters that we measure follow. Semi-annual assessments of potentially short-term dynamic properties include direct assessment of soil surface conditions by measurement of the exposure of bare soil and evidence of erosion. The soil stability test describes the degree of structure and erosion resistance and is used to compare sites with similar soil textures (Herrick et al. 2005). Soil texture and soil bulk density describe the physical structure of the soil and influence many ecosystem processes, particularly water movement in soils (Elliot et al. 1999). Both measures can be used to better interpret other soil parameters. Furthermore, these parameters may provide covariates in analyses to better describe variation among sites. Similarly, soil organic matter, carbon, pH and plant nutrient concentrations can provide a powerful index of productivity and ecosystem processes and are often determinants of vegetation structure (Sollins et al. 1999). Unless alerted by dynamic changes, we will sample slow-changing properties, such as soil texture and nutrient concentrations, less frequently (approximately 5-10 yr cycle).

Sample design

Introduction

A sample design defines locations in space and time for the collection of monitoring data. VCSS objectives identify estimates of both status and trend at park and/or site scales as park managers and the I&M Program have clearly expressed the need for both. However, it is costly to estimate status (requiring an extensive sample) and trend (requiring repeated visits through time) simultaneously. Therefore, our sample design represents compromises between these needs via allocation of sample events across time and space within our probabilistically (or “randomly”) selected *survey designs/sites*.

Survey designs are used for unbiased design-based inference to a spatially extensive target population and often have relatively large sample sizes, yet may be sampled less frequently through time. Within survey designs we attempt to balance estimates of status and trend by using complex panel structures to allocate samples through time. In our small parks (FLFO, GRKO and LIBI), we use primarily survey sites, but may add sentinel *designs/sites* in the future. Sentinel sites are used for model-based inference to a site or discrete patches, are typically limited in number, but are sampled more intensively through time. Note that *gradient designs/sites*, a third sample design or site type introduced in Britten et al. (2007) and used in other ROMN protocols (see Schweiger et al., in preparation), are not currently part of the VCSS protocol, but may be added in the future.

We provide an overview of the core components of VCSS sample designs in the following sections. Other narrative sections in the VCSS protocol and its associated standard operating procedures (SOPs) that are related to sample design concepts include Field Methods and Analysis Overview (narrative and analysis SOPs). Appendix 3 provides additional detail, especially for power analyses conducted to assist in development of survey sample designs in small parks.

Survey designs

The ROMN considers survey designs to be the most defensible way to conduct park-wide monitoring, and many of the monitoring protocols for the ROMN rely on this technique at least in part (Britten et al. 2007). Survey designs include fewer assumptions and provide more reliable and defensible parameter estimates for inference to distributed target populations than judgment or model-based approaches (Schreuder et al. 2004; Neusser et al. 1998; Olsen et al. 1999). Moreover, the NPS I&M Program strongly recommends their usage for all applicable monitoring objectives (Fancy et al. 2009). In survey design-based monitoring, estimates of status and trend for a target population are generated using design-based inference (see Analysis Overview and the SOPs VCSS Analyses). In other words, we can estimate status and trend for unsampled locations using design properties.

Target populations

A target population is a statistical construct that defines the resource of interest in long-term monitoring. It is not necessarily the same as the less precisely defined conceptual resource of interest. Survey design-based monitoring requires a target population that is relatively constant in time as target populations that vary through time can lead to inconsistent variance around estimated parameters and complicate logistics.

The general or conceptual ecological resource of interest in VCSS monitoring is a subset of existing vegetation and its supporting soil within each small park. Given the instability of vegetation through time, we use landscape features that are typically slower to change as the basis for deriving the target population in our small park surveys. Our original goal was to define target populations by ecological sites as defined within generalized surface soil maps. Ecological sites are derived from soil series with specific physical characteristics that differ in their ability to produce distinctive types or amounts of vegetation and in their response to management (Society for Range Management Task Group on Unity in Concepts and Terminology 1995). Ecological site types are temporally stable and connect soil types in a park to vegetation as expressed in a given soil series; they are developed by the US Natural Resources Conservation Service (NRCS) as part of the Soil Survey Geographic (SSURGO) Database. However, NRCS classifies only rangelands into ecological site descriptions, which get stored in the SSURGO database, but not ecological types classified as forestland. Therefore, there are no forested or woodland ecological site descriptions in the database. In FLFO, where woodlands are common, we used other features from the SSURGO database to delineate target populations. Using both approaches, we defined the target populations at GRKO, LIBI, and FLFO as all areas within park boundaries, with the exception of wetlands and areas with greater than 50% tree cover (the Forest Service cutoff for forest-woodland delineation). Details outlining criteria used at each of these small parks are provided in tables in Appendix 4.

Given the degree of development of SSURGO data in these landscapes (i.e., it is at a much coarser scale than our needs), we defer the decision about the specific membership of any given site to a field call. This assumes that crews can evaluate a candidate sample site and determine if the location is in an appropriate ecological site based upon the target population criteria and whether the sites were safely accessible and did not fall in a cultural or restricted area at the time of the first sample event. Note that in all three small parks we explicitly excluded areas near cultural features to reduce the chance of a non-target site (based on access or compliance) at time of evaluation.

Sample population

A sample population is the realization of a sampling effort, and is the actual resource sampled by monitoring at survey sites. Ideally, sample and target populations are equivalent. However, logistical constraints and other sources of error inherent in site delineation and sample collection can lead to a lack of response (and therefore undetectable differences) in the target and sample population. Non-response errors include safety or compliance denials (i.e., as created by steep slopes or an unmapped sensitive cultural resource), sample frame errors (i.e., incorrectly mapped ecological sites), damaged or lost samples, or incorrectly collected data. Quality control and proper training can deal with some of these issues and the membership design we use (see below) aids in maintaining valid samples given access and compliance issues; however, some are unavoidable.

In a strict sense, the sampled population within the VCSS protocol is vegetation and soil at survey sites within ecological site types or soil types as defined by the target population that were actually successfully measured during a defined time period. A complex, but accurate example of a sample population might be “accessible vegetation and soil without standing water during typical peak phenology in mid-July during 2006 – 2008 within non-forested ecological site types at Little Bighorn National Battlefield.” All VCSS sampled populations will be clearly

and accurately described in analyses and assessments such that interpretation and reasonable inferences are clearly defined.

Survey design sample frame

The sample frame is the data from which a design algorithm selects potential sample locations. Frames are typically GIS data layer(s) that represent the best available approximation of an environmental variable, or set of variables, known or expected, to drive patterns of variability in the target population within a defined region (e.g., soil types, a hydrologic gradient, or management units). Sample frames must contain all internal boundaries (such as different types of ecological sites within a park). For the VCSS sample design, the ROMN developed sample frames within a GIS layer using soil geodata (SSURGO; NRCS). These data were intersected (thereby removing) with known or expected areas of sensitive or protected sites and developed park infrastructure as derived from multiple data maintained and/or created by each park. The sample frame for FLFO also incorporated limitations based on accessibility (slopes greater than 45 degrees were removed from the sample target).

Sample frames and monitoring sites are shown in Figure 4 through Figure 6. The design process and these images include a core of base sites (primary location selections) and oversample sites (statistically valid replacements for primary sites, to be added if primary sites fail to meet target criteria) within each soil and ecological type (SSURGO; NRCS). Again, areas of cultural sensitivity or those with existing infrastructure were systematically excluded from consideration making our target area (sample frame) limited to park areas without substantial human use and infrastructure. Tables 4.1-4.3 in Appendix 4 summarize the frames for these small parks by ecological site type.

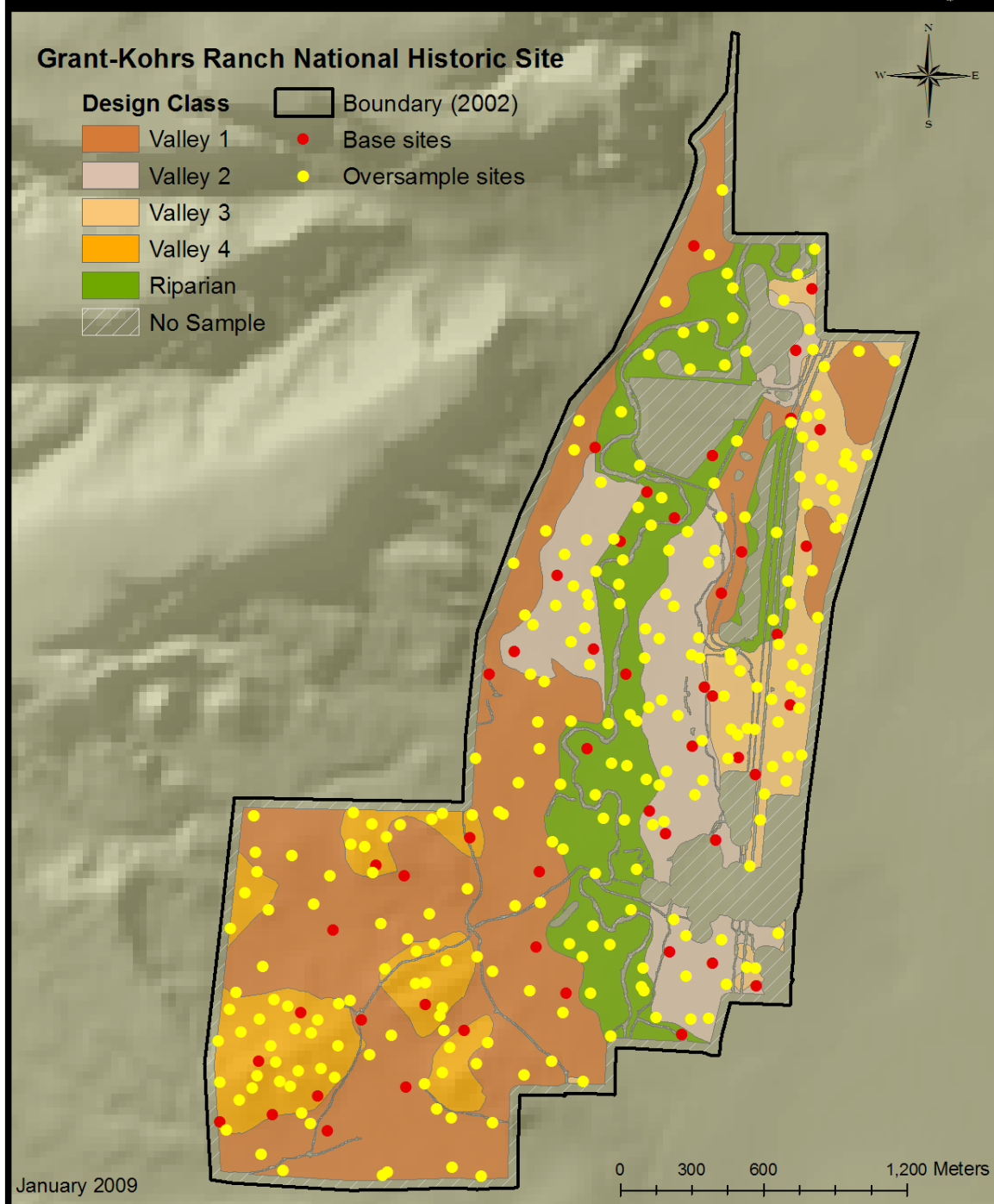


Figure 4. GRKO ecological site based sample frame, sample design, and park unit boundary. See Table 1 in Appendix 4 for a summary by type.

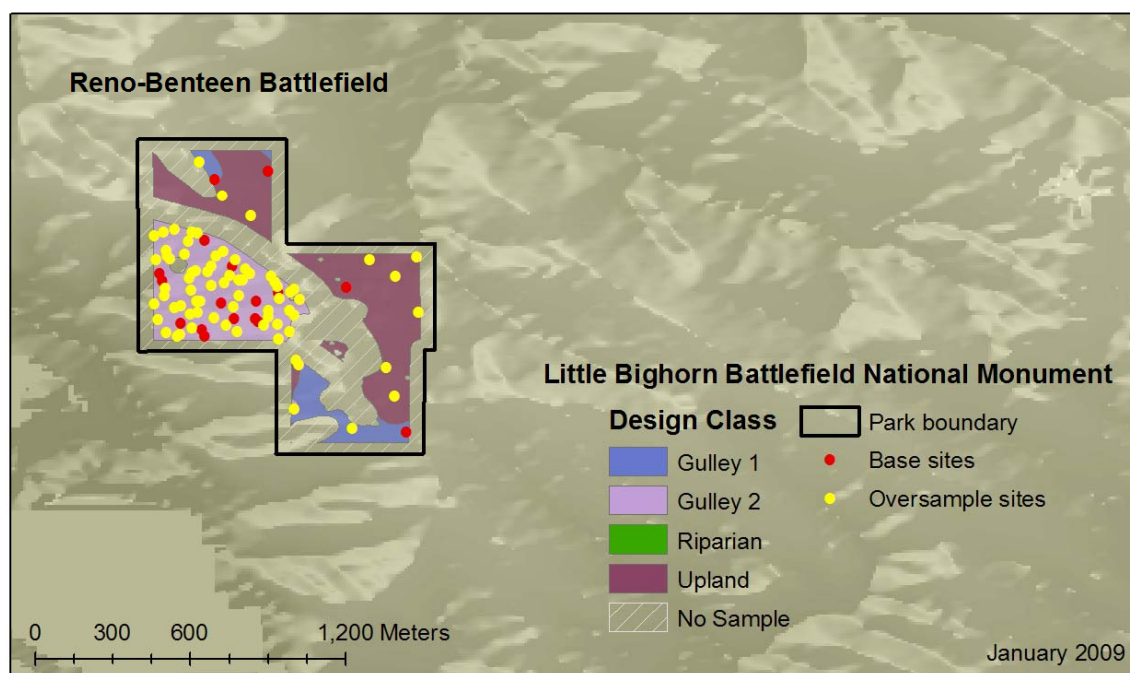
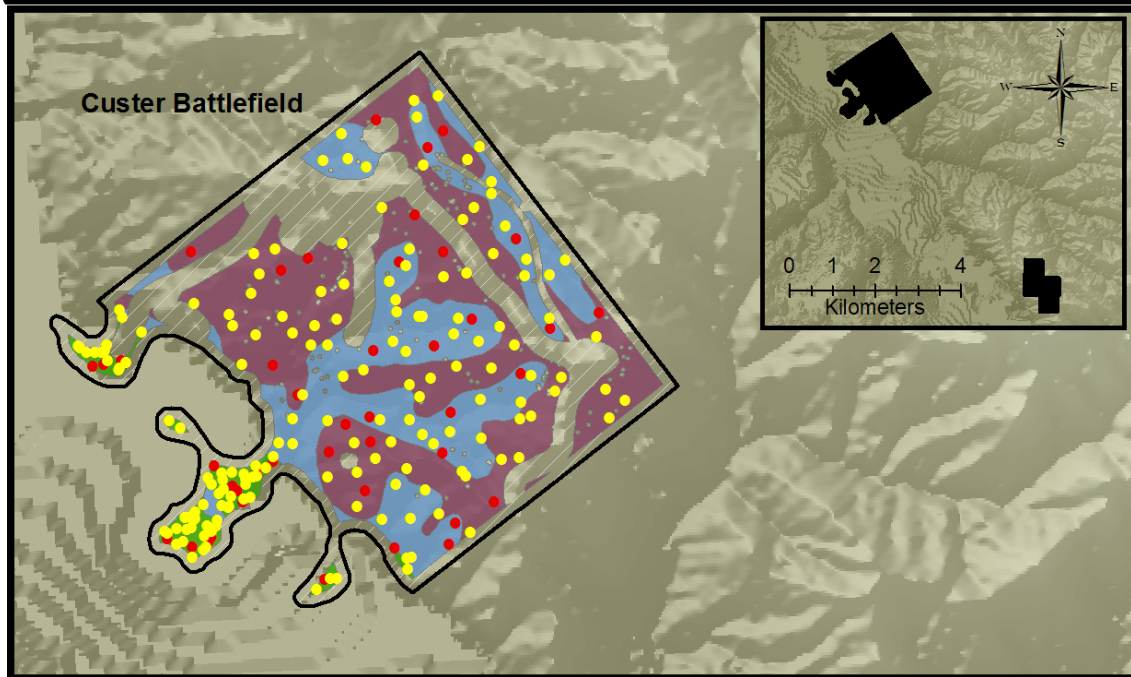


Figure 5. LIBI ecological site based sample frame, sample design, and park unit boundary. See Table 2 in Appendix 4 for a summary by type.

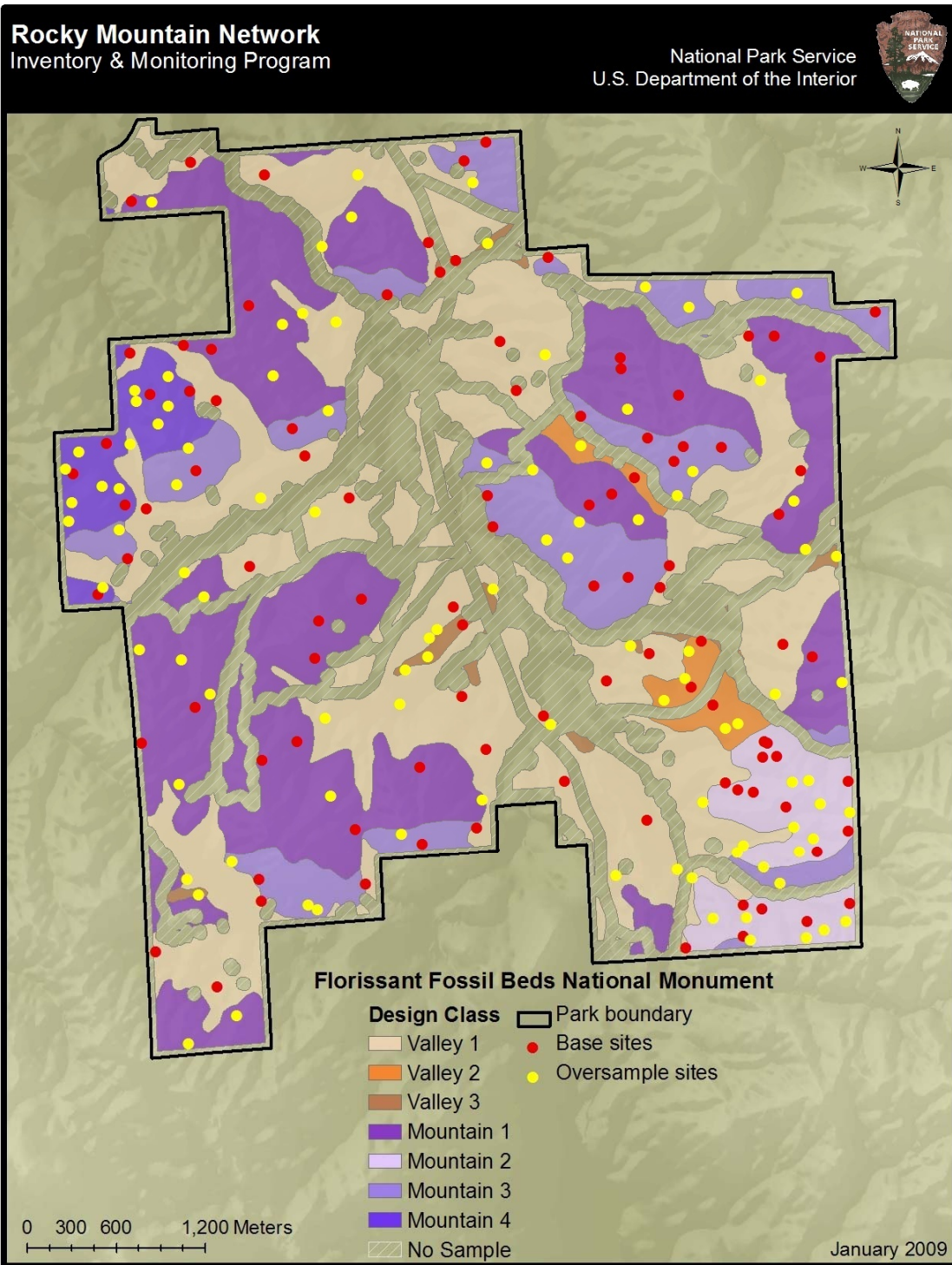


Figure 6. FLFO ecological site based sample frame, sample design, and park unit boundary. See Table 3 in Appendix 4 for a summary by type.

Membership design

The membership design specifies how sites in a survey design are chosen across space (McDonald 2003). As with all ROMN survey designs (Britten et al. 2007), the VCSS survey uses a Generalized Random Tessellation Stratified (GRTS) design (Stevens and Olsen 2003, 2004). Probability based surveys (such as GRTS) provide representative and defensible information because the site selection process allows unbiased estimation of both status and, with repeated visits, trend across a heterogeneous resource (Larsen et al. 1995). Key features of GRTS designs include: (1) spatial balance, (2) an unbiased variance estimator, (3) (optionally) a “neighborhood” variance estimator with improved precision, (4) valid addition (or replacement) of sites (Stevens 1997; Stevens and Olsen 2003, 2004; Theobald et al. 2007), and (5) (optionally) variable probability sampling across subpopulations and/or explicit stratification. An additional attribute of GRTS designs is the capacity to increase sample size given changes in design requirements (such as the allocation of sites to panels) and in environmental drivers and other forcing factors. The GRTS design lends itself very well to this as “oversample” sites can be added from the list of replacements while the overall validity of the “base” site distribution is retained. These attributes help ensure that VCSS survey designs are representative of the target population of interest in each ROMN park (Lohr 1999), may be efficiently implemented, and allow unbiased inference from sampled sites to un-sampled elements of the resource of interest (Hansen et al. 1983).

The ROMN small park designs use a GRTS design and variable probability sampling across areas delineated by ecological site types, soil types, topography, and geologic features. Variable probability creates subpopulations from the different design types in a park. We are not using explicit stratification in small park VCSS survey designs. The designs have 300 sites equally allocated to each defined type in each park (this sample size is not the same final implemented sample size) with 50 base and 250 oversample sites. The oversample sites follow the same proportional allocation to subpopulations as the primary sites. The final set of sites in a sample (e.g., all those that fit our target population definition) must be in the order established by the GRTS design. If a base site is determined to be non-target, it is replaced by the next available site with the same subpopulation type in the oversample list. GRTS designs can be easily augmented with additional sites (retaining design validity) if more or different sites are needed based on pilot results. These designs were used in pilot studies in each park (see below and Appendix 3). Our intention is to also use the monitoring locations defined by these designs in formal long-term monitoring at each park. Figures 4-6 illustrate the spatial distribution and allocation of base and oversample survey sites across in the three small parks using a GRTS design (note that this site membership is not the same as the final allocation to panels).

All ROMN GRTS designs are created in R using the library ‘spsurvey’ (Kincaid 2005, ver. 2.0, available from: <http://cran.r-project.org/>). Copies of original files are preserved and maintained by the Network including the statistical (R) code containing the original settings and functions, the sample frame shapefile(s) and summary data, and the design points.

Revisit design (sample size)

The revisit design defines the temporal sampling pattern for the selected sites (McDonald 2003) including the details of sample size for each sample interval (e.g., year). ROMN VCSS small park survey designs are split into panels that are visited on alternating schedules (e.g., once every

4 years, twice every 4 years). Panels are a group of sample units that are always sampled together, and the pattern of visits to panels across time is the revisit (or panel) design. Panel designs provide balanced replication of sites over time so that spatial and temporal effects may be modeled and both status and trend may be accurately estimated.

Draft ROMN VCSS revisit designs are based on pilot research in each park and power analysis of the ability of various alternative revisit designs to detect trend and minimize standard error around status. The following sections provide an overview of this process as applied for GRKO, where we have collected sufficient pilot data (see Appendix 3 for a more detailed description of all that follows).

GRKO and other small park pilot studies

Prior to developing the VCSS protocol, there was a lack of appropriate data on vegetation and soil in GRKO (and FLFO and LIBI) to parameterize models for power for status and trend estimation. Therefore, we implemented a pilot study in 2006 at GRKO focused on collecting data on vegetation and soil response measures following the standardized techniques detailed in this protocol. Similar efforts were successfully started in LIBI and FLFO. In addition, the pilots also provided key information on accuracy and precision of the response design, indicator selection, and operational constraints. We collected three years of pilot data from GRKO – a useful, but entirely too short time period for reliable parameterization of models. Methods under development will expand our pilot data using simulation (Garman et al. 2009) such that we have a longer term dataset from which to assess power (granted this introduces assumptions about the reliability of the simulation). As we finish field efforts for pilots in LIBI and FLFO, we will develop these same models and simulations and present all of this material in future VCSS reports. For GRKO, we began implementation of the design presented below in 2009. Our expectation is that sample size and the revisit design in all three small parks will be similar to this design even after revised power estimates from simulation.

Power analysis

Power analysis provides a ‘reality check’ on project goals and objectives through an *a priori* understanding of the ability and confidence with which one can estimate the condition of an extensive and variable resource (status) and detect trends in that resource over time. The ROMN uses power analysis primarily to understand the implications of an ‘affordable’ sample size and to contrast the allocation of this sample size into alternative revisit structures that optimize tradeoffs among trend and status estimation as well as overall operational reality. The five key steps in our power analysis are as follows:

Step 1: Developing linear models and variance components

We first develop linear models following Urquhart et al. (1993, 1998), Larsen et al. (1995, 2001), and Urquhart and Kincaid (1999) using four representative response measures collected over 3 years during the GRKO pilot (Table 1). The models are an expansion of a linear regression analysis (Draper and Smith 1967) to allow more detailed interpretation of the factors (via their variance components) influencing the variance in the slope. The relevant variance components in the model include site, year, the interaction of site and year, and a residual or error term that represents all other “unexplained” variance in the data (Table 1).

Step 2: Determining the ‘affordable sample size’

As we developed the ROMN monitoring plan (Britten et al. 2007) it became clear that our sample size and panel designs within any protocol would largely be a function of operational constraints, not the optimum for trend detection or for precisely estimated status. After much debate, we determined our average maximum sample size for VCSS surveys in the three small parks in any given year is 10 to 12 sample events per park. We believe we can maintain an annual sample effort of 30 to 36 survey sample events under current I&M funding scenarios and all other network responsibilities.

Step 3: Allocating sample size into panel designs

After reviewing the statistical and monitoring literature from other similar long-term monitoring efforts (mostly EPA projects), we determined that a split revisit design that partitions sites into

Table 1. Summary of variance components and other parameters used in linear modeling from four GRKO pilot study representative response measures.

Response Variable	Year	Mean (<i>not transformed</i>)	Standard Deviation (<i>not transformed</i>)	Source	Var. Comp. (<i>natural log transformed</i>)	Variance (%)	Site Correlation (<i>significance</i>)
Perennial Grass Cover (Plots)	2006	64.911	20.083	Year*Site	0.045	14.81	0.6311 ***
	2007	58.246	26.236	Year	0.114	37.22	
	2008	32.567	12.417	Site	0.101	33.05	
				Residual	0.046	14.93	
Annual Grass Cover (Plots)	2006	0.040	0.200	Year*Site	0.556	100.49	0.2136 ns
	2007	0.680	2.947	Year	-0.019	-3.49	
	2008	0.033	0.089	Site	0.017	3.00	
				Residual	0.000	0.00	
Exposed Mineral Soil (Plots)	2006	4.420	8.198	Year*Site	0.072	3.87	0.6212 ***
	2007	3.776	4.065	Year	0.055	2.97	
	2008	7.342	7.171	Site	1.078	58.24	
				Residual	0.646	34.92	
Tot Veg Cover (Plots)	2006	79.881	20.239	Year*Site	0.003	1.36	0.3138 ***
	2007	78.708	15.947	Year	0.148	68.24	
	2008	39.242	12.499	Site	0.018	8.11	
				Residual	0.048	22.29	

Notes: Sample size varies with year. All responses are from plot based data; Year.rho is set to 0.10 for all variables (see text). *** indicates significance of Pearson's 'r' site autocorrelation estimate. When the site autocorrelation is not significant (annual grass cover) we set the site autocorrelation to 0. All tests use alpha = 0.05.

two panel types with different sample size and revisit patterns would be used for our final design. Known as “partially augmented, serially alternating” designs, these structures offer the best compromise between estimating status and trend (Urquhart et al. 1993, 1998; Larsen et al. 1995, 2001). We picked panel designs that were within the realm of our budget, had similar annual and total unique sample size, but were different in terms of how they allocated samples across panels. We compared these designs to one another and to two simple (i.e., baseline) designs, one with

simple annual revisits (all sites visited every year) and a never revisit design where all new sites are selected each year (Table 2, Appendix 3).

Step 4: Setting the detectable trend

The minimally detectable difference (MDD; or amount of trend a design can detect) is a key parameter in power analysis. We use a proportional change or annualized rate of change in a response measure as our minimally detectable difference. *The annual rate is equivalent to the slope of the regression line in the linear models.* We sought to limit the complexity of the results we present here by choosing a small annual trend of 2% - significant enough to be of interest to land managers, but subtle enough to provide resolution of the differences in our proposed designs. Designs capable of detecting small trends will do better in detecting larger trends in the same resource, so power should be improved when rates of change are more rapid (i.e., with an annualized rate of 5%). However, because the MDD is a key (but usually unknown) parameter we do make comparisons with other values in Appendix 3.

Step 5: Estimating power for trend and standard error for status

The derivation of the equations for power to detect trend and standard error are presented in detail in Urquhart et al. (1993, 1998) and Larsen et al. (1995, 2001) and follow directly from the linear model (Stoddard et al. 1996). The statistical and analytical basis, assumptions, and justifications are well documented in these publications. The parameters (derived from GRKO pilot data) in the power analysis are presented in Table 1.

Summary of results

The literature behind our approach to developing the revisit design for small park VCSS surveys has a rich discussion of how parameters in the model can impact power for trend, standard error around status, and subsequent design decisions. We restricted the comparisons evaluated and discussed below to a small subset of the parameters in the models, focusing on the aspects that we either have control over (e.g., panel design, response measure) or that we do not, yet can have a strong impact on results (e.g., total unique sample size). Our results are preliminary until we can augment them with output from simulations that will expand the data set (and develop similar results for FLFO and LIBI). We describe below the results from our preliminary analyses and explore the effect of panel design, response measures, sample size and uncontrolled factors.

Effect of panel design

Panel design structure is the primary parameter we can control in our design choice. It is how total sample size, strongly constrained by budget, is allocated across time to balance estimation of status and trend. Differences for power for trend and standard error for status using total vegetation cover were surprisingly small among the five designs we analyzed but did vary with bare soil (Appendix 3, Figure 1). Our preferred design demonstrated slightly quicker convergence of the standard error toward the mean, suggesting higher potential for accurate status estimates in the shortest possible time-frame.

Effect of response measure

The choice of what to measure at VCSS sites is determined by many aspects other than power for trend and precision of estimates of status. However, if a response measure has poor statistical attributes it may either be a limited choice given inherent variability in the response and/or the VCSS methods used to collect it. Future work will develop additional statistics for VCSS

response measures (e.g., signal to noise ratios; *sensu* Kaufmann et al. 1999) to further refine the choices of response measures in the protocol.

Using our preferred design, results suggest some differences in anticipated power depending on the response measure analyzed (see Figure 3 in Appendix 3). Annual grasses, although less abundant than perennial grasses, demonstrated less inter-annual variability (reducing the effect of Year in models) resulting in more rapid accumulation of power and decrease in standard error. In contrast, bare soil cover, which was highly variable among sites and years (possibly indicating room for improvements to field methods, training, etc.) had slower increase in power and decrease in standard error. Perennial grass and total vegetation responses were similar in GRKO and fell in between annual grass and bare soil.

Effect of total sample size

Sample size is intuitively the aspect of a design that would seem to be ‘the most important’ in determining its qualities. Yet, in long-term monitoring design sample size is neither a simple design specification to determine nor often the most important. Using our preferred design, differences in power for trend and standard error of status were surprisingly small for total vegetation cover with increases in sample size above the affordable size. Bare soil exhibited more marked increase in power for trend and decrease in standard error as sample size within our preferred design increased (see Figure 3 in Appendix 3). However larger gains in power and decreases in standard error are realized with shifts in panel design structure.

Parameters not under direct control

Many other parameters can have as strong (or stronger) affect on the results of power analysis. In particular, effect size (annualized trend, or the minimally detectable difference) and the year variance component can dramatically alter the results from power models. These can be controlled by choice of response measure (i.e., only use responses with a small year variance), but if a response is monitored for other reasons the impacts may be simply a ‘fact of life.’

The magnitude of the effect size has one of the largest impacts on ability to detect trend, but no effect on the SE around status. For both total vegetation and bare soil a 10% annualized trend has markedly higher power than a 2% trend with the same number of elapsed years (Figure 4, Appendix 3). Unfortunately, the effect size often is not knowable; thus, it is difficult to examine its influence on a design effectively, *a priori*. If vegetation or soil attributes change at a rate closer to 10% vs. 2% our preferred design will detect this with a high degree of confidence within only a few years.

Most effects of design features on status and trend can be managed through design and sample size choices - except for the year-effect variance component (Urquhart et al. 1993; 1998). If we artificially create small year effects in GRKO pilot data we gain reasonable power and SE after 5-10 years for total vegetation and bare soil (see Figure 5 in Appendix 3). However, as the year effect increases (to the realized values from the GRKO pilot), the time required to reach 80% power or attain likely acceptable SE increases dramatically. If year effect exists even in small amounts, the sample size of an analysis reverts to the number of years for which there are data, and the number of visits and/or numbers of sites has no practical effect on trend detection. The only real recourse is to monitor for a longer period of time to accrue sufficient power.

Final design

Our final selection of a small park VCSS survey revisit design is provisional given the preliminary data and analyses conducted thus far. However, we are comfortable with the choice of our preferred design (Table 2). It is the best fit to our operational constraints. It has marginally better performance than the other split panel designs we tested and is better than the two baseline designs in nearly all tests. Figure 7 gives an example of the power for trend and standard error of four response measures collected using our preferred design.

Table 2. Draft panel structure to be used in small park VCSS survey designs. See also Table 2 in Appendix 3.

“Preferred Design” ([1-3⁴₆], [2-2⁴₂])

	Year									
Panel	1	2	3	4	5	6	7	8	9	10
A	6				6				6	
B		6				6				6
C			6				6			
D				6				6		
E	2	2			2	2			2	2
F		2	2			2	2			2
G			2	2			2	2		
H				2	2			2	2	
Within Season	1	1	1	1	1	1	1	1	1	1
Total # Events	9	11	11	11	11	11	11	11	11	11

Total unique sample size = 32 over 4 years; sample events accrued during this period = 42 (including within season revisits)

Values in the cells are expected sample sizes within each panel. Empty cells have no sample events. Only 10 years are shown but 80 were evaluated in power analysis. The pattern repeats in the same manner for years 11 – 80 (and thereafter). The notation commonly used to describe panel designs is a pair of digits. The first digit is the number of consecutive occasions on which a panel is sampled; the second is the number of consecutive occasions on which a panel is not sampled (McDonald 2003). The number of panels within a revisit form may be noted with a superscript and the sample size within each panel with a subscript.

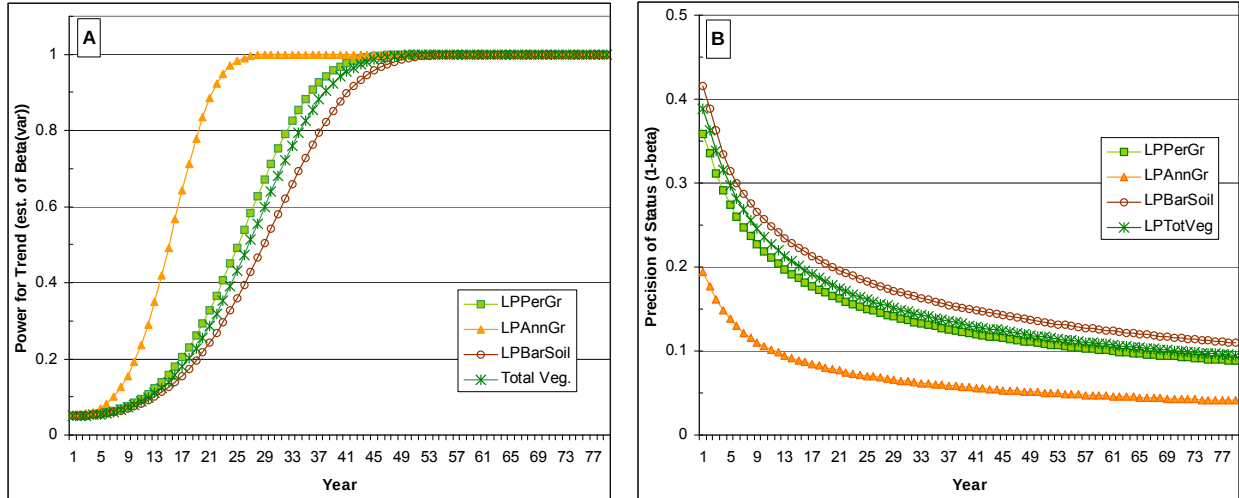


Figure 7. Examples of power analyses results. (A): Power for trend and (B) SE for status of four response measures collected using our preferred design and a 2% trend.

Notes: The four response measures in the figures are detailed in Table 1. The year, site, site * year and residual variance components, and site rho are calculated from GRKO pilot data. We set year rho to 0.10 and the annualized percent trend to 2%. When we are able to expand these analyses to include simulations and develop models for other parks, we may see meaningful changes and have to change the revisit design. While we do not expect this to happen, a key advantage of a GRTS design is the ability to recast the panel membership of existing sites into new structures. Often it is even possible to capture the bulk of results that were collected from an earlier panel structure. Perhaps the most troublesome outcome from this work is the generally poor performance of these designs in estimating population or net trend and status. This is largely due to the large year variance component in the response measures we tested (especially total vegetation cover). Performance is better with responses where concordant year variation is relatively lower (annual grass cover). However, when any meaningful year effect exists the only solution for the estimation of net trend is to continue monitoring over the long term. Our monitoring is expected to provide a mechanism for detecting gradual, on-going, and variable changes in natural resource conditions across heterogeneous areas. For surveys of extensive, heterogeneous resources, it is important to visit sites on a multi-year rotational cycle, expanding the number of sites visited each year rather than sampling each unit each year (Urquhart et al. 1993, Larsen et al. 1995). The most important difference between designs becomes apparent in how they perform with small numbers of sites (Urquhart et al. 1993), and this is particularly relevant for our capabilities given our budget limitations.

Sentinel design/sites

The ROMN considers sentinel designs to be a valid sample design form in a limited set of circumstances (Stehman and Overton 1994; Stoddard et al. 1998; Britten et al. 2007). Most importantly, sentinel designs are not appropriate for making inference to unsampled locations without complex process models (Olsen et al. 1999). We use sentinel designs when the ecological process of interest is “well mixed” - suggesting most any site is likely appropriate for its measure, there is a clear need to understand a specific location in a park, a modeling process is available for extrapolating sentinel results to broader regions, the costs for surveys are insurmountable, or the benefit for incorporating an existing sample location is large.

The ROMN has yet to develop sentinel VCSS monitoring in any network parks, but may consider adding sentinel sites in large parks and/ or the small parks if there is a demonstrated need to collect data more intensively in any given area of interest to park management.

Sample population

We assume the sample population is the same as the target population, that being a narrowly defined, homogeneous area. Meeting this assumption requires that our sample site(s) adequately represent the entire connected patch around a sentinel site.

Sample frame

Typically, sentinel designs do not rely on an algorithm (like GRTS) to select locations from a sample frame. However, GIS data similar (or identical) to survey design sample frames may be used to simply locate park sentinel sites. Using the same frame for both survey and sentinel designs is advantageous in linking the two design forms. If sentinel sites are generated using a computer based model it is likely that a frame analogous to that used in GRTS will be needed.

Revisit design (sample size)

Any future pilot work will likely include site specific power analysis for sentinel designs similar to the linear modeling approach detailed above (Larsen et al. 2001). By definition, site specific power analysis treats the N in question as the total number of visits to a site (both within and across years). As the period of monitoring increases, it becomes feasible to evaluate trends at individual sentinel sites (as well as survey sites specified by a GRTS design). However, as with VCSS surveys, sentinel sample size (both the total number of sites and the number of visits to these sites per year) will likely be constrained more by budget than by idealized power for trend detection.

Field Methods

Introduction

To monitor vegetation composition, structure, and soils in grassland, shrubland, and woodland habitats, the ROMN focuses on basic community structure attributes (vegetation, litter, and ground surface), species composition, diversity, and soils. Our response design (Messer et al. 1991; Stevens and Urquhart 2000) is derived from Herrick et al. (2005) and USDA Forest Service (2005). Transect and plot based methods are used to estimate cover and frequency of vegetation, invasive species, litter, and extent of bare ground; soil chemistry; and soil surface conditions. All field methods are designed to: (1) support our monitoring objectives (2) detect ecological trends of interest, (3) accurately sample all response measures, and (4) provide methodologies that are repeatable (i.e., precise) when implemented by different crew personnel, in a wide range of conditions, and over a period of many years.

All field sampling is performed according to a set of standard operating procedures (SOPs). The purpose of detailed SOPs is to ensure that over time, and as personnel change, methods remain consistent to reduce bias and variance introduced by the observers. The rationale for our approach and the field methods are summarized here, but details are provided in each individual SOP.

Timing of sampling (index period)

The selection of when to sample within a sample interval (e.g., a given month, week, or day during a year, or a particular hour during a 24-hour period) is part of the response design. The timing of sampling (index period) must be carefully chosen and justified. Index-period sampling focuses the time of sampling on the most ecologically relevant period(s) for a given response measure so the data collected will function as the most useful barometer of a vital sign or of the condition of target populations within a given sampling interval (Larsen et al. 1995; Kaufmann et al. 1988; Landers et al. 1988; Messer et al. 1986). Index-period sampling also reduces inter-annual variability. Index-period sampling can also be used to deal with phenological changes in a resource (if these can be identified *a priori*).

The VCSS protocol uses an index period defined as the week(s) nearest to the peak of the growing season. This pattern should allow a similar period for growth and flowering of local herbaceous species, but should precede senescence and decay. Although it would be best to visit all sites on the same phenological date (e.g., 60 days into the growing season) this date changes each year and would be operationally impossible. Further, the annual schedule of site visits will be different each year (due to rotation of sites within a park and among parks). The ROMN will make every effort to consistently schedule visits to fall within a similar calendar period based on the practical sampling season.

Establishing / relocating sites

Site dossiers

The initial step in the VCSS protocol is to determine where and when sampling will occur. Sites to sample in any given year are determined by the sampling design and the exact timing by the relevant index period for the park. When sites are selected, site dossiers are created to include maps of each site and relevant metadata (directions, estimated travel time, etc.). If sites were visited in previous years, field crews receive written components of dossiers that are based on the

information provided in the original “Site Description” form (*SOP VCSS Completing Site Description Forms*). A site overview photo and detail of the center monument are collected for each site (in each year sampled); these photos (especially the last visit) are important additions to the annual dossiers.

Field navigation

Sample site locations are uploaded to Global Positioning System (GPS) units. Field crews navigate to these locations by GPS (*SOP VCSS Navigating to Sites*) and traditional orienteering skills using dossier maps, large area topographic maps (e.g., *Trails Illustrated*), site descriptions, and a compass. Navigating to some sites will require off-road driving, foot travel by trail, and more commonly, foot travel off-trail. Appropriate park staff should always know about and approve these activities. Additional information regarding safely traveling and working in parks can be found in *SOP Admin Safety Preparation and Training*.

Determining target status of a site

Once a field crew has navigated to the site, they must determine whether the site is appropriate for sampling. Factors that impact a site’s suitability include accessibility, representativeness, safety, and resource sensitivity (*SOP VCSS Site Suitability*). If a site is not appropriate and must be relocated, the procedures described in *SOP VCSS Moving and Replacing Sites* may be used. In some cases, moving sites will not be appropriate and instead, sites will need to be replaced. In this case, a new site location should be selected from the oversample list and a new site established (*SOP VCSS Moving and Replacing Sites*). It is critical that the fate of sites in the survey design be carefully recorded and tracked.

Once the site location is established, sites should be marked to facilitate long-term monitoring (*SOP VCSS Site Layout*). Each site should be marked with a monument only once with subsequent visits locating and utilizing the pre-existing monuments. However, movement, damage, or removal of monuments, or changes in environmental and/or management conditions may require that some sites are relocated, re-marked, and/or replacements sites added as this protocol is performed over many years.

In addition to marking sites, it is critical that the site be adequately described to enable efficient location of sites in subsequent years and to provide a detailed overview of site environment (e.g., slope, aspect, etc.). A Site Description form should be used to clearly identify (using UTM coordinates) and describe the location of the site (e.g., general topography, hydrology), and to describe the locations of the four monuments (*SOP VCSS Completing Site Description Forms*). If available, crews should carry a copy of the Site Description form and the most recent photos of the site with them for each site visited.

Site layout and measurements

After crews have completed the site description forms, they should next lay out the plots and transects within the site. The VCSS site configuration is derived from the “spoked wheel” designs created by USDA Agricultural Research Service, Jornada (Herrick et al. 2005) and the USDA Forest Service, FIA Program (USDA Forest Service 2005). The layout consists of three transects, each extending 36.6m from a center monument, one-168m² circular plot nested within another 1012m² circular plot at the end of each transect, and ten-1m² plots (Figure 8). Crews estimate percent cover by species and ground cover type along transects, document frequency in

the 1m² plots, and measure and describe woody vegetation in the larger, 168m² circular plot, when applicable. There is the option to conduct a relevé style survey in the largest circular plot when funds allow. Directions for establishing the location of all transects and plots can be found in *SOP VCSS Site Layout*. Additionally, Appendix 2 provides a recommended approach for completing work in the field.

Photographs

Repeat photography provides a visual summary of each site, its context and, as images are accumulated, how general site characteristics change through time. Photography is incorporated into this protocol for several reasons including communicating information as well as assisting plot relocation. After marking each transect, photographs are taken of the site and transect locations. *SOP VCSS Photo Documentation* provides instructions for all official photography of the site. Photo points are identified by the name or code designation of the site-transect-plot combination that they represent (e.g., GRKO.0001 – Trans.1 – Plot 3). Detailed instructions on camera settings, use with GPS, and photo file management are also provided in *SOP VCSS Photo Documentation*.

Vegetation

Our primary response variables are canopy cover and frequency of herbaceous vegetation and ground cover (e.g., litter, bare soil). Canopy cover is the vegetation covering the ground surface as viewed from above and is recorded by species. Advantages of using cover to measure vegetation and substrate include 1) cover is a direct measure of vegetation biomass, 2) cover equalizes the contribution of abundant, small stature species and species that are larger in size, but fewer in number, and 3) cover estimations do not require an account of each individual, so assessments may be quicker (Elzinga et al. 1998). Documenting the cover or extent of exposed surfaces (e.g., no vegetation cover) and characterizing the surface components provides one indication of the susceptibility of the surface to erosion.

The protocol also includes frequency measurements in the 1m² plots as a complimentary counterpart to canopy cover. Frequency is the percentage of total plots that contain at least one individual of a given species and is usually a measure that is easier to repeat than estimating cover since it only requires noting presence of a species rather than estimating cover area. Frequency is not greatly affected by changes of biomass and is not likely to capture fluctuating, individual responses to annual swings in climate; since frequency is sensitive to shifts in spatial distribution and changes in density, it should be an effective measure to monitor changes in exotic species population dynamics. Frequency is also a measure that is being used in other Intermountain Region I&M networks' plant community protocols. Adopting this measure enables the ROMN to integrate VCSS data with broader, regional analyses.

Field crews measure vegetation composition using both transect and plot based methods. Plot estimates are often better at detecting low cover species than transect point-intercept methods (Elzinga et al. 1998). However, point-intercept methods are a fairly objective method for estimating cover (Barbour et al. 1987) and can be used for larger areas. Point-intercept measurements are taken along three-36.6m transects at each site and are used to estimate relative cover of species, litter, and bare ground (*SOP VCSS Transect Methods*). Ten-1m² plots within each site are used for fine scale estimates of vegetation and ground cover frequency (*SOP VCSS*

Plot Methods). By utilizing both methods, the VCSS provides a robust and repeatable metric of vegetation composition.

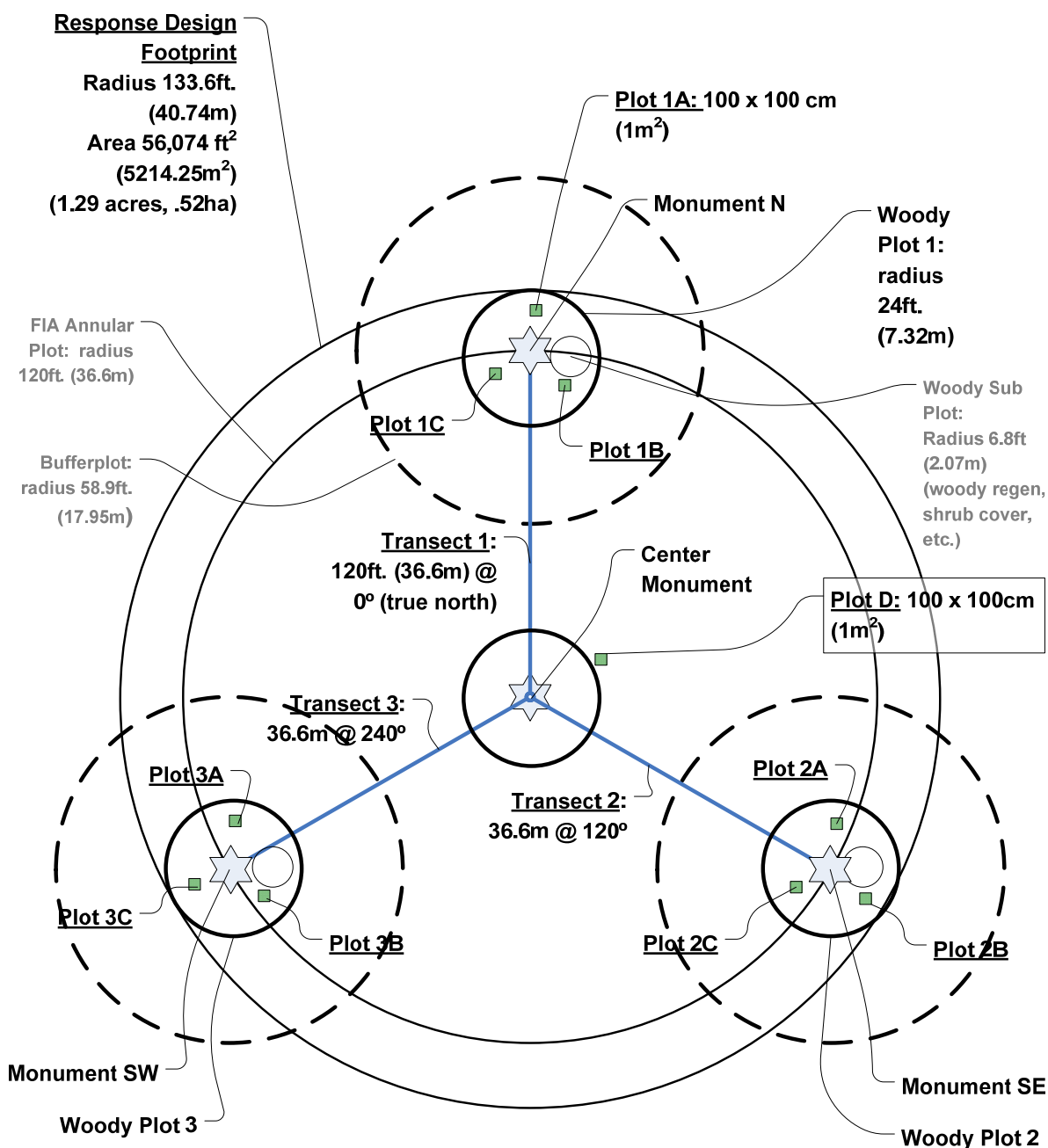


Figure 8. Vegetation monitoring response design (field plot design) proposed for implementation in shrub and grasslands within ROMN small parks. The four monuments (stars at plot centers) should be fixed, metal markers (with ID caps) to insure accurate re-location of sample units over time.

Soils

Soil at each site is characterized to assess the inherent (slow-changing) and dynamic properties of the surface profile including physical, chemical and biological indicators (Karlen et al. 2003).

Key indicators of soils and ecosystem function include cover and composition of vegetation, exposure of mineral soils, soil stability, compaction of top soils, water movement and infiltration and the storage, cycling, and abundance of nutrients (Herrick et al. 2002, Karlen et al. 2003, Herrick et al. 2005). Soil surface condition, cover of litter, bare ground, rock, and nonvascular layers are measured along transects and plots in concert with vegetation sampling (*SOPs VCSS Transect and Plot Methods*). To complement these measures, a detailed soil characterization is conducted to describe inherent soil physical and chemical properties. It includes measures of soil texture, nutrient and mineral concentrations (e.g., P, Mg, K, Al, Ca, C and N), pH, % organic matter, cation exchange capacity, bulk density, and soil aggregate stability (*SOP VCSS Soil Characterization*). Following the initial characterization, inherent properties of soils will be sampled every 5-10 years; whereas measures of more dynamic indicators, including soil aggregate stability and cover versus bare soil estimates occur at every visit. If costs allow, soil pH and total carbon and nitrogen will also be measured after each visit (every 2-3 years). With the exception of aggregate stability, all soil tests are based on soil cores taken in the field and sent to a cooperating laboratory.

A more in-depth description of these soil characters and rationale for including them follow. *Soil aggregate stability* is a direct measure of the ability of the soil to adhere to cohesive units (peds). It is a function of soil type and condition and requires ongoing inputs of carbon (plant biomass) to bind soil particles together (Herrick et al. 2005). We estimate the stability of the soil at 18 locations per site (six per transect) at two depths, the top 1cm and from 2cm below the surface. Decreasing stability indicates increasing potential for erosion and loss of soil carbon, and increasing stability indicates potential compaction or other hardening.

Soil texture is a description of the percent sand, clay, and silt in a soil and is a critical component of soil monitoring (Elliot et al. 1999). Numerous soil properties are influenced by texture including: drainage, susceptibility to erosion, organic matter content, cation exchange capacity, and pH buffering capacity. For instance, soil with a high percentage of silt and clay particles has a greater erodibility than a sandy soil under the same conditions. We expect that texture will not change as rapidly as vegetation or other soil properties and will be measured at only the initial site visit.

Bulk density is a measure of soil mass per volume and is an indicator of soil strength and structure. Soil compaction leads to an increase in bulk density and can affect porosity of soils and plant growth. Measuring bulk density is also necessary to convert soil nutrient concentrations to a volumetric measure (Elliot et al. 1999).

The ability of soils to retain positively charged ions is referred to as *cation exchange capacity* (CEC). Essential plant nutrients, such as calcium (Ca^{2+}), magnesium (Mg^{2+}), and potassium (K^{+}), are cations and CEC describes the ability of negatively-charged clays and organic matter in the soil to hold on to these cations. Mineral deficiencies are more likely to occur and soil pH tends to decrease faster in soils with low CEC (Robertson et al. 1999).

Soil organic matter is the fraction of the soil that consists of plant or animal tissue in various stages of decomposition. Soil organic matter enhances aggregate stability, cation exchange capacity, the soil's capacity to hold water, nutrient availability, and pH buffering capacity (Sollins et al. 1999).

Soil pH measures the activity of hydrogen (H⁺) ions in soil solution. Many plant nutrients become less available to plants in acidic soils and atmospheric deposition may lead to changes in soil pH (Robertson et al. 1999).

Along with all the other soil parameters, we estimate the concentration of plant *mineral nutrients* in the soil. Productivity is often linked to the availability and balance of plant nutrients. *Total nitrogen and carbon* content are also measured and can be a useful indicator of ecosystem processes such as carbon sequestration, decomposition, and the potential for a site to leach nitrate (Sollins et al. 1999).

Site Disturbances

Observing and documenting land use and natural episodic events can provide insight into understanding patterns in vegetation distribution across the landscape. For example, the introduction of change into a system could affect species' ability to survive in the altered environment. These species may decline, and species better suited to the new environmental conditions begin to establish, thereby shifting community composition (Barbour et al. 1987). For example, a wildfire or logging may modify soils, alter the water balance, bring in more sunlight, and introduce new vectors for the seed dispersal of new species (DeBano et al. 1998, Fleming and Baldwin 2008).

In order to provide context for observed vegetation and soils status and trends, we document potential stressors in and around each site. Using applicable metrics from the 2008 Human Disturbance Index developed by the Colorado Natural Heritage Program, (Rocchio 2007) and the California Rapid Assessment Method for Wetlands (Collins et al. 2008), we indicate a condition score within the framework of three categories: buffer/landscape, hydrology, and physical disturbance. The scores from each weighted category are then combined to generate one condition score for the site being evaluated. The ROMN has developed an additional, separate Natural Disturbance model that is analyzed independently. *SOP VCSS Site Disturbance* provides detailed instructions outlining how to complete both disturbance assessments.

Standard Operating Procedures (SOPs)

Introduction and overview

A full list of VCSS Grassland, Shrubland, and Woodland SOPs are included below. Details of methods discussed in this narrative are included in these separate files.

The ROMN also maintains a set of common data management, administrative, and equipment operating procedures that is shared by all Vital Signs protocols. These standard procedures are included in the document with the protocol-specific SOPs and cover all methods to ensure safety, resource protection, and compliance of a field crew working in Network parks. Guidance for permitting, safety training, communications and radio use, finding housing, hiring crews, and end of season procedures are also covered. Other standard SOPs provide instructions for operations of equipment shared by all protocols, such as compasses, GPS units, and digital cameras. Lastly, there are SOPs that are part of the ROMN Data Management plan that apply to the VCSS protocol. These address topics such as data deliverable standards, data quality assurance/ control, archiving data, and equipment maintenance/storage.

Standard Operating Procedures associated with this protocol

SOP VCSS Site Suitability
SOP VCSS Moving and Replacing Sites
SOP VCSS Navigating to Sites
SOP VCSS Site Layout
SOP VCSS Completing Site Description Forms
SOP VCSS Photo Documentation
SOP VCSS Transect Methods
SOP VCSS Plot Methods
SOP VCSS Unknown Plant Species
SOP VCSS Soil Characterization
SOP VCSS Optional Relevé Plot
SOP VCSS Tree/shrub Plots
SOP VCSS Site Disturbance
SOP VCSS Post-Sampling Event Procedures
SOP VCSS Paper Field Forms
SOP VCSS Electronic Field Data Entry
SOP VCSS Basic Analysis
SOP VCSS Design-based Analysis
SOP VCSS Hypothesis Testing

Shared ROMN SOPs

SOP Admin Safety Preparation and Training
SOP Admin Permitting
SOP Admin Training
SOP Admin Seasonal Hiring
SOP Admin Park Logistics
SOP Admin End of Season
SOP Equipment Using a Digital Camera
SOP Equipment Using the Garmin GPs 76 csx
SOP Equipment Field Communications
SOP Equipment Vehicles
SOP DM Data Deliverable Standards
SOP DM Data Quality Control (QC)
SOP DM Archiving Data

Managing a sampling season

Introduction

A successful (efficient, safe, complete) field data collection effort requires planning and scheduling beyond hiring a crew and showing up at the park. The following timeline provides some guidance for critical steps and approximate dates for completion.

General timeline

1. Field Crew, initiate hiring: **January / February**
2. Review and revise protocols: **February**
3. Review sample frame, design points, and panel for annual site selection: **February**
4. Submit permit requests: **February / March**
5. Brief the ROMN Technical Committee: **March**
6. Set schedule (draft): **March**
7. Make lodging reservations: **March**
8. Other logistics: **March - May**
9. Vehicle rentals: **April-May**
10. Equipment to purchase: **April-May**
11. Equipment to ship: **May**
12. Coordination with park staff and other personnel: **May**
13. Training preparations: **May**
14. Final permits acquired (verify): **May**
15. Final equipment inventory: **May**
16. Crew training: **late May, early June**
17. Field work: **May – September (depends on park and annual conditions)**
18. Season wrap-up: **August – September**
19. Data entry, quality assessment and error corrections: **October/ November**
20. Finalize database and close-out annual effort (triggers data manager to add annual data to master database files): **December/ January**

Communication with parks' staffs

It is important to maintain an ongoing dialogue with park staff when planning a sample season, conducting field sampling, and analyzing/reporting on data. For example, direct communication with park staff is critical if park housing is needed/ desired or special access is needed.

Many of the relevant topics are addressed in the ROMN standard field operating procedures and these procedures should be used as a guide when working with park staff. These topics include:

1. Permitting;
2. Logistics (calendar, housing, transportation, meetings, local training, etc.);
3. Safety (park-specific needs and requirements);
4. Radios (programming, cell phone options, etc);
5. Resource protection.

Data management (field preparation)

It is critical to communicate with the ROMN data manager and technical support staff to ensure proper data management for the field season. Plans for data and equipment need to be synchronized between principal investigator, crew leader(s), and data manager, as well as verification of roles and responsibilities. Steps to take prior to departing for the field include:

1. Ensure equipment is functioning properly (laptop, camera, GPS, etc.);
2. Complete quality assurance measures (especially paper and digital forms) – e.g., are database lookup menus accurate, current, and tested?
3. Update digital forms so that they are current and functioning properly (with fields properly connected to the database);
4. Load database, forms, previous years' data/photos, etc. onto field laptop computer;
5. Upload sites onto GPS for navigation.

Data Management

Introduction

The ROMN is the owner and long-term steward for all VCSS data and the management of these data follows the ROMN Data and Information Management Plan (NPS 2007). Data management requirements for I&M network monitoring protocols include explicit procedures to enter, edit, document (metadata), store, and archive data according to each vital sign protocol (Figure 9). All VCSS field data, photos, and GPS waypoints are entered and stored in a relational MS Access database that conforms to NPS database standards, as defined by the [Natural Resources Database Template specifications](#) Version 3.2, including quality control and quality assurance procedures (NPS 2007). ROMN maintains an annual and a master VCSS MS Access relational database. Data entry and quality control and quality assurance procedures are applied to the annual VCSS database followed by the transfer of the annual data to the VCSS master database and subsequent archiving of the annual database. The VCSS master database is the main repository of all VCSS field data and derived metrics for analyses and reporting. VCSS annual and master databases are backed-up on a daily basis on site and on a weekly basis off-site.

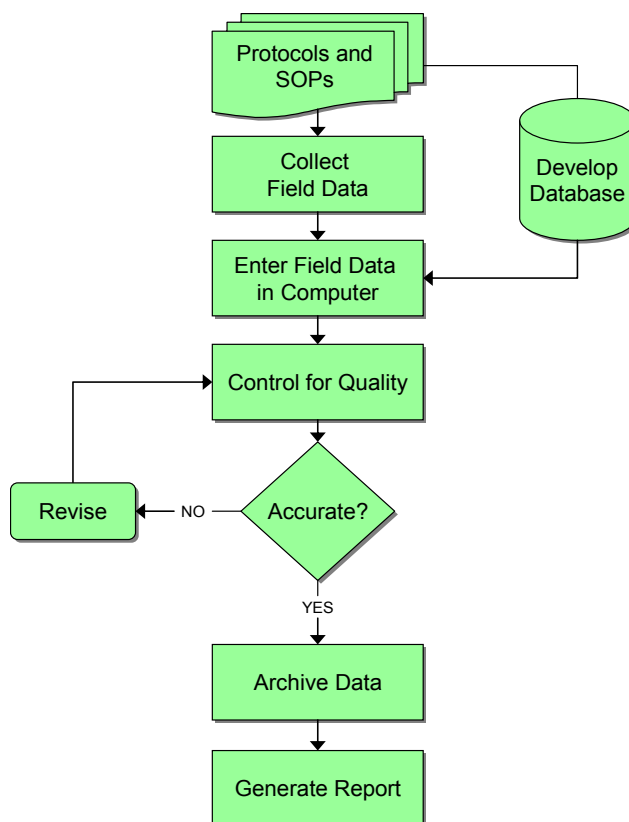


Figure 9. Example Data Flow Model for VCSS

Sensitive Data Management

National guidance for sensitivity restricts general public accessibility to data determined to be sensitive by park management.

Therefore, the VCSS protocol:

1. Follows established guidelines for managing sensitive information (NPS 2007);
2. Contains measures for identifying and flagging sensitive information;
3. In cases where sensitive information is intentionally or unintentionally located in the field, provides a means of collecting data that does not jeopardize the sensitive resources (NPS 2007).

Analysis Overview

Introduction

The ROMN VCSS analyses fall into three general categories: parameter estimation, multivariate and other forms of more complex modeling, and comparisons to thresholds (hypothesis testing). All VCSS data analysis follow from the sample design used to generate the data. At this point in VCSS protocol development, before much significant data collection has occurred, it is difficult to present specific procedures for data analysis and interpretation. For this reason, we approach data analysis and reporting as a set of options that will be narrowed as data compilation and descriptive analysis progresses. After several years of data collection a more definitive SOP can be written that explicitly states the approach and steps required for data analysis collected by this protocol.

All analyses, with the potential exception of trend, are performed annually. Trend analyses are calculated on 5-10 year cycles depending on final revisit panel design.

Parameter estimation

Model-based basic summaries

Compiling basic summary information and performing preliminary data assessment includes estimating statistics of status such as means and associated variance parameters for measured response variables. For survey designs with multiple sites, data come from each site. However, in lieu of design-based analysis (see below), the proper inference for these analyses is the set of sites used in the analyses. Sentinel VCSS sites may be treated in the same way, with the same inferential capacity.

Statistics may be reported using tables or figures – simple is generally better; for example, a histogram depicting the cover and standard deviation for the most abundant species in each park (Figure 10). Cumulative summary techniques (CUSUM; Page 1996) are more sophisticated (but still largely graphical) tools that can be used to look for change in a response measure based on the measured pattern of responses and systematic deviations from this pattern (Barnard 1959; Page 1996).

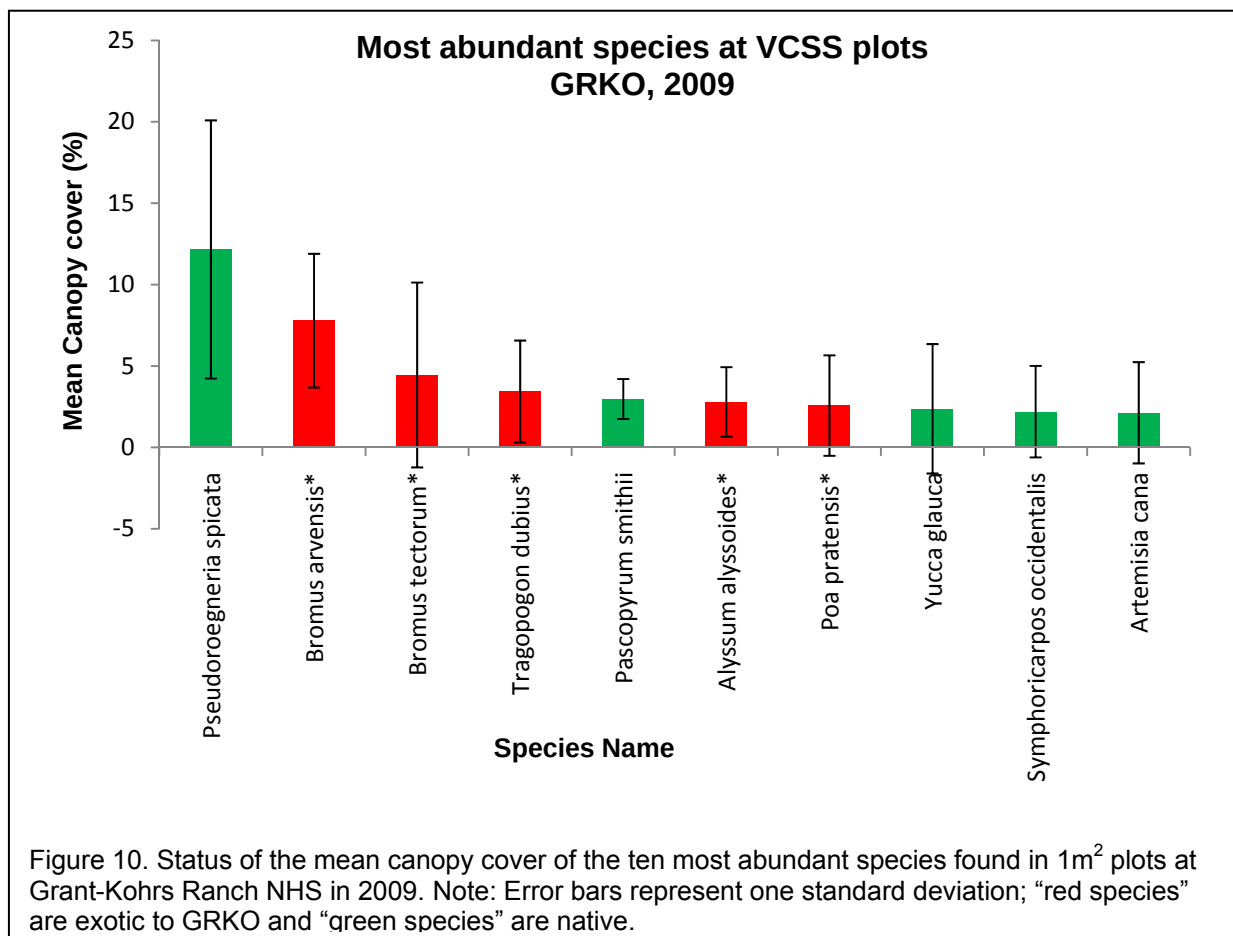
These analyses can be completed annually (using single season data) or across more than one year (if trend is accounted for, see below). They may also be used in more thorough, periodic (triggered by end of a design panel) assessments of status (again, with careful treatment of any trend).

Design-based basic summaries

Design-based analysis is a fundamentally different approach than more familiar model-based approaches. The key advantage of the design-based approach is that estimates apply to an entire target (or more correctly sampled) population with a known level of confidence. The number of assumptions required to draw this inference are minimal and well known (Olsen et al. 1999). It is an ideal tool for meeting the long-term, park-wide monitoring mandate of the Vital Signs program (Fancy et al. 2009).

After we have adjusted sample weights and tested for trend in a data set (see below), we apply these tools to generate status statistics such as cumulative distribution functions, means and their

variances for VCSS response measures. Design-based analyses are well documented (Horvitz and Thompson 1952; Cordy 1993; Diaz-Ramos et al. 1996; Stevens 1997). The algorithms used are beyond our scope here (see *SOP VCSS Design-based Analysis* and Diaz-Ramos et al. 1996). In summary, they resemble traditional formulae for a statistic, but incorporate sample weights for each site in the analysis with the value of the response measure at the sample point to account for



the selection probabilities in the sample design.

In the VCSS design, with its unequal selection probabilities, sites that are selected with higher weights have less influence on the final statistic. This is why the coupling of design-based analysis with complex survey designs is so important.

With GRTS VCSS survey designs we can generate more precise variance estimates around design-based estimates of status using a proprietary technique developed by Stevens and Olsen (2003). Known as the local neighborhood variance, it is derived from smoothed or averaged contrasts among values in the local neighborhood of a sampled point. It provides estimates 20 to 60 percent smaller (i.e., more precise) than similar traditional survey-design variance estimators (Horvitz and Thompson 1952).

Weight adjustment

Prior to any parameter estimation that incorporates survey-design properties, inclusion probabilities must be adjusted. Information from the evaluation of survey sites and their subsequent status (sampled, not part of the target population, etc.) is used to recalculate the initial sample weights. These new values are then used in all design-based statistics. If there are subpopulations, strata, or nested subset of sites with different response designs different sample weights may be generated for these sets of sites.

Trend

Status and trend are intertwined in our analysis; accounting for temporal trends is necessary for proper assessment of status, and accounting for spatial variability is necessary for proper interpolation of trend assessment. We use linear models (see also Appendix 3; Larsen et al. 2001; Kincaid et al. 2004) and/or non-parametric trend analyses (Mann-Kendall tests; Hirsch and Slack 1984, Helsel and Hirsch 2002) to detect and quantify trend. Trend itself is one, if not *the* most important VCSS statistic we estimate. For status estimates, if trend is present we proceed with analyses that account for trend. If there is no trend in the data, we can combine data across sample periods (years) in the model- and design-based analysis summarized above although this must be clearly stated in any interpretation and presentation of the results.

Unfortunately, no specific methods for estimating trend from data collected under a GRTS unequal probability sampling design with panels currently exist. However, GRTS designs are conservative relative to a simple random sample (Stevens and Olsen 2003, 2004) and so traditional analysis assuming a simple random sample with no panels is appropriate (Starceovich 2007).

More Complex Models

Accurately measuring the status and trend in VCSS response measures is our primary objective. However, relevant details in the spatial and temporal variability of vegetation and soil response are often not directly explainable using only the response measures of the VCSS protocol. Therefore more complex models may be developed that use combinations of measured and modeled drivers and covariates (e.g., climate, landscape composition, etc.) to better explain and interpret our results (see Figure 2). These models run the gamut from multivariate regressions to species level measures of similarity. As the VCSS protocol matures, modeling efforts will include species level bioassessment models such as multimetric indices (e.g., Indices of Biotic Integrity; Karr 1991; Jones 2004) and multivariate indices (e.g., Observed : Expected or RIVPACS; Hawkins et al. 2000; Clarke et al. 2003). Such modeling can facilitate prediction, if carefully applied and interpreted. In some cases these models do not allow the incorporation of design properties so inferential capacity is more limited.

Model selection algorithms such as Akaike's Information Criteria (AIC) are also used to aid interpretation of ecological processes by helping select the best model that quantifies pattern or process in VCSS response (Akaike 1973; Burnham and Anderson 2002). These tools facilitate a data-based choice among competing models. To perform these analyses, each measured indicator variable of interest (e.g., total cover of vegetation) is modeled as the dependent variable, and ecologically possible (or *all* possible) combinations of known or predicted drivers are tested as independent variables. Buckland et al. (1997) proposed a procedure based on an average of several plausible models that improved selection of models used for deriving parameter

estimates. This approach weights the models according to AIC values; thus the most plausible models receive the highest weight, while the least plausible models receive little or no weight. The ROMN will use model selection and averaging to support interpretation of patterns and trends in our indicator variables by helping identify key connections between drivers and responses.

Comparisons to Thresholds; Reference Conditions

A final example of analysis we use involves comparisons of the status or trend in a VCSS response with a defined threshold or criteria in a reference condition(s). Empirical or modeled reference conditions for most VCSS responses are typically not known and will take time to develop. Several approaches for defining reference conditions and thresholds within these distributions have been identified in the literature (e.g., Hughes et al. 1990; Daily et al. 1997; With and King 1997; Lindenmeyer et al. 1999; Rogers and Biggs 1999; Williams and Tonnessen 2000; Carpenter and Turner 2000; Stoddard et al. 2006). Methods the ROMN are exploring for VCSS response measures include: 1) measuring vital signs at sites that are minimally or least disturbed in or around a park and using these values as thresholds (Hughes 1995, Bailey et al. 2004); 2) using ambient, measured distributions of a vital sign as develop through survey designs in a park (with thresholds placed within these distributions arbitrarily at the 5th or 25th percentile, where dose-response relationships suggest break points or where maximum species richness occurs (Stoddard et al. 2006)); 3) interpretations of historical conditions; and 4) best professional judgment (i.e., applying desired future condition concepts from park General Management plans). The ROMN will develop reference conditions through cooperative research projects and adventitiously from outside research. *Clearly, reference conditions and thresholds are key parts of a mature monitoring effort as they are the primary mechanisms for interpreting data and connecting to management objectives for a given park.*

Once reasonable numeric thresholds or criterion exists for a given response, several statistical methods can be applied to compare measured VCSS response to these values. Many of the analyses discussed above allow this, especially the linear models we commonly use to estimate status and trend. For population-scale, design-based results (in the form of CDFs), non-parametric tests that incorporate design structures are available. Specifically, the Wald statistic and two Chi-squared statistics suggested by Rao and Scott (1981) can be used for testing differences between CDFs (Kincaid 2004).

VCSS Reporting

Monitoring and Assessment Reports

The ROMN views the communication of our results and program effectiveness as critical. All the elements of the VCSS protocol interact with one another in the production of scientifically sound, consistent, and comparable monitoring information required to support park management and decision making. The ROMN reports are a key step in the Service's effort to "improve park management through greater reliance on scientific knowledge" (NPS 2006a); effective communication of scientific results serves as the final link in transforming data into information.

The ROMN reporting plans are outlined in Chapter 7 of the Vital Signs Monitoring Plan (Britten et al. 2007). The plan guides the general goals and concepts for reporting and communicating all ROMN data and information including monitoring results for VCSS. In general, the ROMN is committed to regular reporting of VCSS information to internal and external audiences to maximize the usefulness of our data. We report annually on all protocols including simple summaries of annual accomplishments (e.g., annual monitoring tasks or objectives and number and types of sample events by park), data summaries (e.g., means and variance for VCSS metrics), discussion of noteworthy observations and/or issues, etc.

The Network is currently (2011) preparing a detailed Communication Plan, which will identify audiences, best formats and media, and delivery systems for all ROMN results including VCSS information. Currently, we see the primary audience for many of the ROMN products as being park staff, where the key role of the program is to provide resource managers with the information they need to make better-informed decisions and to work more effectively with other agencies and individuals for the benefit of park resources. However, certain data are also needed at the regional or national level for a variety of purposes, and as stated by the National Park Advisory Board, the findings "must be communicated to the public, for it is the broader public that will decide the fate of these resources." Our specific internal audiences include 1) ROMN park managers, 2) ROMN park resource professionals and other park staff, 3) the ROMN Technical Committee, 4) the Intermountain Region, 5) the Office of Monitoring and Evaluation and other offices and divisions of the Natural Resource Program Center, and 6) the office of the Associate Director for Natural Resource Stewardship and Science. Our external audiences include: 1) the academic community, 2) other government agencies, 3) non-profit/non-governmental organizations and 4) the general public.

We anticipate providing quality-assured ROMN data and information including (non-sensitive) data, annual reports, synthesis reports, and other products (such as project summaries) via the Internet. As part of the ROMN communication plan, we will analyze systems and strategies from other networks, NPS offices, other agencies, and academic institutions to find the most effective way to distribute information.

Details describing the contents and procedures for each report are outlined below and will be in the ROMN Communications Plan, when complete. Data collected for this protocol may be incorporated into other projects ad hoc both within the government system and with outside researchers. These may relate to vegetation and soils (e.g. a specific species of concern) or something unrelated to the objectives of the monitoring, such as locating graves at LIBI.

Annual reports

The routine preparation of data summaries and basic interpretation on a predictable and recurring basis can: 1) foster program support by establishing a client base, 2) motivate continued progress in program components, and 3) serve as the foundation for more comprehensive, interpretive reports. Therefore, the ROMN produces annual summaries of all monitoring activity and present these in the hierarchical web based format (they are also available in a summary form in a traditional report format). VCSS annual reports provide a general accounting of yearly monitoring activities, issues and problems as they arise, and a status summary of measured indicators. By using the web, VCSS reports can be easily scaled and presented by park or across the entire network. These include protocol reviews (see below) that allow active improvement of all ROMN monitoring.

Also on an annual basis, the ROMN provides non-sensitive and non-proprietary monitoring data and information to NPS Natural Resource Program Center data and information management and delivery systems. We provide this information as bundled snapshot summaries for a particular field season, meaning that one year's worth of data will be distributed along with supporting protocols, reports, and any other documentation. These annual reports and the associated databases are available government-wide and to the public.

Comprehensive synthesis and analysis reports

Detailed status and trend analyses and syntheses will be conducted on five to ten (5-10) year cycles (depending on the final realization of panel designs and sampling cycles). Comprehensive synthesis reports will also use the hierarchical web based format outlined in the ROMN Vital Signs Monitoring Plan (Britten et al. 2007). They will also be available in a traditional report format made available in hardcopy and digitally from ROMN websites (i.e., via a portable document format). The comprehensive reports will include park- and network-level assessments. Park-level assessments will emphasize detecting and interpreting trends in individual vital-sign measures, and in interactions among drivers/stressors and responses measured at similar scales and across multiple scales. The latter, for example, will consider the role of broad-scale landscape patterns on plot-based measures such as upland vegetative composition. Where evidence of resource degradation exists, mitigation measures may be recommended. Network-level assessments will compare status (e.g., number of species, areal extent of patch types per time unit) and trends of vital-sign measures among ROMN parks with qualitative summaries and quantitative (where possible) methods. Comparisons with regional networks will also be considered. The latter will depend on the availability of commensurate measures. Currently, the ROMN, Northern Colorado Plateau Network, Southern Colorado Plateau Network, Northern Great Plains Network, and the Greater Yellowstone Network are informally coordinating the development and use of several protocols that will facilitate these integrated regional analyses. These include comprehensive protocol review reports (see below) that allow active improvement of all ROMN monitoring.

Protocol review reports

The purpose of the protocol review report is to evaluate the VCSS procedures and determine where procedures fall short of stated expectations and make suggestions for protocol revisions. The VCSS protocol review will be conducted annually in between field seasons (February) and also at the completion of each monitoring "cycle" (tentatively, every 5 years). The annual reports will be posted on the ROMN intranet site. The periodic reports will also be available on the

intranet, and in hard copy form. The primary audience for this report is the ROMN Board, park superintendents, the Technical Committee, park natural resource staffs, network staff, service-wide program managers, and outside scientists.

Data and information objectivity, utility and integrity and peer review

All ROMN data and reports will be prepared and reviewed to ensure the data and products are of a high level of technical quality and accuracy and that all information disseminated or utilized by the ROMN complies with basic standards of quality that maximize the objectivity, utility, and integrity of information (NPS Director's Order #11B: Information Quality – Ensuring Objectivity, Utility, and Integrity of Information Used and Disseminated by the National Park Service (<http://www.nps.gov/policy/DOrders/11B-final.htm>)). ROMN reports will be published in the [NPS Natural Resource Report or Natural Resource Technical Report series](#) and will comply with peer review guidelines for those publications.

Administration and operations for VCSS monitoring

Introduction

The administration and operations required for the VCSS protocol fall under the auspices of the Annual Administrative Report and Work Plan (AARWP) process for the ROMN and all NPS I&M networks. Each year, the ROMN program manager assigns a VCSS protocol ROMN ecologist/crew leader lead (see Staffing Options in the ROMN Vital Signs Monitoring Plan, Britten et al. 2007) to be responsible for all aspects of the annual work planning, field monitoring, data management, and reporting cycle.

Annual Work Planning

Annual work planning includes: determining annual sampling goals and objectives, budgeting, field season planning and preparation (permits, communication and planning with park staff, hiring field crew(s), arranging and conducting training, arranging housing, procuring equipment, arranging field crew transportation, etc.), and data management preparation. The ecologist/crew leader develops annual work plans and solutions in coordination with the program manager and data manager and ensure that VCSS plans integrate with the annual AARWP and ROMN Data and Information Management Plan.

Budget

The ROMN AARWP process involves comprehensive network-wide annual planning and reporting of program, protocol, and project goals, objectives, and budgets. The annual VCSS plans and administrative reporting process is a subset of the AARWP process. The ROMN ecologist/crew leader is responsible for developing the VCSS component of the AARWP including the annual budget.

The ROMN has conducted small park pilot VCSS monitoring in GRKO and LIBI (2006-08) and FLFO (2008-2010) and post-pilot sampling in LIBI and GRKO (2009-2010). As a planning tool for VCSS monitoring and overall ROMN planning and budgeting, costs for the pilot efforts are presented in **Error! Reference source not found.** and can serve as a guideline for future cost estimates. The mean level of seasonal effort through 2010 follows in Table 4. A budget for FLFO is not displayed since sampling in 2008 was not representative of future efforts planned at FLFO and largely handled in-house without the aid of seasonally hired employees or interns.

Compliance and Permitting

Compliance

Compliance is being handled on a park-by-park scale. The ROMN utilizes the Intermountain Region Environmental Screening Process for each protocol and park.

Table 3. Average annual costs for VCSS monitoring in GRKO and LIBI utilizing student interns from 2006-2008. ROMN ecologist/crew leader salary and travel is not accounted for here but in the general ROMN personnel and travel budget.

Item	Cost
Crew members (2 interns for 12 weeks)	\$12,000
Vehicle lease	\$2,500
Gas for vehicle	\$1,000
Travel for 2 crew members	\$2,500
Total	\$18,000

The general process is for the ROMN to designate an Interdisciplinary Team (IDT) of experts familiar with the park and protocol and potentially impacted park resources. The IDT usually consists of the ecologist/crew leader, a park resource management specialist(s) with expertise in natural and cultural resources of the park, the park compliance officer (or designee), and other subject matter experts (depending on specific resources that might be impacted (e.g., a wildlife biologist if there is a Threatened or Endangered animal potentially impacted). Considerations include National Historic Preservation Act, ethnographic resources, Endangered Species Act, Wilderness Act, Clean Water Act, and wetlands.

Table 4. Mean annual survey sample events and sampling days required for VCSS sampling in ROMN parks from 2006-10.

ROMN park	Number of sample events	Number of days required	Notes
GRKO	15	13	Annual averages for GRKO VCSS pilot monitoring, 2006-10
LIBI	10	8	Annual averages for LIBI VCSS pilot monitoring, 2006-10
FLFO	12	9	2008-2010 FLFO figures

document), the Site Layout VCSS SOP, and the monitoring design (including the map of all proposed sampling locations with alternates and replacement locations). Supporting documentation and discussions may be necessary, depending upon requests of park staffs.

Permitting

The ROMN policy is that NPS research permits will be acquired for each protocol and each park. This is to ensure that ROMN monitoring activities are documented within the official NPS Research Permitting and Reporting System ([RPRS site](#)). The ROMN permitting SOP details the steps and timing for obtaining a permit and reporting annual results for VCSS monitoring activities.

In general, permit applications should be submitted in February to allow sufficient time for processing before fieldwork begins. Annual planning files (ROMN records) include former abstracts and similar content for previous applications. Applications for parks where monitoring occurred in previous years should be registered as “continuing research projects” to insure continuous tracking information.

The RPRS requires annual reports of monitoring activities. The format and schedule for ROMN RPRS reporting is included in the *SOP Admin Permitting*.

Field monitoring

The ecologist/crew leader serves as the field monitoring crew leader during the field season. This includes supervising crews to accomplish annual sampling and other project goals. The ecologist/crew leader will consider the safety of field crews as paramount and will never compromise safety to meet project goals. He/she will ensure that crew members have appropriate safety training and equipment. Details of field crew safety are included in *SOP Admin Safety Preparation and Training* and are applicable to all ROMN field protocols and projects.

The ecologist/crew leader also serves as the liaison with park staff and others (e.g., other cooperators) ensuring that they are aware of field monitoring plans and operations and that these are carried out in accordance with park policies and preferences.

Field crews

The ROMN monitoring program is evolving and the Network continues to consider the costs:benefits of hiring options for field crews. Options include using volunteers, Student Conservation Association (SCA) interns, other interns, students hired through a university cooperative agreement, employees hired under the Student Temporary Employment Program (STEP) or Student Career Employment Program (SCEP) authorities, employees hired by the ROMN under seasonal or term employment hiring authorities, and employees hired and managed by a ROMN park (and based at that park).

In previous years, the ROMN has utilized volunteers, SCA interns, “other” interns (Tehabi Program interns from Utah State University), STEP employees, and ROMN park employees. These are currently the preferred crew member pool of options, which may narrow over time as we gain more experience with the different hiring structures. We may also utilize “mixed crews” (e.g., a volunteer and a STEP employee). The procedures for hiring and managing crew members under these options are documented in the Network’s *SOP Admin Seasonal Hiring*.

Competent, well-qualified, and detail-oriented observers are essential for the collection of credible, high-quality vegetation data. Crew members must be skilled in accurately identifying plant species. They should also have good organizational skills, and the ability to work methodically and consistently.

Crew members must also be physically fit, able to carry a 40 lb. pack and have tolerance for working outdoors in a range of conditions from hot and humid conditions found at LIBI in July to cool wet and remote conditions found in GLAC (once large park protocol is being implemented). They must also be able to travel to and work safely under sometimes difficult and/or remote field conditions.

Crew members will at times be working without direct ecologist/crew leader supervision. Therefore, individuals need to be mature enough to work and travel safely and independently.

Training is essential for developing skilled field observers. The ecologist/crew leader is responsible for ensuring that field crews have adequate training for their work. This includes training in VCSS field and data management methods and safety (usually in coordination with the park).

During the first week of the field season, all crew members read and become familiar with the monitoring protocol. Crew members also acquaint themselves with the flora of individual parks. Photographs of invasives and common species and keys for each park’s species are provided. *SOP Admin Training* contains more detail.

Revising the Protocol

Protocol evaluation

Methodological details of the ROMN VCSS protocol are re-evaluated after 1-2 seasons of data collection. An official programmatic review of the VCSS vegetation approach to vital signs, including the objectives, designs, methods, and results as well as the ability of the Network to sustain these protocols, is conducted after at least two parks complete full panel cycles (5-6 years). Subsequent reviews should be conducted at least every 10 years, and more frequently as desired by the ROMN staff, WASO I&M, the ROMN board of directors and the ROMN technical committee.

Change history

Previous version	Date	Author	Change description	Reason

Literature cited

- Akaike, H. 1973. Information theory and an extension of the maximum likelihood principle. Pages 267–281 in B. Petrov and F. Czakil, eds., *Proceedings of the second international symposium on information theory*. Budapest: Akademiai Kiado.
- Bailey, R.C., R.H. Norris, and T.B. Reynoldson. 2004. *Bioassessment of freshwater ecosystems using the reference condition approach*. Kluwer Academic Publishers, New York, New York, USA.
- Barbour, M.G., J.H. Burk, and W.D. Pitts. 1987. *Terrestrial plant ecology*. The Benjamin/Cummings Publishing Company, Inc. Menlo Park, California, USA. 634 pp.
- Barnard, G.A. 1959. Control charts and stochastic processes. *Journal of the Royal Statistical Society*, B21:239-271.
- Baron, J. 2006. Hindcasting nitrogen deposition to determine an ecological critical load. *Ecological Applications*: 16(2):433-439.
- Britten, M., E.W. Schweiger, B. Frakes, D. Manier, and D. Pillmore. 2007. *Rocky Mountain Network vital signs monitoring plan*. Natural Resource Report NPS/ROMN/ NRR-2007/010. National Park Service, Fort Collins, Colorado, USA.
- Buckland, S.T., K.P. Burnham, and N.H. Augustin. 1997. Model selection: An integral part of inference. *Biometrics* 53(2): 603-618.
- Burke, J., E.W. Schweiger, and M. Britten. *Landscape dynamics protocol*. Rocky Mountain Inventory and Monitoring Network, National Park Service. Fort Collins, CO.
- Burnham, K.P., and D.R. Anderson. 2002. *Model selection and multimodel inference: a practical information-theoretic approach*. Springer-Verlag, New York, New York, USA.
- Carpenter, S.R., and M. Turner. 2000. Opening the black boxes: ecosystem science and economic valuation. *Ecosystems* 3:1–3.
- Clarke, R.T., J.F. Wright, and M.T. Furse. 2003. RIVPACS models for predicting the expected macroinvertebrate fauna and assessing the ecological quality of rivers. *Ecological Modelling* 160:219–233.
- Collins, J.N., E.D. Stein, M. Sutula, R. Clark, A.E. Fetscher, L. Grenier, C. Grosso, and A. Wiskind. 2008. *California rapid assessment method (CRAM) for wetlands*. Version 5.0.2. 151 pp.
- Cordy, C. 1993. An extension of the Horvitz-Thompson theorem to point sampling from a continuous universe. *Probab. Stat. Let.* 18:353–362.

- D'Antonio C.M., T.L. Dudley, and M. Mack. 1999. Disturbance and biological invasions: direct effects and feedbacks. Pages 143-452 in Walker L, ed. *Ecosystems of disturbed ground*. Elsevier, Amsterdam.
- Daily, G.C., P.R. Ehrlich, L.H. Goulder, J. Lubchenco, P.A. Matson, H.A. Mooney, S.H. Schneider, G.M. Woodwell, and D. Tilman. 1997. Ecosystem services: benefits supplied to human societies by natural ecosystems. *Issues Ecol.* 2:1–16.
- DeBano, L.F., D.G. Neary, and P.F. Elliott. 1998. *Fire's effects on ecosystems*. John Wiley & Sons, Inc., New York, New York, USA. 333 pp.
- De Leo, G.A., and S. Levin. 1997. The multifaceted aspects of ecosystem integrity. *Conservation Ecology* [online]1(1):3. Available from the Internet. URL: <http://www.consecol.org/vol1/iss1/art3/>.
- Diaz-Ramos, S., D.L. Stevens, Jr., and A.R. Olsen. 1996. *EMAP statistical methods manual*. Corvallis, Ore.: U.S. Environmental Protection Agency, Office of Research and Development, NHEERL-Western Ecology Division. Report nr EPA/620/R-96/002.
- Draper, N.R. and H. Smith. 1967. *Applied regression analysis*. John Wiley and Sons, Inc., New York, New York, USA.
- Ehrenfeld, J.G., P. Kourtev, and W. Huang. 2001. Changes in soil functions following invasions of exotic understory plants in deciduous forests. *Ecological Applications* 11(5): 1287-1300.
- Elliott, E.T., J.W. Heil, E.F. Kelly, and H.C. Monger. 1999. Soil structural and other physical properties in G.P. Robertson (Ed). *Standard soil methods for long-term ecological research*. Oxford University Press. Cary, North Carolina, USA. pp. 74-88.
- Elzinga, C.L., D.W. Salzer, and J.W. Willoughby. 1998. *Measuring & monitoring plant populations*. BLM Technical Reference 1730-1. Bureau of Land Management, Denver, Colorado, USA. 492pp.
- Elzinga, C.L., D.W. Salzer, J.W. Willoughby, and J.P. Gibbs. 2001. *Monitoring plant and animal populations*. Blackwell Science, Inc. Malden, Massachusetts, USA. 360 pp.
- Fancy, S., J. Gross, and S. Carter. 2009. Monitoring the condition of natural resources in US national parks. *Environmental Monitoring and Assessment* 151:161-174.
- Fleming, R.L. and K.A. Baldwin. 2008. Effects of harvest intensity and aspect on a boreal transition tolerant hardwood forest. I. Initial postharvest understory composition. *Canadian Journal of Forest Research* 38(4): 685-697.
- Garman, S., B. Schweiger, C. Lauver, R. Bennetts, D. Manier, P. Ward, T. Mau-Crimmins. 2009. *Complex Survey Design Simulator (CSDsim) VERSION 1.01 – 1/2/09*.

- Hansen, M.H., W.G. Madow, and B.J. Tepping. 1983. An evaluation of model dependent and probability sampling inferences in sample surveys. *Journal of American Statistical Association* 78(384): 776–793.
- Hawkins, C.P., R.H. Norris, J.N. Hogue, and J.W. Feminella. 2000. Development and evaluation of predictive models for measuring the biological integrity of streams. *Ecological Applications* 10:1456–1477.
- Helsel, D.R., and R.M. Hirsch. 2002. Statistical methods in water resources: Techniques of water-resources investigations of the United States. Geological Survey Book 4: Hydrologic Analysis and Interpretation Chapter A3.
- Herrick, J.E., J.R. Brown, A. Tugel, P.L. Shaver and K.M. Havstad. 2002. Application of soil quality to monitoring and management: paradigms from rangeland ecology. *Agronomy Journal* 94: 3-11
- Herrick, J.E., J.W. Van Zee, K.M. Havstad, L.M. Burkett and W.G. Whitford. 2005. Monitoring manual for grassland, shrubland and savanna ecosystems. USDA-ARS Jornada Experimental Range, Las Cruces, New Mexico and University of Arizona Press, Tucson, Arizona. 2 vol., 236pp. available online at <http://usda-ars.nmsu.edu/>.
- Hirsch, R.M. and J.R. Slack. 1984. A nonparametric trend test for seasonal data with serial dependence. *Water Resour. Res.* 20:727–732.
- Holling, C.S. 1992. Cross-scale morphology, geometry, and dynamics of ecosystems. *Ecological Monographs* 62:44, 447-502.
- Horvitz, D.G. and D.J. Thompson. 1952. A generalization of sampling without replacement from a finite universe. *J. Am. Stat. Assoc.* 47:663–685.
- Hughes, R.M. 1995. Defining acceptable biological status by comparing with reference conditions. In: W. Davis and T. Simon, Editors, *Biological Assessment and Criteria: Tools for Water Resource Planning and Decision Making for Rivers and Streams*, Lewis Publishers, Boca Raton, FL, USA, pp. 31–47.
- Hughes, R.M., T.R. Whittier, C.M. Rohm, and D.P. Larsen. 1990. A regional framework for establishing recovery criteria. *Environmental Management* 14:673–684.
- John Milner Associates, Inc. July 2004. Grant-Kohrs Ranch National Historic Site, Cultural Landscape Report Part One: Landscape History, Existing Conditions, and Analysis and Evaluation. Grant-Kohrs Ranch NHS, Deer Lodge, Montana. Prepared under contract for the NPS. 400 pp.
- Jones, W.M. 2004. Using vegetation to assess wetland condition: A multimetric approach for temporarily and seasonally flooded depressional wetlands and herbaceous-dominated intermittent and ephemeral riverine wetlands in the northwestern glaciated plains ecoregion, Montana. Report to the Montana Department of Environmental Quality and the U.S. Environmental Protection Agency. Montana Natural Heritage Program, Helena, Montana.

- Karlen, D.L., C.A. Ditzler, and S.S. Andrews. 2003. Soil Quality: why and how? *Geoderma* 114:145-156.
- Karr, J.R. 1991. Biological integrity: A long-neglected aspect of water resource management. *Ecological Applications* 1:66–84.
- Karr, J.R. 1986. Biological Monitoring and Assessment in the Solution of Environmental Problems. In: W. D. Severinghaus and T. D. James, *Proceedings of the Conference on Applications in the Guild Concept to Environmental Management*. Champaign, IL.
- Kaufmann, P.R., A.T. Herlihy, J.W. Elwood, M.E. Mitch, W.S. Overton, M.J. Sale, J.J. Messer, K.A. Cougan, D.V. Peck, K.H. Reckhow, A.J. Kinney, S.J. Christie, D.D. Brown, C.A. Hagley, and H.I. Jager. 1988. Chemical Characteristics of Streams in the Mid-Atlantic and Southeastern United States. Vol. 1, Population Descriptions and Physiochemical Relationships. EPA/600/3-88/021a. Washington, DC: Environmental Protection Agency.
- Kaufmann P.R., Levine P., Robison E.G., Seeliger C., Peck D.V. 1999. Surface waters: Quantifying physical habitat in wadeable streams. Washington (DC): U.S. Environmental Protection Agency. Report nr EPA/620/R-99/003. 158 p.
- Kincaid, T.M., D.P. Larsen, and N.S. Urquhart. 2004. The structure of variation and its influence on the estimation of status: Indicators of condition of lakes in the Northeast, U. S. A. *Environmental Monitoring and Assessment* 98:(1-3):1-21.
- Landers D.H., W.S Overton, R.A. Linthurst, and D.F. Brakke. 1988. Eastern Lake Survey: Regional estimates of lake chemistry. *Environmental Science & Technology* 22(2):128-35.
- Larsen, D.P., T.M. Kincaid, S.E. Jacobs, and N.S. Urquhart. 2001. Designs for evaluating local and regional scale trends. *BioScience*:51(12):1069-1078.
- Larsen, D.P., N.S. Urquhart, and D.L. Kugler. 1995. Regional scale trend monitoring of indicators of trophic condition of lakes. *Water Resources Bulletin*:31(1):117-140.
- Lindenmayer, D.B., R.B. Cunningham, M.L. Pope, and C.F. Donnelly. 1999. The response of arboreal marsupials to landscape context: a large-scale fragmentation study. *Ecological Applications* 9:594–611.
- Lohr, S.L. 1999. *Sampling: design and analysis*. Duxbury Press, N.Y.
- Mack, M.C. and C.M. D'Antonio. 1998. Impacts of biological invasions on disturbance regimes. *Trends in Ecology and Evolution* 13:195-198.
- McDonald, T.L. 2003. Review of environmental monitoring methods: survey designs. *Environmental Monitoring and Assessment* 85:277-292.

- Messer, J.J., C.W. Ariss, J.R. Baker, S.K. Drouse, K.N. Eshleman, P.R. Kaufmann, R.A. Linthurst, J.M. Omernik, W.S. Overton, M.J. Sale, R.D. Schonbrod, S.M. Stambaugh, and J.R. Tuschall, Jr. 1986. National Surface Water Survey: National Stream Survey, Phase I – Pilot Survey, EPA/600/4-86/026, US Environmental Protection Agency, Washington, DC, 179 pp.
- Messer, J.J., R.A. Linthurst, and W.S. Overton. 1991. An EPA program for monitoring ecological status and trends. *Environ. Monit. Assess.* 17:67–78.
- National Park Service. 2006. Vital Signs monitoring - Guidance for designing an integrated monitoring program. <http://science.nature.nps.gov/im/monitor/GoalsObjectives.cfm>. Retrieved January 8, 2009.
- National Park Service. 2006a. Natural resource monitoring - program administration and organizational framework. < <http://science.nature.nps.gov/im/monitor/ProgramGoals.cfm>>. Retrieved August 23, 2006.
- National Park Service. 2007. Data and Information Management Plan, Version 1.0, Rocky Mountain Network-National Park Service, [<http://www1.nrintra.nps.gov/im/units/romn/>], Fort Collins, Colorado.
- Natural Resources Conservation Service (NRCS). SSURGO data found at the Soil Data Mart. <http://soildatamart.nrcs.usda.gov/State.aspx>.
- Neusser, S.M., F.J. Breidt, and W.A. Fuller. 1998. Design and estimation for investigating the dynamics of natural resources. *Ecological Applications* 8:234-245.
- Olsen, A.R., J. Sedransk, D. Edwards, C.A. Gotway, W. Liggett, S. Rathbun, K.H. Reckhow, and L.J. Young. 1999. Statistical issues for monitoring ecological and natural resources in the United States. *Environmental Monitoring and Assessment* 54: 1–45.
- Page, E.S. 1996. Cumulative sum control charts. *Technometrics*. 3:1–g.
- Pieopho, H. and J. Oguto. 2002. A Simple Mixed Model for Trend Analysis in Wildlife Populations. *Journal of Agricultural, Biological, and Environmental Statistics*, 7:350 – 360.
- Rao, J.N.K., and A.J. Scott. 1981. The analysis of categorical data from complex sample surveys: Chi-squared tests for goodness of fit and independence in two-way tables. *Journal of the American Statistical Association* 76:221–230.
- Robertson, G.P., P. Sollins, B.G. Ellis, K. Lajtha. 1999. Exchangeable ions, pH, and cation exchange capacity in G.P. Robertson (Ed). *Standard Soil Methods for Long-Term Ecological Research*. Oxford University Press. Cary, NC, USA. p 106-114.
- Rocchio, J. 2007. Floristic quality assessment indices for Colorado plant communities. Unpublished report prepared for the Colorado Department of Natural Resources and US EPA Region 8. Colorado Natural Heritage Program, Colorado State University, Fort Collins, Colorado.

- Rogers, K., and H. Biggs. 1999. Integrating indicators, endpoints and value systems in strategic management of the rivers of the Kruger National Park. *Freshwater Biology* 41:439–451.
- Schreuder, H.T., R. Ernst, and H. Ramirez-Maldonado. 2004. Statistical techniques for sampling and monitoring natural resources. USDA Forest Service, Rocky Mountain Research Station, RMRS-GTR-126.
- Schweiger, E. W., E. Gage., K. Driver, D. Shorrock, I. Ashton, J. Burke, L. O’Gan, D. Pillmore, M. Britten. In Review. Monitoring Wetland Ecological Integrity in the Rocky Mountain Network; Main Narrative Version 2.2. Natural Resource Report NPS/ROMN/NRR—20XX/XXX. National Park Service, Fort Collins, Colorado.
- Schweiger, E. W., D. Shorrock, I. Ashton, J. Burke, L. O’Gan, D. Pillmore, M. Britten in prep. Stream Ecological Integrity; Standard Operating Procedures for Wadeable and Non-wadeable Survey, Gradient and Base Flow Sentinel Sites. Version 0.1. National Park Service, Rocky Mountain Inventory and Monitoring Network, Fort Collins, CO, 265pp., plus appendices.
- Society for Range Management Task Group on Unity in Concepts and Terminology. 1995. New Concepts for Assessment of Rangeland Condition. *Journal of Rangeland Management* 48(3):271–282.
- Sollins, P., C. Glassman, E.A. Paul, C. Swanston, K. Lajtha, J.W. Heil, and E.T. Elliott. 1999. Soil carbon and nitrogen: pools and fractions in G.P. Robertson (Ed). *Standard Soil Methods for Long-Term Ecological Research*. Oxford University Press. Cary, NC, USA. p 89-105.
- Starcevich, L.A.H. 2007. Lake chemistry power analysis for the Sierra Nevada Network of the National Park Service--DRAFT. Corvallis, OR.
- Stehman, S.V., and W.S. Overton. 1994. Environmental sampling and monitoring. Pages 263–306 in G. P. Patil and C. R. Rao, eds., *Handbook of statistics*. New York: Elsevier Science B.V.
- Stevens, Jr., D.L.. 1997. Variable density grid-based sampling designs for continuous spatial populations. *Environmetrics* 8:167-195.
- Stevens Jr., D.L., and A.R. Olsen. 2003. Variance Estimation for Spatially Balanced Samples of Environmental Resources. *Environmetrics* 14:593–610.
- Stevens Jr., D.L., and A.R. Olsen. 2004. Spatially balanced sampling of natural resources. *J. Am. Stat. Assoc.* 99:262-278.
- Stevens Jr., D.L., and N.S. Urquhart. 2000. Response designs and support regions in sampling continuous domains. *Environmetrics* 11:13–41.
- Stoddard J.L., Urquhart N.S., Newell A.D., Kugler D.L. 1996. The Temporally Integrated Monitoring of Ecosystems (TIME) project design, Detection of regional acidification trends. *Water Resources Research* 32: 2529-2538.

- Stoddard J.L., Driscoll C.T., Kellogg J.H., Kahl J.S. 1998. Can site-specific trends be extrapolated to a region? An acidification example for the northeast. *Ecological Applications* 8(2):288-99.
- Stoddard, J.L., D.P. Larsen, C.P. Hawkins, R.K. Johnson, and R.H. Norris. 2006. Setting expectations for the ecological condition of streams: The concept of reference condition. *Ecological Applications* 16(4):1267–1276.
- Theobald, D.M., D.L. Stevens, Jr., D. White, N.S. Urquhart, and A.R. Olsen. 2007. Using GIS to generate spatially-balanced random survey designs for natural resource applications. *Environmental Management*:40(1):134-146.
- Urquhart, N.S. and T.M. Kincaid. 1999. Designs for detecting trend from repeated surveys of ecological resources. *Journal of Agricultural, Biological, and Environmental Statistics*: 4(4):404-414.
- Urquhart, N.S., W.S. Overton, and D.S. Birkes, 1993. Comparing Sampling Designs for Monitoring Ecological Status and Trends: Impact of Temporal Patterns. In: *Statistics in the Environment*, V Barnett (Editor). John Wiley & Sons, Ltd., Sussex, England, pp . 71-88.
- Urquhart, N.S., S.G. Paulsen, and D.P. Larsen. 1998. Monitoring for policy-relevant regional trends over time. *Ecological Applications* 8:2, 246-257.
- U.S. Department of Agriculture, Forest Service. 2005. Forest inventory and analysis national core field guide, volume 1: field data collection procedures for phase 2 plots, version 3.0. U.S. Department of Agriculture, Forest Service, Washington Office. Internal report. On file with: U.S. Department of Agriculture, Forest Service, Forest Inventory and Analysis, Rosslyn Plaza, 1620 North Kent Street, Arlington, VA 22209.
- Williams, M.W., and K.A. Tonnessen. 2000. Critical loads for inorganic nitrogen deposition in the Colorado Front Range, USA. *Ecological Applications* 10:1648–1665.
- With, K.A., and A.W. King. 1997. The use and misuse of neutral landscape models in ecology. *Oikos* 97:219–229.

Appendix 1. Previous Park Monitoring and Mapping Efforts

Florissant Fossil Beds National Monument - FLFO

- Two (2) FIA plots (1 sampled in 2003) occur within FLFO boundaries; one additional plot is located within a narrow (~3000m) buffer and several more are located in the surrounding Pike National Forest (~11 within a 7500m buffer).
- Spackman (Colorado Natural Heritage Program, Colorado State University) conducted a vascular plant inventory of the park between 2001-2005, but permanent plots and monitoring were not part of this effort.
- Fire management crews (Nate Williamson et al. based at ROMO) installed and assessed plots in FLFO.
- The NPS Vegetation Mapping Program completed the VegMap project in 2004; the project database contains 716 marked plots from that effort.
- Recent records (research permitting and report system) do not show other relevant projects. The Ecological Society of America “VegBank” (a vegetation plot database) has no records for FLFO.

Grant-Kohrs Ranch National Historic Site - GRKO

- Vascular plant survey completed in 2000 (Rice); these data are preserved and accessible in a geodatabase.
- Hansen et al. (1995, 1998) conducted extensive surveys and classification of riparian areas and associated wetlands along the Clark Fork River within the Ranch (and throughout Montana); sites and descriptions may benefit future wetland monitoring (however, activities associated with the Superfund clean-up partially dictates future riparian monitoring at GRKO).
- The VegMap project (NPS Vegetation Mapping Program) was completed in 2007.
- National Inventory programs EMAP/REMAP address the GRKO landscape at a broad scale, but this scale is not directly applicable to ROMN monitoring efforts. The Record of Decision for the Clark Fork River Superfund Site includes monitoring of the vegetation in association with the clean-up efforts; ROMN will maintain a relationship with US EPA Region 8, and the Reclamation Research Unit to acquire these data as they are available and support coordination of techniques. The sampling design for GRKO includes some sites within the Clark Fork floodplain and wet meadows (allowing for overlap between upland monitoring and future wetland monitoring designs).

Little Bighorn Battlefield National Monument - LIBI

- National Inventory programs EMAP/REMAP address the LIBI landscape at a broad scale, but this scale is not directly applicable to ROMN monitoring efforts.
- Hansen et al. (1995) conducted extensive surveys and classification of riparian areas and associated wetlands along the Little Bighorn River (and throughout Montana); sites and descriptions may benefit future wetland monitoring.

- The VegMap project (NPS Vegetation Mapping Program) was completed in 2007; survey locations from that effort are recorded in the project database.
- The park vascular plant survey is complete (Bock 2007); these data are available through NPSSpecies; survey locations are unknown.

Appendix 2. General Process for Field Sampling

1. The general procedure for field sampling vegetation and soils is based on a simple set of processes as illustrated in a flowchart in Figure 1.
2. Check-in with park unit staff. Confirm communication procedures (radio/phone and check-out).
3. Before leaving the vehicle (or other location where equipment is stored), check for possession of all personal, safety, and professional equipment; be sure batteries are charged; be sure sufficient field forms and back-ups are packed.
4. Consult the site list for the set of sites you will visit on this trip. Consult the unit map with the sites to determine an efficient travel pattern for the day. You cannot skip sites off the master list (unless officially rejected due to a non-representative placement, logistical or safety concerns), but you do not have to do them in order (i.e., determine the 3-4 sites you might visit today and then determine the order you will visit them based on efficient, safe, and legal travel).
5. Turn-on the GPS and select the first site on your list as a navigation point (optionally, you can program all sites for the day, or longer, into the GPS as a set of navigation points.) Following safe and approved travel routes, maps, photos, and your compass (as back-up) use the GPS to navigate to the site (for more information on using the GPS, consult *SOP VCSS Navigating to Sites*).
6. As you approach the site (the location of the center monument), be careful to minimize trampling and damage to any natural or cultural resources. Observe the landscape (including land use), any natural or anthropogenic disturbance, geology, soils, and vegetation around you to support recognition of the context of the site, assist in relocation of existing monuments, and recognize hazards and obstructions within the 0.5 hectare sample area. Upon establishing the center point, determine (roughly the directions of the 3 transects (and associated plots) and especially avoid unnecessary trampling in these areas (e.g., put your packs and gear down elsewhere, away from sample areas, to avoid associated impacts).
7. For established sites (with an existing monument), use the file photographs and the metal detector to locate the center monument.
8. Collect the gear required to establish the three 36.6m long transects (2 compasses, 3-50m tapes and 4 chaining pins), and carefully (to avoid trampling) and accurately (using the compasses to stretch/thread a straight line) establish the north transect (#1, 0° true azimuth). Confirm that the Woody Plot (containing the 3 plots) can be established around the north monument; if acceptable, insert the pin, and fasten the tape at 36.6m. Use the same procedure to establish the southeast (#2, 120° true azimuth) and southwest (#3, 240° true azimuth) transects.

9. Collect a site overview photo (see *SOP VCSS Photo Documentation* and consult the Site Description form for previous location; otherwise, choose a location useful for paired comparisons of the landscape and future plot relocation). Record any new overview site locations by taking a GPS waypoint. Collect a photo of the central monument (from 2m south looking down at it).
10. One/ two persons collect the north transect photo; then, two people begin sampling the north transect.
11. If the crew is >2 people, then while transect sampling begins, another member collects photos of transect #2 and #3 (*SOP VCSS Photo Documentation*), and tasks should be assigned and conducted simultaneously for efficiency. If there are only 2 in the crew, then collect each photo then begin sampling the line. A crew of 2 can choose to do all transects then all plots, alternate transects and plot; they may want to also complete soil core and soil structure sampling before moving onto the next transect, or alternately, do cores and soil stability at the end; this order can be tested for efficiency. If there are 3 in the crew, a pair always conducts line and plot measurements, the third person should focus on photos then soil testing for each transect. If there are 4 in the crew, after transects are photographed, this pair moves to Plot 1A (the end of transect #1) and begins plot photographs and sampling, while the other pair conducts the line sampling, and begins the soil sampling. Plot estimates and soil measurements (cores and stability) will likely take the most time, so balancing assignments and sharing tasks is necessary to determine the most efficient way to complete the design. (RECORD notes on trials, difficulties, and discoveries in a field book for reporting at the end of the season.) (See Figure 1 in *SOP VCSS Site Layout* for conceptual diagram.)
12. Confirm that all data have been collected and recorded (if not, go back to that step and collect the pertinent information). Confirm that you have collected all equipment, forms, personal gear, etc. In prototype years, collect an additional location waypoint at the center monument (for later relocation); if there is a permanent marker in the field, this step is not necessary.
13. If you are doing another site, select the site from the list; select that site as the navigation target in the GPS; consult your map and compass, and navigate to the next point. If you are done for the day, return to park offices and check-out with park unit staff; upload data from the PDA, transfer data from tablet computer to a laptop and back-up the data (jump drive or hard-drive), or make copies/ enter data from paper forms if you are doing this in a park office (otherwise you can do this “back at camp”).

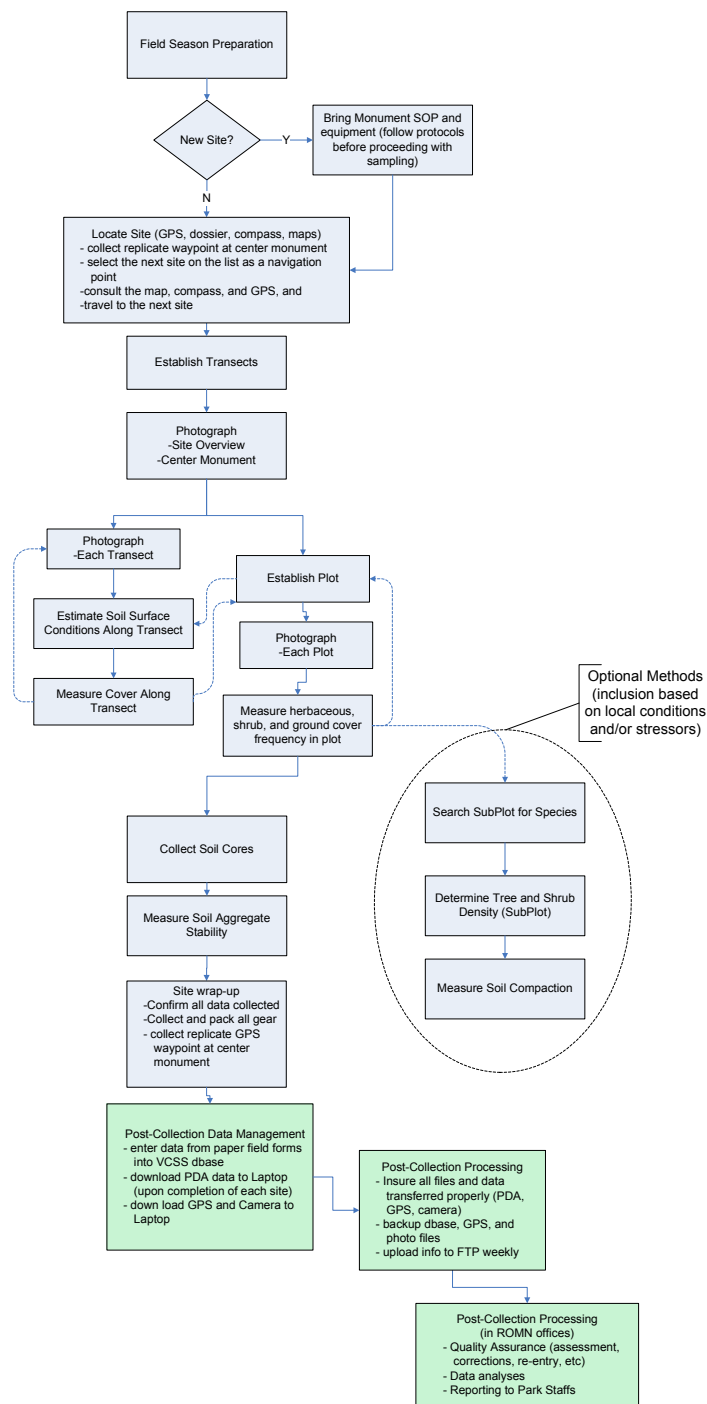


Figure 1. Workflow for Shrub-grassland sampling; field methods (blue) and basic data management procedures (green).

Appendix 3. Power Analysis and Design Comparison Details

Introduction

The details provided here augment the cursory discussion of these topics in the VCSS protocol for monitoring of vegetation and soil in the Rocky Mountain Network (ROMN) of the National Park Service (NPS). To assist in setting realistic long-term monitoring goals, we conducted a power analysis to determine the power to detect trend and standard error around status of select vegetation and soil response measures over time. Power analyses are helpful in determining sample sizes that will provide information to detect changes in the population of interest over time at the desired level of change. The VCSS target and sample populations, sample frame and membership design are summarized in the Sample Design section of the main narrative.

Power Analysis and Design Comparisons

Revisit design (sample size)

The revisit design defines the temporal sampling pattern for the selected sites (McDonald 2003) including the details of sample size for each sample interval (e.g., year). ROMN VCSS small park survey designs are split into panels that are visited on an alternating schedule (e.g., once every 4 years and 2 consecutive years every 4 years). Panels are a group of sample units that are always sampled together, and the pattern of visits to panels across time is the revisit (or panel) design (i.e., the pattern of visits within and across years to sites in panels, number of sampling occasions when a panel is sampled, and the interval between samples of panels). Panel designs provide balanced replication of sites over time so that spatial and temporal effects may be modeled and both status and trend may be accurately estimated.

Draft ROMN VCSS revisit designs are based on pilot research in each park and power analysis of the ability of various alternative revisit designs to detect trend and minimize standard error around status. The following sections provide an overview of this process for Grant-Kohrs Ranch National Historic Site (GRKO) where we currently have sufficient data.

Small park pilot studies

Prior to 2006, existing data representing vegetation and soil in GRKO, Florissant Fossil Beds National Monument (FLFO) and Little Bighorn Battlefield National Monument (LIBI) were insufficient to parameterize models for power for status and trend estimation. Therefore, we implemented a pilot study in 2006 at GRKO focused on collecting data on vegetation and soil response measures following the standardized techniques detailed in this protocol. Similar efforts were successively started in LIBI and FLFO. In addition to the power work detailed below, the pilots also provide key information on accuracy and precision of the response design, indicator selection, and operational constraints.

Ten base sites from the GRTS design at GRKO were sampled annually over three years with a subset of sites revisited within each season. An additional 11 GRTS sites were sampled to supplement the core group of ten. Because all sites were from the GRTS design they are representative of the target population at GRKO. Simulations by the Northern Colorado Plateau Network (Steve Garman, now USGS-GRD) suggest ten sites revisited within and across years is a useful sample in upland systems to quantify sources of variation in vegetation data that control the power of a survey design to detect trend and the standard error around a status estimate.

Future work

Currently we have three years of pilot data from GRKO – a useful, but short time period for reliable parameterization of models. Methods under development will expand our pilot data using simulation (Garman in prep) to synthetically generate a larger dataset and Monte Carlo style bootstrapping to generate population parameter estimates for power assessment (granted this introduces assumptions about the reliability of the simulation). As we finish field efforts for pilots in LIBI and FLFO, we will develop these same models and simulations and present all of this material in future VCSS reports. For GRKO, we will begin implementation in 2009 of the design presented below. Our expectation is that sample size and the revisit design in all three small parks will be similar to this design even after revised power estimates from the simulation.

Large park pilot studies

Details of survey designs and VCSS pilots in large parks remain largely unresolved and are not addressed here. Such studies in GLAC, GRSA and ROMO will focus on many issues; some of these are related to survey designs while others are related to objectives, logistics and finances.

Power analysis

An overview of the five key steps in our power analysis is presented here. Power analysis provides a ‘reality check’ on project goals and objectives through an *a priori* understanding of the ability and confidence with which one can estimate the condition of an extensive and variable resource (status) and detect trends in that resource over time. Statistical power is the ability to detect an effect given that the effect actually exists (the probability of *not* making a Type-II error of failing to detect a real trend). The ROMN uses power analysis primarily to understand the implications of an ‘affordable’ sample size and to contrast the allocation of this sample size into alternative revisit structures that optimize tradeoffs among trend and status estimation as well as overall operational reality.

We define trend as a non-cyclic, directional change in a response measure that may, or may not, follow a pattern (Urquhart et al. 1998). See Britten et al. (2007) for how we distinguish statistical, biological, and management relevant trends. Some response measures may have a temporal pattern that is not a trend, and vice versa. For example, an ascending line has trend but no pattern, while a sine curve has pattern but no trend. Trend may be site-specific (often called individual) or apply to an entire target population as an average (or net) trend. VCSS power analysis is focused on net change in the target population or the slope of a response as measured at multiple survey sample sites in a park across time. Finally, if trend is present, we expect a linear trend (Urquhart and Kincaid 1999); the methods described below use a conservative approach based on this assumption, by seeking linear trend without asserting that a detected trend is linear (i.e., the underlying linear component will be different than zero when a trend is present).

We define status as the mean response of a measure over all years without a trend (i.e., when the slope of the trend line is zero; Urquhart et al. 1998). If the trend slope is not zero, then status is the response mean projected along the trend line (curve) to a defined year or sampling interval (Urquhart et al. 1993). Power for status is difficult to estimate in lieu of specific thresholds in a response measure that allow a hypothesis test; these thresholds are not currently defined for any VCSS response measure. As a viable alternative, we develop estimates of the standard error

(confidence interval) around annual means (status). This is not a power test, but it allows a relatively quantitative evaluation of the precision of proposed designs for estimating status.

Unfortunately, no specific methods for estimating trend from data collected under a GRTS unequal probability sampling design with panels currently exist. However, GRTS designs are conservative relative to a simple random sample (Stevens and Olsen 2003, 2004) and so traditional analysis assuming a simple random sample with no panels is appropriate (Starcevich 2007). Moreover, to accurately estimate power to detect trend, analysis methods and tests of trend used in the power analysis should reflect future data analysis approaches as closely as possible. The linear modeling approach described below is often used for detecting trend from panel designs and will be used by ROMN for most VCSS trend (and some status) tests.

Step 1: Developing linear models and variance components

We first develop linear models following Urquhart et al. (1993, 1998), Larsen et al. (1995, 2001), and Urquhart and Kincaid (1999) using four representative response measures collected over 3 years during the GRKO pilot (Table 1). Preliminary data analysis indicated that outcomes better meet model assumptions if a natural logarithmic transformation is applied. The models are an expansion of the usual linear regression equation (Draper and Smith 1967) to allow more detailed interpretation of the factors (via their variance components) influencing the variance in the slope. Variability around the slope affects the detection of net trend by its influence on the precision with which trend may be estimated (Larsen et al. 2001). Equation 1 illustrates the relationship between variance in the slope and the multiple sources of variance as estimated via variance components developed from mean squares and formulae (Larsen et al. 1995).

$$\text{Var(slope)} = \frac{\frac{\sigma^2_{\text{site}}}{N_{\text{site}}} + \sigma^2_{\text{year}} + \frac{\sigma^2_{\text{year*site}} + \frac{\sigma^2_{\text{residual}}}{N_{\text{revisit}}}}{N_{\text{site}}}}{\sum (Y_t - \bar{Y})^2} \quad (1)$$

The relevant variance components in the model include site, year, the interaction of site and year, and a residual or error term that represents all other “unexplained” variance in the data (Table 1). The relationships between these variance components (Equation 1) form the basis for the evaluation of how various design choices can impact the variance around the slope. All analysis was done in SAS 9.2 using Proc Mixed and Type III models following recommendations from S. Urquhart.

The models treat both year and site covariates as random effects (see Urquhart et al. 1993, 1998). Given the small size of GRKO, we do not include additional covariates such as soil type or landscape position that might help reduce uncertainty in the models (Pieopho and Oguto 2002; Stoddard et al. 1996; Starcevich 2007). The GRKO data set is unbalanced across within and among year revisits. An unequal sample size does not change the models but does complicate the calculations (Larsen et al. 2001). VCSS response measures were typically not normally distributed, but these models are robust to most departures from normality (Urquhart et al. 1993).

Our current models do not incorporate design properties (sample weights) but Kincaid et al. (2004) details methods for doing so and we will include this in future revisions to these models. We do not anticipate large changes when this is done as inclusion probabilities are not likely correlated with any trend in our response measures (Urquhart and Kincaid 1999).

Table 1. Summary of variance components and other parameters used in linear modeling from four GRKO pilot study representative response measures collected from 1m² plots at GRKO.

Response Variable	Year	Mean (no transform.)	Standard Deviation (no transform.)	Source	Var. Comp. (natural log transformed)	Variance (%)	Site Correlation (signif.)
Perennial Grass Cover (Plots)	2006	64.911	20.083	Year*Site	0.045	14.81	0.6311 ***
	2007	58.246	26.236	Year	0.114	37.22	
	2008	32.567	12.417	Site	0.101	33.05	
				Residual	0.046	14.93	
Annual Grass Cover (Plots)	2006	0.040	0.200	Year*Site	0.556	100.49	0.2136 ns
	2007	0.680	2.947	Year	-0.019	-3.49	
	2008	0.033	0.089	Site	0.017	3.00	
				Residual	0.000	0.00	
Exposed Mineral Soil (Plots)	2006	4.420	8.198	Year*Site	0.072	3.87	0.6212 ***
	2007	3.776	4.065	Year	0.055	2.97	
	2008	7.342	7.171	Site	1.078	58.24	
				Residual	0.646	34.92	
Tot Veg Cover (Plots)	2006	79.881	20.239	Year*Site	0.003	1.36	0.3138 ***
	2007	78.708	15.947	Year	0.148	68.24	
	2008	39.242	12.499	Site	0.018	8.11	
				Residual	0.048	22.29	

Notes: Sample size varies with year. All responses are from plot based data; Year.rho is set to 0.10 for all variables (see text). *** indicates significance of Pearson's 'r' site autocorrelation estimate. When the site autocorrelation is not significant (annual grass cover) we set the site autocorrelation to 0. All tests use alpha=0.05.

Step 2: Determining the 'affordable sample size'

As we developed ROMN protocols (Britten et al. 2007), it became clear that our sample size and panel designs within any protocol would largely be a function of operational constraints, not an ideal for trend detection or for precisely estimated status. We are forced to balance resources across all our protocols, which of course limits application within each. Nevertheless, power analysis is still very important (maybe even more so) in determining the consequences of implemented designs and allowing fine tuning of complex panel structures that optimize capacity within budget constraints. Power analysis output provides a numerical comparison for fine tuning and comparing designs and justification for seeking additional resources or collaborators. *It cements the critical importance of maintaining over the long term the ROMN monitoring effort in a rigorous and consistent way. The accumulation of data over the long-term is most essential - it is the only way to deal with the nibbling effect of annual variability.*

After much debate, we determined our average maximum sample size for VCSS surveys in small parks in any given year is 10 – 12 sample events per park. We believe we can maintain an annual sample effort of 30 – 36 survey sample events under current I&M funding scenarios and all other

network responsibilities, including VCSS large park sites (when implemented). It is possible that we can rotate sample effort among parks allowing more samples in one year in some parks than others to improve status estimates for that sample year, but often the cost of getting crews to a park is substantial so this may compromise efficiency.

Step 3: Allocating sample size into panel designs

After reviewing the statistical and monitoring literature from other similar long-term monitoring efforts (mostly EPA projects), we determined that a split revisit design that partitions sites into two panel types with different sample size and revisit patterns would be used for our final design. Known as “partially augmented, serially alternating” designs, these structures offer the best compromise between estimating status and trend (Urquhart et al. 1993, 1998; Larsen et al. 1995, 2001). Moreover, they are linked or connected in an experimental design sense because some plots are measured in consecutive years and revisit panels overlap with other panels. Connectivity provides the means to estimate annual means, contrast differences among them, and detect year effects, if present.

There is an almost limitless range of possible panel designs (even within the family of partially augmented, serially alternating structures and our sample size limits) and no existing optimization approach, so we picked panel designs to apply that were within the realm of our budget, had similar annual and total unique sample size, but were different in terms of how they allocated samples across panels. Using these criteria, we chose three partially augmented, serially alternating panel designs (Table 2). We also included a simple annual revisit panel (all sites revisited every year) and a never revisit design (all sites new each year) as baselines. It is not possible to have the same annual (~10) and total unique (~30) sample sizes in the three split panel and two baseline designs so we used the most limiting factor of the annual sample size and required it to be approximately equal across all designs (Table 2).

Urquhart, et al. (1993) found that 10-20% of annual resources could be used for sites visited annually and we attempted to follow this in our split panel designs. Larsen et al. (1995, 2001) suggested that a cycle of four years is optimal (purely in a statistical sense) for panels that are not sampled annually. Our split panel structures also consider the time frame within which a trend estimate is desired and/or attainable. We incorporate ‘ecological knowledge’ (albeit in a largely qualitative way), by accounting for any periodicity in vegetation or soil cycles. For example, if measurements from sites are highly correlated between consecutive years, survey revisits may be spaced to avoid duplication of information unless the measurement of that correlation meets a specific monitoring goal or helps in net trend estimation.

Our power analysis and implementation (at least in the initial stages) include a small number of within season revisits (see the “GRKO.Within” lines in 2). These are important for better understanding the impacts of seasonality and other sources of variation as well as fine-tuning our index period. These sample events may be dropped (or increased) as we learn more about temporal patterns as they typically do not benefit long-term net trend or status estimates. The within season revisits are ideally the first N sites in the GRTS list, but they may be chosen based on logistical considerations as well.

Table 2. Panel structures evaluated in GRKO pilot. Values in the cells are expected sample sizes within each panel. Empty cells have no sample events. Only 10 years are shown but 80 were evaluated in power analysis. The pattern repeats in the same manner for years 11 – 80 (and thereafter). The notation commonly used to describe panel designs is a pair of digits. The first digit is the number of consecutive occasions on which a panel is sampled; the second is the number of consecutive occasions on which a panel is not sampled (McDonald 2003). The number of panels within a revisit form may be noted with a superscript and the sample size within each panel with a subscript.

Design1 ([1-0⁴]₄, [1-3⁴]₇)

Total unique sample size = 32 over 4 years; sample events accrued during this period = 48 (including within season revisits).

Panel.Park	1	2	3	4	5	6	7	8	9	10
GRKO1	4	4	4	4	4	4	4	4	4	4
GRKO2	7				7				7	
GRKO3		7				7				7
GRKO4			7				7			
GRKO5				7				7		
GRKO.Within	1	1	1	1	1	1	1	1	1	1
GRKO Sum	12	12	12	12	12	12	12	12	12	12

Design2 ([1-3¹]₁₆, [2-4⁴]₄)*

Total unique sample size = 32 over 4 years; sample events accrued during this period = 48 (including within season revisits).

Panel.Park	1	2	3	4	5	6	7	8	9	10
GRKO1	16				16				16	
GRKO2	4	4			4	4			4	4
GRKO3		4	4			4	4			4
GRKO4			4	4			4	4		
GRKO5				4	4			4	4	
GRKO.Within	1	1	1	1	1	1	1	1	1	1
GRKO Sum	21	9	9	9	25	9	9	9	25	9

*Note that Design2 is shifted forward one year each in LIBI and FLFO such that the years in which the larger sample size of 15 in panel 1 is implemented is different across the three parks.

Design3 ([1-3⁴₆], [2-2⁴₂]) “Preferred Design”

Total unique sample size = 32 over 4 years; sample events accrued during this period = 42 (including within season revisits)

Panel.Park	1	2	3	4	5	6	7	8	9	10
GRKO1	6				6				6	
GRKO2		6				6				6
GRKO3			6				6			
GRKO4				6				6		
GRKO5	2	2			2	2			2	2
GRKO6		2	2			2	2			2
GRKO7			2	2			2	2		
GRKO8				2	2			2	2	
GRKO.Within	1	1	1	1	1	1	1	1	1	1
GRKO Sum	9	11	11	11	11	11	11	11	11	11

Design4 ([1-0¹₁₂]) “Always revisit”

Total unique sample size = 12 over 1 year; sample events accrued during this period = 13 (including within season revisits)

Panel.Park	1	2	3	4	5	6	7	8	9	10
GRKO1	12	12	12	12	12	12	12	12	12	12
GRKO.Within	1	1	1	1	1	1	1	1	1	1
GRKO Sum	13	13	13	13	13	13	13	13	13	13

Design5* ([1-n⁶⁰₁₂]) “Never revisit”

Total unique sample size = 48 over 4 years; sample events accrued during this period = 52 (including within season revisits)

Panel.Park	1	2	3	4	5	6	7	8	9	10
GRKO1	12									
GRKO2		12								
GRKO3			12							
GRKO4				12						
GRKO5					12					
GRKO6						12				
GRKO7							12			
GRKO8								12		
GRKO9									12	
GRKO10										12
GRKO.Within	1	1	1	1	1	1	1	1	1	1
GRKO Sum	13	13	13	13	13	13	13	13	13	13

Step 4: Setting the detectable trend

The minimally detectable difference (MDD; or amount of trend a design can detect) is a key parameter in power analysis. We use a proportional change or annualized rate of change in a response measure as our minimally detectable difference. The annual rate expresses a long-term proportional change (e.g., 30% change from Year 1 to Year 10) on an annual basis. *The annual rate is equivalent to the slope of the regression line in the linear models.* Our linear modeling treats annualized change as an increase (a positive numeric change) in a response. This is a conservative strategy – Gerrodette (1987) states that a decrease in power is easier to detect than an increase.

Our three year pilot in GRKO is far too short of a time to realistically estimate an annual net trend for any of the response measures we collected. Therefore we sought to limit the complexity of the results we present here by choosing a small annual trend that is significant enough to be of interest to land managers, but subtle enough to provide resolution of the differences in our proposed designs. Designs capable of detecting small trends will do better in detecting larger trends in the same resource, so power should be improved when rates of change are more rapid. Following this reasoning and relevant literature, we use an annual trend of 2% (but make comparisons with other values). A 2% annualized trend equates to an 18% total increase over 10 years, or an increase in total vegetation cover at GRKO from ~79 (measured mean percent cover in 2006) to ~96 in 2016. Whether this is an ecologically meaningful increase in vegetation cover is another issue.

Step 5: Estimating power for trend and standard error for status

The derivation of the equations for power to detect trend are presented in detail in Urquhart et al. (1993, 1998) and Larsen et al. (1995, 2001). The equations for power and standard error follow directly from the linear model (Stoddard et al. 1996). The statistical and analytical basis, assumptions, and justifications are well documented in these publications. We use an R-function developed and provided by T. Kincaid from the EPA and modified by B. Gitzen from South Dakota State. The R code is available from ROMN or T. Kincaid upon request.

Parameters in the power analysis include the variance components as detailed in Table 1, an initial mean value (set to 1 when the response measures is log transformed as all are in these analyses, otherwise the mean for all sample events in year one of sampling), a matrix of sample events (the panel design), and two correlation coefficients. The correlations include a site correlation across years and a year autocorrelation. Their value can impact power estimates, therefore we sought to estimate these parameters using pilot data. We derived site correlation based on linear model estimates (Pearson's 'r') as indicated by Urquhart et al. (1993, 1998) and Stoddard et al. (1996). However, year autocorrelation is poorly defined and difficult to estimate. According to Larsen et al. (1995), the value of the year autocorrelation is expected to be less than 0.25 for most environmental response measures. It is often set to 0 in analyses similar to ours (Urquhart et al. 1993, 1998). Given the importance of temporal coherence in many vegetation attributes, we did not want to zero this out so we choose a small positive value within the bounds recommended in the literature (0.1; as per Larsen et al. 1995).

We lack a test to numerically compare power for trend or standard error for status across different runs of the model. Therefore we compare output based on the time taken to develop an

80% power for trend detection. We selected this level ($\beta = 0.80$) to allow for balance between tolerance for Type I and II errors (it is also a commonly accepted threshold). There is no analogous criterion for standard error of status, so we simply evaluate standard error curves relative to one another. For both power and standard error, values are absolute (meaning that there is no statistical error around them) – facilitating simple comparisons like ours.

Summary of results

The literature behind our approach includes a rich discussion of how each parameter can impact power for trend and design decisions. We restrict the comparisons evaluated here to a small subset of the parameters in the models, focusing on the aspects that we either have control over (e.g., panel design, response measure) or that we do not, yet can have a strong impact on results (e.g., total unique sample size). In each case, we hold constant all other parameters such that differences are only due to the parameter in question. Our goal is to present the key implications of and motivation for our VCSS design choices at GRKO, not to meaningfully add to the literature on this modeling approach. Moreover, our results are preliminary until we can augment them with output from simulations that will expand our pilot time period (and develop similar results for FLFO and LIBI).

Effect of panel design

Panel design structure is the primary parameter we can control in our design choice. It is how total sample size, strongly constrained by budget, is allocated across time to balance estimation of status and trend. Figure 1 presents example power for trend and SE for status curves for the five designs in 2, holding all other parameters constant.

Differences for power for trend and standard error for status using total vegetation cover were surprisingly small among the five designs we analyzed. Bare soil in the annual revisit design (Design4) exhibited slower accumulation of power and decreases in SE for status than the other designs. Design3 ([1-346], [2-242]) had slightly quicker convergence of the standard error towards the mean, suggesting higher potential for accurate status estimates in the shortest possible time-frame. The [1-346] “half” of Design3 provides the foundation for status estimates by designating 24 unique sample sites. The [2-242] “half” further increases the number of unique sites (and spatial coverage of sample sites) to 32, but it also provides data for inter-annual variability estimates by providing two consecutive years of sampling for these sites and one within-year revisit (to the first site sampled each year). Of the split panel designs, Design1 had the slowest accumulation of power for trend and decrease in standard error for status (with the bare soil response).

Effect of response measure

The choice of what to measure at VCSS sites is determined by many aspects other than power for trend and precision of estimates of status. However, if a response measure has poor statistical attributes it may either be a limited choice given inherent variability in the response and/or the VCSS methods used to collect it. Future work will develop additional statistics for VCSS response measures (e.g., signal to noise ratios; *sensu* Kaufmann et al. 1999) to further refine the choices of response measures in the protocol. Figure 2 presents power for trend and SE for status curves for four representative response measures (1) using our preferred panel design (Design3) with all other parameters estimated from GRKO pilot data or held constant.

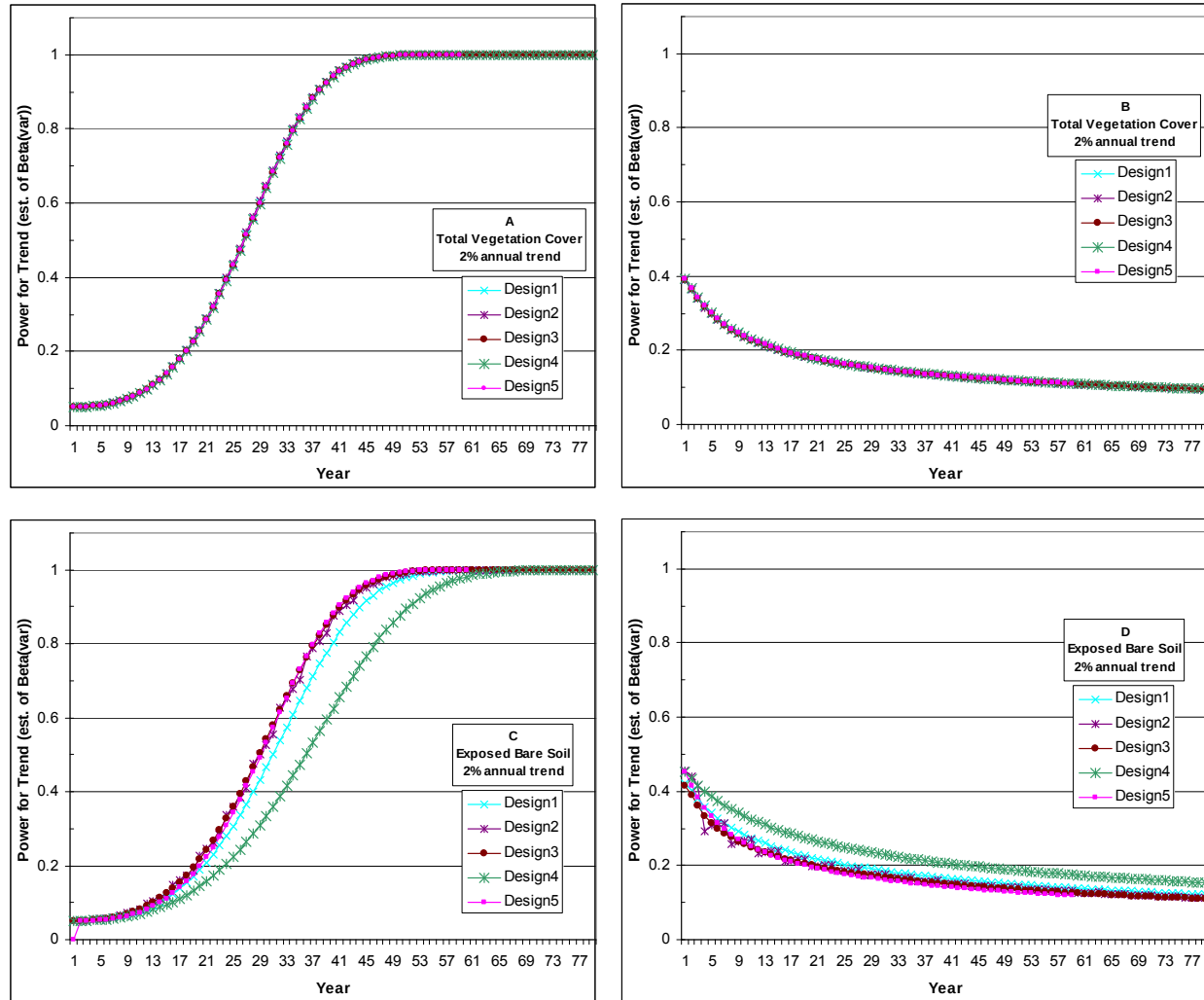


Figure 1. Effect of GRKO panel design: (A) Power for trend total vegetation cover; (B) SE for status total vegetation cover; (C) Power for trend exposed bare soil; (D) SE for status exposed bare soil. Comparison of five panel designs with approximately equivalent sample size allocation (close to the affordable sample size, see Table 2), plot based total vegetation or exposed bare soil as the response measure, year, site, site * year and residual variance components and site rho as calculated from GRKO pilot data (see Table 1), year rho set to 0.10 and annualized percent trend set to 2%. Note that Design5 was run for only 60 years due to matrix memory allocation limits in R.

Total vegetation, perennial grass and bare soil cover exhibit similar power for trend and standard error, with bare soil having slightly slower accumulation of power and decrease in standard error. Annual grass cover has a notably different set of results. Using Design3, measurement of annual grass cover would allow 80% power in a (relatively quick) 20 years with a standard error below 0.10 reached around 10 years. Patterns across all four responses were similar with the other split panel designs but Design3 had marginally better performance. The baseline designs (always and never revisit) did not perform as well as the split panel structures with any of these four response measures.

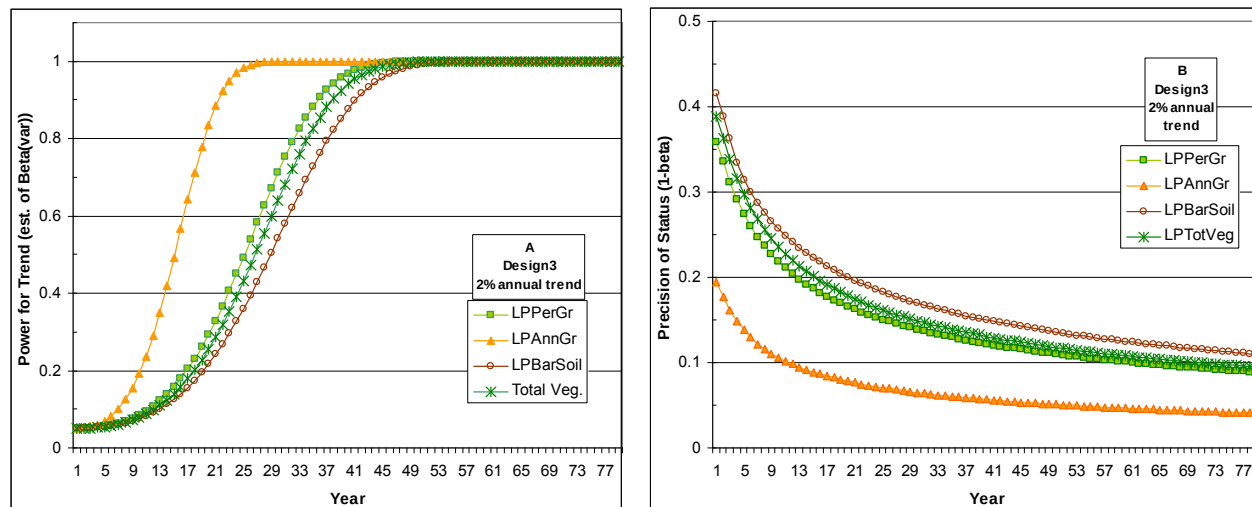


Figure 2. Effect of response measure. (A): Power for trend; (B) SE for status. Comparison of likely ROMN VCSS panel design (Design3) with the affordable sample size allocation (see Table 2), *four response measures* (see Table 1), year, site, site * year and residual variance components and site rho as calculated from GRKO pilot data (see Table 1), year rho set to 0.10 and annualized percent trend set to 2%.

Effect of total sample size

Sample size is the aspect of a design that intuitively seems ‘most important’ in determining the capabilities of a design to estimate status and trends. Yet, in long term monitoring design sample size is neither a simple design specification to determine nor often the most important. Sample size must be considered in the following contexts: (1) when sites are visited in a panel structure, (2) whether a sample is a unique (or new) site or a revisit, and if a revisit, whether it is within a sampling interval (year) or an inter-annual revisit, and (3) whether status or trend is more important. Figure 3 presents power for trend and SE for status curves using our likely panel design (Design3, Table 2) with sample size at 1.5x, 2x and 3x of the default or affordable total unique sample size (32) with all other parameters estimated from GRKO pilot data or held constant. As noted, it is not possible to have both annual and total unique sample size in the baseline designs equal to the split panel structures. We chose the annual sample size as the most limiting factor (maximum N of 13).

Using our preferred design (Design3), differences in power for trend and standard error of status were surprisingly small for total vegetation cover with increases in sample size above the affordable size. Bare soil exhibited more marked increase in power for trend and decrease in standard error as sample size within Design3 increased. However this was not proportional to sample effort (e.g., with a 3x increase in total unique sample size, 80% power for trend is reached in about 30 years vs. about 38 with the affordable N). Larger gains in power and decreases in standard error are realized with shifts in panel design structure (see Figure 1).

Revisiting sites across time has an important implication for design specification. In multi-site monitoring, the total variance of trend estimates among samples is usually large, and the proportion attributable to a site effect is substantial (e.g., individual VCSS sites often differ much more than locations within the site). If one sample of sites was taken at one time and another

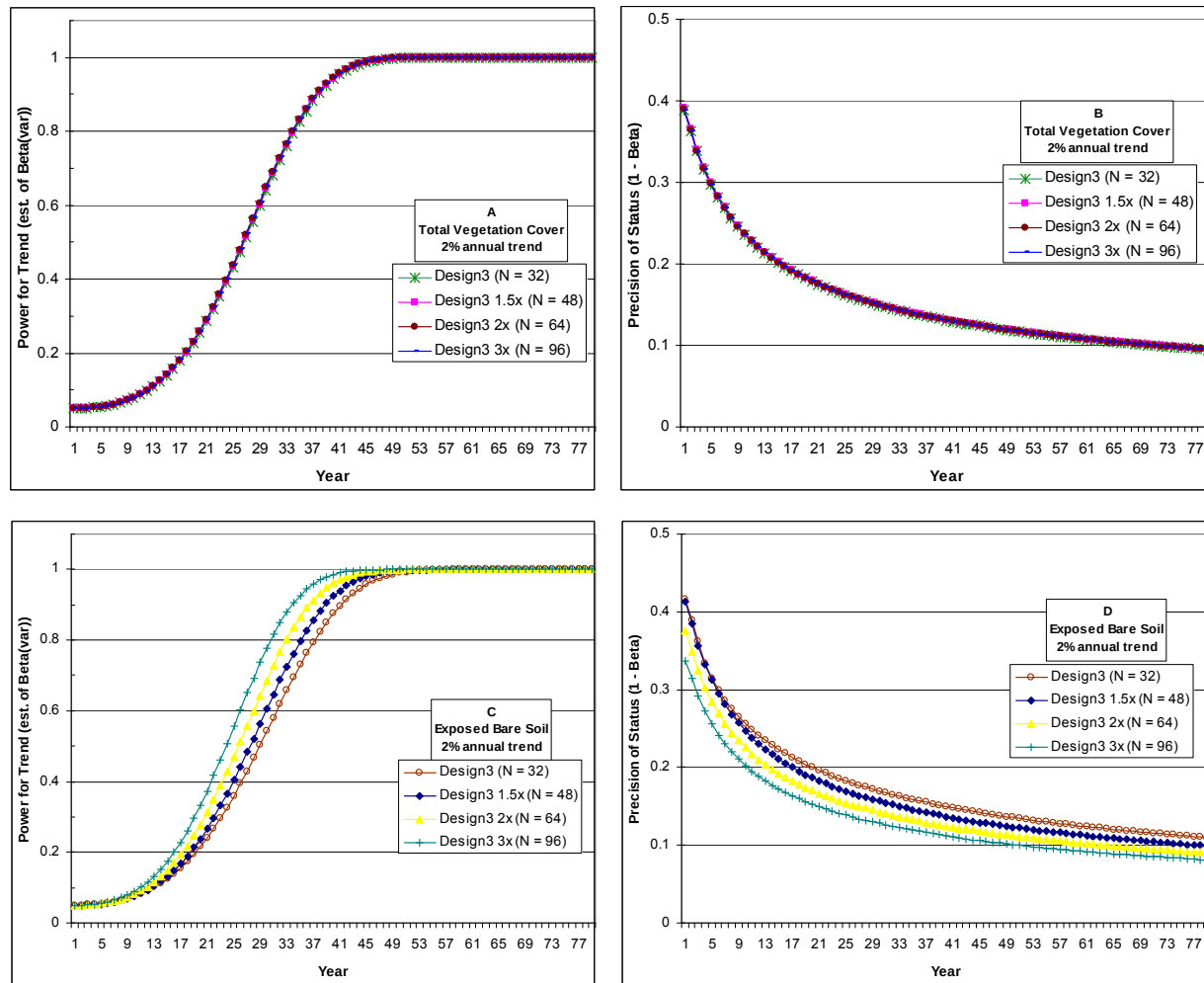


Figure 3. Effect of sample size: (A) Power for trend total vegetation cover; (B) SE for status total vegetation cover; (C) Power for trend exposed bare soil; (D) SE for status exposed bare soil. Comparison of likely ROMN VCSS panel design (Design3) with sample size allocation 1.5x, 2x and 3x the affordable sample size (see Table 2); plot based total vegetation or exposed bare soil as the response measure, year, site, site * year and residual variance components and site rho as calculated from GRKO pilot data (see Table 1), year rho set to 0.10 and annualized percent trend set to 2%.

independent sample at another time, the site component of variance would be included in the variance of each sample (i.e., there would be a better spatial distribution to estimate status). However, if each site is considered a “block,” and sites are periodically revisited, the site component of variance disappears from the variance of a slope (Urquhart et al. 1993, 1998). Revisiting sites across years eliminates site-to-site variation in the same way that self-pairing in experimental studies eliminates the variation introduced across subjects. The positive implications of this (i.e., trend becomes much more discernible) suggest that the chosen VCSS design must have revisits to some sites across time. Some of these revisits can be disjointed and spread across larger gaps in time as with the [1-346] “half” of Design3. This allows these sites to ‘rest’ from any observer effect and to accrue more effort to sampling more unique sites. Other revisits should be in the portions of a design that is visited in successive years (the [2-2⁴₂] “half” of Design3). Finally, repeatedly sampling at least one site twice within the same year will help

separate within year variability from between year variability; therefore, we propose sampling one site from the $[2 \cdot 2^4 \cdot 2]$ set of panels twice each year. This combination of site revisit schedules will allow estimation (and partitioning) of annual variability – building the capacity of the long-term VCSS design to detect subtle trends in the indicators.

While trend is important, status is important as well; thus, some number of unique sites must be included in a design. Revisiting sites reduces the influence of the residual variance component on trend detection capability, while adding additional sites reduces the effect of both the residual and the interaction variance components. Therefore, when resources are fixed, sampling additional sites rather than revisiting sites is always an improvement (unless the interaction term is zero). The amount of benefit derived from adding sites to the sample is related to the relative magnitudes of the two variance components. An increase in the number of sites visited also increases the possibility of identifying subpopulations with common trend characteristics, as a result of the larger sample size.

Parameters not under direct control

We intentionally limited the presentation above to the parameters that we have control over (although total and annual sample size is really determined by our budget). However, many of the other parameters can have as strong (or stronger) affect on the results. In particular, effect size (annualized trend, or the minimally detectable difference) and the year variance component can dramatically alter the results from power models. These can be partially controlled by choice of response measure (i.e., only use responses with a small year variance), but this precludes ecological importance with statistical power; clearly some indicators and associated response measures will be preferred by science and management but not offer optimal statistical power. We do our best to develop a monitoring approach and methods that minimize measurement variance, but in the end, some of these variables will remain in our protocols because of their perceived importance for defining ecosystem condition. The following summarizes key impacts of these other parameters. These are dealt with in more detail in the relevant literature, which should be consulted for a complete treatment.

Effect size

Figure 4 presents an example of the impact of the annualized trend or minimally detectable change size as measured by the slope of the line. The magnitude of the effect size has one of the largest impacts on ability to detect trend, but no effect on the SE around status. For both total vegetation and bare soil a 10% annualized trend has markedly higher power than a 2% trend with the same number of elapsed years. Unfortunately, the effect size often is not knowable; thus, it is difficult to examine its influence on a design effectively, *a priori*. Our current pilot data set is not long enough to derive a meaningful trend estimate – we may be able to augment this from our planned simulations. Alternatively, the expected effect size might be specified as some level of change that is unacceptable for management reasons (e.g., it will not meet a park's desired future condition) and the sample design set up to ensure that this level of change is detectable.

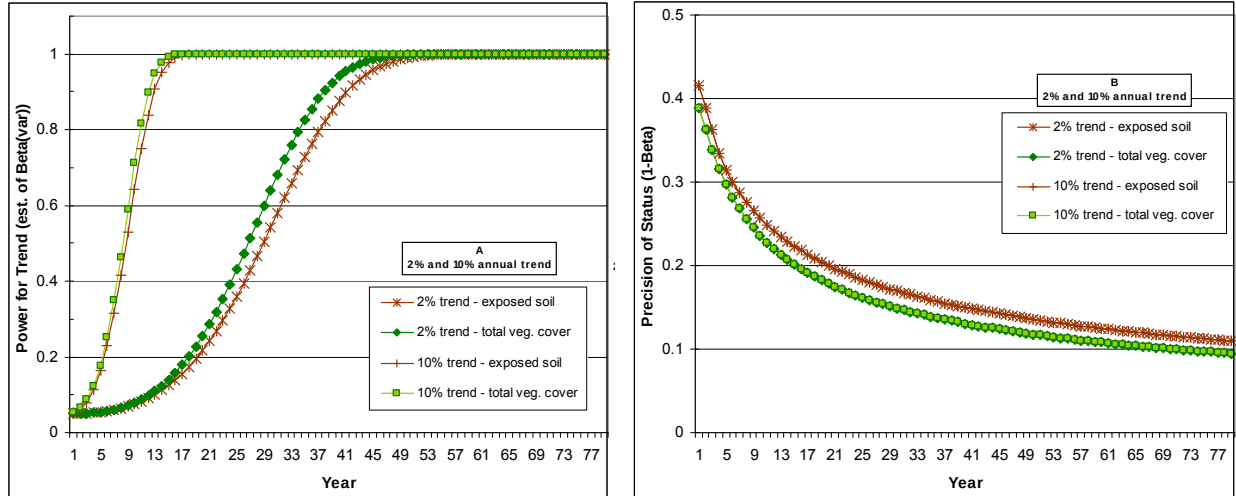


Figure 4. Effect of annualized trend (MDD). (A): Power for trend; (B) SE for status. Comparison of likely ROMN VCSS panel design (Design3) with the affordable sample size allocation (see Table 2), plot based total vegetation and bare soil cover as the response measures, year, site, site * year and residual variance components and site rho as calculated from GRKO pilot data (see Table 1), year rho set to 0.10 and annualized percent trend set to 2% and 10%.

Year variance component

Figure 5 presents an example of the of the year variance component. We varied this variance component and held all other parameters constant; however, this is not entirely appropriate because in a real world situation any change in the concordant year variation across all sites in a design would also lead to changes in other parameters. For illustration purposes our treatment is useful.

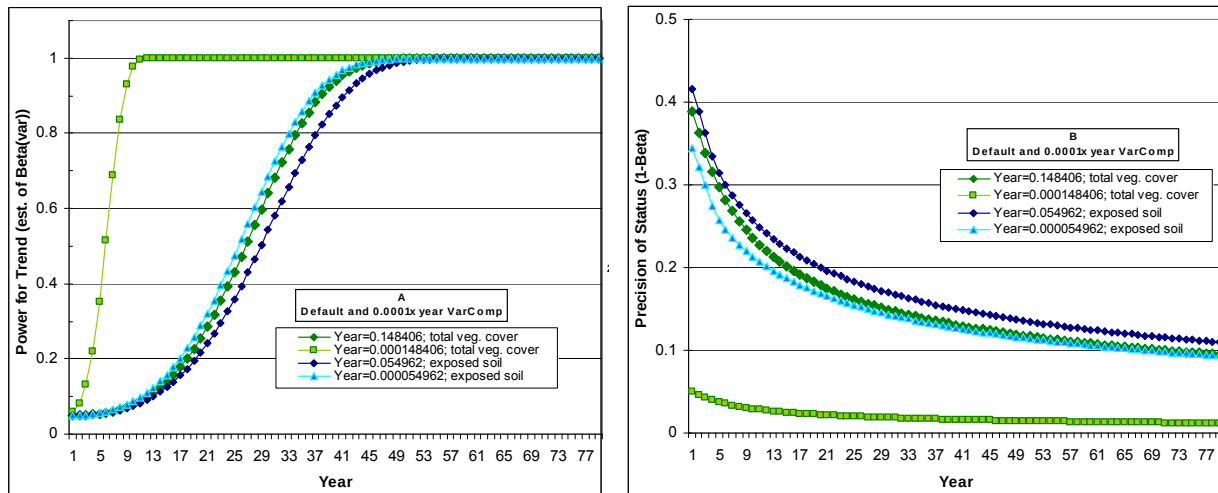


Figure 5. Effect of year variance. (A): Power for trend; (B) SE for status. Comparison of likely ROMN VCSS panel design (Design3) with the affordable sample size allocation (see Table 2), plot based total vegetation and bare soil cover as the response measures, site, site * year and residual variance components and site rho as calculated from GRKO pilot data (see Table 1), year rho set to 0.10 and year variance component set to calculated value and 0.001x this value.

Most effects of design features on status and trend can be managed through design and sample size choices – except for the year-effect variance component (Urquhart et al. 1993; 1998). The year effect is the variation of the target resource (response) across years for all sites in a target population; it is not the variation in an indicator across years at a single site. If a trend is present, year variance is the deviation away from the trend line (or curve) after which trend is accounted. Small year effects (e.g., the 0.001x inflated values in Figure 5) allow reasonable power and SE after 5-10 years for total vegetation cover. However, as the year effect increases (to the realized values from the GRKO pilot), the time required to reach 80% power or attain likely acceptable SE increases dramatically. The impact of year variance does not act independently from the other parameters in the model. Therefore, when we artificially decreased its level for total vegetation cover, we changed its relative amount much more than when we did the same for bare soil cover, which explains the more dramatic shift with total vegetation than with bare soil cover.

If year effect exists even in small amounts, the sample size of an analysis reverts to the number of years for which there are data, and the number of visits and/or numbers of sites have no practical effect on trend detection. If the year effect is large, no amount of design manipulation can overcome its effect on trend detection. The only real recourse is to monitor for a longer period of time to accrue sufficient power. In some cases, it can be cost-effective to visit a site other than on a yearly basis (i.e., to skip some years) with little loss in trend detection capability (Larsen et al. 2001).

However, year effects can be circumvented or controlled through a variety of other ways. Measures and methods that are more immune to year effects can be used (Stoddard et al. 1996; Kaufmann et al. 1999; Kincaid et al. 2004). Classification of sites into subpopulations whose variance structures differ (Stoddard et al. 1996) can improve power within each subpopulation due to the decreased variance across all sites. Finally, we can identify logically sound factors with which year variation is correlated and use these to remove the year effect with a linear model (Larsen et al. 2001, 2004). If year effects are likely to be important, identifying and monitoring possible controlling factors become as important as monitoring the indicators themselves. These options are being explored with ongoing VCSS pilot work.

Final design

Our final selection of a small park VCSS survey revisit design is provisional given the developmental nature of this program. The final choice is also not necessarily obvious given the complexity involved and lack of a specific optimization process. Lastly, the choice to use some form of a partially augmented, serially alternating designs is taken from the literature, and we are assuming previous work in other systems will prove relevant for optimizing monitoring small park vegetation and soils over many years. However, with these caveats, we are comfortable with the choice of Design3. It seems to offer the best fit of a revisit schedule to our operational constraints and performs marginally better than the other split panel designs (and the two baseline designs) in nearly all tests.

When we are able to expand these analyses to include simulations and develop models for other parks we may see meaningful changes and have to change the revisit design. While we do not expect this to happen, a key advantage of a GRTS design is the ability to recast the panel membership of existing sites into new structures. Often it is even possible to capture the bulk of results that were collected from an earlier panel structure.

Perhaps the most troublesome outcome from this work is the slow accumulation of power for estimating population or net trend and status, which, for example, suggests it could take 30 years to accurately (80% power) detect a 2% per year decline. This is largely due to the large year variance component in the response measures we tested (especially total vegetation cover). Performance is better with responses where concordant year variation is relatively lower (annual grass cover). However, when a year affect exists the only solution for the estimation of net trend is to continue monitoring over the long term.

Our monitoring is expected to provide a mechanism for detecting gradual, on-going, and variable changes in natural resource conditions across heterogeneous areas. For surveys of extensive, heterogeneous resources, it is important to visit sites on a multi-year rotational cycle, expanding the number of sites visited each year rather than sampling each unit each year (Urquhart et al. 1993, Larsen et al. 1995). The most important difference between designs becomes apparent in how they perform with small numbers of sites (Urquhart et al. 1993), and this is particularly relevant for our capabilities given our budget limitations.

Literature cited

- Britten, M., E.W. Schweiger, B. Frakes, D. Manier, and D. Pillmore. 2007. Rocky Mountain Network Vital Signs Monitoring Plan. Natural Resource Report NPS/ROMN/ NRR-2007/010. National Park Service, Fort Collins, Colorado.
- Draper, N R. and H. Smith. 1967. Applied Regression Analysis. New York: John Wiley and Sons, Inc.
- Garman, S., B.Schweiger, C.Lauver, R. Bennetts, D. Manier, P. Ward, T. Mau-Crimmins. 2009. Complex Survey Design Simulator (CSDsim) VERSION 1.01 – 1/2/09.
- Gerrodette, T. 1987. A power analysis for detecting trends. *Ecology* 68(5): 1364-1372.
- Kaufmann P.R., P. Levine, E.G. Robison, C. Seeliger, D.V. Peck. 1999. Surface waters: Quantifying physical habitat in wadeable streams. Washington (DC): U.S. Environmental Protection Agency. Report nr EPA/620/R-99/003. 158 p.
- Kincaid, T.M., D.P. Larsen, and N.S. Urquhart. 2004. The structure of variation and its influence on the estimation of status: Indicators of condition of lakes in the Northeast, U. S. A. *Environmental Monitoring and Assessment* 98:(1-3):1-21.
- Larsen, D.P., N.S. Urquhart, and D.L. Kugler. 1995. Regional scale trend monitoring of indicators of trophic condition of lakes. *Water Resources Bulletin*:31(1):117-140.
- Larsen, D.P., T.M. Kincaid, S.E. Jacobs, and N.S. Urquhart. 2001. Designs for evaluating local and regional scale trends. *BioScience*:51(12):1069-1078.
- Larsen, D.P., N.S. Urquhart, and D.L. Kugler. 2004. Regional scale trend monitoring of indicators of trophic condition of lakes. *Water Resources Bulletin* 31(1):117-140.
- McDonald, T.L. 2003. Review of environmental monitoring methods: survey designs. *Environmental Monitoring and Assessment* 85:277-292.
- Pieopho, H. and J. Oguto. 2002. A Simple Mixed Model for Trend Analysis in Wildlife Populations. *Journal of Agricultural, Biological, and Environmental Statistics*, 7:350 – 360.
- Starcevich, L. A. H. 2007. Lake chemistry power analysis for the Sierra Nevada Network of the National Park Service--DRAFT. Corvallis, OR.
- Stevens Jr., D. L., and A. R. Olsen. 2003. Variance Estimation for Spatially Balanced Samples of Environmental Resources. *Environmetrics* 14:593–610.
- Stevens Jr., D. L., and A. R. Olsen. 2004. Spatially balanced sampling of natural resources. *J. Am. Stat. Assoc.* 99:262-278.
- Stoddard JL, Urquhart NS, Newell AD, Kugler DL. 1996. The Temporally Integrated Monitoring of Ecosystems (TIME) project design, Detection of regional acidification trends. *Water Resources Research* 32: 2529-2538.
- Urquhart 1993 - should be Urquhart, N. S., W. S. Overton, and D. S. Birkes, 1993. Comparing Sampling Designs for Monitoring Ecological Status and Trends: Impact of Temporal Patterns. In: *Statistics in the Environment*, V Barnett (Editor). John Wiley & Sons, Ltd., Sussex, England, pp . 71-.88.
- Urquhart N.S., S.G. Paulsen, and D.P. Larsen. 1998. Monitoring for policy-relevant regional trends over time. *Ecological Applications* 8:2, 246-257.
- Urquhart N.S. and T.M. Kincaid. 1999. Designs for detecting trend from repeated surveys of ecological resources. *Journal of Agricultural, Biological, and Environmental Statistics*: 4(4):404-414.

Appendix 4 Target Population Tables

Table 1. Factors considered when defining target population at GRKO

GRKO			
Design Class	SSURGO Components		
	MapUnit Name	Geomorphology	Ecoclass names
Categories for sample design	Correlated name of the mapunit; aggregated from a variety of soil attributes and interpretations	geomorphic features on which the referenced map unit component typically occurs; a feature on the earth's surface	identifies the ecological sites, multiple classification systems used (NRCS, USFS, etc) from various concatenated fields; descriptive name of a particular ecological community; differs between rangeland and forested
Valley 1	Varney Clay Loam, 0 To 4 Percent Slopes	alluvial fan, stream terrace	Silty, 10 to 14 inch Ppt zone, northern Rocky Mountain valleys, west
	Varney Clay Loam, 4 To 8 Percent Slopes	alluvial fan, stream terrace	Silty, 10 to 14 inch Ppt zone, northern Rocky Mountain valleys, west
	Cetrack Loam, 0 To 4 Percent Slopes	alluvial fan, stream terrace	Silty, 10 to 14 inch Ppt zone, northern Rocky Mountain valleys, west
	Con Loam, 0 To 4 Percent Slopes	alluvial fan, stream terrace	Silty, 10 to 14 inch Ppt zone, northern Rocky Mountain valleys, west
	Con Loam, 4 To 8 Percent Slopes	alluvial fan, stream terrace	Silty, 10 to 14 inch Ppt zone, northern Rocky Mountain valleys, west
	Con Loam, 8 To 15 Percent Slopes	alluvial fan, stream terrace	Silty, 10 to 14 inch Ppt zone, northern Rocky Mountain valleys, west
	Varney-Con Loams, 4 To 8 Percent Slopes	alluvial fan, stream terrace	Silty, 10 to 14 inch Ppt zone, northern Rocky Mountain valleys, west
	Varney-Con Loams, 8 To 15 Percent Slopes	alluvial fan, stream terrace	Silty, 10 to 14 inch Ppt zone, northern Rocky Mountain valleys, west
Valley 2	Tetonview Loam, 0 To 4 Percent Slopes, Rarely Flooded	flood plain	Wet meadow, 10 to 14 inch Ppt zone, northern Rocky Mountain valleys, west
	Tetonview-Blossberg Loams, 0 To 4 Percent Slopes, Rarely Flooded	flood plain	Wet meadow, 10 to 14 inch Ppt zone, northern Rocky Mountain valleys, west
	Tetonview Loam, 0 To 4 Percent Slopes	stream terrace	Wet meadow, 10 to 14 inch Ppt zone, northern Rocky Mountain valleys, west
Valley 3	Beaverell Cobbly Loam, 0 To 4 Percent Slopes	alluvial fan, stream terrace	Shallow to gravel, 10 to 14 inch Ppt zone, northern Rocky Mountain valleys, west
	Beaverell Cobbly Loam, 4 To 8 Percent Slopes	alluvial fan, stream terrace	Shallow to gravel, 10 to 14 inch Ppt zone, northern Rocky Mountain valleys, west
	Beaverell Loam, 0 To 4 Percent Slopes	alluvial fan, stream terrace	Shallow to gravel, 10 to 14 inch Ppt zone, northern Rocky Mountain valleys, west
Valley 4	Roy-Shawmut-Danvers Complex, 15 To 35 Percent Slopes	alluvial fan	Silty, 15 to 19 inch Ppt zone, northern Rocky Mountain valleys, west
	Miscellaneous Water		
Riparian	Pits, Gravel		
	Aquents-Slickens Complex, 0 To 2 Percent Slopes, Occasionally Flooded	flood plain	
	Slickens-Aquents Complex, 0 To 2 Percent Slopes, Occasionally Flooded	flood plain	
No Sample			

Table 2. Factors considered when defining target population at LIBI

LIBI			
Design Class	SSURGO Components		Ecosite Description
	MapUnit Name	Geomorphology	
Categories for sample design	<i>Correlated name of the mapunit; aggregated from a variety of soil attributes and interpretations</i>	<i>geomorphic features on which the referenced map unit component typically occurs; a feature on the earth's surface</i>	<i>For map legends, tables, etc "Soil attribute/Texture"</i>
Gulley 1	Midway Silty Clay Loam, Hilly	hills	Gulley (Midway,Clapper-Midway,Haverson/ Silty clay loam)
Gulley 1	Clapper-Midway Complex, Haverson Loam, 0 To 2 Percent Slopes	paleoterraces	
Gulley 1	Shale Outcrop	stream terraces	
Gulley 2	Shale Outcrop-Midway Complex, Steep		Gulley (Shale,Shale-Midway)
Riparian	Haverson And Glenberg Soils	stream terraces	Riparian
Upland	Hesper Silty Clay Loam, 4 To 8 Percent Slopes	paleoterraces	Upland
Upland	Midway Silty Clay Loam,	hills	
Upland	Pierre Clay, Rolling	hills	
Upland	Pierre-Lismas Clays, Hilly	hills	
Upland	Thurlow Silty Clay Loam, 0 To 1 Percent Slopes	stream terraces	
Upland	Thurlow Silty Clay Loam, 4 To 8 Percent Slopes	hills	
No Sample			

Table 3. Factors considered when defining target population at FLFO

FLFO			
Design Class	SSURGO Components		Ecosite Description
	MapUnit Name	Geomorphology	
Categories for sample design	<i>Correlated name of the mapunit; aggregated from a variety of soil attributes and interpretations</i>	<i>on which the referenced map unit component typically occurs; a feature on the earth's surface</i>	<i>For map legends, tables, etc "Soil attribute/Texture"</i>
Mountain 1	Guffey-Herbman association, 5 to 50 percent slopes	Mountain	Mountain (Guffey-Hertman/Sandy loam)
Mountain 2	Catamount-Guffey complex, 15 to 40 percent slopes	Mountain	Mountain (Catamount-Guffey/Sandy loam)
Mountain 3	Herbman gravelly sandy loam, 5 to 55 percent slopes	Mountain	Mountain (Herbman/Bedrock)
Mountain 4	Herbman gravelly sandy loam, 5 to 30 percent slopes	Mountain	Mountain (Herbman/Sandy loam/)
Valley 1	Fourmile-Lymaning-Vale complex, 2 to 30 percent slopes	Pediment	Valley (Fourmile-Lymaning-Vale/Clay loam)
Valley 2	Fourmile very gravelly coarse sandy loam, 3 to 20 percent slopes	Pediment	Valley (Fourmile/Coarse sand)
Valley 3	slopes	Flood plain	Valley (Adderton/Loam)
No Sample			

Appendix 5 Soils Analysis Laboratory Methods

Analysis	Method	Reference
Soil pH	Saturated paste	Ref. 3, Method 21a p. 102
Organic matter	Modified Walkely-Black method	Ref. 2, pp. 995-996
Ammonium-nitrogen	2M potassium chloride extract, automated phenate method by FIA	Ref. 2 pp. 1146-1162
Nitrate-nitrogen	2M potassium chloride extract, or AB-DTPA extract, Cd reduction by FIA	Ref. 2, pp. 1146-1162
Sulfate-S	MCP extraction; analyze turbidimetrically	Ref. 2, pp. 938-941
Cation exchange capacity	Measure Na; account for entrained Na with nitrite	Ref. 2, pp. 1201-1230
Total C	CHN furnace	Ref. 2, pp. 967-977
Total N	CHN furnace	Ref. 2, pp. 1087-1089
Ca, Mg	ICP - NH ₄ OAC	Ref. 2, pp. 91-140
P & K	ICP - AB-DTPA	Ref. 2, pp. 91-140
Texture	Graduate cylinder; density by hydrometer	Ref. 1, method 15-5
Bulk density (graduate cylinder)	Weight of known volume of soil.	Ref. 1, method 13-1

Literature cited

- Klute, A. 1986. Methods of Soil Analysis. Part 1. Physical and Mineralogical Methods. 2nd edition. Soil Science Society of America, Inc., Madison, Wisconsin.
- Spark, D.L., (ed). 1996. Methods of Soil Analysis: Part 3. Chemical Methods. Soil Science Society of America, Inc., Madison, Wisconsin.
- USDA. Diagnosis and Improvement of Saline and Alkali Soils. U.S. Salinity Laboratory Staff. U.S.D.A. Handbook No. 60. 1954.

Appendix 6 VCSS Field Datasheets

Reviewed (initials):	Review Date:	Data entry initials:	Entry Date:
----------------------	--------------	----------------------	-------------

Vegetation Composition and Soil Structure - Site Description

Site ID:

Start Date:

Start Time:

Finish Time:

Weather:

Camera Name:

GPS Name:

Aspect : ☐ N, ☐ NE, ☐ E, ☐ SE, ☐ S, ☐ SW, ☐ W, ☐ NW

Slope: ☐ 0, ☐ 5, ☐ 10, ☐ 15, ☐ 20, ☐ 25, ☐ 30, ☐ 35, ☐ 40, ☐ 45

Topographic Position (Check One)

Level: ☐	Crest: ☐
Lower Slope: ☐	Ledge: ☐
Midslope: ☐	Depression: ☐
Upper Slope: ☐	Streambed: ☐

Hydrologic Environment (Check One)

Perm Flood: ☐	Inter Flood: ☐
Semi Perm Flood: ☐	Seep: ☐
Temp Flood: ☐	Upland: ☐

Range of photo #s

Site Description:

Central Point UTM Coordinates (NAD83)

Easting:
Northing:
UTM Zone:
Error:

Monument Area Description

Central:
North:
South East:
South West:

Overview Point UTM Coordinates (NAD83)

Easting:
Northing:
UTM Zone:
Error:

Site Erosion Indicators

Surface Flow: ☐	NS=None to Slight
Rills and Gullies: ☐	SM=Slight to Moderate
Pedestals: ☐	MM=Moderate
	MX=Moderate To Extreme
	XX=Extreme

Ecological Site Desc. (Name 1-3 dominant species):

Woodland:			
Shrub-Herb:			
Grass-Forb:			
Other (specify):			

PAGE ____ OF ____

Reviewed (initials):	Review Date:	Data entry initials:	Entry Date:
----------------------	--------------	----------------------	-------------

VCSS - Human Disturbance 1

Site ID:	Start Date:	Start Time:	Observer:	
			FinishTime:	Recorder:

Alterations within Buffers and Landscape Context **Score:**

1A. AVERAGE BUFFER WIDTH - This metric is measured by estimating the width of the buffer surrounding the assessment area. Buffers are natural vegetated areas with no or minimal human-use. Buffer boundaries extend from the assessment area edge to intensive human land uses which result in non-natural areas. Some land uses such as light grazing and recreation may occur in the buffer, but other more intense land uses should be considered the buffer boundary. Irrigated meadows may be considered a buffer if the area appears to function as a buffer between the assessment area and nearby, more intensive land uses such as agricultural row cropping, fenced or unfenced pastures, paved areas, housing developments, golf courses, mowed or highly managed parkland, mining or construction sites, etc.

0pts Wide > 100 m
3pts Medium 50 m to <100 m
7pts Narrow 25 m to 50 m
10pts Very Narrow < 25m

1B. ADJACENT LAND USE - This metric is measured by documenting surrounding land use(s) within 100 m of the outer buffer boundary. Enter percentages in the % Adjacent column in the Land Use table that best represent the extent of each land use type in the adjacent area. Be sure that the percentages sum to 100%. THE FINAL SCORE FOR THIS FIELD WILL BE CALCULATED IN THE OFFICE.

0pts Average Land Use Score = > 95
3pts Average Land Use Score = 80 - 95
7pts Average Land Use Score = 40 - 80
10pts Average Land Use Score = < 40

1C. PERCENTAGE of UNFRAGMENTED LANDSCAPE WITHIN ONE KILOMETER - This metric is measured by estimating the area of the largest block of unfragmented area in a one km buffer surrounding the assessment area and dividing that by the total area. This can be completed in the office using aerial photographs or GIS.

0pts Embedded in 90–100% unfragmented, roadless natural landscape
3pts Embedded in 60–90% unfragmented, roadless natural landscape
7pts Embedded in 20–60% unfragmented, roadless natural landscape
10pts Embedded in <20% unfragmented, roadless natural landscape

1D. BUFFER CONDITION - The condition of a buffer is assessed according to the extent and quality of its vegetation cover and the overall condition of its substrate. Evidence of direct impacts by people are excluded from this metric and included in the Land Use Calculations. Buffer conditions are assessed only for the portion of the site border that has already been identified or defined as buffer, based on 1a. If there is no buffer, assign a score of 10.

0pts Buffer is dominated by native vegetation, has undisturbed soils, with little or no human use.
3pts Buffer is characterized by an intermediate mix of native and non-native vegetation, but mostly undisturbed soils and is apparently subject to little or no human visitation.
7pts Buffer is characterized by substantial amounts of non-native vegetation AND there is at least a moderate degree of soil disturbance/compaction, and/or there is evidence of at least moderate intensity of human visitation.
10pts Buffer is characterized by barren ground and/or highly compacted or otherwise disturbed soils, and/or there is evidence of very intense human visitation.

PAGE ____ OF ____

Reviewed (initials):	Review Date:	Data entry initials:	Entry Date:
----------------------	--------------	----------------------	-------------

VCSS - Human Disturbance 2

Site ID:	Start Date:	Botanist:	
		Recorder:	

Hydrological Alterations	Score:
--------------------------	--------

2. HYDROLOGICAL ALTERATIONS - Measured by evaluating land use and human activity within or near the assessment area which appear to be altering hydrology of the site. (See Table 1)

0pts No alterations. No dikes, diversions, ditches, flow additions, pugging, or fill present in assessment area that restricts or redirects flow

4pts Low intensity alteration such as roads at/near grade, pugging, small diversion or ditches (<1 ft. deep) or small amount of flow additions

12pts Moderate intensity alteration such as 2-lane road, low dikes, pugging, roads w/culverts adequate for stream flow, medium diversion or ditches (1–3 ft. deep) or moderate flow additions.

20pts High intensity alteration such as 4-lane Hwy., large dikes, diversions, or ditches (>3 ft. deep) capable to lowering water table, large amount of fill, or artificial groundwater pumping or high amounts of flow additions

Physical Disturbance	Score:
----------------------	--------

3A. SUBSTRATE/SOIL DISTURBANCE - Select one or double check and average. This metric evaluates physical disturbances to the soil and surface substrates of the area. Examples include filling and grading, plowing, pugging (hummocking from livestock hooves), vehicle use (motorbikes, off-road vehicles, construction vehicles), sedimentation, dredging, and other mechanical disturbances to the surface substrates or soils.

0pts No Apparent Modifications

3pts Past Modification but Recovered; OR Recent but Minor Modifications

7pts Recovering OR Recent and Moderate Modifications

10pts Recent and Severe Modifications

3B. ONSITE LAND USE - This metric is measured by documenting onsite land use(s) occurring in the assessment area. Follow the same procedures as in Metric 1a - Adjacent Land Use

0pts Average Land Use Score = > 95

3pts Average Land Use Score = 80 - 95

7pts Average Land Use Score = 40 - 80

10pts Average Land Use Score = < 40

VCSS - Land Use

Site ID:	Start Date:	Observer:	Recorder:
--	---	---	---

Table 1. Land Use		
Current Land Use	% Site	% Adjacent
Paved roads/parking lots		
Developed buildings/infrastructure		
Agriculture (tilled crop production)		
Unpaved roads (e.g., driveways, service roads)		
Mining (e.g., tunnels, pits, slag piles)		
Agriculture (row crops)		
Heavy grazing by livestock (permanent ranching)		
Moderate grazing by livestock (seasonal grazing)		
Light grazing by livestock (occasional use - e.g., by trail stock)		
Haying operations (fields, other evidence)		
Extensive logging or tree removal with >50% of trees > 50cm dbh removed		
Selective logging or tree removal with <50% of trees > 50 cm dbh removed		
Intense recreation (e.g., ATV use/front country camping/popular fishing spot)		
Moderate recreation (high use trail, backcountry campsite)		
Light recreation (e.g., low-use trail, backcountry campsite)		
No obvious human use in recent time (10 yrs), but not pristine area (e.g., fallow, old CRP, etc.)		
Pristine or land managed for native flora / fauna and processes		
Other (explain in notes)		

GRAND TOTAL - These fields are not entered into the database. - This must total to 100		
---	--	--

Notes:

PAGE ____ OF ____

VCSS - Field Data Form - Natural Disturbances

Site ID: _____	Start Date: _____	Observer: _____
		Recorder: _____

Natural Disturbances			
Evidence may be observed while walking through the site, to and from the site, or from best observation location			
-Site to 1km scale -	Code:	Flags:	KEY
Beaver, lodge, dam, canal, runway, food harvesting, gnawing of woody materials, viable beaver habitat (forage, slope, distance to water)	<u>Beaver:</u>		1 - High: Majority (> 50%) of site has recent evidence 2 - Medium: Some recent or old (>10yr) evidence on site 3 - Low: No sign on site, at least some evidence in (~1km) area around site 4 - None: No signs in site or in (~1km) area around site 6 - Other: (explain in notes)
Observation or evidence of elk, moose, deer, or big horn sheep, such as wallows, hoof punching, Do not include herbivory from domestic animals.	<u>Native Herbivory:</u>		
Castings, burrows, etc	<u>Frost Heave:</u>		
Blackened/burned trees, downfall caused by fire, etc. Do not try to identify the source or cause	<u>Rodents:</u>		
Evidence of beetles (any species), dead or dying trees	<u>Fire</u>		
Rock debris, felled trees. Do not try to identify the source	<u>Pest Pathogens:</u>		
Please provide detail in Notes	<u>Landslide:</u>		
	<u>Other:</u>		

Notes:

PAGE ____ OF ____

VCSS - 1m2 Frequency and Cover Plots

Site ID	Transect #	Start Date:	Start Time	Finish Time	Botanist	
					Recorder	

Surface codes: BS=bare soil<5mm, GF=gravel, fine (5-20mm) GC=gravel, coarse (2.1-7.5cm) RC=rock cobble (7.6-25.5cm) RS=rock, stone (>25.5cm) L=litter MC=microbiotic crust NV=nonvascular SD=scat, domestic SW=scat, wild WC=woody debris, coarse (>=7.62cm dia,>.91m lgth) WF= woody, fine (>=.62 dia)

Transect Name:	Plot Name:	Plot Area:	Plant Code or Surface:	Cover Percent:	Plot Area:	Plant Code or Surface:	Cover Percent:	Plot Area:	Plant Code or Surface:	Cover Percent:	
Transect 1 - North:	Plot A:										
	Total Cover										
		Plot B:									
Total Cover											
	Plot C:										
Total Cover											
	Plot D:										
Total Cover											

In the nested plot frequency design EACH SPECIES or SURFACE CODE in area 1 is identified and counted. In area 2 ONLY SPECIES NOT in area 1 are counted. Finally in Area 3 ONLY SPECIES NOT in area 1 or 2 are counted.

PAGE ____ OF ____

VCSS 1m2 Cover and Frequency Plots										
Transect Name:	Plot Name:	Plot Area:	Plant Code or Surface:	Cover Percent:	Plot Area:	Plant Code or Surface:	Cover Percent:	Plot Area:	Plant Code or Surface:	Cover Percent:
Transect 2 - S.E.:	Plot A:									
	Total Cover									
	Plot B:									
	Total Cover									
	Plot C:									
	Total Cover									
NOTES:										

Surface codes: BS=bare soil<5mm, GF=gravel, fine (5-20mm) GC=gravel, coarse (2.1-7.5cm) RC=rock cobble (7.6-25.5cm) RS=rock, stone (>25.5cm) L=litter MC=microbiotic crust NV=nonvascular SD=scat, domestic SW=scat, wild WC=woody debris, coarse (>=7.62cm dia,>.91m lgth) WF= woody, fine (>=.62 dia)

In the nested plot frequency design EACH SPECIES or SURFACE CODE in area 1 is identified and counted. In area 2 ONLY SPECIES NOT in area 1 are counted. Finally in Area 3 ONLY SPECIES NOT in area 1 or 2 are counted.

PAGE ____ OF ____

VCSS 1m2 Cover and Frequency Plots

Site ID

Start Date:

Transect 3

Surface codes: BS=bare soil<5mm, GF=gravel, fine (5-20mm) GC=gravel, coarse (2.1-7.5cm) RC=rock cobble (7.6-25.5cm) RS=rock, stone (>25.5cm) L=litter
MC=microbiotic crust NV=nonvascular SD=scat, domestic SW=scat, wild WC=woody debris, coarse (>=7.62cm dia, >.91m lgth) WF= woody, fine (>=.62 dia)

Transect Name:	Plot Name:	Plot Area:	Plant Code or Surface:	Cover Percent:	Plot Area:	Plant Code or Surface:	Cover Percent:	Plot Area:	Plant Code or Surface:	Cover Percent:
Transect 3 - S.W.:	Plot A:									
	Total Cover									
		Plot B:								
Total Cover										
	Plot C:									
Total Cover										

NOTES:

In the nested plot frequency design EACH SPECIES or SURFACE CODE in area 1 is identified and counted. In area 2 ONLY SPECIES NOT in area 1 are counted. Finally in Area 3 ONLY SPECIES NOT in area 1 or 2 are counted.

PAGE ____ OF ____

VCSS Point Intercept

VCSS Point Intercept											
Site ID	Start Date:	Transect	Start Time	Finish Time	Botanist	Recorder					
Meter	Canopy1	Canopy2	Canopy3	Surface	Disturb	Meter	Canopy1	Canopy2	Canopy3	Surface	Disturb
1.0:						18.5:					
1.5:						19.0:					
2.0:						19.5:					
2.5:						20.0:					
3.0:						20.5:					
3.5:						21.0:					
4.0:						21.5:					
4.5:						22.0:					
5.0:						22.5:					
5.5:						23.0:					
6.0:						23.5:					
6.5:						24.0:					
7.0:						24.5:					
7.5:						25.0:					
8.0:						25.5:					
8.5:						26.0:					
9.0:						26.5:					
9.5:						27.0:					
10.0:						27.5:					
10.5:						28.0:					
11.0:						28.5:					
11.5:						29.0:					
12.0:						29.5:					
12.5:						30.0:					
13.0:						30.5:					
13.5:						31.0:					
14.0:						31.5:					
14.5:						32.0:					
15.0:						32.5:					
15.5:						33.0:					
16.0:						33.5:					
16.5:						34.0:					
17.0:						34.5:					
17.5:						35.0:					
18.0:						35.5:					
						36.0:					

Surface codes: BS= bare soil <5mm, GF= gravel, fine (5-20mm) GC= gravel, coarse (2.1-7.5cm) RC= rock cobble (7.6-25.5cm)
 RS= rock, stone (>25.5cm) L= litter MC= microbiotic crust NV= nonvascular PB= plant base SD=s cat, domestic SW= scat, wild
 WC= woody debris, coarse (>=7.62cm dia, >.91m lgth) WF= woody debris, fine (>=.62 dia)

VCSS - Soil Stability

Site ID	Start Date:	Start Time	Finish Time	Collector	
				Recorder	

SOIL STABILITY CLASSIFICATION

Transect Name:	Transect Location	Sample order	Surface Loss	Sub Surf Loss	Veg Type	Notes:
Transect 1 - North:						
Transect 2 - S. E. :						
Transect 3 - S. W.:						

1 = 50% @ 5 Sec 2 = 50% @ 30 Sec 3 = 50% @ 5 Min or <10% remains 4 = 10 - 25% remains 5 = 25-75% remains 6 = 75 - 100% remains

Veg Cover Types:	NC	No cover
	G	Grass or grass/shrub mix
	F	Forb (perennial)
	Sh	Shrub canopy
	T	Tree canopy
	NV	Non-vascular

VCSS Soil Sample Collection

Site ID	Start Date:	Start Time	Finish Time	Collector	
				Recorder	

SOIL SAMPLES

Transect Name:	Volume:	Notes:
Transect 1 - North:	☐ Chem 1	
	☐ Chem 2	
	☐ Chem 3	
	☐ Bulk	
Transect 2 - S. E. :	☐ Chem 1	
	☐ Chem 2	
	☐ Chem 3	
	☐ Bulk	
Transect 3 - S. W.:	☐ Chem 1	
	☐ Chem 2	
	☐ Chem 3	
	☐ Bulk	

Note: 20 cm soil core sample = 60.28 ml

VCSS - Woody Plot Seedling Counts

Site ID	Start Date:	Transect Name	Start Time	Finish Time	Botanist	
					Recorder	

Tally seedlings in smaller 2.07m auxiliary plot (center is 3.66m east of monument)

[illegible]

Seedlings are < 2.54 cm (1 in) DBH/DRC AND > 15 cm tall (conifers) or 30 cm tall (hardwoods)

PAGE ____ OF ____

Appendix 7. Standard Operating Procedures associated with this protocol

SOP VCSS Site Suitability
SOP VCSS Moving and Replacing Sites
SOP VCSS Navigating to Sites
SOP VCSS Site Layout
SOP VCSS Completing Site Description Forms
SOP VCSS Photo Documentation
SOP VCSS Transect Methods
SOP VCSS Plot Methods
SOP VCSS Unknown Plant Species
SOP VCSS Soil Characterization
SOP VCSS Optional Relevé Plot
SOP VCSS Tree/shrub Plots
SOP VCSS Site Disturbance
SOP VCSS Post-Sampling Event Procedures
SOP VCSS Paper Field Forms
SOP VCSS Electronic Field Data Entry
SOP VCSS Basic Analysis
SOP VCSS Design-based Analysis
SOP VCSS Hypothesis Testing



Standard Operating Procedure (SOP): VCSS Site Suitability

Rocky Mountain Network
1201 Oakridge Drive
Suite 200
Fort Collins, CO 80525
970-267-2150

Version: 1.0

Change History

Previous version	Date	Author	Change description	Reason

Introduction

The location of our long-term monitoring sites is determined from a randomized design executed on the target sample frame as defined for each park. Because this selection is made in the office prior to any field visitation, there may be circumstances that cause a design-selected location to be unsuitable for sampling. Upon arrival at a potential sampling site, field crews should use the following guidelines to determine suitability of the location for sampling.

Steps

Evaluate each site to determine that it meets accessibility and suitability requirements as follows:

Accessibility

1. Are there potential safety hazards (e.g., steep slopes $>45^\circ$, crossing railroad tracks, rattlesnake den)?
2. Is there potential interference with sensitive resources (e.g., grave markers, artifacts, identified sensitive areas)?
3. Are there direct obstructions to monument locations and/ or associated sampling equipment at these locations (e.g., rock, water body, river, road, railroad, sensitive resources)?

Suitability

1. Is the site representative? This protocol uses field samples to represent landscape units beyond the footprint of the sample units. If the predefined site is located within a highly localized pattern that is noticeably uncharacteristic of the surrounding plant community type, such as rare or unusual vegetation, unusual abundance of rock and/or bare ground, then consideration should be given to “rejecting” the site for monitoring. This assessment should be used carefully and conservatively; the goal is to allow logical exclusion of target errors but not to systematically bias samples.
2. Do not sample if the site is inundated by water frequently and continuously enough so that the vegetation community is noticeably different from the surrounding upland vegetation communities (i.e., wetland species are dominant at the site). This may result from overlap with wetlands, water bodies and large seeps and springs, which are not included in this protocol. As above, the goal is to allow logical exclusion of target errors but not to systematically bias samples, therefore temporary conditions and small features will not, necessarily, jeopardize site suitability.
3. Do not sample if there is a safety threat or significant interference with park infrastructure and visitor use. For example, if (1) one or more transects crosses a paved road (in the interest of safety) or any heavily used dirt road or trail, or (2) one, or more, of the four monument locations falls in any kind of dirt road, trail, or ditch, the site may not be suitable. It is “OK” for a transect to cross a dirt road, trail or ditch if these are not primary transportation routes, when safety is not an issue, and only minor infrastructure (e.g. trails) are affected, the site may be adjusted, instead of rejected.

When sites are deemed inaccessible and/ or unsuitable, refer to *SOP VCSS Moving and Replacing Sites* rules to relocate the plot.

If these steps do not eliminate the interference with safety or the design, then reject the point as a sample site, *record why* the site was rejected on a Site Description form, and select the next replacement site on the list for the same ecological type you are replacing (i.e., from the list of “oversample sites”).

Resource protection overview

National guidance for sensitivity restricts general public accessibility to geological and geophysical information and data concerning wells; the nature and specific location of (a) endangered, threatened, rare, or commercially valuable species, (b) minerals or paleontological objects, or (c) objects of cultural patrimony; the nature and location of any archaeological resource for which the excavation or removal requires a permit or other permission; or the specific location of any significant caves (FOIA, 2006). Therefore, the protocol will:

1. Contain measures for identifying and flagging sensitive information;
2. In cases where sensitive information is intentionally or unintentionally located in the field, provide a means of collecting data that does not jeopardize the sensitive resources.

ROMN staff and cooperators will often be working in areas with sensitive cultural resources (these include, but are not limited to: bones, fossils, weapons, bullets, tools, human remains, etc.) and less frequently, sensitive natural resources (e.g., rare plant species or sensitive wildlife habitat). If avoiding these resources results in inability to properly sample the site (using above criteria), the site should be rejected and a new site selected (from the oversample list for that ecological type).

In cases where sensitive resources are near the edge of a site, or when simple movement of the plot will eliminate any potential effects on the resource, use the described method for relocating sites (see *SOP VCSS Moving and Replacing Sites*).

Under no circumstances should you convey the location of sensitive objects to anyone besides official NPS staff. Under no circumstances should you manipulate, move, or otherwise alter sensitive cultural resources.

Natural

Crew members need to be aware of the locations and identification of rare and/or protected species because monitoring sites may intersect with a known population of species of concern. Additionally, crew members should be able to recognize rare species if they discover individual(s) at a site being sampled. In all cases, when details of the location of these species are known, that information should not be shared with the public.

Wilderness management principles, including within *de facto* Wilderness, include important mandates guiding activities within large portions of GLAC and ROMO. Use of some mechanized equipment is restricted in these areas. ROMN monitoring protocols are designed to support compliance with Wilderness management regulations; in all cases, when working within Wilderness, motorized access is restricted and minimum necessary tools are mandatory.

Cultural / Archeological

Sensitive cultural resources abound within network parks, and ROMN field staffs have a critical responsibility to protect these resources and avoid unnecessary impacts due to monitoring activities within parks. Examples of such artifacts include *anything* battle related at LIBI, peel-trees at GRSA and FLFO, rocks on the sand-sheet at GRSA, historic ranching/ homesteading artifacts at GRKO, FLFO, GLAC, and ROMO, and other historic sites, including scientific sites at FLFO, ROMO, and GLAC.

Paleologic

Similarly, sensitive paleologic resources are widely distributed across network parks, and ROMN field staffs have a critical responsibility to protect these resources and avoid unnecessary impacts due to monitoring activities within the parks. This is particularly notable at FLFO, where petrified remains are widespread and part of the core purpose of the Monument. However, archeological sites are known to exist in all parks within the ROMN, and as with cultural resources, natural resource monitoring activities should never impact these sites.

Reporting finds: In cases where an important or very sensitive natural, cultural, or paleologic resource has been discovered, record the location with a waypoint in the GPS, take photographs, and take notes about the object(s) and location of the discovery. Report this information to the park unit staff.

Literature cited

U.S. Department of the Interior. 2006. Freedom of Information Act Program, US Department of the Interior [<http://www.doi.gov/foia/>], November 2006.



Standard Operating Procedure (SOP): VCSS Moving and Replacing Sites

Rocky Mountain Network
1201 Oakridge Drive
Suite 200
Fort Collins, CO 80525
970-267-2150

Version: 1.0

Change History

Previous version	Date	Author	Change description	Reason

Introduction

When a site is first visited, it must be evaluated for accessibility and suitability; criteria are provided in *SOP VCSS Site Suitability*. When there is an “obstruction,” use the following rules to relocate the plot. If these steps do not eliminate the interference with safety or the design, then reject the point as a sample site, *record why* the site was rejected on a Site Description form, and select the next replacement site from the list of “oversample sites.” In order to maintain the designed sampling intensity in each season, and across the panel, when a site is rejected (or removed) it should be replaced with another site from the original sample design. ***Skipping sites or selectively placing a new site is not allowed.***

Steps

Steps to Move Site

1. Move the center monument 10m along the 120° azimuth; if this does not eliminate the problem, move to 20m then 30m along the 120° azimuth line.
2. If moving in a 120° azimuth direction does not remove the interference, then move 10m from the original location along the 240° azimuth; if this does not eliminate the problem, move to 20m then 30m along the 240° azimuth line.
3. If moving in a 240° azimuth direction does not remove the interference, then move 10m from the original location along the 0° azimuth; if this does not eliminate the problem, move to 20m then 30m along the 0° azimuth line.

If none of these solutions work, then reject the point as a sample site and follow the steps outlined below.

Steps to Replace Site

1. Complete a Site Description form clearly noting site as “Rejected.”
2. Locate the site list and map.
3. Select the next site on the over-sample list and add it to the visit schedule for this panel.



Standard Operating Procedure (SOP): VCSS Navigating to Sites

Rocky Mountain Network
1201 Oakridge Drive
Suite 200
Fort Collins, CO 80525
970-267-2150

Version: 1.0

Change History

Previous version	Date	Author	Change description	Reason

Introduction

It is important for efficiency and safety to plan approach to site prior to the day you are setting out to sample. This is especially important if arrangements need to be made for access (e.g., acquiring gate key) or use of a vehicle or gear. This preparation may include identifying multiple egress routes, closest hospitals/clinics, and rendezvous points if someone gets separated from the group. Site coordinates for each site should be uploaded to the GPS units at the beginning of the season using most recent coordinates to aid navigation.

Steps

Equipment

- GPS with appropriate points uploaded
- Maps and/ or aerial photography
- Compass

Procedures

Navigation to a study site

Consult the maps; determine appropriate modes of travel (e.g., vehicle to trailhead, walk to site). Select the target site identifier (e.g., LIBI.G002 for VCSS site #2 at Little Bighorn Battlefield). Navigate roads and trails consulting the map and GPS as needed to confirm proper direction of travel. When leaving the vehicle, mark the location (waypoint) in the GPS if this is not clearly known based on other landmarks. Select map or compare view (your preference) to determine the appropriate direction for travel; consult your compass to know your direction of travel. Navigate to the site using GPS, compass, maps and photos repeatedly as needed. Finish with GPS unit to get as close as possible to the center monument. Be conscientious about minimizing trampling when approaching the center. Try to walk in from the south, where no sampling is done; only one person should walk in the immediate vicinity of where plot center is believed to be; store gear and packs in an area away from transects and plot center, keeping in mind there is a plot seven meters NE of plot center. If you do not immediately find the monument, mark the spot, move away from the area and re-approach using the GPS again to guide you to a new center location; mark and repeat until a clear target area is identified. Use photos, hands, boots, a metal detector or other tools to locate the monument.

Navigation to the point is best accomplished by using the GPS unit with hard-copy maps (e.g., USGS 1:24,000-scale topographic maps and/or local unit maps showing the location of the monitoring sites) or aerial photos (or similar). Never depend solely on the accuracy and indications of the GPS unit, use your brain to incorporate useful local context (e.g., location of access roads, field or sub-unit boundaries and identifiers, watercourses, hazards, etc.); pay attention and know where you are.

For additional information regarding how to operate the GPS unit, refer to the *SOP DM Using the Garmin GPS 76CSx* (NPS 2007).



Standard Operating Procedure (SOP): VCSS Site Layout

Rocky Mountain Network
1201 Oakridge Drive
Suite 200
Fort Collins, CO 80525
970-267-2150

Version: 1.0

Status: In review (April 2009)

Change History

Previous version	Date	Author	Change description	Reason

Introduction

The layout of the response design a modified version of the US Forest Service's Forest Inventory and Analysis program's "spoke-wheel" pattern; three transects extend 36.6 m (at 0°, 120°, and 240° true azimuths, respectively) from a center monument. The ends of each transect are accompanied by a series of nested plots used for sampling additional vegetation and soil conditions. The end point of each transect is a reference point for locating the plots. The plot center and transect end points are marked with pieces of rebar topped with aluminum caps.

Equipment

- GPS – (mapping grade preferred, post-processing correction accepted) with appropriate points uploaded
- Site photographs to aid relocation of site center and transects
- Tapes – 50 m (3)
- Metal stakes (3/8 in, 1 ft long rebar; **4 per site**)
- Aluminum survey caps (2 in diam. holds ~55 char/spaces and protects tip; **4 per site**)
- Die set for marking caps
- Compass
- Hammer / sledge hammer
- Cloth or other covering for protecting caps when pounding them over rebar
- Chaining pins (4-6)
- Clips/clamps to fasten tapes at once looped through chaining pins
- Rope (something non-stretchy) with a knot or similar marker at lengths appropriate for locating and delineating plots (3.66m – distance to sub-plot center from monument, 5m – to 1m² plot corner, 5.73m – this is 2.07m radius from woody sub-plot center at 3.66m, and 7.32 m – the distance to locate Plot D and radius of woody plot)
- 3-4 colored stakes or pin flags to help identify the plot locations and layout transects (more is better, multiple colors preferred)
- Large steel nails to help identify the plot locations (**10 per site**) – in parks where this approved
- Temporary 1 m² plot frame (constructed from 0.5 in diameter PVC pipe or wood and marked with 10 cm intervals along each edge).

Steps

Transects

1. Once the center of the site is located (from uploaded GPS points), first lay out Transect 1. Insert chaining pin or anchor into the ground at site center, fasten the end of one of the 50-m measuring tapes to the eye-loop, and carefully (with minimal trampling) stretch the tape along the 0° azimuth (corrected from magnetic north using known declination when using a compass) to the 36.6 meter mark. If establishing a new site, you will need to

install a stake and monument at this point (use two compasses and back-sighting to locate the correct end point*) (see Marking Plots). If revisiting a site, carefully search the proximity for the second buried monument, 36.6 m north of the center. Previous years' photos, notes, and a metal detector can aid this relocation process.

2. Once the second monument is found or installed, insert another eye-loop stake in the ground just north (0° azimuth) of the monument, and thread the tape through the eye and secure it with a clamp.
3. Following the techniques listed in Steps 1 and 2, lay out Transect 2 along a 120° azimuth and Transect 3 using a 240° bearing.
4. Secure the ends of the tapes so they are tight and straight along the 0° , 120° , and 240° azimuth lines using eye-loop stakes and a strong clip at each end. The tape should lay flat on the ground as much as possible, following the local topography. For the "active" transect, use compass backsighting and a third person to secure 2 midpoints (at 11m and 21m marks) in the tape to avoid shifting due to wind or technician movements; increase the number of securing stakes if conditions require them to insure that the tape remains stretched tightly and precisely along the proper azimuth.

* The back-sighting technique is accomplished by two people, each with a compass at opposites ends of a transect; the person with the tape at the outside end of the transect shifts until the tape is aligned with the appropriate azimuth for that transect (0° , 120° , or 240°); the person at the center does not move from his/her fixed location and helps direct the person laying out the tape and verifies the correct azimuth.

Plots

1. Plots are each 1 m^2 and radiate out 5 m from the endpoint of each transect (at 36.6 m) in the same configuration as the transects radiate out from the center point. Plot A is always 0° , Plot B 120° , and Plot C 240° from the transect endpoints. In addition to these nine- 1 m^2 plots, a tenth plot (Plot D) is located 7.32 m, 60° from plot center. Include Plot D's data with the plot data collected on Transect 1.
2. To locate each plot, take a bearing from the transect endpoint and stretch out a 5-m cable/rope (non-elastic, low stretch is essential) or meter tape tied to a nail that you can anchor in the ground. This marks the distance and bearing to the lower left corner of the plot (facing away from transect endpoint). Use another nail to permanently mark this location (if approved). If revisiting an established plot, use location, photos, and metal detector to relocate the plot.
3. Place assembled plot frame on the ground. Carefully align the frame so that the left edge (as you face away from the transect endpoint) would overlap the 5-m wire if it was extended another meter. Secure the outer-right corner with a nail or pin flag to help prevent the plot from shifting. Sampling of this plot normally occurs at this time.
4. After sampling Plot A, continue to locate and sample Plots B, C, (and D if working on Transect 1).
5. Additional plots in woody habitats (e.g., the Woody Plot or Buffer Plot – see Figure 1 and Field Methods) are circular; they are delineated using a wire/rope or tape marked precisely at the correct radius (e.g., 7.32 and 2.07 m) for the circular plot to be scribed.

6. Anchor the wire at the appropriate center point.
7. At the larger plots, pull the line taught and periodically (every 3-10 m depending on visibility) mark the perimeter of the plot using pin flags or similar marking flags.
8. Sample plots and transects according to the specified procedures.

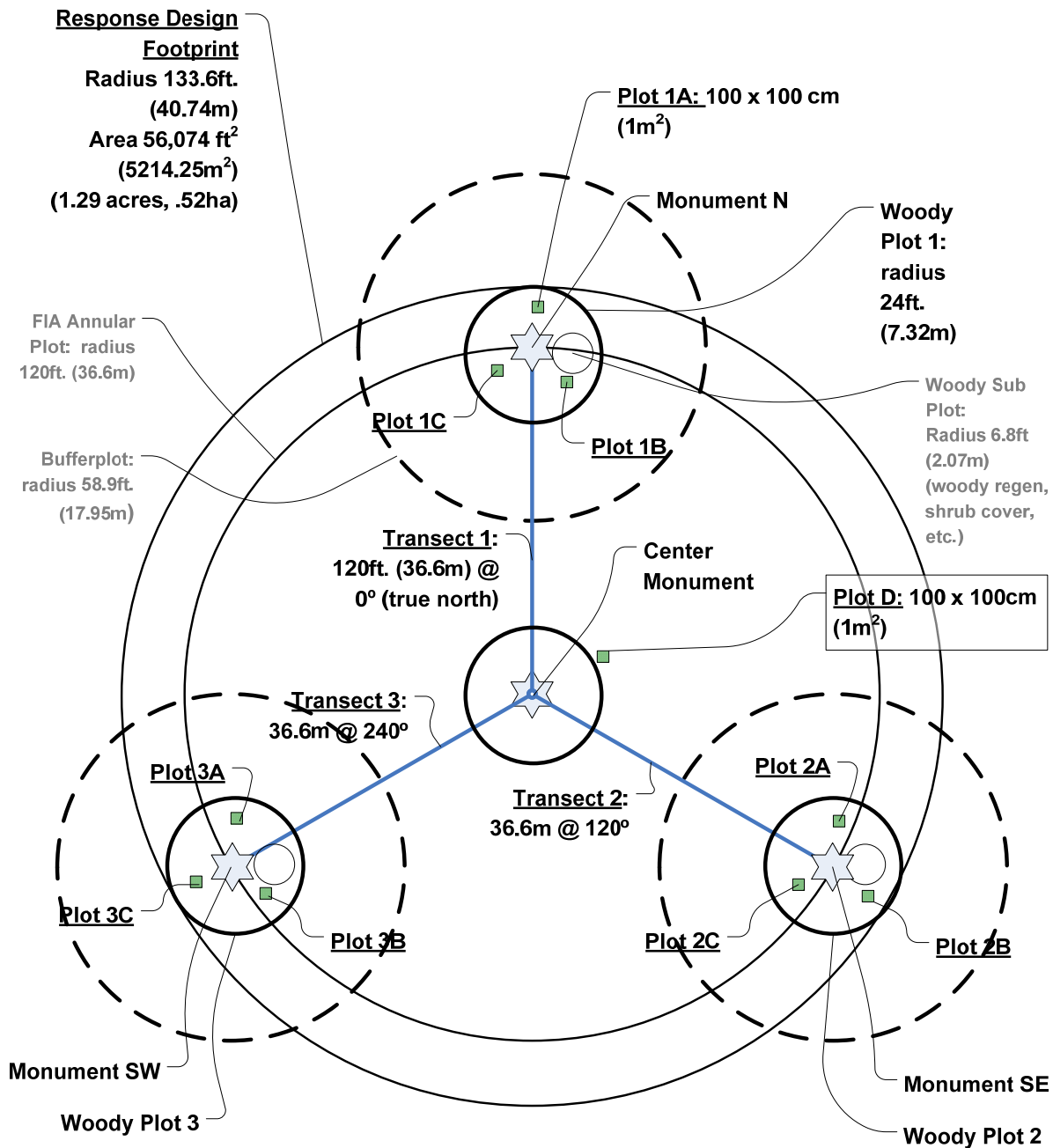


Figure 1. Schematic of the ROMN VCSS site layout.

Marking Sites

Markers

ROMN VCSS site markers are a set of four, 3/8 in. x 12 in. to 24 in. metal stakes (e.g., precut sections of 3/8 in rebar) driven into the ground to surface level at plot center and at transect ends. The stake is fitted with an aluminum cap labeled:

NPS ROMN I&M VEG

Monitor Site

G.####
(site code)

Est.20XX
Do Not Disturb

(where G.#### is an alpha-numeric site code corresponding to the original design and database files). The stake/cap should not protrude from the surface, and may be slightly buried to conceal it. A metal detector is useful to aid relocation of monuments. The three outer stakes are spatially distributed 36.6 m (120 ft) from the center and are critical for correctly re-locating precise transect and plot locations.

Purchase caps or stakes with identifying information pre-stamped, if possible (*see below for current vendor). Alternately, using a die-set, add identifying information to 4 caps per site to receive monuments.

Marking transects

1. Find the location of the central monument (the UTM coordinates in the GPS); to locate the outer end-points of each transect, refer to the layout design procedures and Figure 1. Repeat steps 2-7 for each end point.
2. Drive the metal stake into the ground at the precise monument location. The top of the stake should be just below (2 cm) below the surface.
3. Use the die set to add site information to the aluminum cap (this may be done prior to the field visit when target sites have been confirmed in advance – i.e., don't mark the site number if that site might be rejected).
4. Mark the cap as follows (complete the year with current year, replace the #### with the alpha numeric site code and the “-#” with a site level code corresponding with location in the design; “C” for center, “T1” for north, “T2” for SE, and “T3” for SW transect end points):
5. Attach the cap to the stake (use a hammer with some sort of covering to protect the surface of the cap; insure that it is securely attached).
6. Verify that each stake (with cap) does not extend above the normal, soil surface. If it protrudes, remove the cap and sink the stake ~2 cm deeper.
7. Collect a GPS location for the new mark by calculating an average of at least 30 points.

Marking plots:

To locate the 1m² plots, refer to the layout design procedures and Figure 1.

1. Pound one 6-10” metal nail into the ground, slightly below the soil surface, to mark each plot *if approved through individual park compliance*.
2. After entire site-layout and marking is complete, collect site photos (*SOP VCSS Photo Documentation*).

*aluminum cap vendor used as of 2010: Stakemill, www.stakemill.com, 6060 126th Ave N Largo, FL 33773, Phone (727) 538-0886, Fax (727) 538-2046; \$3.65 each.

Literature cited

U.S.D.A. 2005. Volume I: Field Data Collection Procedures for Phase 2 Plots. Forest Inventory and Analysis, National Core Field Guide, version 3.0. U.S. Department of Agriculture, Forest Service. 208pp.



Standard Operating Procedure (SOP): VCSS Completing *Site Description* Forms

Rocky Mountain Network
1201 Oakridge Drive
Suite 200
Fort Collins, CO 80525
970-267-2150

Version: 1.0

Change History

Previous version	Date	Author	Change description	Reason

Introduction

This SOP provides instructions for completing electronic and paper versions of the Site Description form. This SOP is most critical for gathering baseline information when first establishing a site; it also includes general instructions and forms for documenting site information during scheduled return visits. The SOP VCSS Completing Site Description Form was adopted with modifications from USDA-ARS “Monitoring Manual for grassland, shrubland and savannah ecosystems” (Herrick et al. 2005).

Every time a visit is made to a VCSS site, a Site Description form should be completed to clearly define (using UTM coordinates) and describe (e.g., general topography, hydrology, and ecology) the location of that site (Appendix 1). If using a field computer rather than paper forms, this information will be recorded once at the site installation in the Sample Site Description form and subsequently on the Site Visit Event form. If using paper forms, a Site Description form is used at every sample event. Crews should carry a copy of previous Site Description form/ Site Visit Event Information form (if applicable), and the most recent photos of the site with them to each site visited.

Additional information recorded on the Site Description (paper) or Site Visit Event Information (electronic) form includes the description travel route(s) to the site, the general location of the site, and descriptions of the locations of the four monuments. Record additions and changes to descriptions from previous visits on this year’s site description form (and record the file IDs for the photographs associated with it, see below). Record site level assessments of soil surface conditions based on evidence of surface movement of water on the Site Description form. Semi-quantitative categories for characterization of evidence of sheet flows, pedestal and rill formations are used to indicate lack of infiltration and presence of the potentially degrading force of water on the surface (Pyke et al. 2002). Detailed instructions on completing all fields are included in this SOP.

Steps

Completing sample Site Description when establishing new sites

The following descriptors assume that the data recorder will be using the ROMN VCSS Access database.

LocationID, SiteID, ParkCode, and Date Created: These fields should be automatically populated. If not, enter SiteID using the format XXXX.G-000, where Xs are the 4-letter park code (e.g., GRKO, LIBI, GRSA, ROMA, GLAC, FLFO) and 0s are the site number (from GPS waypoint). Don’t worry about LocationID.

Description: Enter the location of the transect and directions for locating the starting Monument for the transect.

SiteEstablishedBy: Enter the name of the person who decided on site location.

StartUTMX, StartUTMY, UtmZone and Datum: These fields should be automatically populated. If not, enter UTM coordinates and associated data for center monument of site from GPS unit.

EstHError: Enter error from GPS unit (measure of horizontal accuracy of averaged points taken).

Aspect: For each transect end, enter aspect (azimuth) from center of site.

Slope: Enter slope (percent) from center of site.

AccNotes: Enter notes about how positional (horizontal) accuracy was calculated.

TopoPosition: Choose from drop-down list.

HydrologicDescription: Choose from drop-down list for this field when using the database or from the paper copy list provided as a field aid.

CommunityType: Choose from drop-down list for this field when using the database or from the paper copy list provided as a field aid.

Dominant vegetation: List three most common species at site

Notes: Enter any additional comments about this sampling location.

*If using paper forms, enter the above data on the **Site Description** form. Some of the fields requiring additional instructions are:*

Topographic Position: see Appendix 2 for descriptions

Hydrologic Environment: see Appendix 2 for descriptions

Monument Area Description: record any distinguishing features in the area that might aid in relocation

Site Erosion Indicators (soil surface condition): see Appendix 3 for descriptions

Completing electronic field data (Site Visit Event) form

Use the **Site Visit Event** form at sites that have been previously installed and for which electronic **Site Description** forms have already been completed.

Location ID: Choose from drop-down list

SiteID, Start Date, StartTime: These fields should be automatically populated. If not, enter data. Use format for SiteID as described in #1 for completing Location form.

Weather: Enter general description of current weather conditions; may want to note any recent precipitation

Overview Photo: Enter photo number from camera for overview shot

Center Point Photo: Enter photo number from camera photo of center monument

Monuments: Enter any descriptive features surrounding monuments that might aid in relocation

Notes: Enter any general comments about site

Transect Name: Choose from drop-down list (Transect 1=N, T2=SE, and T3=SW); **SAVE** at this point (checkmark in bottom-left corner of page)

StartTime: This field should be automatically populated

Botanist: Choose name of person determining species names along transects from drop-down list

Recorder: Choose name of person documenting data from drop-down list

Notes: Enter any general comments regarding transects

SurfaceFlow: This is the first of three fields that describe the soil condition at the site. The purpose is to evaluate and monitor susceptibility to erosion. **Error! Reference source not found.** 3 provides descriptions of each classification Choose surface condition class from drop-down list for this field when using the database or from the paper copy list provided as a field aid

RillsGullies: Choose surface condition class from drop-down list for this field when using the database or from the paper copy list provided as a field aid

Pedestals: Choose surface condition class from drop-down list for this field when using the database or from the paper copy list provided as a field aid

*If using paper forms, these fields are included on the **Site Description** form.*

Literature cited

Herrick, J.E., J.W. Van Zee, K.M. Havstad, L.M Burkett and W.G. Whitford. 2005. Monitoring Manual for Grassland, Shrubland and Savanna Ecosystems. USDA-ARS Jornada Experimental Range, Las Cruces, New Mexico and University of Arizona Press, Tucson, Arizona. 2 vol., 236pp. available online at <http://usda-ars.nmsu.edu/>

Pyke, D.A., J.E. Herrick, P.L Shaver, and M. Pellant. 2002. Rangeland health attributes and indicators for qualitative assessment. Journal of Range Management 55: 584-597.

Appendix 1. Sample Site Description paper field form

Reviewed (initials):	Review Date:	Data entry initials:	Entry Date:
----------------------	--------------	----------------------	-------------

Vegetation Composition and Soil Structure - Site Description

Site ID:

Start Date:

Start Time:

Finish Time:

Weather:

Camera Name:

GPS Name:

Aspect : ☐ N, ☐ NE, ☐ E, ☐ SE, ☐ S, ☐ SW, ☐ W, ☐ NW

Slope: ☐ 0, ☐ 5, ☐ 10, ☐ 15, ☐ 20, ☐ 25, ☐ 30, ☐ 35, ☐ 40, ☐ 45

Topographic Position (Check One)

Level: ☐	Crest: ☐
Lower Slope: ☐	Ledge: ☐
Midslope: ☐	Depression: ☐
Upper Slope: ☐	Streambed: ☐

Hydrologic Environment (Check One)

Perm Flood: ☐	Inter Flood: ☐
Semi Perm Flood: ☐	Seep: ☐
Temp Flood: ☐	Upland: ☐

Range of photo #s

Site Description:

Central Point UTM Coordinates (NAD83)

Easting:	
Northing:	
UTM Zone:	
Error:	

Monument Area Description

Central:	
North:	
South East:	
South West:	

Overview Point UTM Coordinates (NAD83)

Easting:	
Northing:	
UTM Zone:	
Error:	

Site Erosion Indicators

Surface Flow: ☐	NB=None to Slight
Rills and Gullies: ☐	SM=Slight to Moderate
Pedestals: ☐	MM=Moderate
	MX=Moderate To Extreme
	XX=Extreme

Ecological Site Desc. (Name 1-3 dominant species):

Woodland:			
Shrub-Herb:			
Grass-Forb:			
Other (specify):			

PAGE ____ OF ____

Appendix 2. Topographic position, surface type, and hydrologic environment descriptions

Topographic position:

- Level (no slope)
- Lower-slope (at/near the base of a hill, gully, etc.)
- Midslope (in the middle section of a hill, gully, etc.)
- Upper-slope (the top of the hill on or near the shoulder/ridge)
- Crest (the top of a ridge, hill or mountain; a saddle between two drainages)
- Ledge (a nearly level shelf or terrace in the midst of a steep slope or cliff face)
- Depression (bottom surface of a “closed” basin)
- Streambed (bed of a single or braided watercourse or intermittent wash or drainage; water not currently flowing)

Hydrologic environment:

- Permanently flooded (water covers the surface in all seasons, all years)
- Semi-permanently flooded (water persists throughout the growing season)
- Seasonally/temporarily flooded (surface water present for extended periods, but absent by the end of the growing season, very variable water table)
- Intermittently flooded (surface water during times of high precipitation and associated run-off; generally dry)
- Seep (intermittent, seasonal, or permanent flow of water from a subterranean source)
- Upland (the plot cannot be characterized as a wetland; water table is almost always well below the surface)

Appendix 3. Classes for characterization of soil surface conditions using site soil erosion indicators

Degree of Degradation	Surface Flow Evidence	Rills and Gullies	Pedestals and Terracettes
	Erosion caused by overland flow, i.e., as water moves across the soil surface. Evidenced by litter, soil or gravel redistribution along flow-paths, especially small debris piles. Wind-scoured areas (may create blowouts) are recognized by removal of finer particles of the topsoil, sometimes leaving gravel, rock, or exposed roots on the surface. Deposition areas are often associated with vegetation or topographic relief.	Rills are small eroded rivulets that are generally linear and do not necessarily follow microtopography. A gully is a channel that has been cut into the soil by moving water; they generally follow natural drainage patterns. Gullies and rills are a natural component of many landscapes, but excessive grazing, vehicles or road drainages may cause excessive formation or expansion	Pedestals are rocks or plants that appear elevated because of soil loss from wind or water erosion around them (also by frost heaving or soil/litter deposition). Terracettes are small benches of deposited soil behind obstacles. Both are important indicators of movement of soil by water and/or wind. Terracettes caused by livestock or wildlife movements, e.g., across hillsides, are not considered erosion, so they should not be considered here.
Extreme (XX)	Extensive with active erosion and unstable soils (water and/ or wind caused); connections between flow paths lead to wide area affected	Rill formation is severe, well defined, and widespread. Gullies, when present, are actively down-cutting without vegetation to stabilize slopes and bed.	Many rocks and/ or plants pedestalled; exposed plant roots are common. Abundant across the area.
Moderate to Extreme (MX)	Cut/ eroded and depositional areas are common; occasionally connected.	Rill formation is moderate but active and well defined throughout most of the area.	Some rocks and plants with occasionally exposed roots; not ubiquitous across the area.
Moderate (MM)	Erosion is minor with some evidence of erosion and deposition, but not widespread across large areas.	Some intermittent rill formation, not widespread, but in the most exposed areas only.	Some pedestals, but only in major flow paths and exposed slopes; occasional terracettes.
Slight to Moderate (SM)	Flow patterns are stable and short; minor erosion evidence only (few and infrequent).	No recent formation of rills. Gullies, if present, are stabilized by vegetation on slopes and in the bed. (Older features have rounded or muted edges.)	Some evidence of past pedestals in flow patterns, but recent pedestals and terracettes are rare.
None to Slight (NS)	Minimal evidence of current or past soil movement.	No current rill formation. Drainages are natural, stable channels.	Little to no evidence of pedestals or terracettes. (Uncommon or absent)



Standard Operating Procedure (SOP): VCSS Photo Documentation

Rocky Mountain Network
1201 Oakridge Drive
Suite 200
Fort Collins, CO 80525
970-267-2150

Version: 1.0

Change History

Previous version	Date	Author	Change description	Reason

Introduction

Photography is incorporated within these protocols for several reasons, including communicating information and facilitating site relocation. Photo points are identified by the name or code designation of the site-transect-plot combination that they represent (e.g., GRKO -Transect 1-Plot B). Photographs will become part of the permanent records for the site.

Steps

Equipment

- Digital camera (with rotating lens and/or screen for overhead shots)
- White-board (with markers)
- Folding meter stick
- Photo log

Procedures for all photographs

1. Before taking photos at a site, be sure to collect GPS waypoints of the center monument location; and **record** one close-up image (photo) of the GPS unit with date and time on the screen. This is done to enable GPS-photo linking.
2. Use a white-board placed within the foreground of the image to **record** park, site, and sample unit information within the image (see details below). *Carefully align the board to minimize glare and reflection (e.g., angle slightly downward).*
3. Do **not** use the automatic date/time stamp feature on the camera. Date and time data are embedded in the exif data area by most digital cameras. If the image is being cataloged and documented, it has value – imprinting the image reduces the image quality and hence the image value. The exception may be for projects collecting massive numbers of photos – imprinted dates and time could facilitate data linking.
4. Set camera to the highest resolution and “uncompressed” (“tif” or “raw”) format; be sure the camera memory can still hold 30-40 images (allows working two sites between downloads). The resolution/ size trade-off can be manipulated if working in the backcountry and memory space is an issue. It is best to decrease the resolution for web use or thumbnails in the office using software, rather than in the field. Publication quality photos will be taken at a minimum of 4 megapixels. If the camera will allow, the resolution will be set at 1760 x 1168 or higher. The quality will be set for “super fine” or “high.”
5. Unless specified otherwise, all photographs will be in *landscape format* (wider than tall).
6. Ideally, *no more than ¼ (25%) of the photo should be sky*, and no more than ¼ (25%) of the photo should be obstructed (e.g., by nearby trees, rock outcrops, etc.); however, this may not be possible in all circumstances.
7. Set the view (zoom) on the camera to the widest angle.
8. **Record** the image number (i.e., camera code) along with the site and sample unit information in the database (if applicable) and into the photo log.

9. **Download** photos after completion of each site, or as soon as possible when working away from the necessary equipment (e.g., in the backcountry). After file download is confirmed, delete the files from the camera.
10. Any time the camera battery needs to be replaced, check to make sure the time and date are set correctly.

Site overview

The site overview photo should be taken from the same location for each visitation event (this location must be established in the first year/plot establishment phase). The overview photo is the first photo taken at the site and must be taken *after* all of the transects are in place. If possible, the picture should capture the entire site (length of all transects) and utilize distinct and permanent landmarks in the landscape that provide orientation (e.g., mountain peak). Additional photographs may be needed to illustrate ecological context of the location. A description of the photo location and the UTM coordinates of this location should be **recorded** on the Site Description form and marked in the GPS. When collecting a waypoint, average at least 30 points, which provides a better estimate of location. When capturing the picture, hold the camera approximately 1.5 m above the ground surface (remember a maximum of $\frac{1}{4}$ sky); **record** the site/date information on the white board, e.g.,

GRKO-00##
“Overview”
YYYY MM DD

A second person should hold the white-board in the near foreground, about 5 m away, and angled away from the sun. **Record** 1-2 images of each transect and its surroundings (only make duplicates if weather, light, exposure or similar conditions require a second attempt).

Center Monument

The photograph of the center monument is taken immediately following the site overview photo and should be captured by standing approximately 2 m south of the monument, looking north at the monument. In cases where vegetation and/or terrain preclude this position, the precise location used should be clearly described and documented (2 m directly E or W of the monument is preferred). This photo should show the exposed monument (when possible) positioned in the center, and as much of the surrounding area as is possible based on the capabilities of the camera. Include the white-board in the photo, as described above (substitute “Center” for “Overview”).

Transects

Transect photos can be collected immediately, in succession, after the overview and monument photos (whereas, plot photos must be collected as the plots are sampled). For each transect, after precisely locating the measuring tapes:

1. Move to the 1m mark (away from the monument at the origin) and face away from the center monument.
2. Hold the camera approximately 1.5 m above the ground surface (remember a maximum of $\frac{1}{4}$ sky).

3. **Write** the site/transect/date information on the white board, e.g.,

GRKO-00##
Trans #
YYYY MM DD

4. A second person should hold the white-board in the near foreground, about 5 m away (6 m mark on the tape), and angle away from the sun.
5. Take a photo; (**record** 1-2 images of each transect and its surroundings; only make duplicates if weather, light, exposure or similar conditions require a second attempt).

Plots

Each plot (a total of 10) will require its own photograph to be taken after the plot is set up, but before taking measurements. Details of these methods are discussed in the Plot (quadrat) sampling procedures (*SOP VCSS Plot Methods*). Each plot photo should be labeled using the white-board as specified above (but, place the board on the ground at the edge of the plot).

GRKO-00##
Tr. # Plot #
YYYY MM DD

Photo processing

All pictures from the camera should be downloaded to the specified folder adding a new folder with the upload date.

1. Downloading the camera is similar to connecting any USB based peripheral. Connect the wires; turn the camera on; look for the camera using the Windows Explorer tool on the computer.
2. Locate the photo files and copy all of them.
3. Create a destination folder (\\VCSS200XX\\Data\\Photos\\YYYYMMDD) where YYYYMMDD represents the date of uploading.
4. Paste the files into the new folder. This folder and contents should be immediately **set to read-only**.
5. Before removing the photographs from the camera, it is important to confirm that all photos have been copied and are uncorrupted. If there's a problem, delete from the computer and re-copy. Once working files are confirmed, delete all photos from the camera.

National Park Service
U.S. Department of the Interior



Rocky Mountain Network
Inventory and Monitoring Program

Standard Operating Procedure (SOP): VCSS Transect Methods

Rocky Mountain Network
1201 Oakridge Drive
Suite 200
Fort Collins, CO 80525
970-267-2150

Version: 1.0

Change History

Previous version	Date	Author	Change description	Reason

Introduction

Monitoring plant species composition and cover is fundamental to understanding changes in grassland, shrubland, and woodland ecosystems. Cover measurements recognize the contribution of small species, are directly related to the biomass of most plant functional types, and “are easily visualized and intuitive” (Elzinga, Salzer and Willoughby 1998, p. 178). Moreover, cover measurements correlate with ecological processes (such as microbial composition and abundance, nutrient cycling, and productivity). Finally, estimating cover remains one of the most common methods in vegetation studies allowing for comparisons between our work and other national and local inventories.

As part of this protocol, cover data are collected along transects using the point-intercept method. This method is used because 1) the point–intercept method may be one of the more accurate ways to estimate cover of finer leaved species such as graminoids (Elzinga, Salzer, Willoughby, and Gibbs 2001) and 2) if executed properly, the point-intercept method could be more objective than ocular estimates of canopy cover (Bonham 1989).

Steps

Equipment

- 2-3 50-m measuring tapes
- Minimum of 5 steel pins with eye-loops (chaining pins) to secure tapes
- Meter stick (for auxiliary measures, and orientation along/under transect)
- “Sampling pin;” a 1-m long rolled steel or brass rod, 2-mm in diameter
- Sand, gravel, cobble gauge (or small measurement caliper)
- Clipboard, pens, pencils, data forms, Rite-in-the-rain backup for field sheets and notes
- “PDA” computer or Toughbook with Access database for Shrub-grassland data; and back-up batteries (optional)
- Paper field forms (Appendix 1)
- Digital camera
- Park plant species list and local field guides for identification of plant species
- Local (park specific) list of plant species and invasive species of concern (based on list of known species occurrences and lists of potential invaders from state, county, tribal, and other agency records) (attached separately).

Point-intercept method

Two people should collect the point-intercept data: one who reads the points, calling out the species, and one who records the data (if using a field computer, the recorder should double check that the correct transect number is selected on the database form prior to the start of the data collection process).

1. Go to the 1-m mark on the meter tape that is laid for the first transect that you are going to sample (assuming 0 cm is at the central monument). Starting to sample at one meter

away from the center avoids sampling too close to the central monument, which can be heavily used and trampled.

2. "Drop" the sampling pin vertically from a height of .5m at the 1-m mark on the tightly stretched tape. Do not guide the pin. It is more important that the pin fall freely than to be exactly at the 1-m mark on the tape to insure an unbiased estimate.
3. Record the *species* of the first leaf, stem, or plant part *intersecting* the vertically dropped pin as "Top canopy." Consider vegetation up to 2 meters in height. If the vegetation is taller than the sampling pin, try dropping the pin at the sampling point, then place your hand toward the top of the pin and slide the rod up (without looking up) until the pin intercepts the tall vegetation.
4. If the pin does not intercept any vegetation, enter "no veg" on the datasheet and proceed to describing the ground cover.
5. Continue on to record all additional species intercepted by the pin (working from top canopy, downward).
 - a. Live or dead, document each species/individual only once even if the pin intercepts it multiple times.
 - b. If the pin intercepts a senescent blade or branch of an individual that is still attached to the plant, this is recorded as any other live plant.
 - c. If the pin intercepts a senescent blade or branch of an individual that is *not* attached to a live plant, it is litter. Litter is defined as "detached dead stems and leaves that are part of a layer that comes in contact with the ground" (Herrick et al. 2005).
 - d. If the pin intercepts a senescent blade or branch of an individual that is completely senesced, but still supporting itself, this is categorized as "standing dead" on the form. Document the species, if identifiable.
 - e. If the pin intersects wood of a diameter >0.62 cm, this is classified as fine woody debris (rather than litter). Wood with a diameter >7.6 cm in diameter is classified as coarse woody debris.
6. Record the substrate type from table in Appendix 2 (bare soil, litter, scat, etc.) for what the pin hits on the ground surface. Record species name if this is a base of a plant.
7. Describe any disturbance to the ground where the sampling pin lands (e.g., rodent activity, footprints).
8. Move precisely 50 cm up the tape and repeat steps 3 - 6 until you reach the 36-m mark.

Transect Invasives

1. After completing the point-intercept sampling of each transect, walk along the full length of the transect, considering the 1/3 of the site represented by the transect, in search of any exotic species that did not get documented in the earlier point-intercept sampling. (Note: this is a wedge-shaped 1700m area, 85m wide at the perimeter)
2. Record species name, abundance, and observer confidence in identification on the Transect Invasives form as found in Appendix 3.

Literature Cited

- Bonham, C.D. 1989. Measurements for terrestrial vegetation. John Wiley and Sons, Inc. New York, New York. 338pp.
- Elzinga, C.L., D. W. Salzer, J.W. Willoughby, and J.P. Gibbs. 2001. Monitoring plant and animal populations. Blackwell Science, Inc. Malden, Massachusetts. 360 pp.
- Elzinga, C.L., D.W. Salzer and J.W. Willoughby. 1998. Measuring & Monitoring Plant Populations. BLM Technical Reference 1730-1. Bureau of Land Management, Denver, Colorado. 492pp.
- Herrick, J.E., J.W. Van Zee, K.M. Havstad, L.M Burkett and W.G. Whitford. 2005. Monitoring Manual for Grassland, Shrubland and Savanna Ecosystems. USDA-ARS Jornada Experimental Range, Las Cruces, New Mexico and University of Arizona Press, Tucson, Arizona. 2 vol., 236pp. available online at <http://usda-ars.nmsu.edu/>.

Appendix 1. Point-intercept Field Form

VCSS Point Intercept											
Site ID	Start Date:		Transect	Start Time	Finish Time	Botanist	Recorder				
Meter	Canopy1	Canopy2	Canopy3	Surface	Disturb	Meter	Canopy1	Canopy2	Canopy3	Surface	Disturb
1.0:						18.5:					
1.5:						19.0:					
2.0:						19.5:					
2.5:						20.0:					
3.0:						20.5:					
3.5:						21.0:					
4.0:						21.5:					
4.5:						22.0:					
5.0:						22.5:					
5.5:						23.0:					
6.0:						23.5:					
6.5:						24.0:					
7.0:						24.5:					
7.5:						25.0:					
8.0:						25.5:					
8.5:						26.0:					
9.0:						26.5:					
9.5:						27.0:					
10.0:						27.5:					
10.5:						28.0:					
11.0:						28.5:					
11.5:						29.0:					
12.0:						29.5:					
12.5:						30.0:					
13.0:						30.5:					
13.5:						31.0:					
14.0:						31.5:					
14.5:						32.0:					
15.0:						32.5:					
15.5:						33.0:					
16.0:						33.5:					
16.5:						34.0:					
17.0:						34.5:					
17.5:						35.0:					
18.0:						35.5:					
						36.0:					

Surface codes: BS= bare soil <5mm, GF= gravel, fine (5-20mm) GC= gravel, coarse (2.1-7.5cm) RC= rock cobble (7.6-25.5cm)
 RS= rock, stone (>25.5cm) L= litter MC= microbiotic crust NV= nonvascular PB= plant base SD=s cat, domestic SW= scat, wild
 WC= woody debris, coarse (>=7.62cm dia, >.91m lgth) WF= woody debris, fine (>=.62 dia)

Appendix 2. Cover classes for characterization of surface features/ substrate

Code	Type Description	Example(s) / Additional Description
NV	Non-vascular plant (macrobiotic forms)	Mosses, lichens, fungi , or microbiotic crusts
L	Litter (lying prostrate on the surface, or if elevated, only supported by other dead plant matter, rocks, etc. – not standing on its own)	Leafy and woody debris, scattered and broken is litter, decomposed beyond recognition as leaf or wood or other is duff (i.e., not litter). Branches or pieces of woody are classified as fine or coarse woody debris.
SW	Scat – wild	Feces from wild animals including (not limited to): elk, deer, rabbit, moose, bear, bighorn sheep, mtn. goat, ptarmigan, coyote, wolf, fox, etc.
SD	Scat – domestic	Feces from cows and horses, if applicable domestic sheep and goats)
BS	Bare soil – sand or finer (<2mm; gritty, up to sand grain size)	Duff and/or bare mineral soil (not covered by litter);
GF	Rock – fine/ medium gravel (2mm – 20mm; sand to large marble size)	Bare mineral soil (may include some duff, but not covered by litter) dominated by loose rock that ranges from 2mm (1/13 inch) to 20mm (just less than 1inch).
GC	Rock – coarse gravel (20mm – 75mm; marble to tennis ball size)	Bare mineral soil (not covered by litter) dominated by loose rock that ranges from 2cm (<1inch) 7.6cm (3 inches)
RC	Rock – cobble (75mm – 250mm; tennis ball to basket ball size)	Dominated by large particles of mineral soil (very little duff and not covered by litter) and loose rock that ranges from 7.6 cm (3 inches) to 25.5 cm (10 inches).
RS	Rock- stones and boulders (> 250 mm diameter)	A large rock that cannot be considered ground or soil – if it is a representative part of cobble cover, then use the previous category.
WC	Coarse woody debris	Downed logs with a diameter ≥ 7.62 cm along a length ≥ 0.91 m.
WF	Fine woody debris	Downed branches with a diameter ≥ 0.62 cm. Smaller pieces are considered litter.
PB	Plant base	Section of plant just above-ground that is usually remnants from previous years' growth; point of emergence of cluster of stems or blades ; usually seen in bunch and ring grasses

Appendix 3. Transect Invasives Field Form

Transect Based Invasive Plant Presence - Event Field Form

Park code: _____ Date: _____ Start time: _____ Stop time: _____.

Site code: _____ Site name/ descriptor: _____

Personnel (botanist and recorder): _____

Notes: _____

[illegible]



Standard Operating Procedure (SOP): VCSS Plot Methods

Rocky Mountain Network
1201 Oakridge Drive
Suite 200
Fort Collins, CO 80525
970-267-2150

Version: 1.0

Change History

Previous version	Date	Author	Change description	Reason
	5/27/09	DS	Changed name of 1m ² plots from cover plot to plot	Simplification and accuracy – both frequency and cover data now collected in these plots

Introduction

In addition to transect based methods (*SOP* VCSS Transect Methods), crews will measure plant and ground cover frequency in 10 plots within each site. Frequency measurements will be nested within 1m² quadrats at 0.01m², 0.1m², and 1 m² increments. Plot based methods complement point-intercept methods because they may provide a more comprehensive representation of site species composition and may allow for a more consistent record of changes in time (because plots can be revisited).

Frequency is the percentage of total possible plots occupied by each species being measured and a very repeatable measurement that performs equally well in a range of habitats featuring different growth forms. Because it is not as sensitive to annual biomass changes, frequency measurements are more robust to annual and seasonal changes in plant individuals. Additionally, frequency measurements may be taken any time after germination; this consequent independence from peak phenology creates a larger sampling window (Elzinga et al. 2001).

Frequency, by species within 1m² plots, is a measure that is also being used in other Intermountain Region I&M Networks' plant community protocols. Although there is some overlapping information in the transect and plot based methods, replicated plots (especially when combined with a large-plot search) have been shown to improve estimates of composition by capturing rare and widely dispersed species (Stohlgren, et al. 1998). Adopting this measure will enable the ROMN to integrate VCSS data with broader, regional analyses.

Steps

Equipment

- Rope (or wire) with a knot or similar marker at precisely 5 m length to locate the plot corner
- 3-4 colored stakes or flags to help identify the plot locations (more is better, multiple colors preferred)
- Large steel nails to help identify the plot locations (**10 per site**) – in parks where this approved
- Temporary 1 m² plot frame (constructed from 0.5 in diameter PVC pipe and marked with 10 cm intervals along each edge).
- Digital camera (may be IR or visible as funding and availability dictate)
- 2 meter sticks
- Appropriate field forms (paper or digital; use or derive from existing forms in Appendix 2 and similar Plot Detail Forms on the PDA or tablet computer)

Procedures

With the plot frame aligned along the correct bearing and anchored on the ground (See *SOP* VCSS Site Layout), you are ready to measure frequency and to estimate cover.

Table 1. Quadrat sizes and dimensions

Quadrat Size	Quadrat Dimensions
0.01 m ²	10 cm X 10 cm
0.1 m ²	20 cm X 50 cm
1 m ²	100 cm X 100 cm

1. Collect a photo prior to sampling the plot.
 - a. Verify that the image area in the camera is set to the proper area (sample frame plus small buffer) and resolution (highest).
 - b. Place the white-board along the lower right plot border, within the view of the camera (or set the data capture feature of the camera) to record the 'site/ transect/ plot/ date' information. The white board should not be in the plot.
 - c. Take a picture trying to minimize shadows in the plot.
2. Beginning with the smallest (0.01m²) quadrat, identify and record all surface cover types and known species rooted in that quadrat. Sample the larger quadrats by increasing size (0.1m², then 1 m² – see Table 1), recording only the species and cover types that did not occur in the smaller, nested quadrats. Be sure to note in which quadrat each species and surface type occurs.
3. Estimate the absolute canopy cover (see Figure 1 and Appendix 3 for guidance) of each species and cover class within the plot frame using the marks on the frame (10x10cm sections = 1% of the area each) and hand-held estimation tools (circles and squares cut to 100cm²) to assist you. These tools are used to assist in estimating cover because they are a known area; hold the tool over the plants in the plot to judge whether the cumulative cover of the species is half, one, or several (count) of these units. For small, well spaced species, create an index by approximating the number of individuals per 100cm² (1%) area; once you establish an index, always use the same index value for that species (i.e., at other plots and other sites). Divide the plot into half or quarters to allow for sub-estimates when the vegetation is dense, diverse or otherwise make the estimation complicated. We are estimating canopy cover; this means that you need to estimate the cover of an individual, or bunch, or indexed set of individuals, based on the approximate, irregular, but nearly regular, circumference of the leafy canopy cover (See Figure 7.1). Do not include dead branches (e.g., of shrubs), but do include “dead centers” of bunchgrasses (e.g., *Muhlenbergia* spp.). Do not try to estimate “interlacing” of leaves with open space, but estimate the cover of the unit based on the perimeter. In most cases, the total cover within the plot will make up greater than 100% because it incorporates vertical structure.
4. Record a species code and cover estimate for each species found in the plot (species code is omitted for non-vegetation classes).
5. For species that are small and rare (cover cannot be reasonably estimated using our resolution) record a .05 (or “tr”) in the value column (this is not always accurate, but will be interpreted as “trace” amount). Generally it is best to assess cover for each species for the entire plot, then move on to the next species. Recommended, but optionally, begin with the most abundant species, then move on to less abundant species until all have been recorded; reversing this order can be useful as well.

6. Survey the plot and create a list and estimate cover of surface types present in the plot using codes from Appendix 1.

*Species record notation: the first time recording a species name, write the name out fully; all subsequent documentation should record the data in the database form (or field sheet) for each species using the appropriate 6 digit alpha-numeric code (first three letters of Genus, first three letters of specific epithet). These may be available from a “Look-up” list in the database when you have a field computer (see Toughbook, PDA and/or database SOPs). When you are using paper forms, keep a copy of the park species list handy and refer to it when necessary.

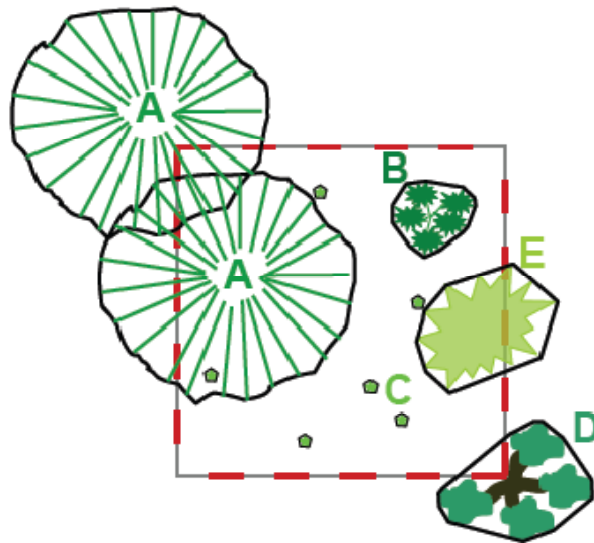


Figure 1. Foliage polygons, indicated in black lines, for different types of plants (all shapes are intended to be leaves, not flowers). The 1m² plot frame is indicated in gray, with red-gray dashes each being 10 cm in length. Cover of the species as represented here would be: A, 36%; B, 5%; C, 2%; D, 0.0%; and E, 7% (adapted from Symstad et al. 2006).

Literature Cited

- Elzinga, C.L., D.W. Salzer, J.W. Willoughby, and J.P. Gibbs. 2001. Monitoring plant and animal populations. Blackwell Science, Inc. Malden, Massachusetts. 360 pp.
- Stohlgren, T. J., K.A. Bull, and Y. Otsuki. 1998. Comparison of rangeland vegetation sampling techniques in the central grasslands. *Journal of Range Management* 51(2): 164-172.
- Symstad, A.J., D. Licht, et al. 2006. Ocular Cover Estimates of Herbaceous and Shrub Species, version 1.1. Plant Community Monitoring Protocol for Northern Great Plains I&M Network. Preliminary Operating Procedure (POP) #2. National Park Service, Northern Great Plains Network, Rapid City, South Dakota. 8pp.

Appendix 1. Cover classes for characterization of surface features/ substrate

Code	Type Description	Example(s) / Additional Description
NV	Non-vascular plant (macrobiotic forms)	Mosses, lichens, fungi , or microbiotic crusts
L	Litter (lying prostrate on the surface, or if elevated, only supported by other dead plant matter, rocks, etc. – not standing on its own)	Leafy and woody debris, scattered and broken is litter, decomposed beyond recognition as leaf or wood or other is duff (i.e., not litter). Branches or pieces of woody are classified as fine or coarse woody debris.
SW	Scat – wild	Feces from wild animals including (not limited to): elk, deer, rabbit, moose, bear, bighorn sheep, mtn. goat, ptarmigan, coyote, wolf, fox, etc.
SD	Scat – domestic	Feces from cows and horses, if applicable domestic sheep and goats)
BS	Bare soil – sand or finer (<2mm; gritty, up to sand grain size)	Duff and/or bare mineral soil (not covered by litter);
GF	Rock – fine/ medium gravel (2mm – 20mm; sand to large marble size)	Bare mineral soil (may include some duff, but not covered by litter) dominated by loose rock that ranges from 2mm (1/13 inch) to 20mm (just less than 1inch).
GC	Rock – coarse gravel (20mm – 75mm; marble to tennis ball size)	Bare mineral soil (not covered by litter) dominated by loose rock that ranges from 2cm (<1inch) 7.6cm (3 inches)
RC	Rock – cobble (75mm – 250mm; tennis ball to basket ball size)	Dominated by large particles of mineral soil (very little duff and not covered by litter) and loose rock that ranges from 7.6 cm (3 inches) to 25.5 cm (10 inches).
RS	Rock- stones and boulders (> 250 mm diameter)	A large rock that cannot be considered ground or soil – if it is a representative part of cobble cover, then use the previous category.
WC	Coarse woody debris	Downed logs with a diameter ≥ 7.62 cm along a length ≥ 0.91 m.
WF	Fine woody debris	Downed branches with a diameter ≥ 0.62 cm. Smaller pieces are considered litter.
PB	Plant base	Section of plant just above-ground that is usually remnants from previous years' growth; point of emergence of cluster of stems or blades ; usually seen in bunch and ring grasses

Appendix 2. Plot cover and frequency measurements form

VCSS - 1m ² Frequency and Cover Plots										
Site ID	Transect #	Start Date:	Start Time	Finish Time	Botanist					
					Recorder					
Surface codes: BS=bare soil<5mm, GF=gravel, fine (5-20mm) GC=gravel, coarse (2.1-7.5cm) RC=rock cobble (7.6-25.5cm) RS=rock, stone (>25.5cm) L=litter MC=microbiotic crust NV=nonvascular SD=scat, domestic SW=scat, wild WC=woody debris, coarse (>=7.62cm dia, >.91m lgth) WF= woody, fine (>=.62 dia)										
Transect Name:	Plot Name:	Plot Area:	Plant Code or Surface:	Cover Percent:	Plot Area:	Plant Code or Surface:	Cover Percent:	Plot Area:	Plant Code or Surface:	Cover Percent:
Transect 1 - North:	Plot A:									
	Total Cover									
	Plot B:									
	Total Cover									
	Plot C:									
	Total Cover									
	Plot D: 									
	Total Cover									

In the nested plot frequency design EACH SPECIES or SURFACE CODE in area 1 is identified and counted. In area 2 ONLY SPECIES NOT in area 1 are counted. Finally in Area 3 ONLY SPECIES NOT in area 1 or 2 are counted.

PAGE ____ OF ____

VCSS 1m2 Cover and Frequency Plots

Site ID

Start Date:

Transect 3

Surface codes: BS=bare soil<5mm, GF=gravel, fine (5-20mm) GC=gravel, coarse (2.1-7.5cm) RC=rock cobble (7.6-25.5cm) RS=rock, stone (>25.5cm) L=litter
MC=microbiotic crust NV=nonvascular SD=scat, domestic SW=scat, wild WC=woody debris, coarse (>=7.62cm dia, >.91m lgth) WF= woody, fine (>=.62 dia)

Transect Name:	Plot Name:	Plot Area:	Plant Code or Surface:	Cover Percent:	Plot Area:	Plant Code or Surface:	Cover Percent:	Plot Area:	Plant Code or Surface:	Cover Percent:
Transect 3 - S.W.:	Plot A:									
	Total Cover									
		Plot B:								
Total Cover										
	Plot C:									
Total Cover										

NOTES:

In the nested plot frequency design EACH SPECIES or SURFACE CODE in area 1 is identified and counted. In area 2 ONLY SPECIES NOT in area 1 are counted. Finally in Area 3 ONLY SPECIES NOT in area 1 or 2 are counted.

PAGE ____ OF ____

VCSS 1m2 Cover and Frequency Plots

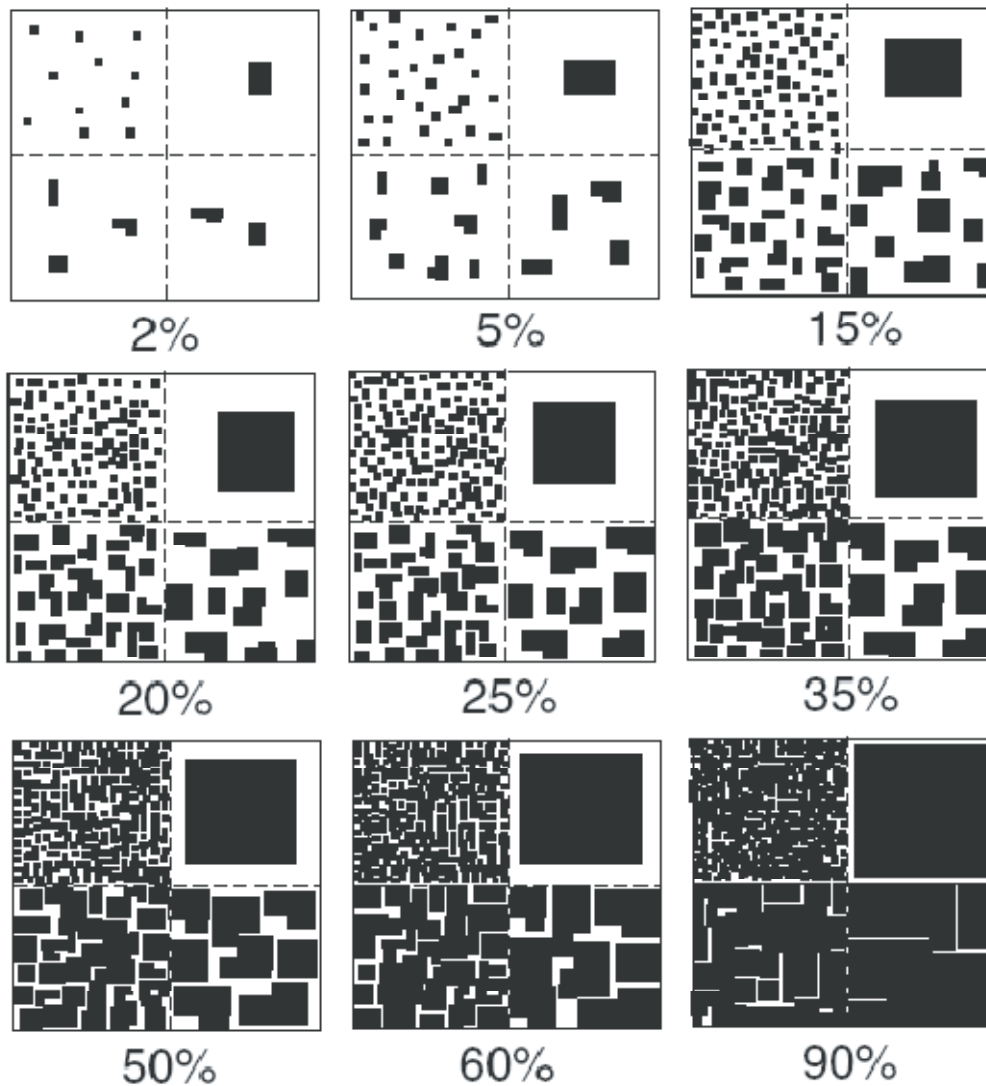
Transect Name:	Plot Name:	Plot Area:	Plant Code or Surface:	Cover Percent:	Plot Area:	Plant Code or Surface:	Cover Percent:	Plot Area:	Plant Code or Surface:	Cover Percent:
Transect 2 - S.E.:	Plot A:									
	Total Cover									
	Plot B:									
	Total Cover									
	Plot C:									
	Total Cover									
NOTES:										

Surface codes: BS=bare soil<5mm, GF=gravel, fine (5-20mm) GC=gravel, coarse (2.1-7.5cm) RC=rock cobble (7.6-25.5cm) RS=rock, stone (>25.5cm) L=litter MC=microbiotic crust NV=nonvascular SD=scat, domestic SW=scat, wild WC=woody debris, coarse (>=7.62cm dia, >.91m lgth) WF= woody, fine (>=.62 dia)

In the nested plot frequency design EACH SPECIES or SURFACE CODE in area 1 is identified and counted. In area 2 ONLY SPECIES NOT in area 1 are counted. Finally in Area 3 ONLY SPECIES NOT in area 1 or 2 are counted.

PAGE ____ OF ____

Appendix 3. Cover estimation guide for percent of area covered (from Schoeneberger et al. 2002).





Standard Operating Procedure (SOP): VCSS Unknown Plant Species

Rocky Mountain Network
1201 Oakridge Drive
Suite 200
Fort Collins, CO 80525
970-267-2150

Version: 1.0

Change History

Previous version	Date	Author	Change description	Reason

Introduction

No matter how botanically talented a field crew is, there will likely be plant species encountered in the field that cannot be identified. This can be attributable to a variety of reasons. Even though we plan to sample during peak phenology at each park, prime sampling time can shift from year to year and crews are only at each park for a short, predetermined period of time. Therefore, some plant species may not be exhibiting diagnostic features at time of sampling. Additionally, crew membership changes almost annually, so institutional knowledge may not accrete with time if a ROMN staff ecologist is not present during sampling. Consequently, unknown plant specimens will be collected, which may or may not be immediately identifiable. It is extremely important to take care to include all distinguishing characteristics with each collection. This includes reproductive structures, if present, roots, and sufficient vegetative material (i.e. leaves and stems) to identify form and structure. Specimens may be placed in paper or plastic bags in the field, clearly identified by assigned Unknown name following the system described in later sections below, location, and date of collection.

IF SPECIMENS WON'T OR CAN'T BE IDENTIFIED BY THE END OF THE DAY OR UPON RETURN TO "BASE" WITHIN 1-2 DAYS FROM COLLECTION, PLACE THE SPECIMEN INTO A PLANT PRESS. Too often specimens taken from the field get left pressed between pages of a field guide or in bags languishing at the back of the refrigerator until they are unable to be recognized or preserved.

It is very important to identify all species if possible, and if not, track unknowns from one year to the next until which time they will eventually be identified. Be sure to collect specimens even if it seems like there is no hope of a positive ID. In future years, with diagnostic characters present, we may learn the name of that seemingly nondescript, lanceolate basal leaf. Please follow the procedures in this SOP so we can attain a complete, high quality species dataset.

Steps

Equipment

- Gallon size zip plastic bags or paper bags
- Sharpies for marking unknown labels
- Plant press
- Newspaper/blotters for press
- Unknown species collection forms (Appendix 1)

Procedures

1. Use an alpha-numeric code for unknown species. Number these unknowns continuously so that Unknown forb #1 is the same at every site in the park (if it occurs there). For example: Unk.G.1 = unknown graminoid #1; Unk.F.1=unknown forb #1.
2. For common, but unidentifiable species in the plots, assign and record an unknown code as above (using S, G, F, T, V for Shrub, Graminoid, Forb, Tree, Vine). Then fill in an "unknown species" form (Appendix 1), and make detailed notes on species characteristics including stem and leaf morphology, perennial or annual (if known), etc. Survey the surrounding area for a well developed example – take a close-up picture (or,

series of photos if needed to show attributes, e.g., leaf and flower – be sure to record the photo identifier(s) in the dataform). **Do not pick or collect any individuals**, *unless it is necessary for later identification, and we have permission of the park unit*. Then, carefully collect a sample including the an entire individual down to enough root to show root tops (~2-4 inches) and carefully place it in a bag if specimen can be identified later in the day or in a prepared plant press. Instructions for pressing unknown plant specimens are found in Appendix 2. Specimens collected for identification must be destroyed once a determination has been made.

Appendix 1. Unknown Species Information and Collection Forms

Unknown Species Information Form (* Include Information from the 1st 6 lines (bold) on all collections*)

Park: _____ Date: _____
Site code: _____ Site name/description: _____
Botanist: _____

Transect/ Subplot (circle one): 1 (North), 2 (SE), 3(SW)
Plot (circle one): A (North), B(SE), C(SW)

Unknown Species Code: _____

Photo ID(s): Overview/ environment: _____, Whole plant: _____,
Inflorescence (macro): _____, Leaf (Macro) _____,
Leaf/ stem (macro): _____, Other char. _____: _____.

Notable features of the habitat (microhabitat characteristics):

Notable features of the growth form (plant type, rooting pattern, and general description):

Most salient feature (something unique to assist in recognition):

Leaf characteristics (type, margin, surface, colors):

Flower characteristics (inflorescence type; #sepals, petals, stamen, anthers; location, pubescence, color) :

Stem characteristics (shape, pubescence, markings, color, branching pattern):

Specimen collected: Yes No

Best Guess (at species ID):

Confirmed to be (post field verification/ ID):

Collected specimen storage location (for non-NPS herbaria, include contact information):

Specimen Collection ID tag (Should be accompanied by Species Information Form) Park: _____ Date: _____ Site code: _____ Site name/description: _____ Botanist/ collector: _____ Transect/ Subplot (circle one): 1 (N), 2 (SE), 3(SW) Plot (circle one): A (N), B(SE), C(SW) Unknown Species Code: _____ Brief Description: _____ _____ _____	Specimen Collection ID tag (Should be accompanied by Species Information Form) Park: _____ Date: _____ Site code: _____ Site name/description: _____ Botanist/ collector: _____ Transect/ Subplot (circle one): 1 (N), 2 (SE), 3(SW) Plot (circle one): A (N), B(SE), C(SW) Unknown Species Code: _____ Brief Description: _____ _____ _____
Specimen Collection ID tag (Should be accompanied by Species Information Form) Park: _____ Date: _____ Site code: _____ Site name/description: _____ Botanist/ collector: _____ Transect/ Subplot (circle one): 1 (N), 2 (SE), 3(SW) Plot (circle one): A (N), B(SE), C(SW) Unknown Species Code: _____ Brief Description: _____ _____ _____	Specimen Collection ID tag (Should be accompanied by Species Information Form) Park: _____ Date: _____ Site code: _____ Site name/description: _____ Botanist/ collector: _____ Transect/ Subplot (circle one): 1 (N), 2 (SE), 3(SW) Plot (circle one): A (N), B(SE), C(SW) Unknown Species Code: _____ Brief Description: _____ _____ _____
Specimen Collection ID tag (Should be accompanied by Species Information Form) Park: _____ Date: _____ Site code: _____ Site name/description: _____ Botanist/ collector: _____ Transect/ Subplot (circle one): 1 (N), 2 (SE), 3(SW) Plot (circle one): A (N), B(SE), C(SW) Unknown Species Code: _____ Brief Description: _____ _____ _____	Specimen Collection ID tag (Should be accompanied by Species Information Form) Park: _____ Date: _____ Site code: _____ Site name/description: _____ Botanist/ collector: _____ Transect/ Subplot (circle one): 1 (N), 2 (SE), 3(SW) Plot (circle one): A (N), B(SE), C(SW) Unknown Species Code: _____ Brief Description: _____ _____ _____

Appendix 2. Guidelines for pressing plant specimens

1. Plants should be pressed as soon as possible after they have been collected. They are more easily arranged in the press if they are not wilted.
2. Specimens should be carefully shaken to remove any dirt or debris that may be attached to roots, stems, leaves or flowers. Gently rinse muddy plants to remove mud and blot rinsed plants dry with paper or cloth toweling before pressing.
3. If a plant press is available, fill the plant press from the bottom first, working toward the top layers. A double piece of newsprint should be laid on the 1st blotting paper and cardboard layer with the fold of the paper at one edge of the plant press. The newsprint is then opened and the plant is carefully arranged on the bottom sheet. Place a field collection label alongside the plant. This label should contain important information about the specimen, such as date of collection, identification and description, location of collection site (GPS reading of latitude and longitude), digital camera image, etc. The top layer of newsprint is then folded over the top of the plant, and then it is covered with another blotter sheet, then another piece of cardboard. **Note:** if without a plant press, an alternative option would be to carefully place a specimen between the pages of a book or notebook.
4. Fill the press, one layer at a time, then compressed using bolts or straps.
5. A good pressing job requires practice and patience. You must smooth and flatten leaves individually. Most leaves should be arranged with their top surface facing upward, but turn 1 or 2 leaves upside down to show their undersurfaces. If the plant is too bushy, trim away some of the foliage, but not so much that the general character and shape of the plant is betrayed. Roots are generally spread in the manner that they occur underground. If they are too thick, slice them lengthwise in order to thin them for pressing. Arrange flowers in various positions so that all their features can be shown. Seeds, cones, and fruits are generally air dried separately in a ventilated location out of direct light.
6. After filling with specimens, the press should be placed in a warm, ventilated location for several days to allow the plants to dry completely. This process can be enhanced in a warming oven or a chamber with a warming light bulb designed for that purpose. If plants are particularly moist, or many plants are being pressed at once, it is a good idea to open the press each day and replace the newsprint with dry sheets so that the specimens don't mold. Check the plants each day and remove those that are completely dry. Thicker plants may take as long as two weeks to completely dry.



Standard Operating Procedure (SOP): VCSS Soil Characterization

Rocky Mountain Network
1201 Oakridge Drive
Suite 200
Fort Collins, CO 80525
970-267-2150

Version: 1.0

Change History

Previous version	Date	Author	Change description	Reason

Introduction

In addition to vegetation measures, soil at each site will be characterized to characterize inherent and dynamic soil properties. Semi-annual panel visits will focus on assessing core indicators of dynamic surface properties, including the potential for erosion and stability of top soils. Periodic (approximately decadal) profile characterizations will measure the physical and chemical properties, including nutrient storage and cycling capacity, water availability and acidification. This SOP describes the method for conducting tests of soil aggregate stability and bulk density for semi-annual sampling, as well as methods for collecting soil cores in the field for subsequent transport and laboratory analysis. Procedures for soil aggregate tests largely follow Herrick et al. (2005) and procedures for the remaining soil tests follow guidance by Robertson et al. (1999). Soil cores will be sent to a cooperating laboratory for the analysis of soil texture (0-20 cm), nutrients and mineral concentrations (e.g., P, Mg, K, Ca), soil pH, carbon and nitrogen content, % organic matter, and cation exchange capacity.

Steps

Soil Surface Condition

For each site, a brief survey should be done to describe soil condition and potential for erosion in the area. There are three main classes to describe: surface flow, rills and gullies, and pedestals and terracettes and each of these can range from extreme degradation to none. Examples of each condition are illustrated in Figure 1. A table describing conditions can be found in Appendix 3. These assessment methods are derived from Herrick et al. (2005). This survey should be done when first arriving at a site and the average conditions across the entire site are recorded.

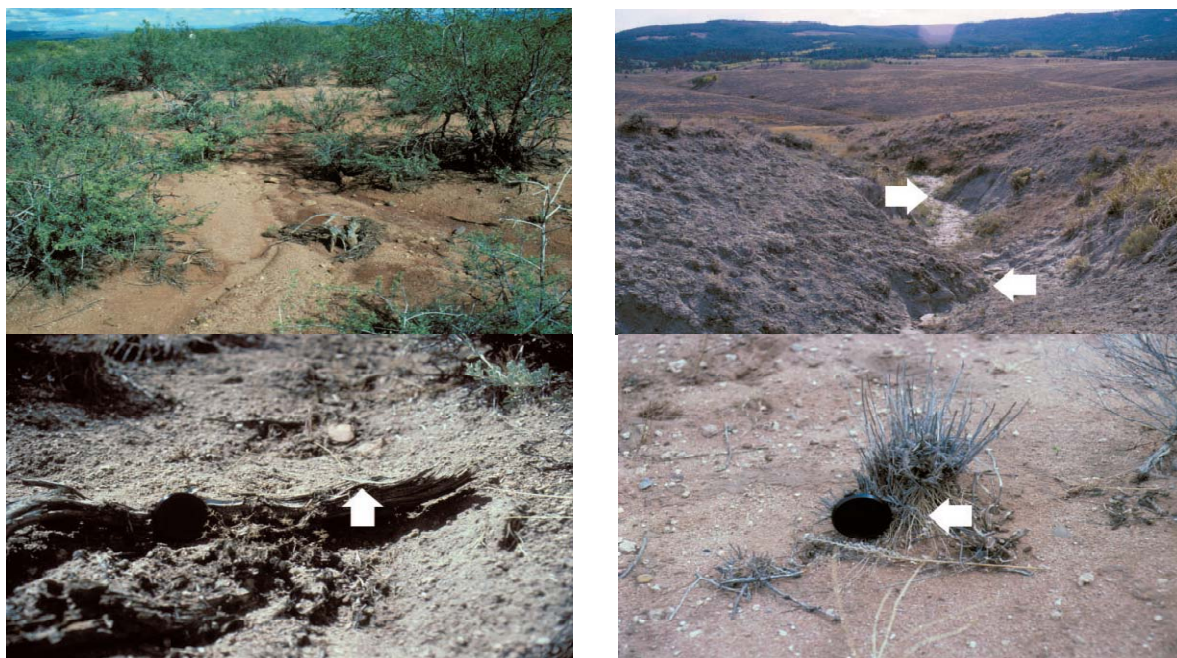


Figure 1. Photographs of soil surface conditions from Pellant et al (2005) based on arid landscapes. Top Left: Extreme surface flow indicative of high overland water flow. Top Right: An eroded gully with arrows indicating active erosion. Bottom Left: A plant pedestal caused by wind erosion, note the exposed roots. Bottom Right: A terracette caused by litter obstruction in the water flow pattern.

Soil aggregate stability

The soil stability test describes the degree of structure and erosion resistance and is used to compare sites with similar soil textures (Herrick et al. 2005). This test should be conducted with every site visit.

Equipment

- Measuring tape (same as those already stretched out for vegetation transects)
- Soil Aggregate Stability Test Kit
- Approximately 1 L (1/4 gallon) clean (deionized preferred) water
- Stopwatch (or other watch with minutes and seconds)
- PDA or Toughbook with database and/or paper data form(s)
- Small spray bottle to mist soils

Procedures

1. Select six random distances along each transect. Either use a random number table, or spin your compass bezel without looking at it and select a distance based on the number at the mark; each degree represents 1 m along the transect, i.e., $10^\circ = 10$ m and $360^\circ = 36.0$ m). Use the same six distances for sampling locations along each transect. Don't sample within 1m of the center monument because of potential disturbance/ trampling from the monitoring crews.
2. Samples are collected approximately 10 cm away from the transect on the side opposite where crews walk; move to this location.
3. Excavate a small trench (10-15 mm deep) for access, and then remove a surface fragment from the end of the trench (top 1 cm) using the sample spoon, or a small knife. The sample should be approximately 2-3 mm thick and 6-8 mm diameter. Minimize shattering by slicing the soil around the sample, lifting out a larger piece then needed and trimming it, and misting the sample area if the surface is very dry and brittle. Place the sample on a sieve and store it in the box (keep samples from each transect, and surface and subsurface separate, to record them as replicates associated with this sample unit, i.e., on the same field event form).
4. Excavate your trench deeper to a depth of 3-4 cm. Using the same technique as above, remove a subsurface sample from 2-2.5 cm below the surface (clearing the soil from above this point will aid in removing a clean sample).
5. Record canopy type (e.g., shrub, tree) above excavation site from list on field form.
6. Collect all 36 samples from the site (12 per transect) and systematically store them in separate compartments in the soil kits, keeping track of the origin of each sample (i.e., transect, distance, depth). It may be easiest to collect one transect at a time. On hot/sunny days, do not leave the lid closed on the samples for more than 1 min because it can alter stability. Instead, allow samples to dry with the lid off. Samples must be dry prior to testing.
7. Prepare the Soil Stability field form so you can quickly record values for each sample as they are attained (timing will be critical once the soil samples enter the water, so be ready; this process is easier with two people).

8. Fill each compartment of the empty box with clean water (fill each compartment to near the top).
9. Prepare the field form for rapid data entry (Soil Sampling Event form, Appendix 1).
10. One at a time, lower each sieve into the respective water-filled compartment, and using the stopwatch, record the condition 50% decay (melt) after 5s, 30s, and 5min. You may place the next sample into the water after recording the decay of the previous sample after 30s (i.e., stagger the start-times about 30 seconds apart). When running multiple samples, *keep track of the time* for each ped separately, and be sure to go back to samples after 5 min to record the amount of decay and begin the next step. Refer to Appendix 2 for photographed examples of this method.
11. If the ped is still intact (>10 % remaining) after 5 min, give the sieve 5 dips in and out of the water, then record the amount of the original sample that remains into one of the four classes (i.e., <10%, 10-25 %, 25-75 %, or 75-100 %). Your data will be used to classify each sample later based on the Stability Class Table (Table 1); record notes that may facilitate this classification.
12. Special cases:
 - a) Where there is no ped structure (i.e. too loose or sandy to have a sample in the sieve), lightly mist the sample with de-ionized water prior to testing. If the sample with still not hold together, this sample should be categorized as stability class 1 (Table 1).
 - b) If the soil surface is covered by a lichen or crust, include the crust in the sample. If there is moss, sample from under the moss.
 - c) In cases where the sample is hydrophobic due to high organic matter content (it tends to float), categorize as stability class 6 (Table 1).

After all peds have finished, then transfer the recorded data to the PDA or laptop for subsequent data management.

Table 1. Soil Stability Classes (adapted from Herrick et al. 2005, p 25).

Stability class	Criteria for classification
1	50% of structure lost within 5 seconds of immersion (melts and falls through the sieve)
2	50% of structural integrity lost 5-30 seconds after immersion.
3	50% of structural integrity lost 30 seconds – 5 minutes after immersion or <10% of the soil remains after 5 dipping cycles.
4	10-25% of the soil remains after 5 dipping cycles.
5	25-75% of the soil remains after 5 dipping cycles.
6	75-100% of the soil remains after 5 dipping cycles.

Soil bulk density & texture

Soil texture, stability and bulk density describe the physical structure of the soil and influence many ecosystem processes, particularly water movement in soils (Elliot et al. 1999). As a slow-changing, inherent soil property, texture will be measured during the initial site visit and thereafter every 5-10 yrs. Soil texture measures the percent composition of sand, silt, and clay (Elliot et al. 1999). Bulk density and field stability are two indicators of soil structure, which are potentially dynamic soil properties (Karlen, et al. 2003). Bulk density ranges between 0.6 and 1.8 g/cc and more typically ranges between 1.0 and 1.4 g /cc. Soil texture and bulk density are used

to better interpret other soil parameters. For instance, soil aggregate stability tests (above) should only be compared among sites with similar texture. Furthermore, these parameters may provide covariates in analyses to better describe variation among sites.

Equipment

- Soil corer (marked at 20 cm)
- Whirlpaks or plastic bags
- Knife
- Soil knife or trowel
- Sharpie or markers

Procedures

1. Use the second location of the six randomly selected for soil stability to identify where the core will be taken along the transect (3 per site). Move 1 m perpendicular from the transect on the side away from where the crews walk; this will be the location used for the core.
2. Remove surface vegetation and litter to expose mineral soil.
3. Carefully drive the soil core to 20 cm depth. While the corer remains in the soil, use trowel to excavate around it. Place the trowel under the corer to prevent soil from falling out the bottom and carefully remove the corer from the soil.
4. Check to make sure that the soil level inside the core is the same as outside. If it is noticeably lower, then compaction has occurred and one should consider discarding the core. If compaction is minor and limited to within the core, bulk density and derivative values will not be compromised; if, on the other hand, compaction has pushed soil below the core tip, then bulk density will be underestimated. If the sample is compromised, discard it, and move 1 m toward the end (36.6m) of the transect and take another core.
5. Using the knife, carefully cut the soil off at the bottom of the core. Discard.
6. Place the entire soil corer into the whirlpak or plastic bag. Push the soil out of the core into the plastic bag.
7. Note the volume of the core. Bulk density is a measure of soil mass per volume. Therefore, it is essential to have an accurate volume of the corer. As long as the same soil corer is used, the volume should be constant and based on the diameter of the corer (2 cm) and depth of the core (20 cm).
8. Close and label the bag. Label with date, site, transect, and volume. Keep the sample in the shade.
9. When possible, fill hole with litter and any loose dirt to reduce future erosion.
10. The samples can be kept closed in plastic bags for a few days as long as they are kept cool. However, if you cannot ship samples to the laboratory within a week, the samples should be air-dried. If this is the case, find a location inside (housing/laboratory/office), place samples on a table, open the top of sample bags, and let sit until dry (or until you ship them). If there is a fan available, running it above the samples will hasten this process.

11. When possible, pack the sample and others in a box. Mail to the following address requesting soil texture and bulk density analysis (current as of April 2011; check address at later dates):

Dr. James Self
Soil, water, and plant testing laboratory
Colorado State University
Room A319, Natural and Environmental Sciences Building
200 West Lake Street
Fort Collins, Colorado 80523-1120

Alternative method for bulk density in rocky soils (USDA 1999):

Materials needed:

Field

- Plastic wrap
- 140 cc syringe
- Water
- Trowel/soil knife
- Sealable bags and marker pen
- 2-mm sieve

Lab

- Scale
- 30mL measuring scoop
- Paper cup or bowl
- Drying oven

In the field:

1. Dig a hole in a spot that is as level as possible. Dig a bowl shaped hole three inches deep and approximately 5 inches in diameter. Avoid compacting the soil while digging. Place all the soil and the gravel removed from the hole in a plastic bag.
2. Using the 2-mm sieve, sieve the soil in the plastic bag to separate the gravel. Collect the soil in a plastic sealable bag. Put the gravel aside to be used in Step 2. Seal and label the plastic bag. If the soil is too wet to sieve, don't replace the rocks. Instead, dry and sieve later. The volume of gravel will need to be determined and subtracted from the total volume of the soil sample taken in the field.
3. Line the hole with plastic wrap as shown in Figure 2. Leave some excess plastic wrap around the edge of the hole. Place the sieved rocks and gravel carefully in the center of the hole on top of the plastic wrap. Assure that the pile of rocks *do not* protrude above the level of the soil surface.



Figure 2. Hole with plastic wrap and stones used to determine soil bulk density.

4. Use the 140 cc syringe to keep track of how much water is needed to fill the lined hole. The level of the water should be even with the soil surface. Add water slowly. The amount of water represents the volume of soil removed. Record the total amount of water in cubic centimeters ($1 \text{ cc} = 1 \text{ cm}^3$) on the soil datasheet (Table 2). Remove the rocks and place in a graduated cylinder 1/3 full of water. The change in the water level is the volume of rocks ($1 \text{ mL} = 1 \text{ cm}^3$).

In the lab:

1. Weigh the soil sample in its bag. If the sample is too heavy for the scale, transfer about half of the sample to another plastic bag. The weights of the two sample bags will need to be added together. Enter the weight (sum of two bags, if applicable) on the soil datasheet. Weigh an empty plastic bag to account for the weight of the bag. Enter the weight (sum of two bags, if applicable) on the datasheet.
2. Extract a subsample to determine water content and dry soil weight. Mix sample thoroughly in the bag by kneading it with your fingers. Take a 30mL (1/8-cup) level scoop subsample of loose soil (not packed down) from the plastic bag and place it in a paper cup (a glass or ceramic cup may be used).
3. Weigh the soil subsample in its paper cup. Enter the weight on the datasheet. Weigh an empty paper cup to account for its weight.
4. Place the paper cup containing the subsample in a microwave and dry for two or more four minute cycles at full power. Open the microwave door for one minute between cycles to allow venting. Weigh the dry subsample in its paper cup and enter the weight on the datasheet. Alternatively, dry the soil in an oven at 105°C for 24 hours or overnight. To test that the sample is dry, weigh, dry the sample (for a couple more hours in the oven or minutes in the microwave), and reweigh. When there is no difference between the two weights, the sample is dry.

CALCULATIONS

Soil water content (g/g) = (weight of moist soil - weight of oven dry soil)/weight of oven dry soil

Soil bulk density (g/cm³) = oven dry weight of soil/volume of soil

Soil water-filled pore space (%) = volumetric water content x 100/soil porosity

Volumetric water content (g/cm³) = soil water content (g/g) x bulk density (g/cm³)

Soil porosity (%) = $1 - (\text{soil bulk density} / 2.65)$

Volume of Rocks (cm³) = Fill 1/3 of a graduated cylinder with water, and record the amount.

Add the rocks to the cylinder and record the change in the water level. The difference is the volume of rocks ($1 \text{ mL} = 1 \text{ cm}^3$).

Volume of Soil (cm³) = Total soil volume - volume of rocks

Table 2. Data Sheet for soil bulk density via the excavation method for rocky soils

	Sample site (Target region- Peak-Aspect)	(n) Volume of water (cm ³)	(E) Weight of field moist soil + bag (grams)	(F) Weight of bag (grams)	(G) Weight of paper cup (grams)	(I) Weight of paper cup + soil (g)	(K) Dry weight of soil + cup (g)	*(L) Dry weight of soil (g)	** (M) Soil H ₂ O content (g/g)	***Soil bulk density (g/cm ³)
1										
2										
3										
4										
*Dry weight of subsample= (K-G)				**Soil H ₂ O content = (I-K)/L						
***Soil bulk density= [(E-F)/(1 +M)]/(n) n=volume of soil in cm ³ < 2mm										

Soil pH, chemistry, and soil organic matter

Soil organic matter, carbon, pH and plant nutrient concentrations can provide a powerful index of productivity and ecosystem processes and are often determinants of vegetation structure (Sollins et al. 1999). Global and local disturbances can alter soil chemistry which may result in altered vegetation composition. Soil cores will be taken during the initial site visit and thereafter every 5-10 yrs and analyzed for a complete matrix of plant nutrients, % organic matter, cation exchange capacity, pH and total carbon and nitrogen. When funds are available, soil cores can be taken more frequently and a minimum analysis may include pH, total nitrogen and total carbon.

Equipment

- Soil corer (marked at 20 cm)
- Whirlpaks or plastic bags
- Soil knife or trowel

Procedures

1. Use the first, third, and fifth locations of the six randomly selected for soil stability to identify where the core will be taken along the transect (9 per site). Move 1 m perpendicular from the transect on the side away from where the crews walk; this will be the location used for the core.
2. Remove surface vegetation and litter to expose mineral soil.
3. Carefully drive the soil corer to 20 cm depth. Remove corer and place soil from corer into whirlpak labeled with date, park, site, and transect. Use soil knife or trowel to assist in the removal, as needed.
4. When possible, fill hole with litter and any loose dirt to reduce future erosion.
5. Move to the second and third random distance and repeat steps 2-4, placing all three cores from one transect into a single bag. This results in 1 composite sample per transect and three samples per site.
6. Close whirlpak/bag and place in shade.
7. The samples can be kept closed in plastic bags for a few days as long as they are kept cool. However, if you cannot ship samples to the laboratory within a week, the samples should be air-dried. If this is the case, find a location inside (housing/laboratory/office), place samples on a table, open the top of sample bags, and let sit until dry (or until you ship them). If a fan is available, running it above the samples will hasten this process.

8. When possible, pack the sample and others in a box. Mail to the following address requesting analysis for pH, electrical conductivity, cation exchange capacity, organic matter, nitrate-nitrogen, phosphorus, potassium, zinc, iron, manganese, copper, total nitrogen and carbon, calcium and aluminum. After the first visit or when money is limiting, this list can be reduced to pH, total carbon, and total nitrogen. Address is current as of April 2011, but please confirm address prior to mailing.

Dr. James Self
Soil, water, and plant testing laboratory
Colorado State University
Room A319, Natural and Environmental Sciences Building
200 West Lake Street
Fort Collins, Colorado 80523-1120

Literature Cited

- Elliott, E.T., J.W. Heil, E.F. Kelly, H.C. Monger. 1999. Soil structural and other physical properties in G.P. Robertson (Ed). Standard Soil Methods for Long-Term Ecological Research. Oxford University Press. Cary, NC, USA. p 74-88
- Karlen, D.L., C.A. Ditzler, and S.S. Andrews. 2003. Soil Quality: why and how? *Geoderma* 114:145-156.
- Herrick, J.E., J.W. Van Zee, K.M. Havstad, L.M Burkett and W.G. Whitford. 2005. Monitoring Manual for Grassland, Shrubland and Savanna Ecosystems. USDA-ARS Jornada Experimental Range, Las Cruces, New Mexico and University of Arizona Press, Tucson, Arizona. 2 vol., 236pp. available online at <http://usda-ars.nmsu.edu/>
- Pellant, M., P. Shaver, D.A. Pyke, and J.E. Herrick. 2005. Interpreting indicators of rangeland health, version 4. Technical Reference 1734-6. U.S. Department of the Interior, Bureau of Land Management, National Science and Technology Center, Denver, CO. BLM/WO/ST-00/001+1734/REV05. 122 pp.
- Robertson, G.P., P. Sollins, B.G. Ellis, K. Lajtha. 1999. Exchangeable ions, pH, and cation exchange capacity in G.P. Robertson (Ed). Standard Soil Methods for Long-Term Ecological Research. Oxford University Press. Cary, NC, USA. p 106-114
- Sollins, P., C. Glassman, E.A. Paul, C. Swanston, K. Lajtha, J.W. Heil, E.T. Elliott. 1999. Soil carbon and nitrogen: pools and fractions in G.P. Robertson (Ed). Standard Soil Methods for Long-Term Ecological Research. Oxford University Press. Cary, NC, USA. p 89-105
- USDA. 1999. Soil quality test kit guide. Soil Quality Institute. USDA
http://soils.usda.gov/sqi/assessment/files/test_kit_complete.pdf

Appendix1. Soil Sampling Forms

VCSS - Soil Stability						
Site ID	Start Date:	Start Time	Finish Time	Collector		
				Recorder		
SOIL STABILITY CLASSIFICATION						
Transect Name:	Transect Location	Sample order	Surface Loss	Sub Surf Loss	Veg Type	Notes:
Transect 1 - North:						
Transect 2 - S. E. :						
Transect 3 - S. W.:						

1 = 50% @ 5 Sec 2 = 50% @ 30 Sec 3 = 50% @ 5 Min or <10% remains 4 = 10 - 25% remains 5 = 25-75% remains 6 = 75 - 100% remains

Veg Cover Types:

NC	No cover
G	Grass or grass/shrub mix
F	Forb (perennial)
Sh	Shrub canopy
T	Tree canopy
NV	Non-vascular

VCSS Soil Sample Collection

Site ID	Start Date:	Start Time	Finish Time	Collector	
				Recorder	

SOIL SAMPLES

Transect Name:	Volume:	Notes:
Transect 1 - North:	☐ Chem 1	
	☐ Chem 2	
	☐ Chem 3	
	☐ Bulk	
Transect 2 - S. E. :	☐ Chem 1	
	☐ Chem 2	
	☐ Chem 3	
	☐ Bulk	
Transect 3 - S. W.:	☐ Chem 1	
	☐ Chem 2	
	☐ Chem 3	
	☐ Bulk	

Note: 20 cm soil core sample = 60.28 ml

Appendix 2 Pictorial demonstration of soil classification using the stability test

Sequence for stability class = 1.



Original sample



After 5 seconds



After 5 minutes



After 5 dips

Sequence for stability class = 4



Original sample



After 5 seconds



After 5 minutes



After 5 dips

Sequence for stability class = 5.



Original sample



After 5 seconds



After 5 minutes



After 5 dips

Sequence for stability class = 6.



Original sample



After 5 seconds



After 5 minutes



After 5 dips

USDA-ARS Jornada Monitoring Manual, Herrick et al. 2005, p.26

Appendix 3 Classes for characterization of soil surface conditions using site soil erosion indicators

Degree of Degradation	Surface Flow Evidence	Rills and Gullies	Pedestals and Terracettes
	Erosion caused by overland flow, i.e., as water moves across the soil surface. Evidenced by litter, soil or gravel redistribution along flow-paths, especially small debris piles. Wind-scoured areas (may create blowouts) are recognized by removal of finer particles of the topsoil, sometimes leaving gravel, rock, or exposed roots on the surface. Deposition areas are often associated with vegetation or topographic relief.	Rills are small eroded rivulets that are generally linear and do not necessarily follow microtopography. A gully is a channel that has been cut into the soil by moving water; they generally follow natural drainage patterns. Gullies and rills are a natural component of many landscapes, but excessive grazing, vehicles or road drainages may cause excessive formation or expansion	Pedestals are rocks or plants that appear elevated because of soil loss from wind or water erosion around them (also by frost heaving or soil/litter deposition). Terracettes are small benches of deposited soil behind obstacles. Both are important indicators of movement of soil by water and/or wind. Terracettes caused by livestock or wildlife movements, e.g., across hillsides, are not considered erosion, so they should not be considered here.
Extreme (XX)	Extensive with active erosion and unstable soils (water and/ or wind caused); connections between flow paths lead to wide area affected	Rill formation is severe, well defined, and widespread. Gullies, when present, are actively down-cutting without vegetation to stabilize slopes and bed.	Many rocks and/ or plants pedestalled; exposed plant roots are common. Abundant across the area.
Moderate to Extreme (MX)	Cut/ eroded and depositional areas are common; occasionally connected.	Rill formation is moderate but active and well defined throughout most of the area.	Some rocks and plants with occasionally exposed roots; not ubiquitous across the area.
Moderate (MM)	Erosion is minor with some evidence of erosion and deposition, but not widespread across large areas.	Some intermittent rill formation, not widespread, but in the most exposed areas only.	Some pedestals, but only in major flow paths and exposed slopes; occasional terracettes.
Slight to Moderate (SM)	Flow patterns are stable and short; minor erosion evidence only (few and infrequent).	No recent formation of rills. Gullies, if present, are stabilized by vegetation on slopes and in the bed. (Older features have rounded or muted edges.)	Some evidence of past pedestals in flow patterns, but recent pedestals and terracettes are rare.
None to Slight (NS)	Minimal evidence of current or past soil movement.	No current rill formation. Drainages are natural, stable channels.	Little to no evidence of pedestals or terracettes. (Uncommon or absent)



Standard Operating Procedure (SOP): VCSS Optional Relevé Plot

Rocky Mountain Network
1201 Oakridge Drive
Suite 200
Fort Collins, CO 80525
970-267-2150

Version: 1.0

Implemented when funding is available, and needs expressed, to support analysis of plant species diversity patterns. This large-plot inventory method may be used in tandem or as an alternative to SOP VCSS Plot Methods. Not implemented in FY2006-2010.

Change History

Previous version	Date	Author	Change description	Reason

Introduction

To assist in the early detection of invasive species and to better understand diversity patterns, an optional plant species survey can be conducted at each site. The plant survey is conducted in each circular buffer plots with a 17.95 m (58.9 ft) radius at the end of each transect (see *SOP VCSS Site Layout*, Figure 1: Response Design). These plots should only be searched after all other photographs and data are collected, e.g., measuring frequency in the three (3) 1 m² plots, to avoid immediate effects of damage due to trampling. The dataset is a list of species occurring in the plot (no measures or estimates beyond the proper identification).

Steps

Equipment

- Rope or wire with a knot or similar marker at precisely 7.3 m (24 ft) length
- 4– 8 colored stakes or flags to help identify the plot perimeter
- Local Flora and protocol or park specific species guides
- Toughbook/ PDA and/or appropriate data forms (Appendix 1)
- Camera and/or collecting equipment (if permitted; plant press, plant labels, Unknown species forms – *SOP VCSS Plot Methods*, Appendix 2)

Procedures

1. Circumscribe the plot perimeter using the wire to measure the distance from the monument to the perimeter. Periodically mark (with flagging) the perimeter for later reference.
2. Record every species, common and rare, found within the plot (if a tree bole, or cluster of shrub stems falls >50 % within the plot, count this individual; note, this is more than 50 %, not equal to or greater than 50 % - if you think its 50/50 then do not count it).
3. Estimate the abundance of the species in the plot using broad categories: many, few, and one.
4. For unidentifiable species in the plots, assign and record an unknown code. Number these unknowns continuously so that Unknown #1 is the same at every site in the park and consistent with plot and transect data. Use “S,” “G,” “F,” “T,” and “V” in the name to distinguish among Shrubs, Graminoids, Forbs, Trees, and Vines. For example: Unk.G.1 = unknown grass #1; Unk.F.1=unknown forb #1. Then, fill in an unknown species form (*SOP VCSS Plot Methods*, Appendix 2), and make detailed notes on species characteristics include stem and leaf morphology, pubescence, thorns, color, floral pattern, and perennial or annual (if known and as possible). Survey the surrounding area for a well developed example – take a close-up picture (or, series of photos if needed to show attributes, e.g., leaf and flower – be sure to record the photo identifier(s) in the dataform). *Do not pick or collect any individuals, unless it is necessary for later identification, and we have permission of the park unit.* Then, carefully collect a sample including the an entire individual down to enough root to show root tops (~2-4 inches) and carefully place it in a prepared plant press (*SOP VCSS Plot Methods*, Appendix 2).

Appendix 1. Subplot Species List

Subplot Species List - Event Field Form

Park code: _____ Date: _____ **Start time:** _____ **Stop time:** _____.

Site code: _____ Site name/ descriptor: _____.

Personnel (botanist and recorder): _____

Surface condition classification (assign one code: XX, MX, MM, SM, NS):

Surface Flow: _____, Rills & Gullies: _____, Pedestals/ Terracettes: _____

Photo file ID(s): _____, _____, _____

Transect/ Subplot (circle one): 1 (North), 2 (SE), 3(SW)

Sp. Code

(Consult list)

Abundance

(3=many; 2=a few, 1=one)

Species Name / notes

(Provide name once per site; scientific preferred)

[illegible]



Standard Operating Procedure (SOP): VCSS Tree/ Shrub Plots

Rocky Mountain Network
1201 Oakridge Drive
Suite 200
Fort Collins, CO 80525
970-267-2150

Version: 1.0

Change History

Previous version	Date	Author	Change description	Reason
	5/27/09	DS	Changed names of woody plots as follows: Auxiliary to Woody Subplot Subplot to Woody Plot	clarification

Introduction

This protocol is used in woodlands and shrublands defined as areas where shrubs and trees are common but canopy is interrupted and typically cover is <40%. This protocol is based on FIA protocols and is used to measure tree density, biomass, and regeneration. The following protocol is not appropriate for grasslands.

Steps

Equipment

- Rope or wire with a knot or similar marker at precisely 7.3 m (24 ft) length.
- Rope or wire with a knot or similar marker at precisely 2.07 m (microplot; 6.8 ft)
- 4– 8 colored stakes or flags to help identify the plot perimeter
- Local Floral (botanical) Guide and protocol or park specific species guides
- Diameter (DBH) tape, Biltmore stick, calipers, or similar tool for estimating girth of a tree bole (stem).
- Protocol size-class table (Table 1)
- PDA, Toughbook, and/or appropriate data form (Appendix 1)
- Guides for visual estimates of tree and canopy conditions (Appendix 2)

Procedures

Use the Woody Plot to estimate density, composition, and biomass of live and standing dead trees and shrubs. Size classes of trees are described in Table 1. Trees are alive if they have any living parts (leaves, buds, cambium) at or above the point of diameter measurement, either diameter at breast height (1.4 m from ground; DBH) or diameter at root collar (DRC). To qualify as a standing dead tree, individuals must be at least 12.7 cm in diameter, have a bole which has an unbroken ACTUAL LENGTH of at least 1.4 m (4.6 ft), and lean less than 45 degrees from vertical as measured from the base of the tree to 1.4 m (4.6 ft).

Table 1. Tree and shrub size classes and measurements.

Table Component	Sampling methods
Trees (live or dead) Live trees ≥ 12.7 cm dbh (diameter at 1.4m above ground surface)	Dbh to nearest 0.5 cm; Canopy position and tree condition described (Canopy classes: top, mid, low; Health ratings: appears healthy with little/no sign of pest or infection, clearly infected with disease/pest, near death implies more than 75% of individual dead/dying).
Saplings (live) 1.0-5.0" (2.5-12.6cm) at breast height (1.4m)	Same methods as for trees.
Seedlings (live) Live trees < 2.5 cm at breast height (1.4m)	Tallied by species.
Shrubs * (shrub species, usually with multiple stems from single basal location)	Number of stems at 1.4 m and height by species and number of discrete clusters.
Down, dead * wood ≥ 12.7 cm midpoint diameter	Midpoint diameter to nearest cm; length to nearest 0.1 m; decay stage.

Trees

To qualify as a large tree, the individual must have a diameter at breast height (DBH) ≥ 12.7 cm (5 in).

1. Circumscribe the 7.3 m (24 ft) Woody Plot perimeter using the wire to measure the distance from the monument to the perimeter. Periodically mark (with flagging) the perimeter for later reference.
2. Identify and assign each large tree a unique record number;
 - a) To uniquely identify each individual, work clockwise from azimuth 001 to 360, and work outwards from Woody Plot center to Woody Plot perimeter. *If a tree bole, or cluster of shrub stems falls >50% within the plot, count this individual; note, this is more than 50%, not equal to or greater than 50% - if you think its 50/50 then do not count it.*
 - b) Use numbers 001-100 to assign a code to uniquely and permanently identify each tree on a given Woody Plot.
 - c) Identify the tree to species and record species code (first 3 letters of genus and species). If you cannot identify standing dead to species, categorize as conifer or hardwood.
3. Measure the azimuth (sight to the center of the tree base) and horizontal distance from the Woody Plot center monument.
4. Categorize each tree as live or standing dead using criteria described above.
5. Designate a crown class (Table 2).
6. Record condition by indicating percent of tree canopy that is damaged.
7. Measure diameter of that individual. Diameters are measured at either breast height or at the root collar.

DBH

1. Measure the diameter (wrap the DBH tape around larger trees - units have been converted, so although this is the circumference, the measure is diameter; use calipers for smaller stems (< 10cm)).
2. Measure DBH 1.4 m (4.6 ft) above the ground line on the uphill side of the tree. If a special situation is encountered (e.g. forked tree, large bole) see Appendix 2 for directions.

DRC

Species requiring DRC, referred to as woodland species, are listed in Table 3. These are multi-stemmed woody species.

1. Before measuring DRC, remove the loose material on the ground (e.g., litter), but not mineral soil. Measure the diameter at the ground line or at the stem root collar, whichever is higher.
2. Measure just above any swells present, and in a location so that the diameter measurements are a good representation of the volume in the stems (especially when trees are extremely deformed at the base). Stems must be at least one foot in length and at least 2.54 cm (1.0 in) in diameter 0.3 m up from the stem diameter measurement point to qualify for measurement.

3. Treat clumps of stems having a unified crown and common root stock as a single tree; examples include mesquite, juniper, and mountain mahogany.
4. Whenever DRC is impossible or extremely difficult to measure with a diameter tape (e.g., due to thorns, extreme number of limbs), stems may be estimated and recorded to the nearest class.
5. DRC is computed as the square root of the sum of the squared stem diameters. For a single-stemmed DRC tree, the computed DRC is equal to the single diameter measured. Use the following formula to compute DRC: $DRC = \sqrt{\sum (\text{stem diameter}^2)}$.
6. Estimate height and select canopy class for each tree from Table 2. Height is coarsely estimated to the nearest meter by eye. Canopy class rates tree crowns in relation to the sunlight received and proximity to neighboring trees. Base the assessment on the position of the crown at the time of observation. Example: a formerly overtopped tree that is now dominant due to tree removal is classified as dominant.
7. Quickly assess the condition of the crown for each tree using dead branches and brown leaves (needles) to indicate disease or damage. Record approximate percentages of the crown affected.

Table 2. Forest Inventory Analysis Tree Crown Classes (USDA, 2005).

Canopy Class	Crown Position Description
1 Open Grown	trees with crowns that received full light from above and from all sides throughout most of its life, particularly during its early developmental period
2 Dominant	trees with crown extending above the general level of the crown canopy and receiving full light from above and partly from the sides. These trees are taller than the average trees in the stand and their crowns are well developed, but they could be somewhat crowded on the sides. Also, trees whose crowns have received full light from above and from all sides during early development and most of their life. Their crown form or shape appears to be free of influence from neighboring trees.
3 Co-dominant	trees with crowns at the general level of the crown canopy. Crowns receive full light from above but little direct sunlight penetrates their sides. Usually they have medium-sized crowns and are somewhat crowded from the sides. In stagnated stands, co-dominant trees have small-sized crowns and are crowded on the sides

Table 3. Western woodland species where diameter is measured at root collar (USDA, 2005).

Species	PLANTS Code	Common Name
<i>Juniperus pinchotii</i>	JUPI	Pinchot juniper
<i>Juniperus coahuilensis</i>	JUCO11	redberry juniper
<i>Juniperus californica</i>	JUCA7	California juniper
<i>Juniperus deppeana</i>	JUDE2	alligator juniper
<i>Juniperus osteosperma</i>	JUOS	Utah juniper
<i>Juniperus scopulorum</i>	JUSC2	Rocky Mountain juniper
<i>Juniperus monosperma</i>	JUMO	oneseed juniper
<i>Pinus edulis</i>	PIED	Two-needle pinyon
<i>Pinus monophylla</i>	PIMO	singleleaf pinyon
<i>Pinus discolor</i>	PIDI3	border pinyon
<i>Pinus cembroides</i>	PICE	Mexican pinyon pine
<i>Pinus monophylla</i> var. <i>fallax</i>	PIMOF	Arizona pinyon pine
<i>Acacia</i> spp.	ACACI	acacia spp.
<i>Acer glabrum</i>	ACGL	Rocky Mountain maple
<i>Acer grandidentatum</i>	ACGR3	bigtooth maple
<i>Arbutus xalapensis</i>	ARXA80	Texas madrone
<i>Cercocarpus ledifolius</i>	CELE3	curlleaf mountain-mahogany
<i>Prosopis</i> spp.	PROSO	mesquite spp.
<i>Prosopis glandulosa</i>	PRGL2	honey mesquite
<i>Prosopis velutina</i>	PRVE	velvet mesquite
<i>Prosopis pubescens</i>	PRPU	screwbean mesquite
<i>Quercus arizonica</i>	QUAR	Arizona white oak
<i>Quercus emoryi</i>	QUEM	Emory oak
<i>Quercus gambelii</i>	QUGA	Gambel oak
<i>Quercus oblongifolia</i>	QUOB	Mexican blue oak
<i>Quercus hypoleucoides</i>	QUHY	silverleaf oak
<i>Quercus grisea</i>	QUGR3	gray oak
<i>Quercus rugosa</i>	QURU4	netleaf oak
<i>Quercus</i> spp.	QUERC	oak – evergreen spp.
<i>Robinia neomexicana</i>	RONE	New Mexico locust
<i>Olneya tesota</i>	OLTE	desert ironwood

Saplings

A Woody Subplot is used to measure the density, biomass, and presence of live saplings. Saplings are defined as live woody species with DBH (or DRC for woodland species) between 2.54 and 12.6 cm (1-5 in).

1. Locate the Woody Subplot center 3.66 m (12.0 ft) along a 90° azimuth from center of larger plot (monument). Circumscribe the 2.07 m (6.8 ft) Woody Subplot perimeter using the wire to measure the distance from the Woody Subplot center to the perimeter. Periodically mark (with flagging) the perimeter for later reference.
2. For all saplings within the Woody Subplot, assign a number to uniquely identify each individual, work clockwise from azimuth 001 to 360, and work outwards from Woody Subplot center to Woody Subplot perimeter. Since over time these saplings will be counted as trees in the larger Woody Plot, it is critical that the assigned number is unique to the entire Woody Plot area. The easiest way to do this is to start numbering for saplings with the next in the series from the Woody Plot. Measure azimuth and distance from the center of the Woody Plot for each individual.
3. For saplings, record all the same metrics as for trees including DBH, height, canopy class, and damage.

Seedlings

Seedlings are live trees that are < 2.54 cm (1 in) DBH/DRC and at least 0.15 m tall (conifers) or 0.3 m tall (hardwoods).

1. Count live seedlings within the Woody Subplot to obtain stocking and regeneration information. Specifically, count seedlings in groups by species, up to five individuals per species.
2. If more than five individuals are present, estimate numbers by species.

Literature Cited

U.S.D.A. 2005. Volume I: Field Data Collection Procedures for Phase 2 Plots. Forest Inventory and Analysis, National Core Field Guide, version 3.0. U.S. Department of Agriculture, Forest Service. 208pp.

Appendix 1. Woody Plot Forms

[illegible]

PAGE ____ OF ____

VCSS - Woody Plot Seedling Counts

Site ID	Start Date:	Transect Name	Start Time	Finish Time	Botanist	
					Recorder	

Tally seedlings in smaller 2.07m auxiliary plot (center is 3.66m east of monument)

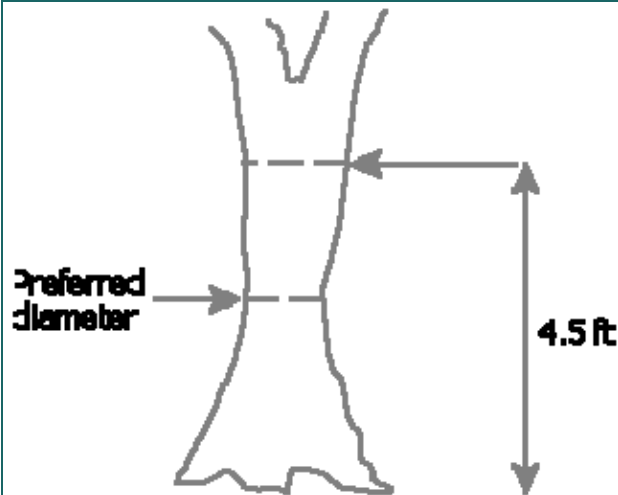
[illegible]

Seedlings are < 2.54 cm (1 in) DBH/DRC AND > 15 cm tall (conifers) or 30 cm tall (hardwoods)

Appendix 2. Illustrations of anomalous tree structure and instructions for measuring DBH

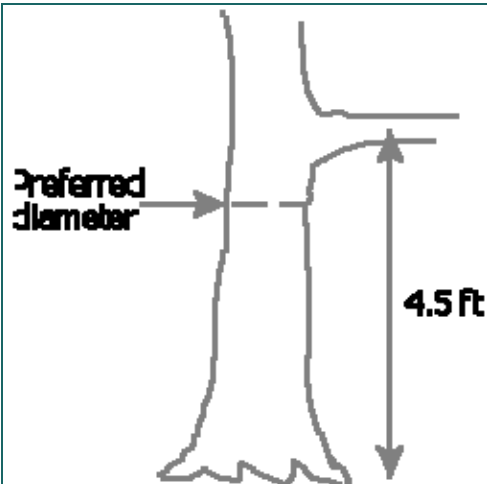
1. The tree tapers in such a way that the diameter at a point below 4.5 ft is actually smaller than the diameter at 4.5 ft.

Measure diameter at the smallest point and record the height at which diameter was measured on the data sheet.



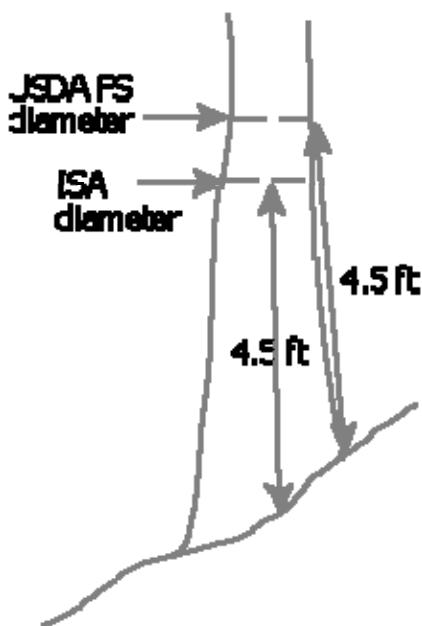
2. Tree has branches or bumps which interfere with DBH measurement.

Measure DBH below the branch or bump. Some references say to measure a foot below the branching point, which assumes this point is the smallest diameter of the trunk below 4.5 ft. Record the height DBH is measured at.



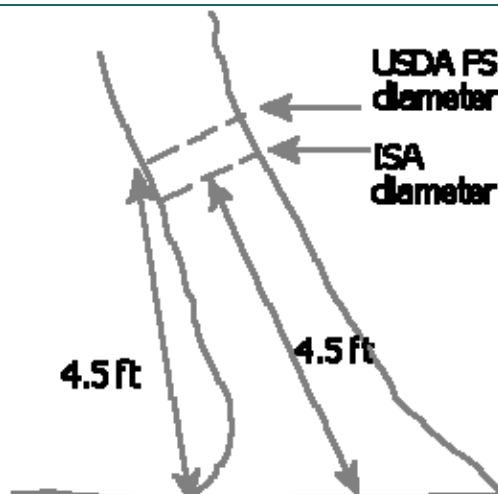
3. Vertically growing tree is on a slope.

There are several commonly accepted ways to find the DBH height. Probably the easiest method is to measure diameter 4.5 ft from the ground on the upper side of the slope. This method is used by the US Forest Service. Some references (e.g., International Society of Arboriculture's Tree Appraisal Manual) say to measure 4.5 ft from the midpoint of the trunk along the slope. However, finding the location of the trunk midpoint is probably subject to more error than finding the upper side of the trunk, so the USFS method is likely to be more repeatable than the ISA method.



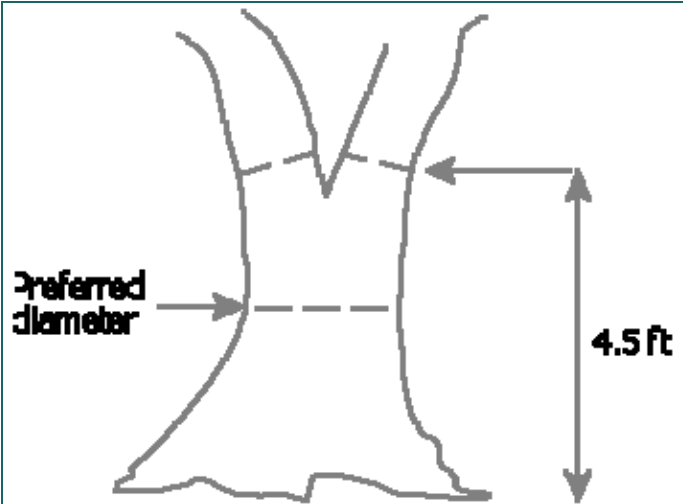
4. Tree leans.

There are several commonly accepted ways to find the DBH height. The US Forest Service measures 4.5 ft up the stem in the direction of the lean. Some references (e.g., ISA) say to measure 4.5 ft from the midpoint of the lean. As noted under 3 above, the USFS method is probably less prone to error and more readily repeatable by different observers.



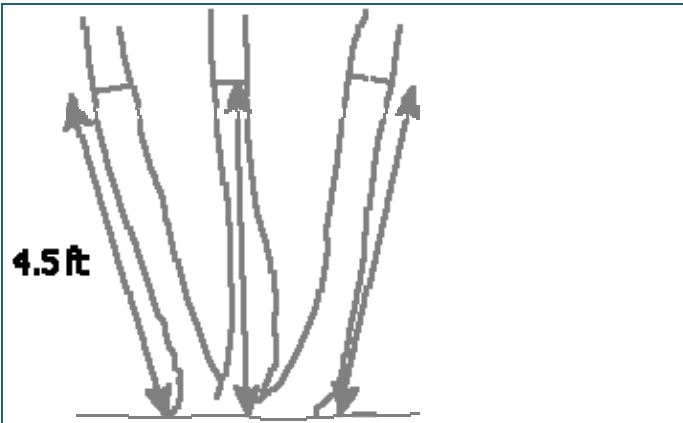
5. Tree forks below DBH or near DBH.

The measurement is recorded at the narrowest part of the main stem below the fork. The height of the DBH measurement and the fork should be noted (e.g., 3 ft diameter at 2 ft [Forks at 4 ft]).



6. Tree splits into several trunks close to ground level.

Measure DBH of each trunk separately, using the principals shown in categories 1-5 above. The DBH for the tree is found by taking the square root of the sum of all squared stem DBHs.



Figures courtesy of the International Society of Arboriculture,
<http://phytosphere.com/treeord/measuringdbh.htm>



Standard Operating Procedure (SOP): VCSS Site Disturbance

Rocky Mountain Network
1201 Oakridge Drive
Suite 200
Fort Collins, CO 80525
970-267-2150

Version: 1.0

Change History

Previous Version	Date	Author	Change description	Reason

Introduction

Observing and documenting land use and natural episodic events can provide insight into understanding patterns in vegetation distribution across the landscape. For example, the introduction of change into a system could impact species' ability to survive in the disturbed area. As these species decline, species better suited to the new environmental conditions begin to establish, thereby shifting community composition (Barbour 1987). For example, a wildfire or logging may modify soils, alter the water balance, bring in more sunlight, and introduce new vectors for the seed dispersal of new species (DeBano, Neary, and Elliott 1998, Fleming and Baldwin 2008). Sites will be evaluated for the presence or absence of such natural and anthropogenic disturbances. The disturbance data are collected to provide context for patterns or trends we may find in the vegetation and may be used in analyses as an explanatory variable.

Steps

In order to get a more complete picture of each site and its surrounding landscape, crews should evaluate disturbance levels and sources as they are walking to each site and be aware of potential stressors while doing transect and plot work. For this reason, under normal circumstances, crews should complete this form last as they are about to leave a site. Data collected to document anthropogenic stressors follow a modified version of the Human Disturbance Index that was developed by the Colorado Natural Heritage Program (Rocchio 2007) and supplemented with metrics from the California Rapid Assessment of Wetlands (Collins et al. 2008); crews will record natural disturbance in a separate section as these metrics are analyzed independently from the human disturbance measures.

Human Disturbance

1. The Human Disturbance Index form (Appendix 1) is divided into three categorical sections: Alterations within buffers and Landscape Context, Hydrological Alterations, and Physical Disturbances. To use the form:
2. Score each metric in every category to best match the condition description.
3. The Adjacent Land Use (Buffer) and Onsite Land Use (Physical Disturbance) metrics require additional steps to compute. These metrics are measured by documenting surrounding land use(s) in the site and within a 100m buffer, respectively. To calculate these scores, estimate the % area under each land use type (see Appendix 1). Do this separately for both Adjacent Land Use and Onsite Land Use metrics. Multiply these percentages by their corresponding coefficients. Add these products to reach a single total for each metric. Use the resulting subtotals to select the corresponding scores for the Adjacent and Onsite land use metrics on the main Human Disturbance Index form.
4. To calculate each category (e.g., Physical Disturbance) subtotal score, sum the two highest (worst) metric scores, divide by 20, then multiply by 100.
5. Each category is assigned a weight. To calculate a final score for the site, multiply the category score by each respective weight, then sum the products to reach a final site score. The final score will fall between 0 and 100 with 0 being the most "pristine" and 100 representing a highly disturbed site.

6. The calculations in Steps 2-4 can largely be done automatically in Excel or with a Visual Basic script. The Network recommends taking advantage of an automated process in order to minimize errors that might be more common if done manually in the field.

Natural Disturbance

ROMN ecologists developed the Natural Disturbance Index form for wetlands, but in the interest of consistency and in making cross-protocol comparisons, the Network is planning to use the same metrics for ROMN upland habitats. This is in part justified because ROMN upland and wetland sites will often be in close proximity to one another; as habitat characteristics shift over time, potentially transitioning to wetter or drier systems, the Network will have meaningful and transferable data in place. However, the weighting and analysis may vary from wetland applications. Currently (2009), more extensive field testing and calibration are needed before making any adjustments for upland systems.

To complete the Natural Disturbance form (Appendix 2):

1. Use the Key to assign a disturbance level to each of the seven metrics (plus “other”).
2. In the Comments field, indicate any qualifications to the assigned rating or any additional information that you want to convey about individual metrics

Literature Cited

- Barbour, M.G., J.H. Burk, and W.D. Pitts. 1987. *Terrestrial Plant Ecology*. The Benjamin Cummings Publishing Company, Inc. Menlo Park, CA. 634 pp.
- Collins, J.N., E.D. Stein, M. Sutula, R. Clark, A.E. Fetscher, L. Grenier, C. Grosso, and A. Wiskind. 2008. California rapid assessment method (CRAM) for wetlands. Version 5.0.2. 151 pp.
- DeBano, L.F., D.G. Neary, and P.F. Folliott. 1998. *Fire's effects on ecosystems*. New York: John Wiley & Sons, Inc. 333 p.
- Fleming, R.L. and K.A. Baldwin. 2008. Effects of harvest intensity and aspect on a boreal transition tolerant hardwood forest. I. Initial postharvest understory composition. *Canadian Journal of Forest Research* 38(4): 685-697
- Rocchio, J. 2007. Floristic quality assessment indices for Colorado plant communities. Unpublished report prepared for the Colorado Department of Natural Resources and US EPA Region 8. Colorado Natural Heritage Program, Colorado State University, Fort Collins, Colorado.

Appendix1. Human Disturbance Index field forms

Reviewed (Initials):	Review Date:	Data entry Initials:	Entry Date:
----------------------	--------------	----------------------	-------------

VCSS - Human Disturbance 1

Site ID:	Start Date:	Start Time:	Observer:
		Finish Time:	Recorder:

Alterations within Buffers and Landscape Context Score:

1A. AVERAGE BUFFER WIDTH - This metric is measured by estimating the width of the buffer surrounding the assessment area. Buffers are natural vegetated areas with no or minimal human-use. Buffer boundaries extend from the assessment area edge to intensive human land uses which result in non-natural areas. Some land uses such as light grazing and recreation may occur in the buffer, but other more intense land uses should be considered the buffer boundary. Irrigated meadows may be considered a buffer if the area appears to function as a buffer between the assessment area and nearby, more intensive land uses such as agricultural row cropping, fenced or unfenced pastures, paved areas, housing developments, golf courses, mowed or highly managed parkland, mining or construction sites, etc.

0pts Wide > 100 m
 3pts Medium 50 m to <100 m
 7pts Narrow 25 m to 50 m
 10pts Very Narrow < 25m

1B. ADJACENT LAND USE - This metric is measured by documenting surrounding land use(s) within 100 m of the outer buffer boundary. Enter percentages in the % Adjacent column in the Land Use table that best represent the extent of each land use type in the adjacent area. Be sure that the percentages sum to 100%. THE FINAL SCORE FOR THIS FIELD WILL BE CALCULATED IN THE OFFICE.

0pts Average Land Use Score = > 95
 3pts Average Land Use Score = 80 - 95
 7pts Average Land Use Score = 40 - 80
 10pts Average Land Use Score = < 40

1C. PERCENTAGE of UNFRAGMENTED LANDSCAPE WITHIN ONE KILOMETER - This metric is measured by estimating the area of the largest block of unfragmented area in a one km buffer surrounding the assessment area and dividing that by the total area. This can be completed in the office using aerial photographs or GIS.

0pts Embedded in 90–100% unfragmented, roadless natural landscape
 3pts Embedded in 60–90% unfragmented, roadless natural landscape
 7pts Embedded in 20–60% unfragmented, roadless natural landscape
 10pts Embedded in <20% unfragmented, roadless natural landscape

1D. BUFFER CONDITION - The condition of a buffer is assessed according to the extent and quality of its vegetation cover and the overall condition of its substrate. Evidence of direct impacts by people are excluded from this metric and included in the Land Use Calculations. Buffer conditions are assessed only for the portion of the site border that has already been identified or defined as buffer, based on 1a. If there is no buffer, assign a score of 10.

0pts Buffer is dominated by native vegetation, has undisturbed soils, with little or no human use.
 3pts Buffer is characterized by an intermediate mix of native and non-native vegetation, but mostly undisturbed soils and is apparently subject to little or no human visitation.
 7pts Buffer is characterized by substantial amounts of non-native vegetation AND there is at least a moderate degree of soil disturbance/compaction, and/or there is evidence of at least moderate intensity of human visitation.
 10pts Buffer is characterized by barren ground and/or highly compacted or otherwise disturbed soils, and/or there is evidence of very intense human visitation.

PAGE ____ OF ____

Reviewed (initials):	Review Date:	Data entry initials:	Entry Date:
----------------------	--------------	----------------------	-------------

VCSS - Human Disturbance 2

Site ID:	Start Date:	Botanist:	
		Recorder:	

Hydrological Alterations	Score:
---------------------------------	---------------

2. HYDROLOGICAL ALTERATIONS - Measured by evaluating land use and human activity within or near the assessment area which appear to be altering hydrology of the site. (See Table 1)

0pts No alterations. No dikes, diversions, ditches, flow additions, pugging, or fill present in assessment area that restricts or redirects flow

4pts Low intensity alteration such as roads at/near grade, pugging, small diversion or ditches (<1 ft. deep) or small amount of flow additions

12pts Moderate intensity alteration such as 2-lane road, low dikes, pugging, roads w/culverts adequate for stream flow, medium diversion or ditches (1–3 ft. deep) or moderate flow additions.

20pts High intensity alteration such as 4-lane Hwy., large dikes, diversions, or ditches (>3 ft. deep) capable to lowering water table, large amount of fill, or artificial groundwater pumping or high amounts of flow additions

Physical Disturbance	Score:
-----------------------------	---------------

3A. SUBSTRATE/SOIL DISTURBANCE - Select one or double check and average. This metric evaluates physical disturbances to the soil and surface substrates of the area. Examples include filling and grading, plowing, pugging (hummocking from livestock hooves), vehicle use (motorbikes, off-road vehicles, construction vehicles), sedimentation, dredging, and other mechanical disturbances to the surface substrates or soils.

0pts No Apparent Modifications

3pts Past Modification but Recovered; OR Recent but Minor Modifications

7pts Recovering OR Recent and Moderate Modifications

10pts Recent and Severe Modifications

3B. ONSITE LAND USE - This metric is measured by documenting onsite land use(s) occurring in the assessment area. Follow the same procedures as in Metric 1a - Adjacent Land Use

0pts Average Land Use Score = > 95

3pts Average Land Use Score = 80 - 95

7pts Average Land Use Score = 40 - 80

10pts Average Land Use Score = < 40

VCSS - Land Use

Site ID:	Start Date:	Observer:	
		Recorder:	

Table 1. Land Use		
Current Land Use	% Site	% Adjacent
Paved roads/parking lots		
Developed buildings/infrastructure		
Agriculture (tilled crop production)		
Unpaved roads (e.g., driveways, service roads)		
Mining (e.g., tunnels, pits, slag piles)		
Agriculture (row crops)		
Heavy grazing by livestock (permanent ranching)		
Moderate grazing by livestock (seasonal grazing)		
Light grazing by livestock (occasional use - e.g., by trail stock)		
Haying operations (fields, other evidence)		
Extensive logging or tree removal with >50% of trees > 50cm dbh removed		
Selective logging or tree removal with <50% of trees > 50 cm dbh removed		
Intense recreation (e.g., ATV use/front country camping/popular fishing spot)		
Moderate recreation (high use trail, backcountry campsite)		
Light recreation (e.g., low-use trail, backcountry campsite)		
No obvious human use in recent time (10 yrs), but not pristine area (e.g., fallow, old CRP, etc.)		
Pristine or land managed for native flora / fauna and processes		
Other (explain in notes)		

GRAND TOTAL - These fields are not entered into the database. - This must total to 100		
--	--	--

Notes:

PAGE ____ OF ____

Appendix 2 Natural Disturbance Index field form

VCSS - Field Data Form - Natural Disturbances			
Site ID: _____	Start Date: _____	Observer: _____	
		Recorder: _____	
Natural Disturbances			
Evidence may be observed while walking through the site, to and from the site, or from best observation location			
-Site to 1km scale -	Code:	Flags:	KEY
Beaver, lodge, dam, canal, runway, food harvesting, gnawing of woody materials, viable beaver habitat (forage, slope, distance to water)	<u>Beaver:</u>		1 - High: Majority (> 50%) of site has recent evidence 2 - Medium: Some recent or old (>10yr) evidence on site 3 - Low: No sign on site, at least some evidence in (~1km) area around site 4 - None: No signs in site or in (~1km) area around site 6 - Other: (explain in notes)
Observation or evidence of elk, moose, deer, or big horn sheep, such as wallows, hoof punching, Do not include herbivory from domestic animals.	<u>Native Herbivory:</u>		
Castings, burrows, etc	<u>Frost Heave:</u>		
Blackened/burned trees, downfall caused by fire, etc. Do not try to identify the source or cause	<u>Rodents:</u>		
Evidence of beetles (any species), dead or dying trees	<u>Fire</u>		
Rock debris, felled trees. Do not try to identify the source	<u>Pest Pathogens:</u>		
Please provide detail in Notes	<u>Landslide:</u>		
	<u>Other:</u>		
Notes: _____			

PAGE ____ OF ____



Standard Operating Procedure (SOP): VCSS Post-Sampling Event Procedures

Rocky Mountain Network
1201 Oakridge Drive
Suite 200
Fort Collins, CO 80525
970-267-2150

Version: 1.0

Change History

Previous version	Date	Author	Change description	Reason

Introduction

This SOP describes the final field procedures to be completed at the conclusion of a sample event. This includes daily safety precautions, managing equipment, how to process paper and electronic data and physical samples after each sampling event and/or after a significant quantity of data is accrued.

Steps

The general steps at the conclusion of field sampling at a site and at the conclusion of a day include:

1. Confirm that all staff are accounted for (if not, remedy).
2. Confirm that all pieces of equipment are accounted for (if not, remedy; see Appendix 1 for equipment list).
3. Confirm that all data have been collected and recorded (if not, go back to that step and collect the pertinent information).
4. Return to park office and check-out with park or network staff (per park policies).
5. Backup data.
 - a) If PDA data collection: upload data from the PDA to a laptop and back-up the data on a jump drive or an external hard-drive.
 - b) If field tablet (e.g., Toughbook) data collection: save a dated copy (YYYYMMDD) of the database in the backup folder (on the same machine) and a copy onto an external hard drive.
 - c) If data are solely collected on paper:
 - i) store originals in a secure location(e.g., a NPS office if available);
 - ii) QA/QC and enter data into laptop database on a weekly basis, if not more frequently
 - iii) make copies, or scan as soon as possible and store in physically separate locations (if possible);
 - iv) if not entering data into field computer, send copies of all field data forms to ROMN offices on a weekly schedule or as soon as possible.

Safety and equipment

You are responsible for your own safety and the safety of the crew; this includes carrying safety equipment (e.g., radios and first-aid kits), personal field gear (e.g., rain gear, water, food), traveling in safe areas and in a safe manner, and checking 'in' and 'out' with park unit staff. See *SOP Admin Safety* for a more thorough discussion of safety related topics.

Crews and individuals are responsible for proper use, maintenance and retention of professional equipment. Do not leave equipment behind when you move to a new plot, transect, or site!

1. Check in with park staff to alert them of your planned activities, travel routes, and site location(s);
2. Check out with park staff when you leave the field and/or park;
3. Check for all equipment (use a list if necessary);
4. If something or someone is missing, immediately contact the proper park authorities and ROMN staff members, and then create a plan.

PDA - Post-processing

The data from the PDA should be up-loaded to a laptop computer daily or upon return to the office or computer location after extended field trips. Frequent, regular up-loads will safeguard against loss of data and will help maintain needed memory space. Data upload requires a physical connection between the PDA and the computer.

1. The PDA should be downloaded to the laptop only upon complete entry of all data from a site. Do not synchronize the PDA and laptop databases while site data are incomplete (e.g., don't upload in two batches if it takes two days to do the site).
2. Set the PDA in the saddle, or using the PDA-specific USB cord, while the laptop is 'ON'.
3. Be sure power is attached so the battery will recharge (verify that this is working and won't drain the vehicle batteries if using an automobile power adapter).
4. Pendragon Forms will automatically generate a copy in an Access database. Make a copy of the Access database file (C:\ProgramFiles\Forms3\Forms32K) into the folder 'C:\Field Crew\VCSS\PDA_data\' and add today's date to the end as the unique identifier (e.g., 'Forms32K_20060531').
5. Using the PDA, check the contents of each "Detail" Form (the one's that contain data). If data remains on the PDA after synchronization, select one or two entries and then without making changes "END" that form. Rerun the synchronization program; repeat this step until all "Detail" Forms have been fully transferred.
6. Make an additional copy of the files onto an external hard drive (e.g., VCSS Field-BU 200GB external HD).

Tablet (e.g., Toughbook) - Post-processing

When working with a full capability field computer (e.g., Toughbook or similar ruggedized tablet), the data are stored directly into a database. After completing sampling at a site, copy the database into a back-up folder; the copied file should be dated and stored in a separate file location on the field computer. Subsequently, upon return to the office or suitable location after extended field trips, all files in the "back-up" folder should be copied to an external hard drive. Frequent, regular up-loads will safeguard against loss of data and will help maintain needed memory space.

1. Copy the database holding previous field work (all dates/sites). Rename the database with the date appended as the end of the filename (_YYYYMMDD);
2. Save the dated copy of the database in the BU (back-up) folder (on the same machine) ;
3. Make an additional copy of the files onto an external drive (e.g., VCSS Field-BU 200GB external HD) once back in the office;
4. Charge both Toughbook batteries for following day's or upcoming field sampling.

GPS

The data from the GPS unit should be up-loaded to a laptop computer daily or upon return to the office or computer location after extended field trips (see *SOP Equipment* Using the Garmin GPS 76 csx for additional instructions, NPS 2007). Frequent, regular up-loads will safeguard against any loss of data. Data upload requires a physical connection to the laptop (the one with the GPS software and the databases) and the Garmin software (DNR Garmin is required to download an Arc-ready "shapefile," but this is not required for this protocol).

The files should be stored in the appropriate project folder and named with the current date added to the end of the file name (use date format YYYYMMDD; see the *SOP DM File Naming Conventions* in the Data Management Plan for further guidance; NPS 2007). The file should immediately be set to “read-only.”

1. Connect the GPS unit to the personal computer using a USB or serial cable;
2. Download GPS data (.txt files) into appropriate folders (e.g., \VCSS2009\Data\GPS\);
3. Fields required from a unit download are: ident (waypoint), lat, long, y_proj, x_proj, comment, altitude, and model;
4. Review the downloaded data for accuracy and completeness;
5. Once the data have been downloaded from the GPS unit, and if/when appropriate, delete field-collected waypoints and tracks from the unit (don’t remove pre-loaded data like site locations);
6. Check the batteries and replace if needed (remove all batteries for storage).

Digital Camera

The data from the camera should be up-loaded to a laptop (portable personal computer) daily or upon return to the office or computer location after extended field trips. Frequent, regular up-loads will safeguard against any loss of data. Data upload requires a physical connection between the camera and the laptop.

1. All pictures from the camera should be downloaded to the specified folder adding a new folder with the upload date (\VCSS20XX\Data\Photos\YYYYMMDD) ;
2. Downloading the camera is similar to connecting any USB based peripheral. Connect the wires; turn the camera on; look for the camera using the Windows Explorer tool on the computer;
3. Locate the photo files (using Explorer tool) and copy all of them;
4. Create a destination folder (\VCSS\20XX\Data\Photos\YYYYMMDD) where YYYYMMDD represents the date of uploading;
5. Paste the files into the new folder. This folder and contents should be immediately *set to read-only*;
6. Before removing the photographs from the camera, it is important to confirm that all photos have been copied and are uncorrupted. If there’s a problem with the upload, delete from the computer and re-copy the files to the laptop computer. Once working files are confirmed, delete all photos from the camera;
7. Check and charge camera battery if needed.

Soil or plant samples

1. If you have collected soil or vegetation samples, remove from bag packs and place in a cool dry place.
2. Follow the procedures for drying and mailing (soils) or pressing and identifying samples (plants) as outlined in *SOP VCSS Unknown Plant Species* and *SOP VCSS Soil Characterization*.

Literature cited

National Park Service (NPS) – Rocky Mountain Network. 2007. Data and information management plan. < <http://www1.nrintra.nps.gov/im/units/romn/datamgmt/index.cfm> >. Accessed July 2007.

Appendix1. Equipment Checklist

Design, Measurement, Estimation Tools

5-6 chaining pins (more if windy or irregular terrain)
6 pin flags (or more if windy or irregular terrain)
2 nails (10 nails if setting up new plot)
1 nail with 5 m mark along rope or wire (1 m² plot corners)
1 nail with 7.3 m mark (knot or similar) along rope or wire (Woody Plot radius)
1 nail with 5.73 m mark (knot or similar) along rope or wire (distance from monument to Woody Subplot center)
1 nail with 2.07 m mark (knot or similar) along rope or wire (Woody Subplot radius)
3 @ 50 m reel tapes (with 3 carabineers and 3 clamps)
1 plot frame (4@ 1m sections, 4@90° elbows)
1 rolled steel pin
1 @ 2 m folding meter stick
1 soil corer
10 plastic bags for soil samples
Whiteboard with dry erase markers (bring 2)
Compasses (ONE PER PERSON)
Hand shovel / spoon / or similar
Stop watch / wrist watch with seconds
Soil stability test kit (4 boxes, one with sieves and spoon)
Soil knife
Plastic percent cover guides
Monuments (4 per site)
3/8 in. rebar (4 per site)
Monument stamping kit – small sledge, monument holder, die set
Plastic or paper bags for unknown plant species collection
2 Sharpies or markers
Plant press and newspapers/blotters
Pencils - many

Data Collection Tools

GPS (with batteries charged and cable)

PDA/ tablet computer (with batteries charged) - Optional

Camera (with batteries charged, charger, cable)

2 clipboards (with BLANK DATA FORMS, see below)

- o 4 Point Frequency Forms
- o 4 Invasive Plant Transect Forms
- o 4 1m² plot (8-12 if species level classification)
- o 4 Woody Plot Forms (when applicable)
- o 4 Woody Sub Plot Forms (when applicable)
- o 4 Woody Plot Species List Forms (when applicable)
- o 2 Site Event Description forms
- o 2 Soils forms
- o Map of park unit with sites
- o Dossier file with site descriptions, photos, etc.
- o Local unit map (for navigation and place names)
- o 1-4 copies of the design and instructions

Safety Equipment

Cell phone (with batteries charged)

Radio and charger

At least 2 First Aid kits

Raingear

Sunscreen

Water

Food (at least a snack)

Good boots or shoes (no sandals), hat, long-sleeved shirt

Compasses and local map (1 per person)



Standard Operating Procedure (SOP): VCSS Paper Field Forms

Rocky Mountain Network
1201 Oakridge Drive
Suite 200
Fort Collins, CO 80525
970-267-2150

Version: 1.0

Change History

Previous version	Date	Author	Change description	Reason

Introduction

The VCSS protocol is designed so that data may be gathered directly into electronic forms using a hand-held computer (PDA, Toughbook, notebook, or similar) or via paper forms. All forms have structure to support easy use for recorders and later for reading and entering data; some forms have more critical formats and structures than others (e.g., scan-able forms) so try not to make errant marks or notes in areas designated for other uses. On the other hand, using paper allows for recording much information not in the form – take advantage of note fields as useful.

Steps

1. Keep paper forms clean, dry, and protected whenever possible
2. Write clearly (be careful when you hurry – don't let a 0 look like a 9 or a 6);
3. Stay in the provided field when possible (color inside the lines);
4. If you abbreviate, define the abbreviation somewhere unless you are using an established set of abbreviations or codes;
5. Always write the date, time, and location on the form. Note as many details of the sample location as needed to relocate the plot (e.g., site #, transect # and Plot letter are all needed to ID a plot);
6. After you finish writing data on the form, move it to a safe location before beginning the next step (e.g., inside a binder, clipboard, or vehicle). Do not pile all your data sheets for the day on the top of your clipboard.
7. Use pencil (pens can bleed) and do not erase. Instead, cross out mistakes and make sure that the correct entries are clear.

Processing

1. Enter data from paper field forms into the Access database as soon as possible (either via the PDA or laptop).
2. Save a copy in the 'C:\\VCSS20XX\\Data\\' folder; make a back-up copy of the file (use same folder structure) onto a Jump Drive or external hard drive; make copies of the originals, and periodically (e.g., weekly) mail the copies to ROMN offices; save the original forms in a safe location until they can be returned to ROMN offices.
3. If there is no time/capability for immediate data-entry, make copies of the data forms (as soon as possible) and store the originals and copies in separate, safe locations until they can be returned to the ROMN offices.
4. Send a copy of all data forms to the office via the U.S. Postal Service (request to use local administration office resources when a Post Office is not available):
Rocky Mountain I&M Network,
National Park Service,
1201 Oakridge Drive, Suite 200
Fort Collins, CO 80525



Standard Operating Procedure (SOP): VCSS Electronic Field Data Entry

Rocky Mountain Network
1201 Oakridge Drive
Suite 200
Fort Collins, CO 80525
970-267-2150

Version: 1.0

Change History

Previous version	Date	Author	Change description	Reason

Introduction

To expedite data processing and improve accurate records, ROMN field crews will be outfitted with digital data entry instruments when practical and readily applicable. VCSS data may be collected in a tablet computer (e.g., Toughbook) ruggedized for outdoor use. The database structure, function, and capacity in the tablet laptop are exact duplicates of that on the field laptop and storage devices.

Steps

Forms for each site are interconnected through the database. Items lower on the list are often dependent on a form listed above for functionality and proper field definitions.

Electronic Forms used on the Toughbook for VCSS

Site Description (Location)

Site Sample Event

Transect Master

Transect Detail (Frequency)

Transect Invasives

Plot Master

Plot Detail

Soil Stability and Chemistry

Sub Plot Detail (Trees)

Trees Measures

Regeneration Measures

Form Descriptions and Instructions

Site Description – This form is preloaded and contains the location information for the plots. See *SOP VCSS Completing Site Description Forms* for details.

Site Sample Event – This form calls for general information that describes the site. It starts by looking up the site-ID from the Site Descriptor Form

Transect Master – This form is the key to describing the plot and accessing the subforms and junior forms that accept the different measures. It starts by looking up the SiteID and Start Date from the Site Sample Event Table.

Transect Detail – SUBFORM - The plant and surface cover measurements for a transect go here.

Transect Invasives – SUBFORM – Record presence of exotic plant species along each transect in this form

Plot Master – This form requires information that is found on the Transect Master form but it is a regular form (not a subform). This form starts by looking up the SiteID, Start Date, and Transect Name from the Transect Master form.

Plot Detail – SUBFORM – This accumulates the vegetative frequency data for each of the three plots related to a transect.

Soil Sampling - SUBFORM - The soil sampling data for a transect goes in this form.

Sub Plot Detail (Trees) – Enter tree, sapling, and shrub data collected in Woody Plot here.

Post-processing

1. Each evening, the data in the tablet should be uploaded to the laptop; this is accomplished by using the USB cable, while the laptop is 'ON'.
2. Make an additional copy of the files onto a jump drive or external hard drive.



Standard Operating Procedure (SOP): VCSS Basic Analysis

Rocky Mountain Network
1201 Oakridge Drive
Suite 200
Fort Collins, CO 80525
970-267-2150

Version: 1.0

Important Note: the following analysis SOPs are the procedures used (at least initially) in the protocol and are not a general review of the statistical theory behind a given method; they provide sufficient detail for the major analyses of data generated by the protocol such that a experienced ecologist or data analyst could replicate the methods; as methods are changed, all changes must be documented clearly in the change history

Change History

Previous version	Date	Author	Change description	Reason

Introduction

The first step to the analysis of vegetation composition structure and soils (VCSS) data is to summarize key parameters for each site and park (e.g., invasive cover or soil pH). This is done to gain a general understanding of park attributes and provides a vital step in the quality control process by identifying outliers. Prior to analysis, data within a site are aggregated (following the steps below) to insure that each analytical unit (site) is accurately represented by the data. Transects and plots within a site are sample units, but not appropriate analytical units, therefore analyses should be conducted using data aggregated at the site level. Thus, from transect and plot replicates, we extrapolate to infer cover estimates to the 0.5 hectare site; in turn, this site represents a larger target area based on the design specifications. After calculating site-level estimates, these values can be averaged park-wide to present the annual distribution of vegetation and soil surface attributes. Zero values should be included in averages. When sites have been visited on multiple dates, these data should be considered carefully; for example, if there is a trend within the panel design this needs to be accounted for before a status estimate.

Steps

1. Quality control; editing; finalization of dataset.
2. Calculate site level averages for parameter(s) of interest (e.g., all cover classes). Be careful about the divisor (e.g., don't use Excel's average formula, rather set the divisor manually; always check to insure you divide the proper number of replicates – usually this is all possible occurrences, not just those recording presence).
3. Calculate mean and variance estimates for park and any meaningful subsets.
4. For key parameters, generate a table and simple graphic (e.g., box-plot) for each park unit.
5. Write a brief summary of the results and their interpretation.
6. Include results and products with the official Research Permit and Reporting System report (and deliver directly to park staff if needed / desired).

Transect techniques

Each VCSS site includes three (3) transects, which serve as local replicates; these are sub-samples and should be aggregated (i.e., averaged). The total length considered for measurement extends from 1m to 36m on each transect (35m each, 105m total); this includes 71 data collection points per transect (213 total per site); multiple data points may be recorded at each of these 213 sites if there are both surface and at least one species present (a point or “hit” is recorded for each species and surface layer at each data collection point). The value for the total number of “hits” at the site should be used in the denominator of averaging steps (allowing for modifications if the dimensions are modified).

Thus, to calculate the percent cover estimate for each site based on the point-intercept data, the averaging equation is:

$$\text{PFCi} = ((\sum c_i) / T) * 100 \text{ where;} \quad (1)$$

PFCi = percent cover for each species/ ground cover type;
 c_i = the number of “hits” per species;
 T = the total number of “hits” across the site;

Plot techniques

The following description and analysis of nested frequency data are extracted from the Heartland I&M Network’s HTLN Analysis SOP found at (http://science.nature.nps.gov/im/units/htln/library/monitoring/protocols/VegMon_SOP12_v2.pdf). Employing the same sampling and analysis methods as other networks working in similar ecosystems helps ensure consistency, allowing us to synthesize and interpret our results across a far broader region.

Core Species and Optimized Frequency: Core species are more frequently encountered in the sampling design than satellite species as a result of their distributional patterns. Grassland, shrubland, and woodland spatial structure (changes in population density) can be measured at the community level by tracking the abundance and distribution of core and satellite species through time. Here core species are defined as those species occurring with $\geq 90\%$ frequency among all sites within the study unit or park (Collins and Glenn 1990). Finer spatial scale patterns can be investigated by applying the same level of frequency ($\geq 90\%$) to define core species at the site level (where a species occurring in nine of the ten plots is defined as a core species). Core and satellite species, due to different patterns of abundance and distribution, respond differently to stochastic variability and therefore when analyzed separately can aid in understanding changes in community structure and local density.

Frequency data used to define core and satellite species are derived from species presence/absence at the site or plot level. In both cases, it is species presence/absence as measured at the 1m² plot frame size. This size quadrat may not be appropriate for all species to measure a change in frequency due to the differences in underlying patterns of abundance and distribution between species. Therefore, in order to track the change in species frequency within and among sites across years, the optimal plot frame size for detecting a change in frequency is determined for each species.

The primary use of frequency data in long term monitoring studies is to act as a surrogate for plant density. That is, the optimal plot size from which to obtain frequency data decreases as spatial structure (local density) of the population increases. Population simulation work demonstrated a plot frame size that returned a mean frequency close to 50% is nearly optimal for detecting changes in species over time across a broad range of spatial structure (Heywood and DeBacker 2007). Here the nested plot frame size that returns a mean frequency value for the site between 20-50% is defined as the optimal plot frame size. Focusing on the low side of the optimal 50% provides both a range for ascribing the optimal plot frame size and allows for species density to fluctuate without being reclassified into a smaller optimal plot frame. The plot frame size that returns a frequency value for each species within the optimal range is identified as the individual species optimal plot frame for detecting a change in its frequency (optimized frequency) over time.

The optimized frequency is determined for all core species at each site for each year. The nested frequency design allows for all species to be sampled together regardless of their optimal plot size.

More importantly, the nested frequency sampling design allows for detecting a change in plant density as indicated by a change in optimized frequency over time. Moreover, variation in optimal plot size for a given species over time indicates larger changes in plant density.

Changes in density of individual core species can be inferred spatially and temporally by reporting the optimized frequency at the site level for each year. It is this ability to detect a shift in optimized frequency across a range of frame sizes for all sampled species that is the strength of the nested sampling design.

Optimized frequency is determined after data collection has occurred and prior to the analysis phase. See below for an example of calculating optimized frequency from sample data:

Nested plot frames are searched from smallest to largest, tallying new species as they are encountered in the field.

1. All species are recorded in the smallest nested plot in which they are first encountered.
2. Species are recorded in a plot frame only once.
3. Species that are recorded in a plot frame are automatically considered as being present in all subsequent larger plot frames in which it is nested.
4. Therefore, as new species are encountered, they are given a value of '1' for the initial plot frame and all larger frames in which they are nested.
5. For all species at each of the ten sampling plots within the site, there are three possible frequency scenarios that can be encountered (below and Table 1):
 - a) Species A is encountered in the smallest plot frame (0.01m^2), recorded as a '1' for that plot frame and also for both larger frames (0.1 m^2 and 1m^2) in which it is nested. Thus Species A is present in all three nested plot frames.
 - b) Species B is encountered in the 0.1m^2 plot frame for which a '1' is recorded for that plot frame and also for the largest frame (1m^2) in which it is nested. Thus Species B is present in the two larger nested plot frames.
 - c) Species C is encountered in the 1m^2 plot frame for which a '1' is recorded for that plot frame. Thus Species C is present in the largest nested plot frame.

Table 1. Three species tallied according to the first individual encountered in the nested plot frames for a single plot within a site.

Site	Plot	Species	0.01 m^2	0.1 m^2	1 m^2
1	A	Species A	1	1	1
1	A	Species B	0	1	1
1	A	Species C	0	0	1

Soil stability

Thirty-six samples per site, twelve along each transect, are collected for testing soil stability; half of these are surface samples, and half are subsurface (2-3cm) samples. The samples from each depth should be analyzed separately. Therefore average eighteen (18) surface samples and eighteen (18) sub-surface samples for each site (results in 2 soil stability estimates per site). To average the site scores, use a rank order of classes (1-6) to represent the stability classes (one is least stable, 6 is most stable) – round decimals appropriately to indicate the proper, “whole number” class.

Invasive species

Analyze the invasive species data as part of species percent cover and frequency analyses as described above and parse out the invasive species element (i.e., separate out based on species). Then, summary data of invasive species and native species can be compared (e.g., mean percent cover, total number of species present). It may also be revealing to look for correlations between 1) soil variables, and 2) distance to road, and cover/ frequency of invasive species. Lastly, use one of the community diversity indices (the formula for Shannon-Wiener's Index of Diversity is provided below) to compare the ratio of invasive species diversity to native species diversity, as well as the ratio of invasive species diversity to overall diversity at each site.

$$H = - \sum p_i \ln (p_i) \quad (2)$$

Where:

p_i = the proportion of total number of species made up of the i th species.

H= Coefficient of Diversity

Trend assessment

When analyzing multiple-date data due to collection of sites using a staggered panel design, assess and account for (if necessary) any trends in the data before averaging for the status estimate. Trends should be assessed using a simple linear model assessment available in most statistical packages (software, e.g., in R this is the `lm` function, in SAS it is PROC). The linear model (trend line) should have the form:

$$St = b0 + b1 * t \quad (3)$$

where;

St = estimate of status at time ' t '.

$b0$ = the derived intercept parameter;

$b1$ = the derived slope parameter;

t = the most recent time period of the data

time units must match the sample interval used to generate $b0$ and $b1$; most often in ROMN-VCSS this will be years

The derived slope ($b1$) and intercept ($b0$) parameters are attained from the statistical analysis. The equation and an r^2 estimate should be provided. The $b1$ value should be highlighted in reporting because it indicates trend in the data (potentially important for management and conservation); the r^2 should be considered in interpretations and presented in reports to indicate the quality of fit of the linear trend model. These analyses should be supported by additional multivariate analyses to attempt to identify and separate sources of variability in the data.

Park-wide cover averages

As previously noted, if analyzing multiple-date data due to collection of sites using a staggered panel design, assess and account for (if necessary) any trends in the data before averaging for the status estimate. Trends should be assessed using a simple linear model assessment (see above).

$$PWA_i = ((\sum c_i) / np) \quad (4)$$

where;

PWA_i = Park-wide Average for park 'i';

c_i = estimated cover for each site (by species);

i = method: separate calculations for each of the field methods (point-intercept, plots);

np = the number of sites assessed in the park (or other sub-unit);

Model Testing

With growing appreciation of the complexity of natural systems and the complex determinants of the ecological conditions (patterns and functions) has come refinement and application of techniques for comparing multiple, complex statistical models. Using a well-designed set of data, we can use statistical models and model selection (based on calculated information content indices) to determine which combination of determinant variables (e.g., system drivers) is most parsimonious in describing the patterns and trends in our data. This approach allows us to assess patterns and trends in our data using a hypothetical set of determinants, from which we allow the information content in the models to select the best fit. Subsequently, if/ when multiple models offer well-founded, supported explanations, averaging of coefficients may be used to generate a new, hybrid model.

Model selection and analyses are best accomplished using modern statistical software (e.g., SAS or R). A trained programmer, or technician, is needed to run these analyses. However, before any models can be analyzed, the set of candidate models must be developed. A set of candidate models generally has two forms, either an exhaustive set of all possible combinations (with or without interactions) of a set of known (or predicted) explanatory variables (the drivers), or a more limited set of these possible combinations with each model having a clear ecological interpretation (i.e., based on theory, observation, etc.).

After a set of models is developed, each model is assessed for quality of fit (with a penalty associated with increasing numbers of variables – for parsimony) – using an information index (e.g., Akaike weight; see Burnham and Anderson 1998 for detailed discussion of application of information indices for model selection). Best approximating models are selected by comparing the Akaike weights (w_i) estimated for each model; the best models have the highest scores (Burnham and Anderson 1998). This analytical approach is important for interpretation and intelligent application (i.e., in management) of monitoring results, because it helps identify the key drivers (variables selected in top models) associated with vegetation and soil dynamics. Results and interpretation of model selection analyses should be applied with some caution because cause-effect relationships are not necessarily indicated by selection of determinant variables; however, this approach is one of the best methods to develop understanding of complicated systems.

Literature cited

- Burnham, K. P., and D. R. Anderson. 1998. Model selection and inference: a practical information-theoretic approach. Springer-Verlag, New York, New York, USA. 353 pp.
- Collins, S. L., and S. M. Glenn. 1990. A hierarchical analysis of species abundance patterns in grassland vegetation. *The American Midland Naturalist* 135: 633- 648.
- Heywood, J.S. and M.D. DeBacker. 2007. Optimal Sampling Designs for Monitoring Plant Frequency. *Rangeland Ecology and Management* 60(4): 426-434.



Standard Operating Procedure (SOP): VCSS Design-based Analysis

Rocky Mountain Network
1201 Oakridge Drive
Suite 200
Fort Collins, CO 80525
970-267-2150

Version: 1.0

Change History

Previous version	Date	Author	Change description	Reason

Introduction

A key aspect of analyses of survey data is the determination of whether a response measure has a trend. Our panel designs distribute a subset of the full spatial distribution of sites among survey years when sites across the park are sampled, and a smaller set of sites that are sampled in staggered, overlapping years to establish temporal connectivity in our design.

When linear models or Mann-Kendall tests suggest there is no trend in a vital sign, unbiased estimates of status may be derived using design-based inference (Hansen et al. 1983; Gregoire 1998) - a powerful analytical strategy unique to population scale objectives and their survey design. Design-based inference is fundamentally different than model-based approaches because design-based inference does not depend on an assumed model of the relationship between samples and the true population. In a design-based approach, expectations are extended over all possible samples based on the weighted values (i.e., measures, averages, etc.) contributed from each sampled site; independence is insured by the design process. Calculation of means are modified from simple mean calculations by weighting (multiplier) each site mean using the inverse of the inclusion probability (from the original design) as the weight; thus, the park-wide average is extrapolated from individual samples based on the area represented by each site in the original design.

Steps

1. Assure that data you are using were previously quality controlled;
2. Verify that summation and averaging steps were conducted properly; always use site level means for analyses (unless a specific application requires otherwise);
3. Retrieve inclusion probabilities for each point from original design files;
4. Calculate site weights as 1 minus the inclusion probability ($1 - \text{Prob}$);
5. Calculate a weighted mean by summing the product of each site weight and the value of interest (e.g., cover) then divide by the product of the sum of the weights and the number of sites. This is represented by the equation:

$$WM_i = \sum (wt)(\bar{X}_i) / N_i \quad (1)$$

Where:

WM_i = weighted Mean for Indicator 'i'

$wt = 1 - \text{Prob. of Inclusion}$ (unique for each site; normalized so sum of weights = 1); data from original design

$\bar{X}_i$ = site level mean estimate (e.g., percent cover, frequency, etc.);

N_i = the number of sites;

Literature cited

- Gregoire, T.G. 1998. Design-based and model-based inference in survey sampling: appreciating the difference. *Can. J. For. Res.* 28:1429-1447.
- Hansen, M. H., W.G. Madow, and B.J. Tepping. 1983. An evaluation of model dependent and probability sampling inferences in sample surveys. *Journal of American Statistical Association* 78(384): 776–793.



Standard Operating Procedure (SOP): VCSS Hypothesis Testing

Rocky Mountain Network
1201 Oakridge Drive
Suite 200
Fort Collins, CO 80525
970-267-2150

Version: 1.0

Change History

Previous version	Date	Author	Change description	Reason

Introduction

Traditional, hypothesis testing data analyses will have a limited, yet important role in ROMN VCSS analyses. Assessment of the park-wide status of a particular resource or indicator is not conducive to these analyses; however, comparison of the current conditions to a former condition, a reference condition, or otherwise desirable (or undesirable) state is well-suited to hypothesis testing. Thus, application of traditional hypothesis testing is incorporated into analysis of vegetation and soil data as status estimates indicate that conditions approach a threshold or other meaningful assessment point (and the test will help provide evidence whether that point has been reached), and it will be applied to repeated measurements to test whether the difference between the two measurements is different from zero (i.e., that there has been significant change). T-tests and analysis of variance (ANOVA) are typical, desirable, parametric tests for these hypotheses.

Steps

1. Verify that dataset was previously quality controlled;
2. Verify that data for analysis are properly averaged (e.g., by site);
3. Isolate data for analyses from other records in the database (export to spreadsheet);
4. Plot the data (X-Y graph) and assess data for pattern; if a pattern is detected, consult statistical text to determine an appropriate, if any, normalization tool; for example, percent (%) data should be arc-sine transformed before analysis to create a normal distribution;
5. Format data to meet requirements of statistical software;
6. Import the data to analysis software;
7. Write code and/ or establish GUI driven method for desired analysis (e.g., ANOVA);
8. Run analyses; copy and save outputs following standard ROMN naming conventions;
9. Isolate critical statistics and record / report in a summary table.

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

NPS 960/107457, April 2011

National Park Service
U.S. Department of the Interior



Natural Resource Program Center
1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525

www.nature.nps.gov