Upland Vegetation and Soils Monitoring Protocol for Park Units in the Northern Colorado Plateau Network

Standard Operating Procedure (SOP) # 1

Preparations for the Field Season and Equipment Needed

Version 1.26 (March 2017)

Revision History Log:

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #
1.00	3/1/2007	S. Garman	Updated equipment list	Provide more logical organization of equipment needs	1.10
1.10	11/2008	R. Weissinger	Updated equipment list	Added forest equipment	1.20
1.20	3/2009	D. Witwicki	Updated Field Data Sheet section and equipment list	Updated for forest, woodland, & oak methods	1.21
1.21	4/2011	D. Witwicki, S. Topp	Revised formatting, added detail, and updated equipment list	Methods changes; to increase useability	1.22
1.22	1/2012	D. Witwicki	Updated equipment list and data sheet list	Reflect methods used in 2011	1.23
1.23	3/2015	S. Karinen	Added instructions for keeping compass declinations current	These change often and need to be updated	1.24
1.24	4/2016	D. Witwicki	Removed instructions to check satellite phone coverage and check out equipment, updated Table 2 for added seedling and sapling density, updated compass declinations	No longer needed, sampling added, updated annually	1.25
1.25	3/2017	S. Karinen	Updated compass declinations	Updated annually	1.26

This SOP describes how to prepare for the field season, including a list of field equipment, and tasks that are performed before each field trip.

Before the Field Season

The following tasks should be completed by the project manager or field crew leader well before the arrival of seasonal field crew members.

1. Post positions for seasonal employees or student interns 3-4 months prior to scheduled field work. Upland vegetation and soils monitoring requires six field crew members that work in pairs. Hiring must be completed at least six weeks prior to the beginning of the field season to allow time for federal background check procedures.
2. Review the entire protocol. Understand the goals and procedures of the monitoring program before beginning other preparations. Discuss any proposed or recent changes to the sampling design or protocol with appropriate I&M personnel. If a change has been implemented since

the last field season, make sure that all field forms, databases, and relevant SOPs have been updated.

3. Compile a list of plots that will be monitored. Discuss the season's objectives with appropriate I&M personnel to develop a field schedule.
4. Schedule field work. Use the guidelines below to develop a field schedule that meets the objectives for the field season and maintains some flexibility for unforeseen events.

   Seasonality of sampling
   Vegetation is sampled during the growing season, typically between mid-May and mid-October. Sampling visits should be scheduled to optimize phenology for the group of NCPN park units included in upland vegetation and soils monitoring. Park units should be visited at approximately the same time each year to maximize repeatability.

   Field crew schedule
   Crew members typically work 8 consecutive 10-hour days, followed by 6 days off, especially when working at distant park units or in the backcountry. Field work that does not require travel and camping will have more flexibility. Office work at the beginning and end of the field season is scheduled for 8-hour days Monday through Friday, and additional office days throughout the field season may be scheduled for trainings, field preparation, or data management.
5. Request research permits. Begin the process at least 10 weeks before the start of the field season to allow ample time for processing.
6. Coordinate with the appropriate park staff to make sure that the proper compliance is followed before installing rebar. It could take several months from the time paper work is submitted until our proposed installations are cleared.
7. Plan travel logistics. Notify appropriate park personnel of the dates the upland field crew will be in their park unit. Discuss housing availability and needs with appropriate parks, and acquire backcountry camping permits.
8. Organize and check all equipment. Equipment is usually tested and inventoried at the end of the field season. Review this list to make sure that you have adequate supplies and that all replacement equipment is ordered and will be available before the field season begins. Table 1 lists equipment needed for each SOP.
9. Review plant species lists for each park unit, and update them with new species detected in the previous field season. Print additional copies, if necessary, so that each two-person team has a copy for the field. Review the species most likely to be encountered in each park and assemble relevant flora, keys, and field herbaria.
10. Update compass declinations for each park using the Magnetic Field Calculator on the NOAA website (http://www.ngdc.noaa.gov/geomag-web/#declination). Update Table 3 with any changes. Print the current declinations and add them to each field binder and Toughbook.

A few weeks before each field visit

The following tasks should be completed by the field crew leader in the weeks before a scheduled field visit.

1. Review existing maps for each park, and request additional maps from the GIS technician if necessary.
2. Pack and review relevant information for each plot including:

   Revisit data sheets – provides directions to the plot, coordinates of monuments, and any other specific information from the previous visit.
   Plot species list- list of species detected during the previous monitoring visit.
   Trip reports - from the previous field season. At the end of each field trip, the crew leader writes a brief report describing general field conditions, access issues, logistical challenges, safety concerns, equipment problems, and suggestions for improving efficiency.
   Access information – contains useful information for navigating to remote areas of park units.
3. Coordinate with the data manager to reserve field laptops and load the database and other relevant information for the plots to be sampled. Transect photos are especially useful for relocating rebar in forest and oak plots and should be loaded onto the laptops.
4. Print and copy backup field data sheets. Pack the appropriate amount data sheets printed on Rite-in-the-Rain© paper for the predicted weather. Copies of each form are found at the end of the appropriate SOP. Data sheets for field measures are listed in Table 2 with the minimum number needed to sample a plot.
5. Coordinate with the GIS technician to reserve GPS units and load UTM coordinates for the plots to be sampled.
6. Contact parks and provide detailed trip information. Contact the resource staff and chief ranger and provide dates the crew will be working in the park, names of field crew members, vehicle descriptions, and approximate locations of monitoring activity.

Immediately before each field visit

The following tasks should be completed by the field crew leader immediately before each field visit.

1. File a backcountry safety plan. The day the crew leaves for a multi-day field trip, the crew leader should email a backcountry safety plan to Glen Canyon dispatch. Crew leaders should review the NCPN Field Safety SOP for specific procedures.
2. Perform a vehicle safety inspection and replace any necessary fluids.
3. Make sure that the **batteries are fully charged for all rechargeable equipment,** including laptops, cameras, GPS units, satellite phones, and vehicle jump starters.

Table 1. Equipment needed to sample an upland monitoring plot by a two-person team.

Item	Number needed	Description	Notes
General Equipment - *necessary for all SOPs*			
GPS with extra batteries	2	Trimble GeoXM or more accurate	main unit and backup
GPS car charger	1		
Digital camera	1		transect and crust photos, scenics
Extra battery for digital camera	1		
Inverter	1	plugs into vehicle	charge satellite phone
Permit	2 per vehicle		one on dashboard, one with crew
Maps	1		
Data sheets	One complete set		Rite in the rain compliment for point intercept and gaps
SOPs	1		
Clipboard	1	lightweight with interior storage	
Field notebook	1 per person	small, Rite-in-the-Rain©	field notes
Pencils	2-3		
Toughbook	1		data entry
Extra battery for Toughbook	1		make sure batteries are fully charged before leaving
USB flash drive	1	rugged, water resistant	data backup after each plot
Car charger for Toughbook	1		
Chair with backrest	1		for data recorder
Safety Equipment - *necessary for all SOPs*			
First aid kit	1		content list in NCPN Backcountry Safety Plan
Satellite phone	1		
Satellite phone charger	1		
NCPN Field Safety SOP	1		
NCPN Accident Report Logs	1		found in NCPN Backcountry Safety Plan
NCPN Medical Information Forms	2	each person carries their filled out form	found in NCPN Backcountry Safety Plan
2-way radios	1		crew communication
Extra radio batteries	min. 3	AA alkaline	radios require 3 per unit
Personal Equipment - *necessary for all SOPs, provided by observers*			
Sunscreen			
Sunhat or baseball hat			
Water bottles			

Item	Number needed	Description	Notes
Raingear (jacket *and* pants)			
Site Characterization – SOP #5, *Necessary for site recon.*			
Ecological site keys/tables	1		
Compass	1	with declination setting	photo direction
Acid bottle filled with 1M HCl	1		test soil effervescence
Soil sieve	1	2 mm	separates rock fragments from fine soil particles
Trowel	1	U-dig-it or other small metal trowel	scoops surface soil into sieve
Spray bottle with water	1	Small plastic	moistens soil sample
Clinometer	1		measures slope
Plot Establishment and Revisits - SOP #6, *Necessary for all visits unless noted with an E = establishment or R = re-visit.*			
Compass	1	with declination setting	set declination, take transect bearings
Pin flags	min. 3	narrow steel pins with flag top	mark locations
50-m transect tapes	2	Plastic reel tapes	set up transects
Chaining pins	min. 6	striped metal pins	secure tapes
Rebar	E – 6 per plot R – 2 per plot	3/8" diameter cut into 18" lengths	permanent markers
Aluminum tags	E – 6 per plot R – 2 per plot	Oval	plot reference information
Sledgehammer	1		drive in rebar
Stamp kit	1	¼” steel	stamp transect information on tags
Wire		18-20 gauge	attach tags to rebar
Wire cutters	1	small	
Tree tags	12	round, numbered	for optional witness trees in forest plots
Nails	12	galvanized steel	for optional witness trees in forest plots
Plot Revisit Form	R	For each plot	provides directions to plot, rebar locations, and comments from previous visit
Photographs - SOP #7, *Necessary for all visits.*			
Sign board	1	5 x 7"	label photos
Chalk	several pieces		
Monopod	1		delineate photo height
2-m folding ruler	1		delineate transect photo location
Point-Intercept Sampling - SOP #8, *Necessary for all visits.*			

Item	Number needed	Description	Notes
Laser	1		sample cover of understory vegetation
Laser monopod	1		mount lasers
Extra laser batteries	min. 3	1.5V silver oxide watch batteries	lasers take 3 per unit
Densitometer	1		sample cover of vegetation about the height of the laser
Screwdriver or multitool	1	small Phillips head	change laser batteries
Biological soil crust darkness guide	1		
Plot species list	1	species previously recorded at plot	
Park species list	1	Annotated species list	assist with plant ID
Basal and Canopy Gap – SOP #9, *Necessary for grassland/shrubland plots.*			
2-m folding engineers ruler	1	Marked with shrub height classes	
Annual species list	1		
Exotic Frequency, Species Richness, Canopy Closure, Shrub and Tree Seedling Density - SOP #10, *Necessary for all plots (unless otherwise noted).*			
Folding ruler	2	2-m folding engineer's ruler, marked with shrub height classes	delineate exotic frequency quadrats; delineate 1-m belt for species richness and shrub/ seedling count; measure shrub height
Modified concave spherical densiometer	1		overstory canopy (forest plots only)
Exotics species list	1	perennial and annual	
Soil Stability - SOP #11, *Necessary for grassland/shrubland and woodland plots.*			
Slake kit	1		holds soil samples
Soil spoon	1		collect soil samples
Deionized or distilled water			dip samples during test
Stopwatch	1		time stability test
Random number	1		determines soil collection locations
Site Impact Assessment - SOP #12, *Necessary for all visits.*			
Stopwatch	1		time exotic species search
Saplings and Overstory Trees - SOP #13, *Necessary for forest, woodland, and oak plots.*			
Diameter tape	1	cloth with diameter in cm	measure trees
15-cm plastic diameter calipers	1	in cm	measure sapling diameter
Round aluminum tree tags	Many	numbered	permanently mark overstory trees
3” nails	Many	galvanized steel	attach tags to trees

Item	Number needed	Description	Notes
2-m folding engineers ruler	1		delineate 5-m belt for sapling count (woodland and forest only)
Flagging tape	1	Orange or other bright color	delineate area for tree census
Fuels - SOP #14, *Necessary for forest and woodland plots.*			
Go-no-go gauge	1		determine size class of woody materials
Transparent plastic ruler	1	Marked in cm and inches	measure litter and duff depth
U-dig it or trowel	1	Small metal	sample litter and duff
20- or 50-m transect tape	1	fiberglass reel tapes	
Modifications for oak plots - SOP #15			
See equipment lists for all relevant SOPs.			
Unknown Plants - SOP #16, *Necessary for all visits.*			
Hand lens	2		
2-gallon resealable plastic bags	several	2- gallon or larger	collect plants
Masking tape	1		label plant collections
Permanent marker	1		label plant collections
Trowel or U-dig it	1	small garden tool	extract specimen roots
Plant press	1	press with card, blotter, and paper	kept in vehicle; store plant collections for identification
Relevant floras and park species lists		various by park	

Table 2. Number of data sheets needed to sample an upland monitoring plot by vegetation type.

	Vegetation type			
Data Sheet	**Grassland/ shrubland**	**Woodland**	**Forest**	**Oak**
Site characterization (initial plot visit only)	1	1	1	1
Site establishment or Re-visit	1	1	1	1
Photos	1	1	1	1
Point intercept	3	3	3	
Point-intercept (oak)				3
Shrub and tree density	3	3	3	3
Exotic frequency, species richness, and canopy closure	3	3	3	
Exotic frequency (oak)				3
Canopy and basal gaps	3			
Soil aggregate stability	1	1		
Overstory trees		1	1	1

Fuels		1	1	
Unknown plants	10	10	10	10
Site impact	1	1	1	1

Table 3. Current compass declinations for each park unit. (Last updated 3/27/2017)

Park	Latitude	Longitude	Declination (Degrees East)	Round to (Degrees East)
ARCH	38.7243566455	-109.594948929	10.3	10
BLCA	38.5702491771	-107.763544925	9.51	10
BRCA	37.5706229863	-112.177338591	11.08	11
CANY	38.2352492104	-109.879218339	10.35	10
CARE	38.0666597962	-111.140787962	10.80	11
CEBR	37.6339313749	-112.843910127	11.31	11
COLM	39.0488918624	-108.689248059	9.97	10
CURE	38.4542548912	-107.332699741	9.40	9
DINO	40.4921561285	-108.836636764	10.22	10
FOBU	41.8605933487	-110.765508028	11.23	11
GOSP	41.6168160897	-112.541287815	11.87	12
HOVE	37.4082448652	-109.02673195	9.90	10
NABR	37.6026153107	-110.005822402	10.31	10
PISP	36.862688385	-112.739116803	11.15	11
TICA	40.4402471332	-111.708767187	11.37	11
ZION	37.3232882632	-113.044108851	11.33	11

Upland Vegetation and Soils Monitoring Protocol for Park Units in the Northern Colorado Plateau Network

Standard Operating Procedure (SOP) # 2

Hiring and Training Field Technicians

Version 1.32 (August 2017)

Revision History Log:

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #
1.00	3/1/07	S. Garman	Addition of reference to SOP #4	To emphasize procedures that minimize crust busting	1.10
1.10	11/2008	R. Weissinger	Addition of safety training	Improve safety of crew	1.20
1.20	3/2009	D. Witwicki	Minor formatting edits	Consistency with other protocols	1.21
1.21	3/2011	D. Witwicki, R. Weissinger, S .Topp	Added detail	To be more useful and comprehensive	1.30
1.30	12/2014	S. Karinen	Added detail to safety section		1.31
1.31	8/2017	D. Witwicki	Changed title and references to “observers”	Edits for publication	1.32

This SOP explains the qualifications needed for permanent and seasonal field personnel and procedures for training seasonal vegetation sampling technicians. Accurate, consistent data collection begins with the hiring process, followed by a rigorous training program. Technicians must also be prepared, both mentally and physically, for the extreme weather and difficult terrain of NCPN parks.

Hiring Field Technicians

The most essential element for the collection of quality data is well-trained, experienced field crews. Given the variability of plant community types across NCPN parks, it is necessary to hire highly skilled personnel with botanical skills and experience working throughout the region. The importance of hiring and training well-qualified field technicians cannot be overemphasized. In order to accurately detect trend across sampling periods, it is imperative that field technicians record vegetation data using the same methods and level of precision year after year.

Staffing requirements

Upland vegetation and soils monitoring requires ecological and vegetation expertise. A permanent or term subject-to-furlough biological science technician (minimum GS-6) leads a crew responsible for vegetation sampling. Five seasonal crew members (NPS, volunteer, intern, or cooperator) comprise the upland vegetation crew. Two of these

seasonal technicians (GS-5 or GS-6), along with the crew leader, each lead a two-person crew while performing field work.

Qualifications and attributes
In addition to the technical skills, experience, and knowledge listed below, certain qualities are necessary for all NCPN field personnel. To maintain data quality, all staff should have the ability to successfully engage in repetitive, detail-oriented work. Technicians must be in excellent physical condition and able to thrive in difficult field conditions. Certification in Wilderness First Responder (or Wilderness First Aid) and CPR is also an asset. Employees should expect to travel to remote parks and work away from home for periods of up to 8 consecutive days and, in many instances, to camp in backcountry situations.

Technical Skills, Experience, and Knowledge
The Upland Crew Leader is a Biological Science Technician that specializes in botany. The technical skills, experience, and knowledge required for all upland vegetation and soils field positions is detailed below.

Lead Biological Science Technician (Upland Crew Leader)
- Ability to identify common upland genera and species by sight.
- Ability to key plants to species using floras and technical keys.
- Experience leading a field crew to collect biological data in remote field settings.

Seasonal Biological Science Technicians (2-person Crew Leads)
- Ability to identify common upland genera and species by sight.
- Ability to key plants to species using floras and technical keys.
- Ability to make logistical decisions on a daily basis and lead a two-person team.
- Ability to communicate effectively with the crew leader regarding planning and completion of daily assignments.

Seasonal Biological Science Technicians (seasonals, interns, or volunteers)
While not imperative, experience conducting quantitative vegetation sampling is a valuable skill in any employee. During the applicant review process, it is important to give priority to those candidates with considerable experience conducting vegetation surveys and, secondly, to candidates with (1) experience conducting any type of field work that involves detailed data collection, (2) extensive experience backpacking and hiking, and/or (3) an academic degree related to vegetation or ecology. Particular attention should be paid to the experience of the observer, his/her ability to learn new plants, physical abilities to withstand difficult field conditions, ability to be productive in a team environment, and overall attitude. NCPN trains biological science technicians in methods specific to our program.

Training Seasonal Vegetation Field Crew Members
To promote accuracy and consistency in data collection among data collectors, training should be designed to calibrate data collectors so that they have comparable skills in identifying species and are recording data in a consistent format. For data collectors who are already competent at identifying plants by sight and taxonomic keying, the need for

training in plant identification may be minimal. If the program is fortunate enough to hire all experienced personnel for a season, then the proposed training program is focused on improving their skills. No data collector is exempt from the training program.

1. Prepare for the training program. The project manager or crew leader acts as the primary instructor; however, experts in various aspects of the protocol (such as First Aid/CPR) should be scheduled to assist in training as necessary. The instructor must prepare training materials, itineraries, and field gear before the training program begins.

2. Issue field gear before training begins. See SOP #1 for a list of field equipment. Provide a copy of this protocol to all trainees, along with a list of recommended personal field and camping equipment, before training begins. Ensure that field crew members examine the list of necessary personal gear (see SOP #1) and that they have all the appropriate equipment by the time field work starts. Make sure that trainees are informed and prepared for the training events. Have the field technicians read the relevant upland SOPs prior to field training.

3. Have all vegetation crew members participate in Upland Monitoring vegetation sampling training. The project manager, field crew leader, and other crew leads provide several days of instruction covering all field-based procedures. All field SOPs should be thoroughly reviewed prior to field exercises so they can be used as references during training. In order to prevent excessive trampling at monitoring sites, these exercises are conducted at highly-impacted sites outside of potential areas for upland vegetation and soils monitoring.

Crew members from previous seasons normally do not need as much training as new crew members; however, all data collectors must attend the entire training each year. For returning crew members, it is especially important to point out changes to the protocol, review any issues with data quality from the previous year, and recommend methods for improving data quality, if necessary. Experienced crew members can assist with training less-experienced field crew members.

It is important that all crew members calibrate their measurement techniques with each other before collecting data at plots. This will ensure that measurements are as consistent as possible among crew members. Crew members should rotate partners often during training so that they can identify discrepancies in data collection techniques and remedy any issues before actual data collection.

The following are essential components of training for upland plot visits:

Navigating and recording waypoints
Training includes traditional navigation techniques using a map and compass, as well as navigation and data recording using handheld GPS units. SOP #3 should be thoroughly reviewed, and any questions should be directed to the NCPN GIS expert. At the training, crew members practice locating the centers of new plots and re-locating rebar marking transect ends of previously established plots. All technicians should also practice logging points on the GPS unit and recording associated information in data dictionaries.

Site characterization
At one or more plot centers, site characterization procedures are explained and demonstrated, including evaluation of ecological site characteristics. Identifying ecological site types is critical during site reconnaissance and plot establishment to determine if the pre-selected plot corresponds to the target ecological site. Ecological site is an underlying stratum in NCPN upland vegetation and soils monitoring, and it is important that the plots selected for monitoring actually represent the intended ecological-site stratum. Tables and dichotomous keys summarizing descriptions of target ecological sites at each park unit are provided to crew members. The project manager provides instructions for using tables and keys and demonstrates their use in the field by visiting examples of target ecological sites.

Electronic data recording in the field
All field data is collected on rugged laptops (i.e., Toughbooks) unless more than 3 plots are visited concurrently. Prior to field exercises, the data manager provides instruction on user protocols, including quality control. The Toughbook Quick Reference Guide should also be reviewed thoroughly by all crew members. Field teams need to accurately record data in the field and consistently check that all data fields are completed in the laptop prior to leaving a plot.

Plot establishment and revisit
Plot orientation and transect set up is demonstrated and practiced. Pay particular attention to taking compass bearings and adjusting compass declination. Throughout the field season, crew members should periodically check each other's accuracy using the compass and clinometer.

Vegetation sampling
Vegetation sampling and site-impact assessment procedures are explained and demonstrated at grassland and/or shrubland sites. For each method, field crew members practice sampling techniques with the project manager or field crew leader observing closely. Field crew members also practice recording observations on paper data sheets and field laptops. Training for protocols specific to forest, woodland, and oak vegetation types occur later in the field season at parks where these vegetation types occur. Periodically throughout the field season, crew members should check that they are performing measurements similarly to other crew members and resolve any discrepancies that they discover.

Photos
Review tips for taking good transect and crust photos, including appropriate orientation of the camera. Make sure to stress the importance of checking time and date settings in the camera at the beginning of each field trip.

4. Stress the importance of crust-friendly and other low-impact procedures. It is critical to minimize the impact on biological soil crusts while monitoring upland plots. Teach crew members to practice minimum-impact procedures while traveling to and from plots, setting up plots, and recording measurements. Also review low impact camping procedures.

5. Emphasize field safety procedures and issues. The NCPN approach to safety requires that the crew 1) keeps NCPN and park staff informed of its activities and 2) is prepared to handle emergency situations. Training includes a minimum of NCPN safety procedures (outlined in detail in the NCPN's programmatic Field Safety SOP, available separately), First Aid/CPR instruction, Job Hazard Analysis (JHA), and review of safety equipment, safety issues specific to the Colorado Plateau, and vehicle safety.

Field Safety SOP
The NCPN Field Safety SOP applies to all NCPN monitoring protocols and outlines the minimum procedures that the NCPN must take to ensure safety for all employees working in the field. This SOP is updated annually and provides detailed safety communication procedures and other important safety information that is summarized below. At the beginning of the field season, each crew member reviews the SOP, and safety procedures are reviewed in detail.

First Aid/CPR
All crew members must have up-to-date certifications in first aid and CPR. The minimum requirement is a one-day CPR/First Aid course. The NCPN will provide this training for all crew members that do not have current certifications. In addition, the crew leader will be trained as a Wilderness First Responder before field work begins.

Job Hazard Analysis
Crew members participate in developing the appropriate JHAs for their position that identify potential hazards and ways to minimize risks (see Appendices A and B for example JHAs). JHAs need to be completed and signed before fieldwork begins.

Safety Equipment
When in the field, each crew carries a well-stocked first aid kit and a satellite phone and/or a SPOT beacon. During training crew members review the items in their first aid kits and are trained on how to use these items. Crew members are also trained on how to use the satellite phone and SPOT beacon. Crew members must know where all emergency equipment is located during field work.

Safety issues specific to the Colorado Plateau region
During training, important safety issues for the NCPN region are discussed, most notably, flooding, heat/cold exposure, hiking safety, and fatigue. Specific issues should be revisited in the field any time they are relevant to the area where the field crew is working. Some potential risks of upland monitoring field work and ways to minimize these risks are outlined below:

- ***Long road trips:*** Travel between parks requires long road trips under varied weather and road conditions.

  Mitigation of risk: Trade off driving duties with other crew members to reduce fatigue. Stop and rest if needed. Drive defensively and with a level of caution relevant to driving conditions.

- ***Backcountry travel:*** Accessing upland monitoring sites requires travel on secondary roads that are gravel or dirt, and some sites require hikes of up to three hours each way. Dirt roads can become impassible during wet weather, and may remain muddy for several days after precipitation. Hiking may be on or

off trail through steep, rocky, sandy, or muddy conditions. Hiking can occur in washes that have flash flood potential.

Mitigation of risk: Be aware of potential hazards and continuously assess risks. Respond prudently.

- ***Varied weather conditions:*** The Colorado Plateau region is characterized by weather conditions that vary considerably through the seasons, day-to-day, and hour-by-hour. Snow, wind, and temperatures below 0°F occur in the winter, and summer temperatures are often well above 100°F. Lightning is common during the summer monsoon storms. Hypothermia and heat-related injury are possible, and occasional discomfort is certain. Successful field work requires preparation for this wide range of conditions.

  Mitigation of risk: Be prepared with water, food, sun-protective clothing, sunscreen, and warm layers and a hat. Be aware of potential hazards and continuously assess risks. Keep open communication with all crew members. Respond prudently.

Vehicle Safety and Care
Review proper use and care of government vehicles, vehicle inspection, tire changing, defensive driving, and safety on 4WD roads.

The NCPN is dedicated to providing training and equipment to maximize the safety of its employees in the field; however, it is ultimately the responsibility of each crew member to be prepared and make good decisions while in the field. Crew members must be prepared to ensure personal safety and survival for up to twenty-four hours in the backcountry. Crew members should use good judgment in the field to determine whether working conditions are acceptable. If a crew member feels that a situation is unsafe, s/he should take action to remove herself or himself from the situation. Safety should always be the first priority of every NCPN crew member.

6. Review dominant plant species. Training consists of field and office-based identification of plants likely to be observed during the field season, with emphasis on grasses and other difficult-to-identify species. Additionally, field crews are introduced to and instructed on the use of available taxonomic keys and reference materials. The field crew leader provides tips for making quality plant collections, documenting unknown species, and vouchering new species. Since the northern Colorado Plateau is ecologically diverse, the field crew leader also provides plant species training throughout the field season at each new park unit, including guided plant walks and a review of field herbaria.

7. Other suggested topics for training.

Program overview – introduction to NCPN goals and projects, overview of upland monitoring sampling design and objectives

Administrative responsibilities and policies – timesheets, travel, work hours, leave policies, and equipment care

Park etiquette – visitor interactions, low impact practices

8. Conduct additional training at plots that are easily accessible. Training continues throughout the 1st field trip to actual plots. Sampling should occur in a park that is easily accessible to account for slower data collection while new crew members are learning. Field partners should also be rotated frequently to continue calibration of field measurement techniques.

Appendix A. Example Job Hazard Analysis for NCPN monitoring fieldwork.

JOB HAZARD ANALYSIS **(CERTIFICATION OF HAZARD ASSESSMENT - 29 CFR 1910.133)** **U.S. National Park Service**	**JOB ACTIVITY: Monitoring Field Work** **DATE: 04/02/2014** **PREPARED BY: R, Weissinger, S.Karinen, D.Perkins, D.Witwicki, K.Lund, B. Gottung, J. Doucette, S. Kast, W. Plafcan** **CERTIFIED BY:**

PERSONAL PROTECTIVE EQUIPMENT REQUIRED: Sun and rain protection, insect repellent, boots, water, communication equipment, shovel, and jack.	**QUALIFICATIONS, EXPERIENCE, OR TRAINING REQUIRED:** Basic backcountry competence

BASIC JOB STEPS	HAZARDS	SAFE JOB PROCEDURE
Break work down to basic elements (such as remove, lift, carry, stop, start, apply, return, squeeze, weld, saw, walk, hold, grind, place, etc.). Describe **what** is done, not how it is done.	For each job step, state what accident could occur and/or what hazard is present. To determine this, ask yourself if the person could fall; overexert; be exposed to burns, fumes, rays, gas, etc.; hit against, be struck by, come in contact with, be caught in, on, or between something?	State how each element of work should be performed to prevent the accident or avoid the hazard. What should the person do or not do? Be specific. What precautions should be taken? Ask yourself what you can do to eliminate, modify, guard, identify, or protect against the potential hazard or accident, including such things as how the worker stands, holds, uses, carries, dresses, etc.
1. Highway driving	a) Varied road conditions and road hazards such as animals and other obstructions b) Fatigue c) Behavior of other drivers d) Phone / mobile device use	Be well rested before road trips and constantly alert to obstructions and behavior of other drivers. Sleep if over tired on the way home after long days. Trade driving with passenger(s). Always wear seatbelt. Both hands on steering wheel at all times. It is against government policy to use your mobile device while driving.
2. Dirt road driving	a) Rough and rutted roads, high-clearance driving b) Muddy roads c) Narrow roads with short sight distances d) Animals and other obstructions e) Oncoming traffic	Be well-rested before road trips and constantly alert to obstructions and behavior of other drivers. If overtired, stop to sleep on the way home after long days. Trade driving with passenger(s). Always wear seatbelt. Both hands on steering wheel at all times. Be wary of washboards and blind corners. Maximum speed on unimproved roads is 30 mph, slower depending on conditions.
3. Inclement weather driving	a) Slippery roads and poor visibility	Drive slowly. Watch for snow, ice, ruts, washed-out roads, washboard surfaces, loose gravel, and flash floods. Be well-rested before road trips and constantly alert to obstructions and behavior of other drivers. If overtired, stop to sleep on the way home after long days. Trade driving with passenger(s).
4. Hiking	a) Steep, loose terrain b) Uneven footing c) Long distances d) Hiking along roads	Wear sturdy shoes and don't rush on uneven terrain. Distribute weight low and close to back in backpack. Rest frequently and drink lots of water and hydrating liquids. Be wary of dangerous animals (domestic or wild). On steep rocky slopes, hikers should space themselves to avoid knocking rocks on hikers below. Wear bright colors when hiking along roads.
5. Stream access	a) Swift currents, deep water b) Flood flows c) Cold water and ice d) Contaminated water	Approach streams cautiously. Don't enter stream if visual estimate of product of depth and velocity is >10 (depth in ft and velocity in ft/s). Safely cross swiftwater utilizing multiple people (side-by-side or in a line, hanging onto each other for stability). Be wary of slippery and loose stream beds and dangerous animals. Be prepared to self-rescue if you fall in. Know how to avoid and treat hypothermia.

6. River work	a) Boating on large rivers (rafting, inflatable kayaks, backpacking rafts) b) Swiftwater & whitewater rapids c) Cold water	Know safe boating practices. Wear a personal floatation device (PFD) at all times when on the water. Conduct a whitewater safety talk before rapids. Be prepared with swiftwater rescue gear, such as flip lines, throw bags, appropriate clothing, etc. Know the river swim position (feet downstream). Attend a swiftwater training, if available. Know how to avoid and treat hypothermia.
7. Dealing with environmental conditions	a) Temperature and sun exposure b) Adverse weather (rain, snow, lightning, wind, and flash floods) c) Rockfall d) Treefall e) Wildfires	Wear sunscreen. Have appropriate extra clothing for weather changes. During lightning, keep to low areas and assume the lightning position if it is nearby. Watch for flash floods. Be prepared to spend the night out. Rest frequently and drink lots of water and hydrating liquids. Camp away from washes and areas that could flood. Consider exposure to potential rockfall or treefall when choosing camp sites. Be aware of wild fires in areas that you are working and keep a safe distance in case you need to evacuate.
8. Dealing with dangerous flora and fauna	a) Animals (rattle snakes, bears, moose, sheep dogs, cows, cougars, mice) b) Insects/Invertebrates (mosquitos, gnats, ticks, kissing bugs, bees, black widows, scorpions) c) Plants (poison ivy, stinging nettle, thorny/spiny plants)	Look for and avoid dangerous flora and fauna while hiking, working, and camping. Give sheep dogs and cows a wide berth. Wear appropriate clothing and shoes to protect yourself from insects and plants. Check for ticks regularly, especially when working where they are common. Know how to administer first aid for bites and stings. Wear orange during hunting season, especially near park boundaries.

Appendix B. Example Job Hazard Analysis for NCPN monitoring office activities.

JOB HAZARD ANALYSIS **(CERTIFICATION OF HAZARD ASSESSMENT - 29 CFR 1910.133)** **U.S. National Park Service**	**JOB ACTIVITY: Office activities** **DATE: 04/02/2014** **PREPARED BY: R, Weissinger, S.Karinen, D.Perkins, D.Witwicki** **CERTIFIED BY:**
PERSONAL PROTECTIVE EQUIPMENT REQUIRED:	**QUALIFICATIONS, EXPERIENCE, OR TRAINING REQUIRED:**

BASIC JOB STEPS	HAZARDS	SAFE JOB PROCEDURE
Break work down to basic elements (such as remove, lift, carry, stop, start, apply, return, squeeze, weld, saw, walk, hold, grind, place, etc.). Describe **what** is done, not how it is done.	For each job step, state what accident could occur and/or what hazard is present. To determine this, ask yourself if the person could fall; overexert; be exposed to burns, fumes, rays, gas, etc.; hit against, be struck by, come in contact with, be caught in, on, or between something?	State how each element of work should be performed to prevent the accident or avoid the hazard. What should the person do or not do? Be specific. What precautions should be taken? Ask yourself what you can do to eliminate, modify, guard, identify, or protect against the potential hazard or accident, including such things as how the worker stands, holds, uses, carries, dresses, etc.
1. Enter data	a) Repetitive motions b) Sitting in one place for long periods of time	Take frequent breaks and switch tasks with other crew members when possible.
2. Move field equipment	a) Back strain from lifting heavy objects	Lift with legs, not back. Ask for assistance when needed.

Upland Vegetation and Soils Monitoring Protocol for the Park Units in the Northern Colorado Plateau Network

Standard Operating Procedure (SOP) # 3

Using Global Positioning System (GPS) Units

Version 1.04 (March 2016)

Revision History Log:

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #
1.00	1/2011	A. Wight	Add cultural feature	Features updated in data dictionary	1.01
1.01	12/2012	A. Wight	Added directions for avoiding the "timed out" file problem.	Clarifying updated TS software directions	1.02
1.02	4/2013	D. Witwicki	Added directions for manually entering waypoints into Trimbles	Requested by field crew	1.03
1.03	3/2016	A. Wight, H. Thomas	Updates based on GPS software updates; updates to definitions and acronyms	To reflect current GPS software and data management terminology	1.04

This Standard Operating Procedure (SOP) explains the procedures and considerations that all observers should follow when navigating to and/or collecting geospatial data at upland vegetation and soils monitoring locations.

This SOP assumes that each observer is familiar with the operation and function of the GPS unit to be used for this project. This SOP is intended to complement, not replace, the operations manual accompanying the GPS unit. Each observer should be familiar with the use of their particular GPS unit before entering the field to collect data or navigate to points.

This SOP is divided into two main sections: 1) Upland Site Characterization and Upland Plot Establishment, and 2) Upland Site Revisit. Each main section contains minimum GPS receiver requirements, followed by brand-specific instructions. The intent is to maintain a high quality of GPS spatial accuracy and collection capabilities

This SOP does not require the use of a specific brand of GPS unit; however, the unit is required to meet the minimum standards listed below.

Definitions and Acronyms

Accepted data	Data that have undergone all QA and QC procedures as defined in the published protocol and associated SOPs.
Coordinate system	Any three-dimensional reference frame that locates objects in space.
Data dictionary	Information (data) that describes features that will be located in the field.
Feature	A physical object or location of an event. A feature can be a point, line, or polygon (area).
FGDC	Federal Geographic Data Committee. The interagency committee that promotes the coordinated development, use, sharing, and dissemination of geographic data.
GIS	Geographic Information Systems. A computerized system used to input, manage, manipulate, analyze and display geographic data in digital form.
GPS	Global Positioning System (unit/receiver/datalogger). A three part system of 1) 25+ Department of Defense satellites, 2) Control segment, 3) Users with receivers.
I&M	Inventory & Monitoring Program of the National Park Service
Master database	Project-specific database that stores the full project dataset and is used for viewing, summarizing, and analysis. Contains only accepted data.
NCPN	Northern Colorado Plateau Network
NPS	National Park Service
Quality assurance (QA) procedures	Procedures used to ensure collection of data with minimal errors.
Quality control (QC) procedures	Procedures used to flag or modify data to ensure that data meet established data quality standards.
Raw data	Data that have not been subjected to either quality control or documentation procedures; includes data recorded by hand on hard-copy forms, digital files from handheld devices, GPS receivers, telemetry data loggers, etc.
SOP	Standard Operating Procedure
Spatial dataset	A dataset that is natively read by mapping software; often produced by mapping software, such as ESRI ArcMap and ArcInfo; also includes georeferenced imagery, geodatabases, as well as hardcopy aerial photographs, satellite imagery and maps.
Tabular dataset	A dataset organized in a table or group of tables where each column and row has a specific interpretation; often produced by MS Excel, MS Access, database, or statistical software, and managed as text, spreadsheet, or relational databases.
Working database	A project-specific database for entering and processing data for the current season (or other logical period of time).

1 Site Characterization and Plot Establishment

The project manager predetermined possible upland monitoring locations (specific XY coordinates in UTM NAD83). Each potential monitoring location must be visited to determine if it meets the criteria prior to becoming a permanent monitoring location. The NCPN requires the use of a mapping grade GPS unit to record these Site Characterization and Plot Establishment data locations.

1.1 Minimum GPS Receiver Requirements

- Capable of uploading pre-determined (potential) upland monitoring locations
- Capable of utilizing data dictionary utilities (NCPN Upland Data Dictionary, see section 2.3)
- Capable of utilizing park-specific background GIS data layers
- Capable of navigation
- Capable of maintaining 4 or more satellites
- Capable of maintaining horizontal errors of less than 5 meters (PDOP (or equivalent error reading) of less than 6)
- Capable of post data collection correction (differential correction)
- Capable of storing date, time, elevation and coordinates of features collected (in addition to data dictionary items)
- Capable of exporting features collected to a GIS data format

1.2 GPS Unit Setup

The NCPN currently uses the Trimble line of mapping grade GPS units and TerraSync Professional software to capture the spatial data for the upland monitoring plot locations (site characterization and plot establishment). The requirements should be transferable to other mapping grade GPS receivers (such as Leica, etc.).

Positional accuracy can be affected by several factors which mapping-grade GPS units can track and to some extent, compensate for. Table 1 lists these functions, their definitions, and the standard settings.

Table 1 Minimum GPS Receiver Settings Standards

Name	Definition	Standard
Almanac	GPS unit collects data containing estimated position of satellites, time corrections, and atmospheric delay parameters.	The unit will automatically collect the almanac. Acquire within 10 days prior to data collection or navigating, download to computer.
Altitude reference	Ellipsoid model	Height Above Ellipsoid (HAE)
Antenna heights	GPS unit height above the ground (average).	1.0 – 1.5 meters
Coordinate System	A reference system consisting of a set of points, lines, and/or surfaces, and a set of rules, used to define the positions of points in space in either two or three	Universal Transverse Mercator (UTM)

Name	Definition	Standard
	dimensions.	
Datum	Geodetic model designed to fit a point on the earth's surface to the ellipsoid.	NAD 1983 (Conus)
Elevation mask	The minimum angle at which a GPS receiver will track satellite vehicles.	15 degrees
Logging intervals	Time interval between positions gathered.	Point: 1 second Line and Polygon: 5 seconds
Minimum number of positions for a point feature	Number of positions received then averaged to create a point feature.	10 - 20
Mode	2-Dimensional or 3-Dimensional	3-Dimensional (4 satellites)
PDOP Mask	Positional Dilution of Precision is a measurement of the geometry of the satellites.	6.0 or less
Satellite vehicles	Number of satellites, currently a constellation of 28 DOD satellites.	4
SNR Mask	Signal-to-Noise Ratio is a measure of the strength of the satellite signal relative to background noise.	4.0
Unit of Measure	Units of measure.	Meters
Zone	In UTM coordinate system, the globe is divided into 60 north-south zones.	Zone 12 North (N)* *Black Canyon & Curecanti are Zone 13 N

1.3 Data Dictionary

A data dictionary should be created to facilitate field data collection as well as assuring necessary data items are (correctly) collected. The minimum elements necessary for the upland data dictionary are shown below. Once the project lead has given the GIS technician the potential upland points for a given park in a given year, those points are then imported with the Upland data dictionary (using Pathfinder Office), creating a data file(s) for Plot Establishment and Site Characterization (when applicable). Appendix A contains more detailed instructions on using the import files and data dictionary. All point features in the Upland Data Dictionary should have the default feature settings of:

Logging Interval	Time = 1 second
Minimum Positions	3
Accuracy	Code
Label 1	PlotID

The following data dictionary digital file (.ddf) can be obtained by contacting the NCPN Data Management staff.

Site Characterization Point Feature

This feature point is used primarily when scouting possible upland plot locations. If the location is accepted as a monitoring plot and the establishment of the plot is commencing *immediately* following decision that the location is appropriate, this data dictionary point may be skipped. Once all plots for a park are selected, this data point is not included in the data dictionary.

Site_Crc Attributes	Attribute Explanation	Entry	Type
PlotID	Numeric unique ID from Project Lead	Entry **not** permitted in the field	Numeric
S_Action	• Accept – decision to accept the site as an acceptable upland monitoring location • Reject – decision to reject the site as an acceptable upland monitoring location	Entry **required** in the field	Menu
Soil_MU	Soil map unit from park applicable soil survey	Entry **not** permitted in the field	Text
EcoType	Ecological type from the park applicable soil survey	Entry **not** permitted in the field	Text
Comments	Any comments regarding the site	Entry permitted in the field	Text – Optional
EvalStatus	Used to indicate to monitoring crew the status of each site (NotEval, accept, reject)	Entry **not** permitted in the field	Text – Optional

Plot Establishment Center Point Feature

The plot establishment point is taken at the center point of a location deemed acceptable as an upland monitoring plot. Using the points loaded into the GPS unit, you can "update" the plot location by opening the point and letting the GPS unit collect locational information. The PlotID will already be filled in. The GPS unit should collect 10-20 "hits" to establish the plot centroid location. Other than collecting (updating) the locational information, there is no further data necessary to collect for this point using the GPS unit.

EstPlotCenter Attributes	Attribute Explanation	Entry	Type
PlotID	Numeric unique ID from NCPN ecologist	Entry **not** permitted in the field	Numeric
Veg_Type	• Forest • Grassland/Shrubland • Oak Scrub • Woodland	Entry **required** in the field (already filled in, update if necessary)	Menu
Comments	Any comments regarding the site	Entry permitted in the field	Text – Optional

Transect Start and End Points Feature

For upland monitoring, there are three 50 meter transects per monitoring plot. Each transect beginning (0 meter) and end (50 meter) point needs to be GPSed.

Trans_Pts Attributes	Attribute Explanation	Entry	Type
PlotID	Numeric unique ID from NCPN ecologist	Entry permitted in the field	Numeric
Transect	• T1_origin – Transect 1, 0m • T1_end – Transect 1, 50m • T2_origin – Transect 2, 0m • T2_end – Transect 2, 50m • T3_origin – Transect 3, 0m • T3_end – Transect 3, 50m	Entry **required** in the field	Menu
Comment	Any comments regarding the site	Entry permitted in the field	Text – Optional

CulturalSite Feature

At many park units, you will find evidence of historic human use, such as lithic scatter or a pile of rusted cans. Use this feature to log cultural resources specified by staff at each park, or log a point any time you come across something particularly interesting.

CulturalSite Attributes	Attribute Explanation	Entry	Type
Type	• Structure • Lithic Scatter • Pot Sherds • Cowboy camp • Fence • Pictograph • Petroglyph • Other	Entry permitted in the field	Menu
Comment	Notes about the location	Entry permitted in the field	Text – Optional
Comment2	Notes about the location	Entry permitted in the field	Text – Optional

Other Optional Point Locations (incidental observations worth recording) Feature:

This point feature is for incidental observations the monitoring crews may encounter. For example, if you found an invasive exotic plant community or wanted to mark a particularly good way to get to the plot, you may want to mark that location with this point feature, briefly commenting why you marked the location.

OtherPt Attributes	Attribute Explanation	Entry	Type
Comment	Incidental observation comment	Entry permitted in the field	Text – Optional
Comment2	Incidental observation comment	Entry permitted in the field	Text – Optional

Routes to Plots

This line feature is for mapping routes to upland monitoring plots that seem somewhat difficult to locate. Once all data collection is complete, on the hike out of the plot, this feature can create a route or trail for future field crews to easily locate the monitoring plot.

Route Attributes	Attribute Explanation	Entry	Type
PlotID	unique PlotID (plot navigating to)	Entry permitted in the field	Text – Optional
Comments	Incidental observation comment	Entry permitted in the field	Text – Optional

All other data required from the GPS unit can be automatically downloaded from the GPS unit (see section 2.6).

1.4 Uploading possible monitoring locations

Mapping grade GPS units have the ability to upload data points to be used in concert with the data dictionary. The (potential) upland monitoring points are imported with the Upland Data Dictionary by the NCPN GIS technician. Importing points (uploading) to the GPS unit eliminates possible plot mis-identification in the field, as well as allowing the user to navigate more easily to an upland plot.

Also, background data layers can be used to assist with navigation. The two GIS data layers found most useful as background layers have been 1) roads and trails and 2) hydrography, both combined with the park boundary.

1.5 Collecting data

Once you've navigated to the plot (or potential plot), it's time to collect the GPS locations necessary. Appendix A contains detailed instructions for use with the Upland data dictionary and various files. Open the file necessary, and begin logging the point and any required data. Each point collected should be allowed to receive 10-20 positions before ending data collection and moving onto collecting another type of point.

1.6 Downloading

When data collection is finished, the GPS data needs to be downloaded. The NCPN GIS technician downloads the data from the GPS unit(s) after each field excursion, and then differentially corrects the data, using the appropriate (closest) base station. The corrected GPS files are then exported to a GIS data format. Table 2 indicates the attributes to capture while exporting the corrected GPS data into a GIS data format ("turn on" in Pathfinder Office).

Table 2 GPS Auto-generated Attributes to Capture

PDOP	Update Status	Height
Correction Status	Data File Name	Vertical Precision
Receiver Type	Total Positions	Horizontal Precision
Date Recorded	Filtered Positions	Standard Deviation
Time Recorded	Data Dictionary Name	Position

Data should be exported using the same coordinate system used in the field (UTM, NAD83 Conus, Zone 12 or 13, meters).

1.7 Uploading to the master Upland Database

Once the GPS field data is validated and verified (GPS points given a visual review, coordinates compared to those from site characterization, transect plot ID attributes verified, and transect locations, ends, and origins verified) in ArcMap, the data is ready to be uploaded into the working Upland Database. The GPS data is exported from ArcMap into an Excel spreadsheet for importing into the Upland Database (see SOP #13, section 3.1).

2 Upland Plot Revisit

Once plots are established, no new data will usually be collected with a GPS unit when the site(s) are revisited. This allows for the use of recreational grade GPS units (Garmins, Magellans, etc.) rather than the sometimes heavier and larger mapping grade GPS units. Mapping grade units are recommended and generally used by NCPN crews to navigate to plots ready to be revisited; however, the following steps demonstrate how one could utilize a recreational GPS unit.

If it becomes necessary to collect additional location data at a plot (e.g., if a rebar is missing and needs to be replaced), the field crew should GPS the new points with the Garmin (or other recreational) GPS unit. The data should be given to the GIS technician, who will determine the new coordinates for the plot, and pass those updated coordinates to the Data Manager for incorporation into the Upland database.

2.1 Minimum GPS Receiver Requirements

- Capable of uploading previously visited upland monitoring plot locations (XY points)
- Capable of storing date and coordinates of features collected.
- Capable of exporting features collected to a format that can be used by GIS
- Capable of maintaining an EHE (Estimate of Horizontal Error) of less than or equal to 12 meters. Maintaining an EHE (or EPE – Estimate of Positional Error) of 12 meters or less meets the National Map Accuracy Standard.
- Capable of tracking a minimum of 4 satellites
- Capable of collecting real-time differentially-corrected positions (DGPS)

2.2 GPS Unit Setup

The upland monitoring plots which are to be revisited in a given year will be given to the NCPN GIS technician. These locations (XYs of the plot centroid as well as all six transect origin and end points) will then be uploaded into any recreational grade GPS unit for relocation purposes. If using a Garmin GPS, data transfer is enhanced by utilizing the freeware DNRGarmin (http://www.dnr.state.mn.us/mis/gis/tools/arcview/extensions.html). Background maps of the area(s) to be visited should be uploaded from Map Source as well. Once the data is transferred to the GPS unit, the GPS unit is ready for field use.

The GPS unit should be configured with the settings in Table 3.

Table 3 Minimum GPS Receiver Settings

Name	Standard
Projection (displayed coordinates)	UTM
Datum	NAD 83
WAAS	Enabled (on)

Appendix A

File Explanations:

Generally, two types of files will be loaded onto the GPS units prior to field work. One will contain just points for site characterization (i.e., informally referred to as "recon" points). The other file will contain existing locational data, both plot centers and transects, as well plot centers of locations to be established. Points that have not yet been characterized and accepted for monitoring can be included in this, if there is not a separate field effort specifically for site characterization. Due to Trimble software's week-old "time-out" issue for GPS files, there may be numbered files. If and when you do get the message "Unable to append to a file over one week old", close the file and open the next numbered file and continue GPSing.

Existing Data Files on GPSes:

- *PARK recon* – (Park/Place Site Characterization) The points contained in this file are the centers of potential plots. Use this file primarily to locate potential monitoring points for site characterization. Log the point, and then choose either Accept or Reject from the data dictionary. If you are immediately setting up the plot, log the plot center with the feature point "Park_Upland" instead.
- *PARK Upland* – (Park/Place established plots and transects) This file contains already established upland monitoring plots and transect end points. It also contains previously 'accepted' sites to be established. This file is useful for navigation purposes when re-reading upland monitoring plots. It also contains any GPSed routes to plots.

Background Layers (Files):

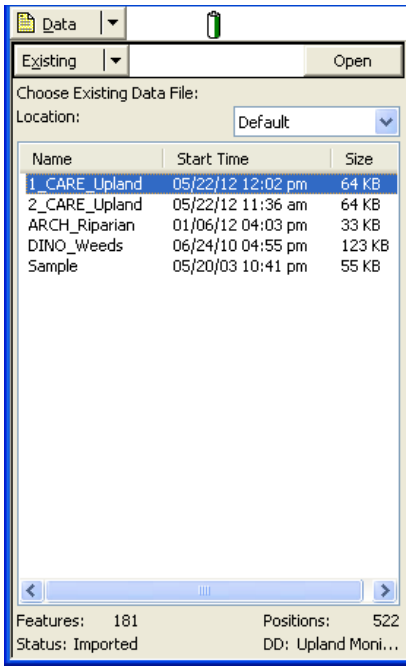
- PARK_Roads – This file contains the roads for the park area. Note that some roads may be closed or impassable. Please rely on current park knowledge for finding the best routes.
- PARK_Drainages – This file contains the "streams" (hydrography) for PARK.
- PARK_Trails – This file contains park designated trails within the park.
- PARK_bnd – This file contains the boundary of the park.

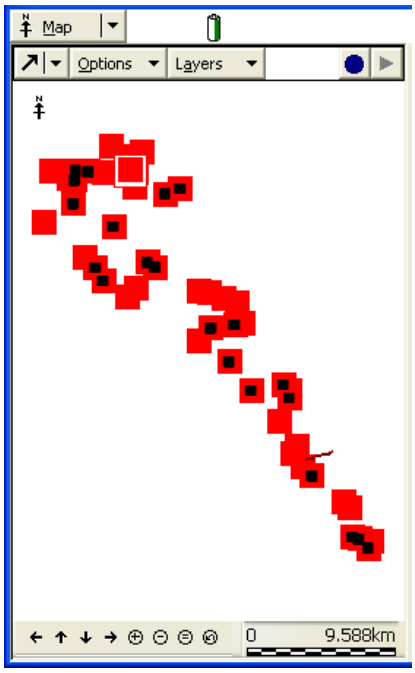
Basic instructions:

The following instructions are based on using a Trimble GPS unit with TerraSync Professional GPS software loaded.

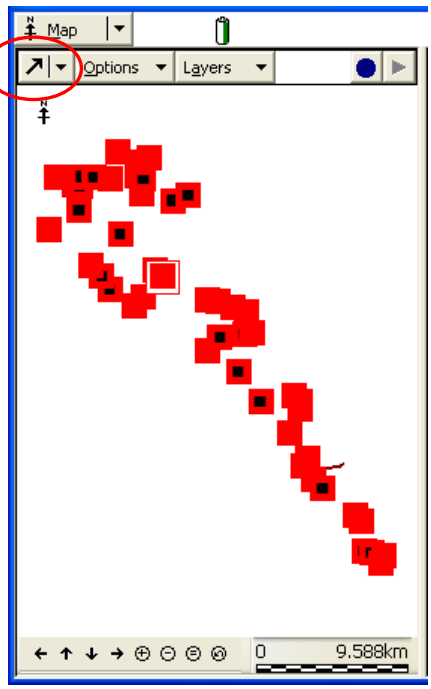
Navigation:

To navigate to a point, open the file which contains the point you want to update. Change the screen to the Map View (click on the Data drop down, and choose Map).



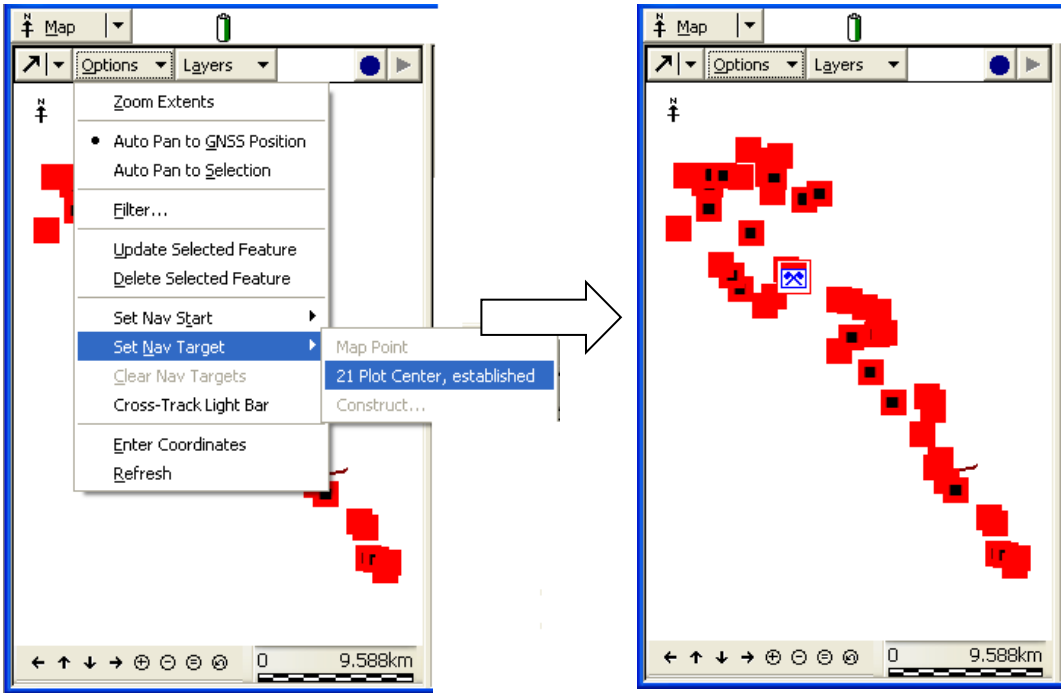


Using the Map Tools (the drop down menu directly underneath Map), use the Select tool to select the point to which you wish to navigate. A box will display around the point.

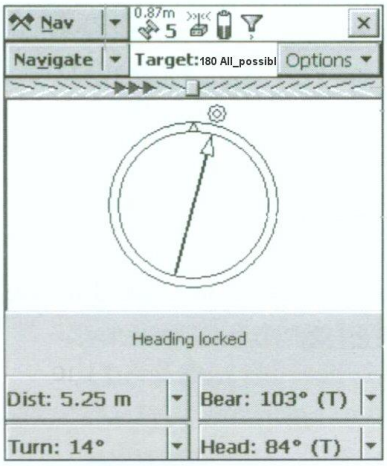


Map Tools dropdown menu, Select tool.

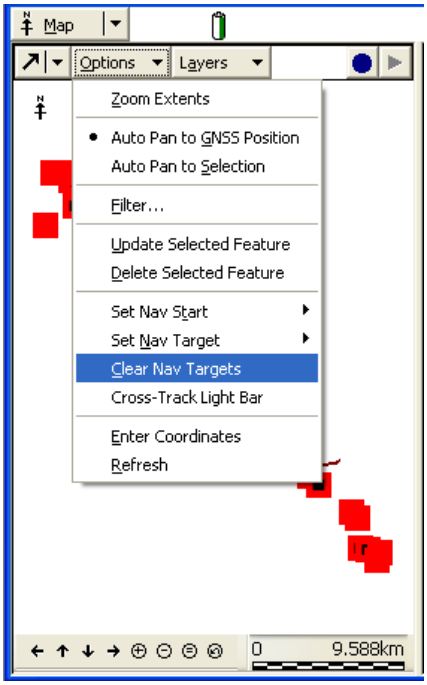
Click on the Options button, then Set Nav Target, then the point file name. The selected point will then be displayed with the target icon. When revisiting established plots, setting the Nav Target can be done in the same manner.



Open the Navigation section (click on Map and chose Navigation). This will open the navigation screen. As you move, this screen will display the information needed to navigate to the point. When you are within 5 meters of the point, the unit will beep, and the screen will change to the map display.



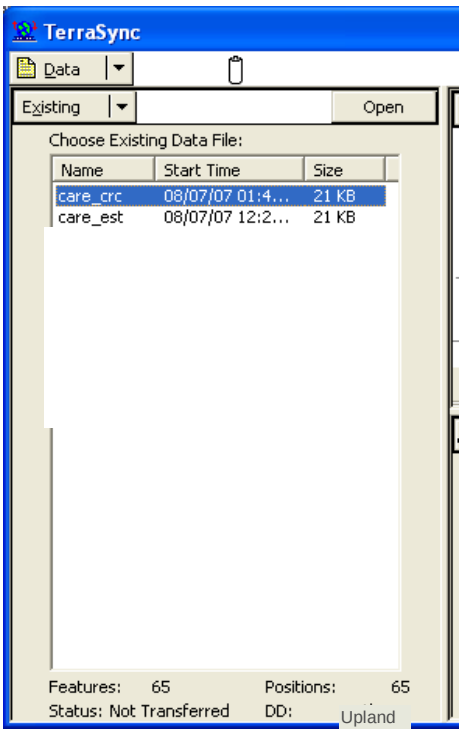
When you've reached your point and/or no longer need to navigate, select the Map screen, then go to Options and select Clear Nav Targets.



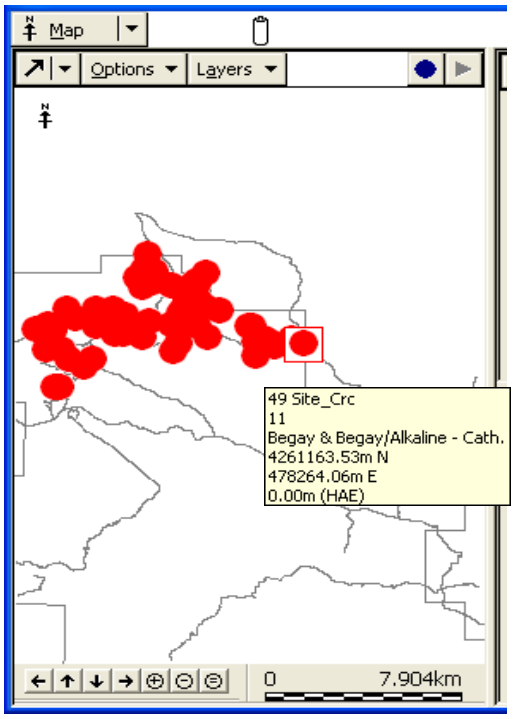
Data Collection:

Site Characterization (recon)

The following instructions are for site characterization when plot establishment does not immediately follow, but the navigation instructions are applicable to either characterization or establishment of a plot. Open up *park*_crc:

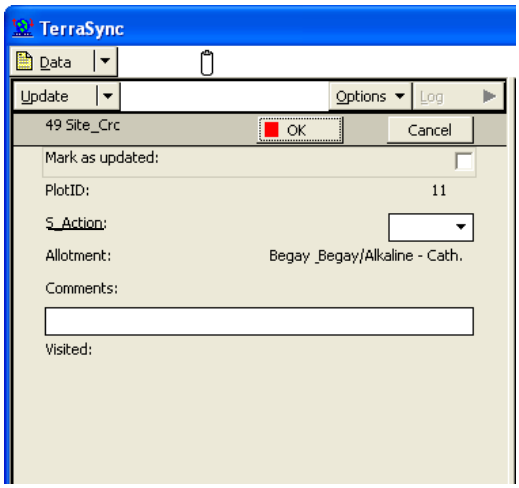


Change the view from the Data view to the Map view (upper left dropdown menu). In this example, the background file is "CARE_RdTrls", so all the roads and trails are displayed in addition to the potential upland monitoring plots.



Note that the PlotID (11) and ecosite/allotment (Begay & Begay/Alkaline – Cath) are displayed. The second label (ecosite/ allotment) does not always have data displayed.

Once you've navigated to the point, double tap on the point from the Map screen to bring up the data dictionary. You'll notice the only field you are required to fill in is the S_Action field (either Accept or Reject) after you've completed site characterization.

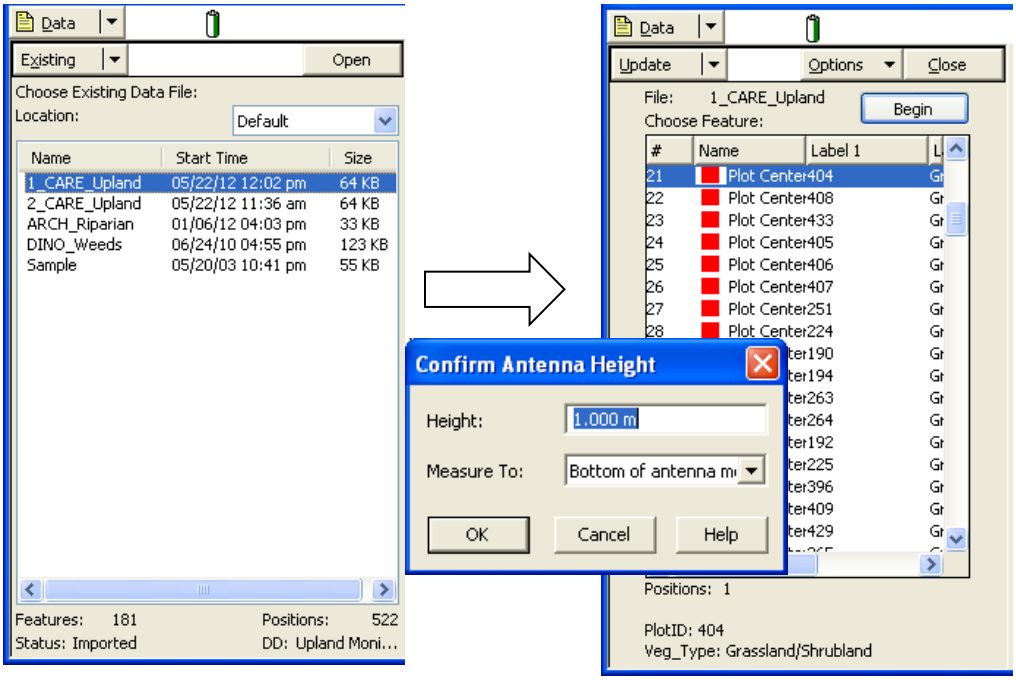


Note: At times, other fields will be added to aide field crews, (such as ecotype and soilmu), but those fields will not require data to be entered in the field. Those data will be displayed as the best guess we could generate in the office. Items not editable in the field will not have a white box around the text.

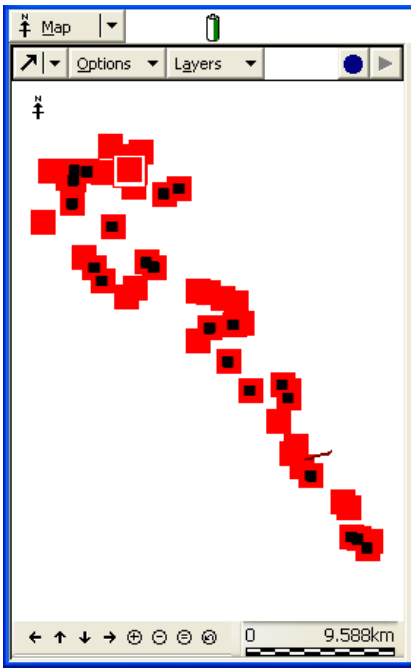
Plot Establishment

For the purposes of these instructions, it is assumed that acceptable plot locations were determined prior to the visit by the plot establishment crew.

Open [*PARK_Upland1*]. Tap OK to Confirm Antenna Height. The file will open, displaying the points contained in list form.



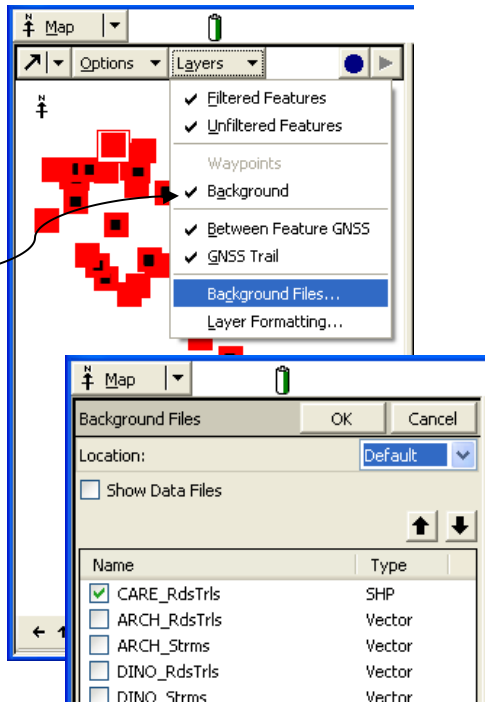
To view the points in the Map display, tap Data and choose Map. The points, with any background data layers will be displayed.



To add background layers, tap Layers/Background Files…

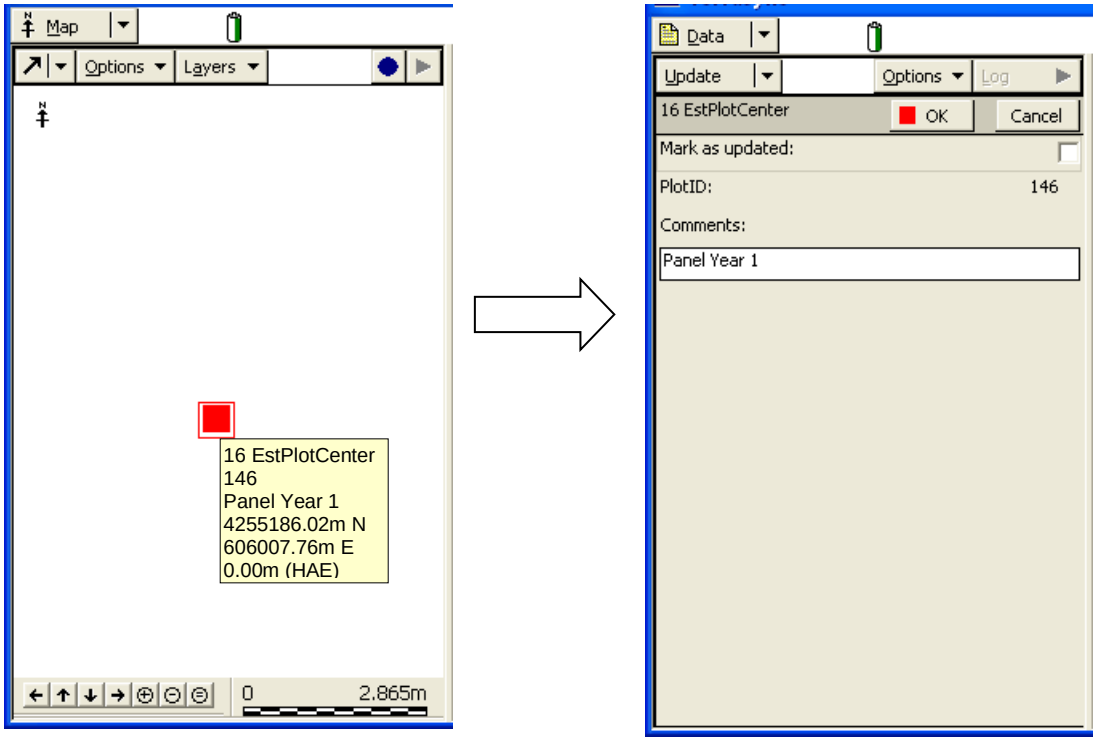
Choose the type of background file that Will help you navigate. You can choose multiple files.

Also be sure that the Background is checked so they background layers will display.



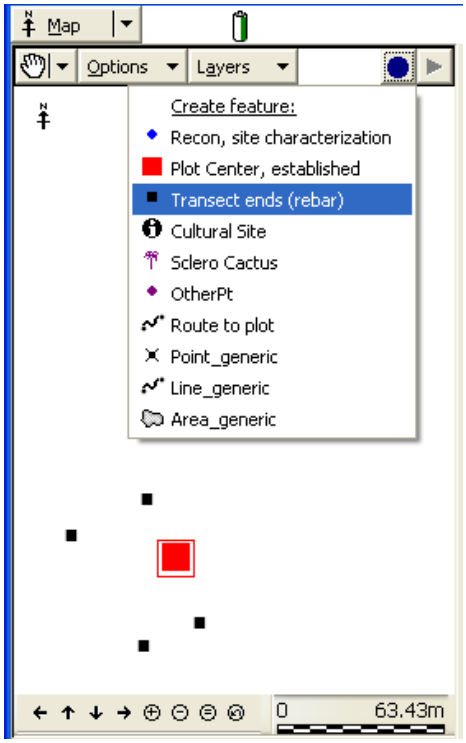
Navigate to the plot (see instructions above for navigation help). When you are nearing the plot, travel carefully so as not to trample the plot you are establishing!

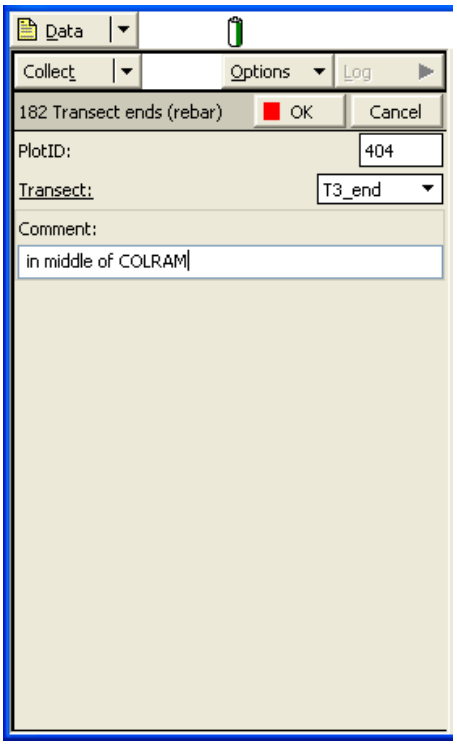
To log the point, double tap the point on the map screen, and the data dictionary will open. Log the point for 10-20 "hits" (seconds), and tap OK. This is called "updating" a point, as you are updating the location as well as any data about the point. Carefully navigate away from the center of the plot to begin setting up the transects.

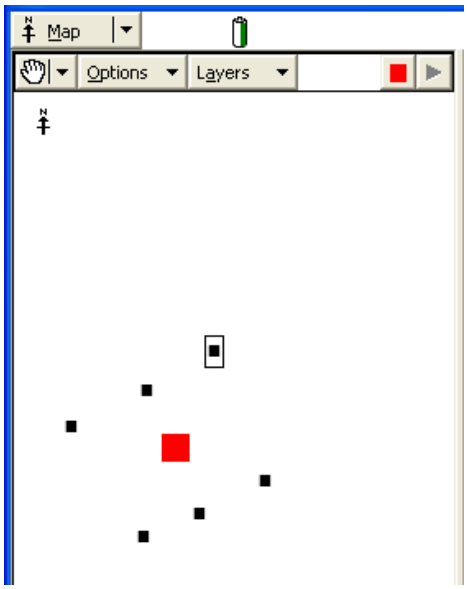


If the file on the GPS unit is too old to allow the location of the plot center to be updated (the error message "Unable to append to a file over one week old"), close the file. Go to Data/ Existing and choose the next file, numerically (e.g., 2_CARE_Upland). You should see the same data, but (hopefully) no error messages when you are updating and/or collecting new data.

Once you are ready, GPS the beginning and end points of each transect. When you are at a beginning or end point, from the Map screen, tap on the blue dot in the upper right corner. This will display the other features contained in the Upland Data Dictionary, including a transect point feature (Trans_Pts). Log each transect point, and fill in the PlotID as well as which Transect origin/end point. Tap OK to save the point.



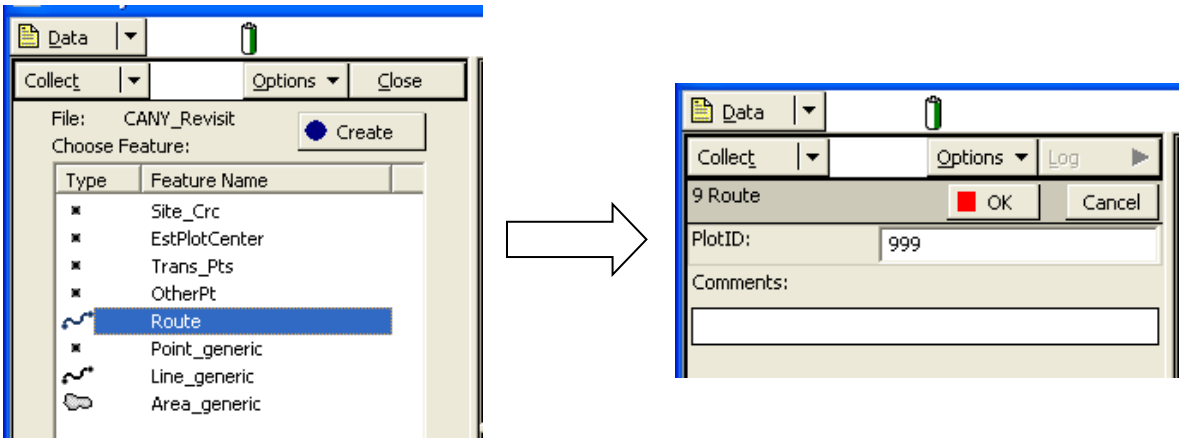




Remember, the locations you record will be used in years to come to relocate plots and transects, so log as accurately as you can. Before leaving an established plot, review the map screen to make sure you've GPS'd all the endpoints and the centroid.

Creating Trails/Routes:
If you feel that the plot you've visited is difficult to navigate to and/or hard to find, you may want to GPS the route you take out. This route can then be shown to future field crews to enable them to get to the plot efficiently.

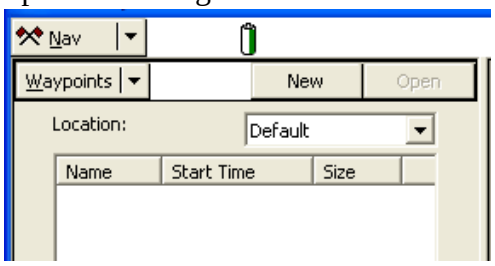
To map the route (trail) from the plot, click on Data/Collect and click on Route, which will bring up a field to fill in the PlotID and any brief comments you'd like to add:



As you walk along, the GPS unit will collect a point every 3 seconds. You will need to have the GPS unit either in your hand or attached somewhere that it can "see" the satellites. You don't need to do anything until you get to the end (as in, back to the paved road or trail or whatever). At that point, just click OK to end, close, and save the feature.

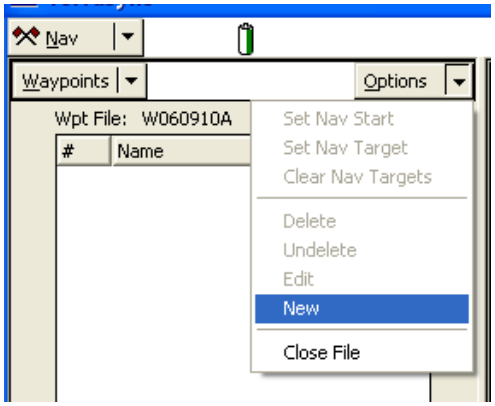
Creating a Waypoint from Coordinates
There may be times when you have a coordinate you need to get to that is not already loaded into the GPS unit. If you have the coordinates, you can create a waypoint, which then you can navigate to.

1. Go to the top left pulldown and select Navigation.
2. Tap on the Navigate button and select Waypoints.

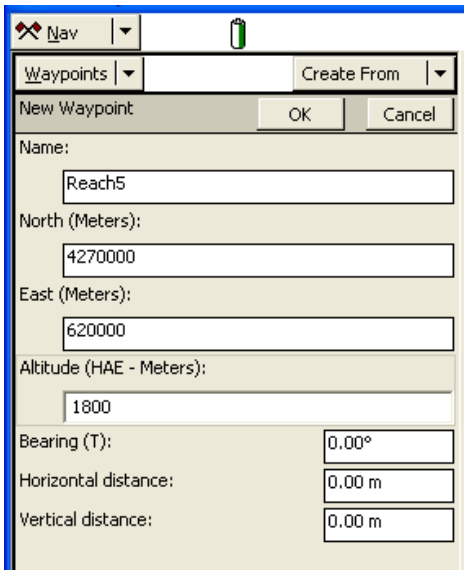


3. Create a new waypoint file by tapping the New button.

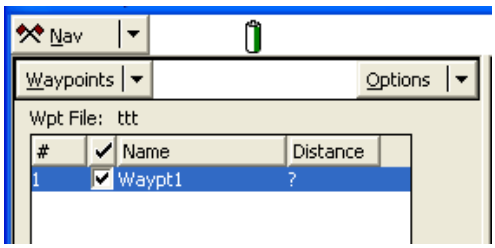
4. You have the opportunity to name the file or use the default. Tap OK.
5. From the Options button, select New.



6. Fill in the Name, North, East and Altitude fields (for elevation, enter a reasonable guess). Filling in the Bearing or Distance fields is not necessary. Tap OK.



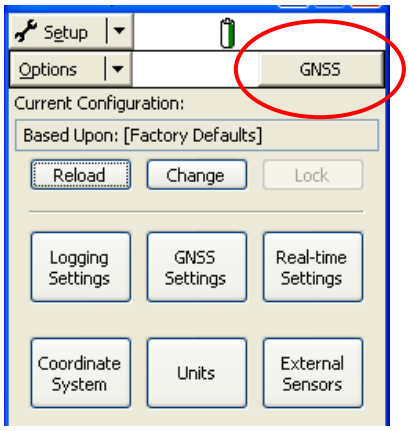
7. Double click the point you just created, and it will automatically set it as the navigation target (note the checkmark).



8. Tap on Waypoints dropdown menu, and choose Navigate. The Navigation screen will open, displaying the bearing and distance to the point you just entered. Now you are able to navigate to the location you just entered. The waypoint will also be displayed on the Map screen with the crossed flags icon.

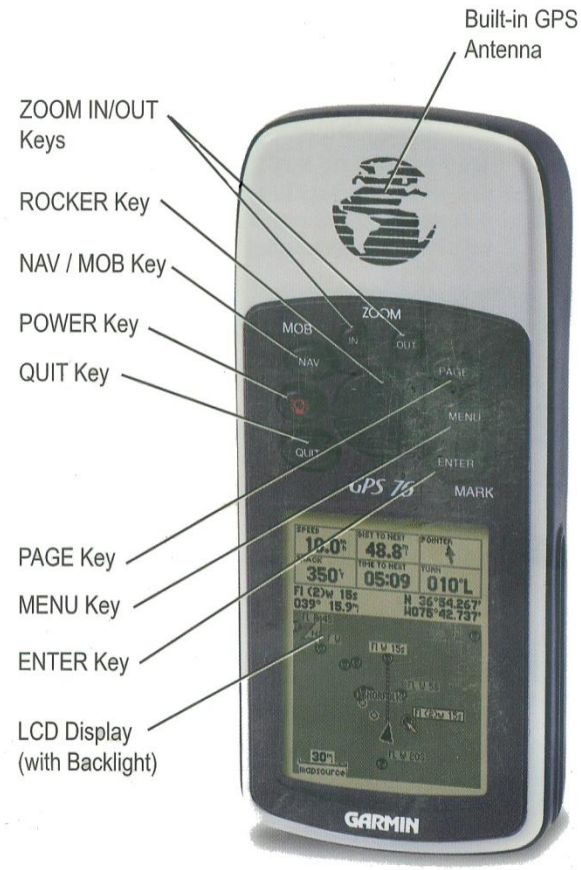
Hints for Trimble units:

- Log a point for a minimum of 10 (to 20) "hits" (about 10-20 seconds).
- Holding the power button down for 30 seconds will soft re-boot the XT GPS. Holding the power button down for 60 seconds will hard re-boot the XT GPS. Neither of these re-boots will lose any data, but you should recheck the coordinate system.
- To re-boot the Junos, there is a little hole on the bottom left side (nestled in with the various buttons). Push that with the tip of the stylus to re-boot the Juno.
- To conserve on battery life, turn the unit off if you aren't using it to navigate. It is recommended that TerraSync be closed *prior* to turning off the unit.
- While carrying extra batteries in the soft GPS cases, face the GPS unit screen to the opposite of the battery to prevent cracked screens.
- If the GPS gets disconnected, go to the Setup screen and tap the GNSS button on the upper right side. A little connecting icon will appear as the unit reconnects to the GPS. A satellite icon will replace the connecting icon when TerraSync is reconnected to the GPS.



- The NCPN has a copy of the TerraSync Guide, which goes into more detail about the many functions of TerraSync. Please contact the GIS technician if you would like to take a look at it.
- Report any idiosyncrasies with the Trimble GPSes to the crew leader who will then notify NCPN data management staff.

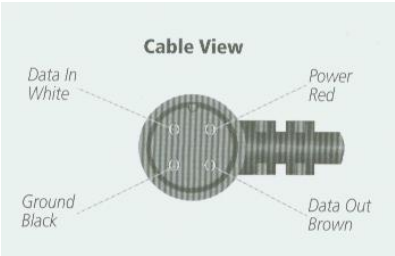
Appendix B



This graphic demonstrates the keys of a Garmin 76 GPS unit, and their functions. These keys are referred to in the following instructions.

1. To Connect GPS to Computer

- Either a serial or USB port cable will accompany the GPS unit. This is the cable that connects the GPS receiver to your workstation computer, allowing the uploading and downloading of waypoints.
- The serial or USB end of the cable attaches to your workstation computer. The other cable end (below) inserts into the Garmin GPS unit (lift bottom of black flap on the back of the GPS unit)



2. To change the displayed map projection:

- Turn on the unit by depressing the POWER key
- Set Projection
    1. Access the Main Menu (press the MENU key twice)
    2. Using the rocker key, scroll down to Setup and press the ENTER key
    3. There are several tabs listed (General, Time, Units, Location, Alarms & Interface) – using the rocker key, scroll over to the Location tab. Scroll down with the rocker key to Location Format and press the ENTER key.
    4. Scroll down the list of formats to UTM UPS, make sure this choice is highlighted, and press the ENTER key.
    5. Scroll down to Map Datum, press the ENTER key. Scroll down through the Map Datum choices, press the ENTER key when NAD 83 is highlighted.
    6. Press the PAGE key to get back to the "GPS Information" screen. (If the GPS Information screen is not showing, press the PAGE key; it will cycle through the screens). The bottom of the screen should now be displaying coordinates as UTM.

3. Set GPS to log differentially correct data

- If not already on, power up the GPS
- Enable WAAS
    1. Access the Main Menu (press the MENU key twice)
    2. Using the key, scroll down to Setup and press the ENTER key
    3. There are several tabs listed (General, Time, Units, Location, Alarms & Interface) – using the rocker key, scroll over to the Location tab. Scroll down with the rocker key to General and press the ENTER key.
    4. Scroll down to WAAS, press ENTER, highlight Enabled, and press ENTER
    5. Press the PAGE key to exit Setup

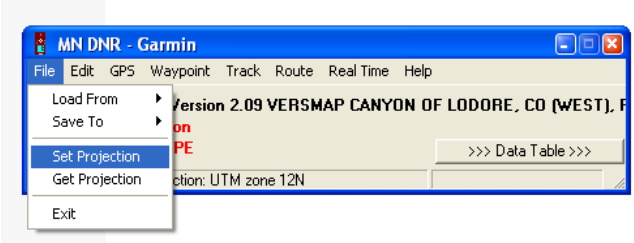
4. In the Field - optional

- Collect (or mark) a waypoint
    1. When at the observation location, check the GPS Information page for number of satellites (4 or more needed) and accuracy (12 meters or less)
    2. Press and hold the ENTER/MARK key until the Mark Waypoint Page is displayed.
    3. Using the Rocker key, change the waypoint ID.
    4. Using the Rocker key, highlight "OK" and press ENTER
- Navigation
    1. Press the NAV key
    2. Select 'Go To Point' then press the ENTER key
    3. Select 'Waypoints' then press the ENTER key
    4. Select 'your point' then press the ENTER key
    5. Highlight the 'GoTo' button, press ENTER
    6. As you start walking, the Pointer will point to your destination

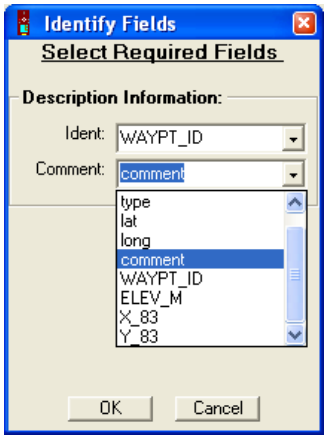
5. Upload Background Data

- Upload background maps from MapSource (proprietary software) if needed

- Upload waypoints using DNR Garmin
    1. Connect GPS to the computer
    2. Turn GPS on, then open DNR Garmin, it will connect to the computer
    3. When the MN DNR – Garmin window opens, make sure that the projection is set to UTM, NAD 83, zone 12N (unless at CURE or BLCA, which are zone 13N). Go to File, then Set Projection to change projection.

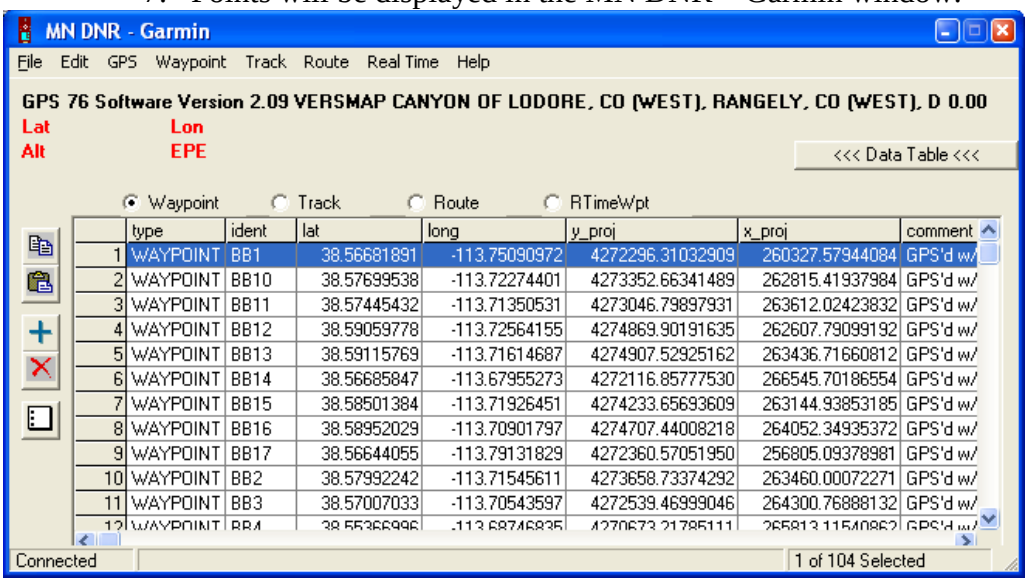


    4. Click on File, then Load From. You can upload a .txt file, .dbf file or a shapefile. Navigate to the file you wish to upload and click Open.
    5. A window will open prompting you select description information. Choose appropriate fields for Ident (ID) and Comment and click OK.



    6. A window will open stating "File was loaded successfully from….", click OK

7. Points will be displayed in the MN DNR – Garmin window.

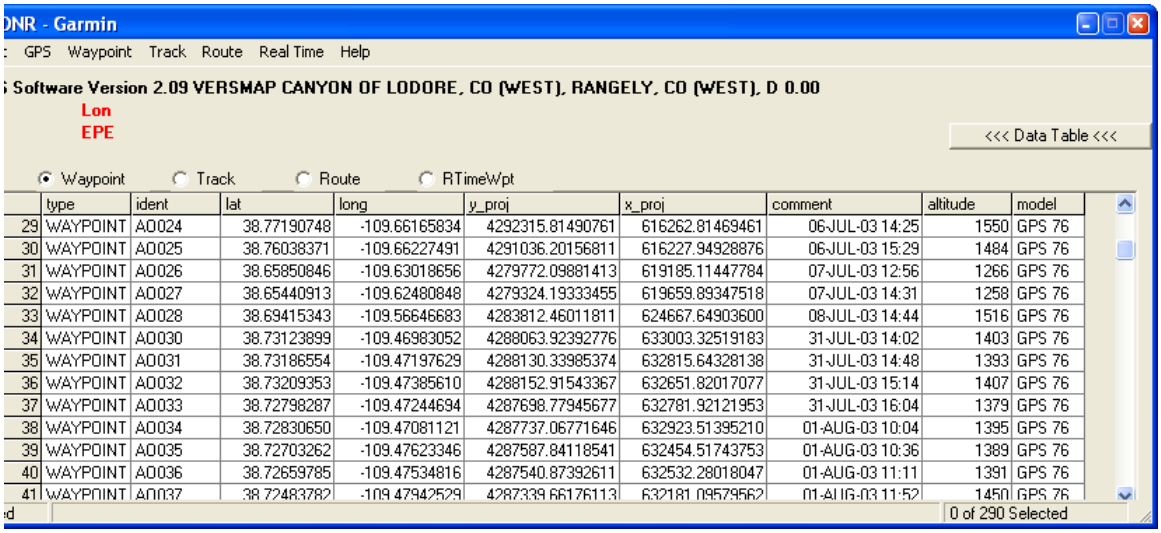


	type	ident	lat	long	y_proj	x_proj	comment
1	WAYPOINT	BB1	38.56681891	-113.75090972	4272296.31032909	260327.57944084	GPS'd w/
2	WAYPOINT	BB10	38.57699538	-113.72274401	4273352.66341489	262815.41937984	GPS'd w/
3	WAYPOINT	BB11	38.57445432	-113.71350531	4273046.79897931	263612.02423832	GPS'd w/
4	WAYPOINT	BB12	38.59059778	-113.72564155	4274869.90191635	262607.79099192	GPS'd w/
5	WAYPOINT	BB13	38.59115769	-113.71614687	4274907.52925162	263436.71660812	GPS'd w/
6	WAYPOINT	BB14	38.56685847	-113.67955273	4272116.85777530	266545.70186554	GPS'd w/
7	WAYPOINT	BB15	38.58501384	-113.71926451	4274233.65693609	263144.93853185	GPS'd w/
8	WAYPOINT	BB16	38.58952029	-113.70901797	4274707.44008218	264052.34935372	GPS'd w/
9	WAYPOINT	BB17	38.56644055	-113.79131829	4272360.57051950	256805.09378981	GPS'd w/
10	WAYPOINT	BB2	38.57992242	-113.71545611	4273658.73374292	263460.00072271	GPS'd w/
11	WAYPOINT	BB3	38.57007033	-113.70543597	4272539.46999046	264300.76888132	GPS'd w/
12	WAYPOINT	BB4	38.55366996	-113.68746835	4270673.21785111	265813.11540862	GPS'd w/

8. If the points are correct, click on WAYPOINT on the top menu, then Upload
9. A window will pop up stating "Transfer Complete. _#_ points uploaded"

6. Downloading Waypoints

- Download waypoints using MN DNR Garmin freeware
  1. Connect the GPS to the computer and turn on the GPS unit, then open the program DNR Garmin on the computer
  2. From the DNR Garmin main menu, click on Waypoint, then Download. Your data will appear in the MN DNR Garmin window (see below). Elements to be included in the downloading process are: type, ident, lat, long, y_proj, x_proj, comment, altitude & model. These fields can be chosen by choosing Waypoint from the main menu, then Waypoint Properties and checking only those fields.



	type	ident	lat	long	y_proj	x_proj	comment	altitude	model
29	WAYPOINT	A0024	38.77190748	-109.66165834	4292315.81490761	616262.81469461	06-JUL-03 14:25	1550	GPS 76
30	WAYPOINT	A0025	38.76038371	-109.66227491	4291036.20156811	616227.94928876	06-JUL-03 15:29	1484	GPS 76
31	WAYPOINT	A0026	38.65850846	-109.63018656	4279772.09881413	619185.11447784	07-JUL-03 12:56	1266	GPS 76
32	WAYPOINT	A0027	38.65440913	-109.62480848	4279324.19333455	619659.89347518	07-JUL-03 14:31	1258	GPS 76
33	WAYPOINT	A0028	38.69415343	-109.56646683	4283812.46011811	624667.64903600	08-JUL-03 14:44	1516	GPS 76
34	WAYPOINT	A0030	38.73123899	-109.46983052	4288063.92392776	633003.32519183	31-JUL-03 14:02	1403	GPS 76
35	WAYPOINT	A0031	38.73186554	-109.47197629	4288130.33985374	632815.64328138	31-JUL-03 14:48	1393	GPS 76
36	WAYPOINT	A0032	38.73209353	-109.47385610	4288152.91543367	632651.82017077	31-JUL-03 15:14	1407	GPS 76
37	WAYPOINT	A0033	38.72798287	-109.47244694	4287698.77945677	632781.92121953	31-JUL-03 16:04	1379	GPS 76
38	WAYPOINT	A0034	38.72830650	-109.47081121	4287737.06771646	632923.51395210	01-AUG-03 10:04	1395	GPS 76
39	WAYPOINT	A0035	38.72703262	-109.47623346	4287587.84118541	632454.51743753	01-AUG-03 10:36	1389	GPS 76
40	WAYPOINT	A0036	38.72659785	-109.47534816	4287540.87392611	632532.28018047	01-AUG-03 11:11	1391	GPS 76
41	WAYPOINT	A0037	38.72483782	-109.47942529	4287339.66176113	632181.09579562	01-AUG-03 11:52	1450	GPS 76

3. Click on File, and then Save To. Navigate to the proper folder on the computer where GPS files are stored.
4. There are several file types which you can save the file as. The NCPN recommends saving the data as a projected shapefile (*.shp) file.
5. Name the file with the date of download in the file name (example: Upland_June10_09.shp) and click the Save button. A window will display "File successfully written to …"

Upland Vegetation and Soils Monitoring Protocol for Park Units in the Northern Colorado Plateau Network

Standard Operating Procedure (SOP) # 4

Crust-Friendly Field Procedures

Version 1.03 (March 2011)

Revision History Log:

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #
1.00	4/2008	R. Weissinger	Formatting only	Improve useability	1.00
1.00	3/2009	D. Witwicki	Formatting only	Standardize among SOP's	1.01
1.01	3/2010	D. Witwicki	Updated within plot methods & definition of extreme disturbance	Improve clarity	1.02
1.02	3/2011	D. Witwicki	Minor rewording	Improve clarity	1.03

Biological soil crust (BSC) is an important ecosystem component on the Colorado Plateau that plays a critical role in nitrogen fixation and soil stability. BSC is easily destroyed through trampling and can take as long as a century to fully develop. NCPN monitoring efforts must minimize "crust busting" because 1) parks value this resource and would like to protect it from trampling, and 2) destruction of crust on plots can impact the validity of the monitoring data, providing a false representation of natural system dynamics. The following procedures were adapted from protocols used by U.S. Geological Survey researchers working in the Colorado Plateau. All crew members must learn and follow these procedures.

Hiking to a monitoring plot

Footprints last a long time in the desert systems of the Colorado Plateau. Walking the same route from a road or trail to a monitoring plot can quickly create the appearance of an established trail. Park visitors tend to gravitate to such trails, and over time, the plot access route can become heavily trampled. Additionally, these trails increase the chance of monitoring plot disturbance by park visitors.

1. When hiking to and from a monitoring plot, select a route that maximizes the use of bedrock, washes, and other large rocks than can be used as stepping stones. Tracks in washes will be erased during the next rain storm. At all times, avoid stepping on crust, no matter how developed it is.

2. Where your footprints will create a noticeable trail, always use a separate route to and from a monitoring plot to avoid trail development.

3. When walking on soil, only leave one set of footprints. That is, walk in single file and step in the footprints of preceding crew member(s).

Walking on a monitoring plot

Crew members must restrict their impact to specific areas of a plot while recording data.

1. When walking around the plot, select a pathway that optimizes stepping on rock, washes, and dead vegetation.

2. If you must step in areas with crust, leave only one set of footprints by walking in existing footprints.

3. Trails may eventually form below each transect in plots with well-developed crust. Be extra cautious to walk only in these trails and to avoid trampling any additional crust.

4. Place packs and the recorder's chair on litter, on bedrock, or in a wash. If these options do not exist, minimize disturbance as much as possible and use previously disturbed areas on return visits.

5. Have the recorder sit by the packs and use a radio to communicate with the observer in plots with well-developed crusts.

6. Carry your water bottle and other necessities with you so that a trip across the plot to reach your backpack is not necessary.

7. In areas with well-developed crusts and very shallow soils, attempt to monument transect ends with shorter pieces of rebar (no less than 9 inches) before using rocks to hold standard lengths of rebar in place.

Revisiting a Plot

When re-measuring a monitoring plot, if soil disturbance due to previous visits is extreme, note this on the site impact data sheet (SOP #12), photograph the disturbance (if possible without walking onto the plot), do not re-measure the plot, and immediately report the disturbance to the project manager. The plot will be either rested before consideration for re-measurement or abandoned to avoid further degradation. Detailed descriptions and pictures will be useful to determine the proper course of action. One example of an extreme disturbance is soil erosion originating from previous trampling that causes deep furrows. Imprints from footprints or trails next to a transect are not considered an extreme disturbance.

Upland Vegetation and Soils Monitoring Protocol for the Park Units in the Northern Colorado Plateau Network

Standard Operating Procedure (SOP) # 5

Site Characterization

Version 1.25 (December 2017)

Revision History Log

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #
1.00	3/2007	S. Garman	Added additional instructions for site rejection	To expedite site assessments	1.10
1.10	4/2008	D. Witwicki	Simplified incomplete "geologic setting" section to "parent material", added parent material definitions, deleted NRCS list of landforms, and updated hypertext link for soils glossary	Instructions for geologic setting were not written and too complicated for field crews, landform list included too much unnecessary information	1.20
1.20	3/2009	D. Witwicki	Updated locating plot center; formatting	To be consistent with previous year's SOP updates	1.21
1.21	7/2009	D. Witwicki	Added photo, vegetation type, grazed; deleted unused soil collection methods	To document rejected plots & sort plots; methods not used	1.22
1.22	3/2010	D. Witwicki	Added instructions for rejecting plot due to cultural resources	To comply with SE Utah Group cultural resources standards	1.23
1.23	4/2011	D. Witwicki	Rewording	Improve clarity	1.24
1.24	12/2017	D. Witwicki, A. Wondrak-Biel	Updated plot figures	For publication	1.25

This SOP provides instructions for characterizing potential field sites and is used only during the initial visit to a plot. A list of necessary equipment for this procedure can be found in SOP #1.

1. Locate Plot Center

A list of plot locations will be provided by the project manager. This list will contain the plot ID, the National Resource Conservation Service (NRCS) soil map unit number of the plot, and the target ecological site of the plot. Visit the locations in the plot ID order to maintain the integrity of the sampling design.

Use a GPS unit to navigate to the pre-determined plot centroid and mark this point with a pin flag. To avoid trampling the area sampled by the middle transect (see Figures 1–3), estimate the location of this transect and traverse the plot about 1-2 meters down slope of the transect.

2. Initial Assessments

2.1 Record General Plot Information

Fill out the information at the top of the data sheet.

Vegetation type and grazing status
Record whether the plot is grassland, shrubland, forest, woodland, or oak, and if it is currently grazed. This information is provided by the project manager.

Soil survey
Determine the soil survey and soil map unit corresponding to the park unit and plot (multiple, non-overlapping soil surveys were conducted in some park units). This information should be condensed in an ecological site table for each park containing soil and vegetation characteristics for ecological sites of interest (see Table 1 example).

GPS location
Record the UTM coordinates (northing and easting) of the centroid, and the datum and zone. Datum should be NAD83.

Photos
Take 4 photos from the centroid, aligning the camera so that you take a picture of the area in the potential monitoring plot (i.e., do not include excessive sky and scenery in the background). Include a sign board in the photo, and stand about 3 m away from it so that it does not dominate the photo. On the signboard, record the 4-letter park code, plot ID, date, and general direction (N, NE, E, SE, S, SW, W, NW) of the photo. If rejecting the plot, be sure to take photos that illustrate the reason(s) for rejection

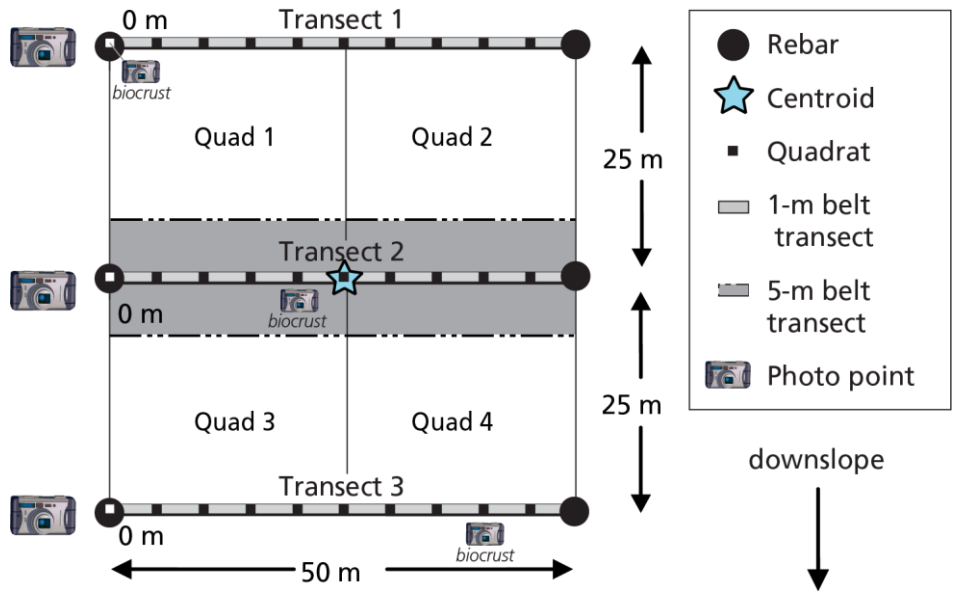


Figure 1. Locations of transects and monitoring measurements at grassland/shrubland plots, including repeat photos, 1-m^2 quadrats for sampling frequency of exotics, one-meter belt transects for measuring shrubs and seedlings, a five-meter belt transect for measuring saplings, and Quad 1 for measuring overstory trees. Soil stability is also collected at six randomized locations along each transect.

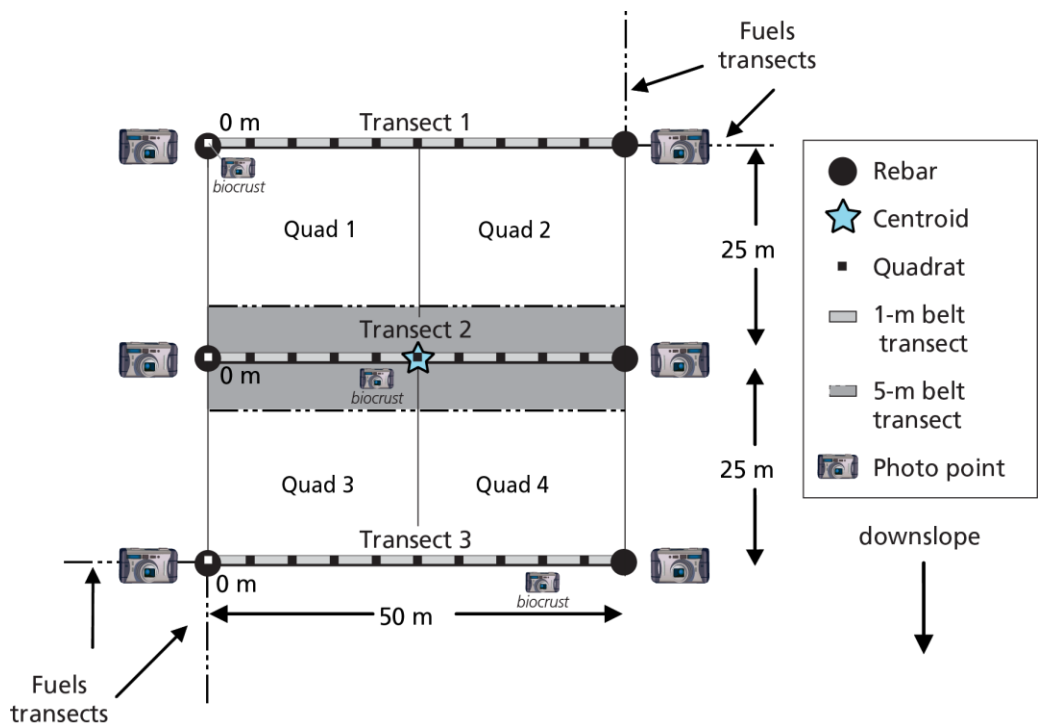


Figure 2. Locations of transects and monitoring measurements at woodland plots, including repeat photos, 1-m quadrats for sampling frequency of exotics, one-meter belt transects for measuring shrubs and seedlings, a five-meter belt transect for measuring saplings, Quad 1 for

measuring overstory trees, and four fuels transects (not drawn to scale). Soil stability is also collected at six randomized locations along each transect.

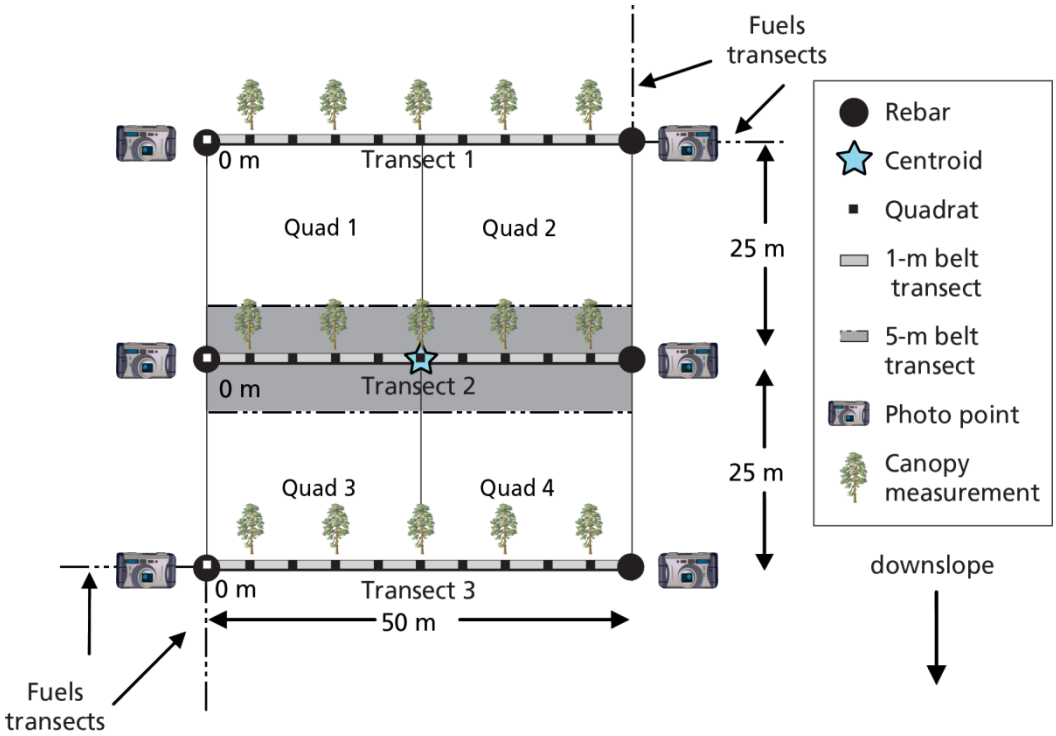


Figure 3. Locations of transects and monitoring measurements at forest plots, including 1-m² quadrats for sampling frequency of exotics, one-meter belt transects for measuring shrubs and seedlings, a five-meter belt transect for measuring saplings, Quad 1 for measuring overstory trees, canopy measurements, and four fuels transects (not drawn to scale).

Table 1. Example of an ecological site table used to organize descriptions of NRCS map units and ecological sites. A similar table is generated for soil map units containing target ecological sites in each NCPN park unit.

Park	Survey area	Soil map unit #	Soil map unit name	Land-scape setting	Comp-onent	% of map unit	Surface texture	Depth class	Parent material	Carbonates	Taxonomy	Slope %	Landscape setting or landform - - component	Ecological site	Potential vegetation	Dynamics
CANY	Soil Survey of Canyon-lands Area, Utah, Parts of Grand and San Juan Counties (UT633)	71	Rizno, dry - Rock outcrop complex, 3-15 percent slopes	Structural benches, cuestas, and mesas	**Rizno**	**45**	**Gravelly fine sandy loam**	**Shallow**	**Eolian deposits over residuum derived dominantly from sandstone and shale**	**Moderately calcareous**	**Torriorthent**	**3-15**	**Structural benches, cuestas, hogbacks, and mesas**	**Semidesert Shallow Sandy Loam (PJ)**	**Blackbrush, Mormon tea, Utah juniper, Colorado pinyon**	**May degrade to rockland due to massive soil loss.**
					Rock outcrop	25										
					Arches	10	Fine sand	Shallow	Eolian deposits derived dominantly from sandstone	Moderately calcareous	Torri-psamment	2-8	Structural benches	Desert Shallow Sand (Blackbrush)	Blackbrush	May degrade to coppice dunes or rockland due to massive soil loss or redistribution.
					Mido	5	Loamy fine sand	Very deep	Eolian deposits derived dominantly from sandstone		Torri-psamment	2-35	Sand drifts	Semidesert Sand (Fourwing Saltbush)	Grasses, Fourwing saltbush	May degraded to unstable sands and sparse vegetation, possibly with coppiced shrubs and Salsola.
					Sazi	5	Very fine sandy loam	Modera-tely deep	Eolian deposits derived dominantly from sandstone	Slightly calcareous	Calciorthid	1-15	Mesas	Semidesert Sandy Loam (Fourwing Saltbush)	Grasses	May degrade to dominance by annuals and bare ground, often including cheatgrass and other invasive exotics.
					Begay	5	Fine sandy loam	Very deep	Eolian deposits derived dominantly from sandstone	Non-calcareous	Camborthid	2-15	Structural benches	Semidesert Sandy Loam (Fourwing Saltbush)	Grasses, Fourwing saltbush	May degrade to dominance by annuals and bare ground, often including cheatgrass and other invasive exotics.
					Ignacio	5	Fine sandy loam	Modera-tely deep	Eolian deposits derived dominantly from sandstone	Non-calcareous	Camborthid	2-6	Mesas	Semidesert Sandy Loam (Fourwing Saltbush)	Grasses, Fourwing saltbush	May degrade to dominance by annuals and bare ground, often including cheatgrass and other invasive exotics.

2.2 Immediate Reasons for Rejection

There are a variety of reasons for immediate rejection of a site that can be ascertained before in-depth assessments and additional trampling of the plot.

- If it is obvious that the transects forming the plot will extend beyond the park boundary.
- If it is obvious that one or more transects will cross a road. Depending on the park and monitoring design, transects can cross closed roads and trails.
- If transects are within 50 m of park buildings.
- If inclusions are present in more than 30% of the area sampled by transects of the plot. Inclusions include bedrock or pockets of non-target ecological site discernable as obviously different vegetation from the target ecological site.
- If any part of a transect extends into a perennial body of water or below a high water mark of a reservoir.
- If any obligate riparian species are present within the plot (e.g., cottonwood, most willows, rushes).
- If any of the 3 transects spans areas presenting safety hazards (e.g., cliff or deep ravine).
- If there are cultural resources within the plot. For Southeast Utah Group park units (ARCH, CANY, HOVE, and NABR), a ½ day training is required for any field crew member assessing plots for the presence of cultural resources.

If a plot is immediately rejected for reasons noted above, record all of the reasons for rejection under in the site selection comments, leave the site, and visit the next plot on the list. Try to include these features in your photographs.

Remember that plots are different sizes based on vegetation type, so use the appropriate size when rejecting plots for the above reasons. Forest and woodland plots require the greatest amount of space, extending approximately 45 m upslope, downslope, and across slope from the centroid due to the orientation of fuels transects (see figures 2 and 3). Grassland/shrubland plots extend approximately 25 m and oak plots extend approximately 10 m up/downslope and across slope from the centroid. If you are not sure whether a plot will fit, use your GPS to estimate the distances and record any potential conflicts in the site selection comments.

During initial and subsequent assessments, never move the plot center to ensure the plot design will fit the spatial and ecological-site requirements. There will be some error in the designation of plot center due to GPS technology, which is acceptable. Purposely moving the plot center, however, introduces bias into the site-selection process and degrades the statistical inference of sample estimates. Reject inappropriate sites – they were selected using tools that accommodate rejection without bias to statistical inference.

3. Field Characterization

3.1 Soil and Vegetation Characterization

Use the Site Characterization data sheet to collect information that will help you decide whether the plot centroid is located on the target ecological site. The target soil component and ecological site for each pre-selected site location will be provided to you by the project manager. Fill out the data sheet using the guidelines below for each letter. The NRCS figures in this SOP have been condensed into two sheets at the end of the SOP that can be taken in the field for quick reference.

A. *Parent Material* – Note the parent material and any information about geology that you can ascertain. The most common parent materials on the Colorado Plateau are alluvium, colluvium, eolian, and residuum. See Table 2 for definitions of common parent materials. Use surface rock fragments or other clues to determine what type of rock the soil is derived from (sandstone, shale, limestone, basalt, etc.). For example, parent materials are mixed eolian deposits derived from sandstone.

Table 2. Definitions for common parent materials of the Colorado Plateau (derived from the NRCS at https://www.soils.org/sssagloss/)

alluvium	Sediments deposited by running water of streams and rivers. It may occur on terraces well above present streams, on the present flood plains or deltas, or as a fan at the base of a slope.
colluvium	Unconsolidated, unsorted earth material being transported or deposited on sideslopes and/or at the base of slopes by mass movement (e.g., direct gravitational action) and by local, unconcentrated runoff.
eolian	Pertaining to earth material transported and deposited by the wind including dune sands, sand sheets, and loess.
residuum	Unconsolidated, weathered, or partly weathered mineral material that accumulates by disintegration of bedrock in place.

B. *Landform* – Use the information from the ecological site table to determine if you are on the correct landform. Geomorphologists have probably identified a few thousand different types of landforms, and it is NOT necessary to familiarize yourself with all of these landforms. It is important to determine whether or not you are on the expected landform for the ecological site of interest. Landforms commonly encountered on the Colorado Plateau are listed and defined in Table 3. Additional landforms are listed in the NRCS "Field Book for Describing and Sampling Soils" (Schoeneberger et al. 2002) and definitions are provided on the NRCS website *https://www.soils.org/sssagloss/*. Fill in the appropriate landform on the data sheet.

Table 3. Definitions for common landforms of the Colorado Plateau (derived from the NRCS at https://www.soils.org/sssagloss/)

alluvial fan	A fan-shaped deposit of loose soil and/or rock material, commonly with gentle slopes, and deposited by a stream at the place where it widens after a narrow upland valley.
alluvial flat	A nearly level, graded, alluvial surface which commonly does not manifest traceable channels or terraces.
alluvial terrace	One of a series of platforms, representing the dissected remnants of an abandoned floodplain, stream bed, or valley floor that is thickly mantled with alluvium.
cuesta	An asymmetric, homoclinal ridge capped by resistant rock layers. A cuesta has a long, gentle slope on one side (dip slope), that roughly parallels the inclined beds, and on the other side has a relatively short and steep or cliff-like slope (scarp) that cuts through the tilted rocks.
hill	A generic term for an elevated area of the land surface above surrounding lowlands, usually with nominal summit area relative to bounding slopes, a well-defined rounded outline, and slopes that generally exceed 15 percent.
hillslope	A generic term for the steeper part of a hill between its summit and the valley bottom or depression at the base of the hill.
mesa	A broad, nearly flat-topped, and usually isolated landmass bounded by steep slopes or precipitous cliffs and capped by layers of resistant, nearly horizontal, rocky summit with the width greater than the height of bounding escarpments.
plateau	A relatively flat area of great extent and elevation; specifically an extensive flat land region considerably elevated above adjacent lower-lying terrain that is commonly limited on at least one side by an abrupt descent.
sand dune	A low mound, ridge, bank, or hill of loose, windblown sand, either barren and capable of movement from place to place, or covered and stabilized with vegetation, but retaining its characteristic shape.
sand sheet	A large, thin sheet of eolian sand, lacking discernible slip faces that are common on dunes.
strath terrace	Erosional surfaces cut into bedrock and thinly mantled with alluvium.
structural bench	A platform-like, nearly level to gently inclined erosional surface developed on resistant strata in areas where valleys are cut in alternating strong and weak layers with an essentially horizontal orientation.
valley	An elongate, relatively large, externally drained depression of the Earth's surface that is primarily developed by stream erosion or glacial activity.
valley floor	A general term for the nearly level to gently sloping, lowest surface of a valley.

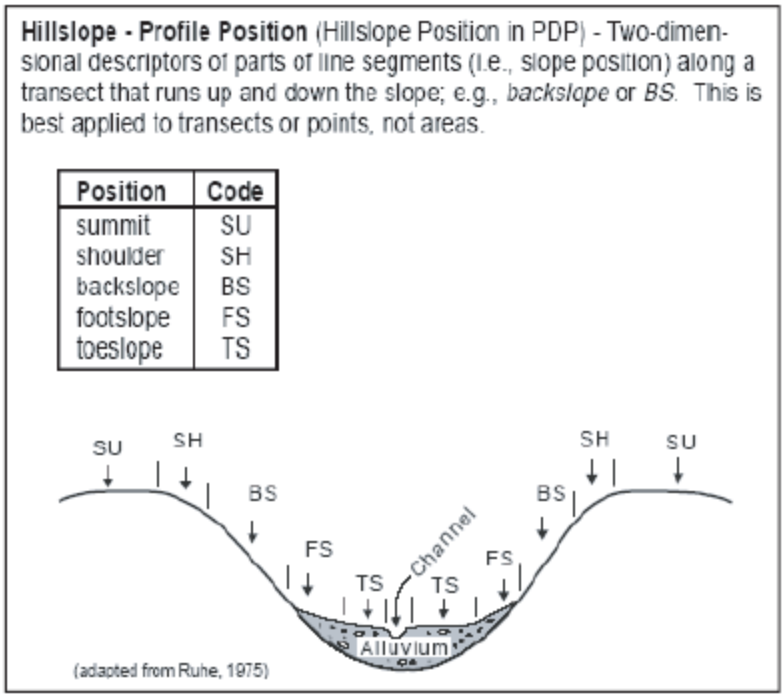


Figure 4. NRCS figure for determining hillslope position (Schoeneberger et al. 2002)

C. *Hillslope position* – Use Figure 4 to select the hillslope position that describes your location. Possible hillslope positions include summit, shoulder, backslope, footslope, and toeslope. Circle the appropriate hillslope position on the data sheet. Hillslope position may not be relevant in some cases, such as for mesa tops or mountain tops. In such cases circle summit on the data sheet.

D. *Slope complexity* – This refers to the relative uniformity of the ground surface leading down slope and across the plot. Figure 5 illustrates examples of simple vs. complex slopes. Decide which best describes your location and circle the appropriate category on the data sheet.

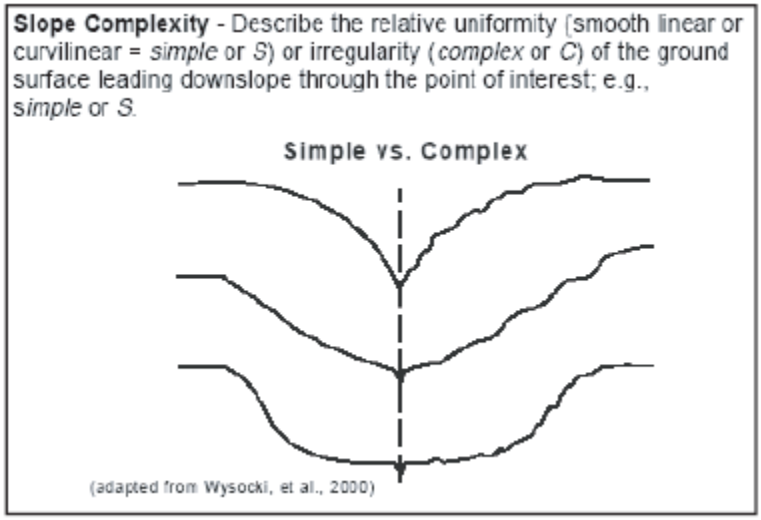


Figure 5. NRCS figure for determining hillslope complexity (Schoeneberger et al. 2002)

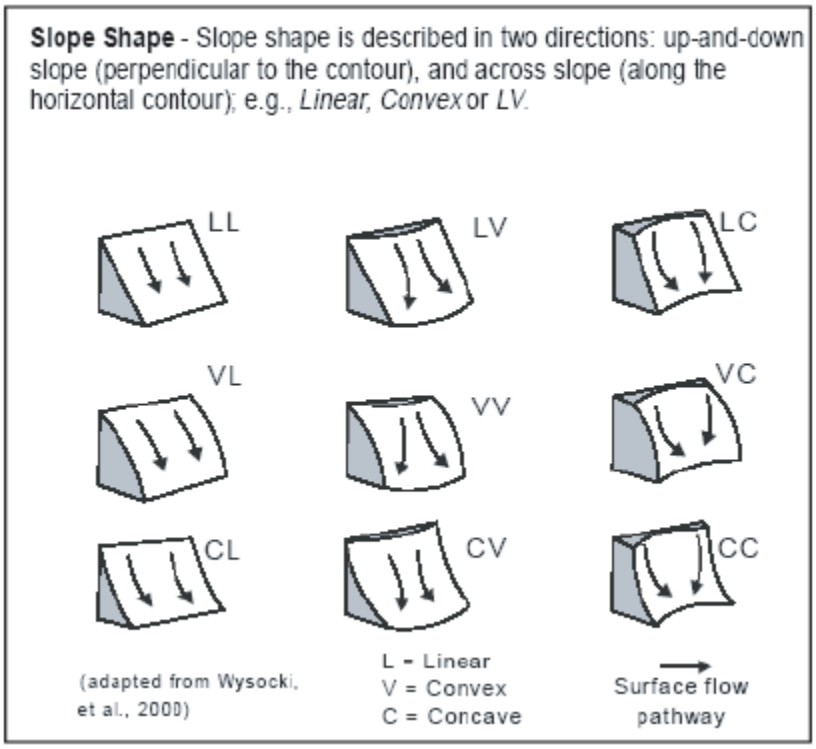


Figure 6. NRCS figure for determining slope shape (Schoeneberger et al. 2002)

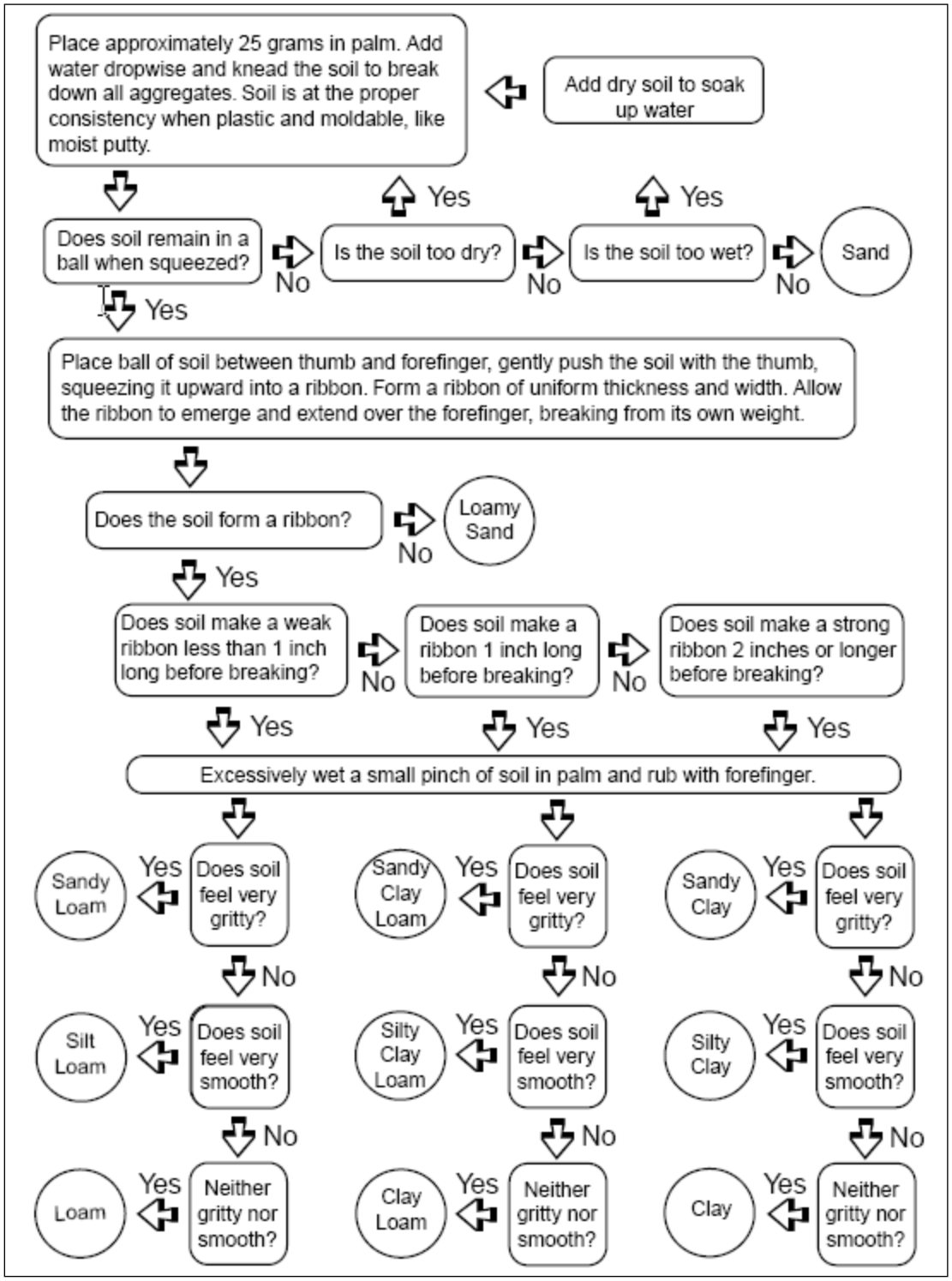
E. *Slope shape* – Determine the slope curvature (linear, concave, or convex) for across slope and downslope. Figure 6 illustrates possible combinations of slope curvature. Circle the appropriate categories on the data sheet.

F. *Percent slope* – Determine the percent slope using a clinometer. This is an approximate measurement used to decide if the slope at your location fits into the range of slopes for the ecological site of interest. Take a reading downslope from the centroid, sighting to the same height above the ground as your eye level. Record the reading in percent (not degrees). If your clinometer only has degrees, use Table 4 to convert to percent slope.

G. *Surface soil texture* – Soil texture refers to the particle size distribution of the fine earth fraction (sand, silt, and clay particles <2 mm in diameter). Use a trowel to scoop a small amount of surface soil into the 2-mm sieve in order to separate rock fragments from the fine fraction. Collect a small amount of sieved soil in your hand and add water slowly using a spray bottle or dropper. Mix the water and soil in your hand and use the key in Figure 7 to determine the soil texture. If you have never textured soil, practice this technique with the guidance of an experienced co-worker before the beginning of the field season. The texture triangle (Figure 8) is also helpful for understanding the relationship between different soil particle sizes in determining soil texture. Write the soil texture in the blank provided on the data sheet.

Table 4. Conversion of slope angle from degrees (Deg) to percent (Pct)

Slope angle	
Deg	Pct
1	1.7
2	3.5
3	5.2
4	7.0
5	8.7
6	10.5
7	12.3
8	14.1
9	15.8
10	17.6
11	19.4
12	21.3
13	23.1
14	24.9
15	26.8
16	28.7
17	30.6
18	32.5
19	34.4
20	36.4
21	38.4
22	40.4
23	42.4
24	44.5
25	46.6
26	48.8
27	51.0
28	53.2
29	55.4
30	57.7
31	60.1
32	62.5
33	64.9
34	67.5
35	70.0
36	72.7
37	75.4
38	78.1
39	81.0
40	83.9
41	86.9
42	90.0
43	93.3
44	96.6
45	100.0



(Herrick et al. 2005)

Figure 7. Soil texture key. Begin in the top left corner and answer the yes/no questions to determine soil texture.

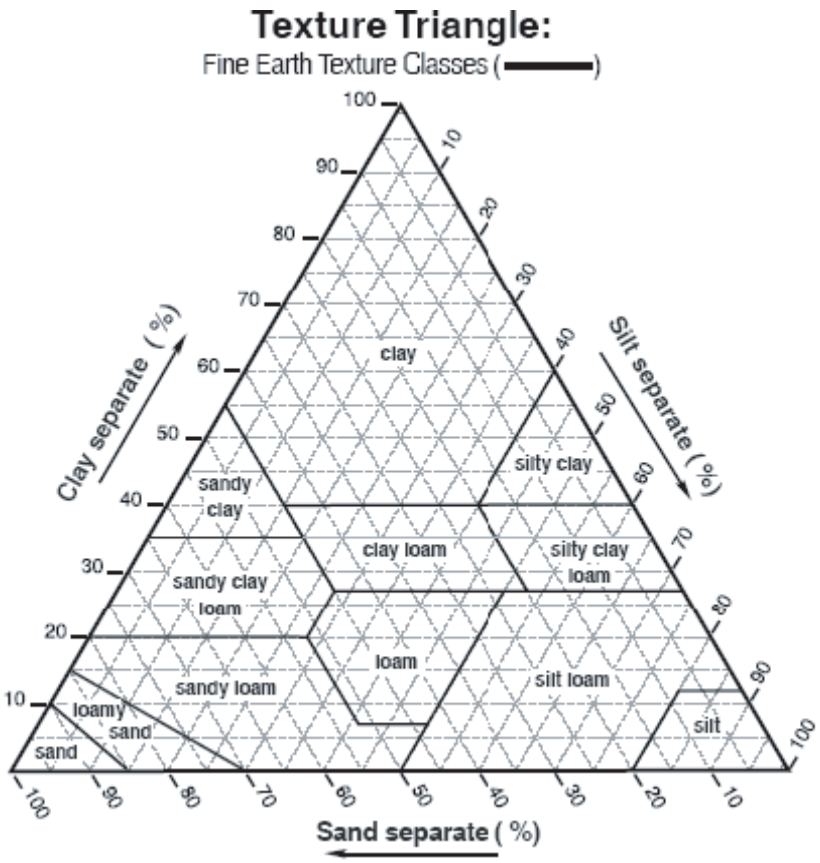


Figure 8. Soil texture triangle (Schoeneberger et al. 2002)

H. <u>*Sand modifier*</u> – If sand is a major part of the soil texture (e.g., loamy sand or sandy loam), determine the predominant size class of sand. Use the sand particle sizes detailed in Figure 9 to choose one of two size classes: very fine/fine/medium or coarse/very coarse. The border between the two classes is 0.5 mm. Circle your choice on the data sheet. If the words “sand or “sandy” are not included in soil texture then circle “n/a”.

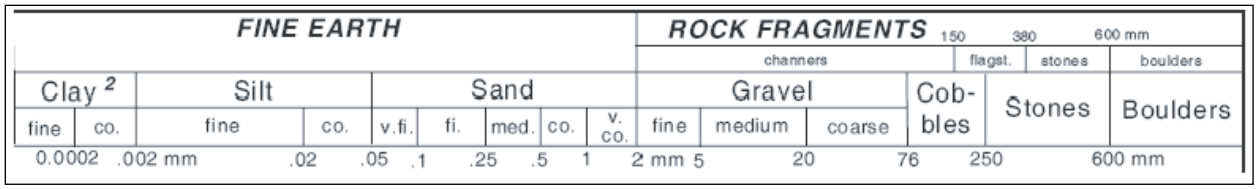


Figure 9. Sizes of soil particles and rock fragments (Schoeneberger et al. 2002). Definitions of channers and flagstones are listed under Size below. (v.fi.= very fine, fi.=fine, med.= medium, co.=coarse, v.co.= very coarse, flagst.=flagstones)

I. *Rock fragment texture modifiers* – Some soil types are further described by rock fragment quantity and size (e.g., very gravelly sandy loam). First, use rock fragments remaining in the soil sieve and exposed on the soil surface to determine the percent of rock fragments by volume. If there is less than 15% rock fragment by volume then no rock fragment texture modifier is necessary. Select "n/a" for quantity adjective and "none" for size.

If there is more than 15% rock fragment by volume, use the following categories to determine the appropriate rock fragment texture modifiers.

QUANTITY ADJECTIVE: Determine the approximate rock fragment content percent by volume and refer to Table 5 for the appropriate rock fragment quantity adjective. Rock fragments 15 to <35% by volume require only fragment size (e.g., gravelly loam), therefore, select "none" for quantity adjective on the data sheet. Use "very" and "extremely" to describe soils with 35 to < 60% and 60 to < 90% rock fragments respectively (e.g., very gravelly loam and extremely gravelly loam). If there is 90% or more of rock fragment then soil is described by only the rock fragment size and not by the fine earth component (e.g., gravel).

SIZE: Use the rock fragment size chart in Figure 9 to determine the largest dominant fragment. The largest dominant fragment is the largest rock fragment class present unless a smaller size-class is present in substantial quantity. A smaller fragment size-class must exceed two times the volume of a larger fragment before it is called the dominant fragment. Definitions for some potentially unfamiliar rock fragment types are listed below.

channer – A thin, flat fragment of sandstone, shale, slate, limestone, or schist as long as 15 cm along the longest axis.

flagstone – A thin fragment of sandstone, limestone, slate, shale, or (rarely) schist as long as 15 to 38 centimeters long.

Table 6 provides examples of rock fragment texture modifiers for rock fragments of different quantity and size.

Table 5. NRCS texture modifiers to describe the amount of rock fragments in soil (Schoeneberger et al. 2002).

TEXTURE MODIFIERS - Convertions for using "Rock Fragment Texture Modifiers" and for using textural adjectives that convey the "% volume" ranges for **Rock Fragments - Size and Quantity**.

Fragment Content % By Volume	Rock Fragment Modifier Usage
< 15	No texture adjective is used (noun only; e.g., *loam*).
15 to < 35	Use adjective for appropriate size; e.g., *gravelly*.
35 to < 60	Use "very" with the appropriate size adjective; e.g., *very gravelly*.
60 to < 90	Use "extremely" with the appropriate size adjective; e.g., *extremely gravelly*.
≥ 90	No adjective or modifier. If ≤ 10% fine earth, use the appropriate noun for the dominant size class; e.g., *gravel*. Use **Terms in Lieu of Texture**.

Table 6. NRCS texture modifiers by rock quantity and size (Schoeneberger et al. 2002).

TEXTURE MODIFIERS - *(adjectives)*

ROCK FRAGMENTS: Size & Quantity [1]	Code		Criteria: Percent (By Volume) of Total Rock Fragments and Dominated By (*name size*): [1]
	Conv.	PDP/ NASIS	
ROCK FRAGMENTS (> 2 mm; ≥ Strongly Cemented)			
Gravelly	GR	GR	≥ 15% but < 35% gravel
Fine Gravelly	FGR	GRF	≥15% but < 35% fine gravel
Medium Gravelly	MGR	GRM	≥15% but < 35% med. gravel
Coarse Gravelly	CGR	GRC	≥ 15% but < 35% coarse gravel
Very Gravelly	VGR	GRV	≥ 35% but < 60% gravel
Extremely Gravelly	XGR	GRX	≥ 60% but < 90% gravel
Cobbly	CB	CB	≥ 15% but < 35% cobbles
Very Cobbly	VCB	CBV	≥ 35% but < 60% cobbles
Extremely Cobbly	XCB	CBX	≥ 60% but < 90% cobbles
Stony	ST	ST	≥ 15% but < 35% stones
Very Stony	VST	STV	≥ 35% but < 60% stones
Extremely Stony	XST	STX	≥ 60% but < 90% stones
Bouldery	BY	BY	≥ 15% but < 35% boulders
Very Bouldery	VBY	BYV	≥ 35% but < 60% boulders
Extremely Bouldery	XBY	BYX	≥ 60% but < 90% boulders
Channery	CN	CN	≥ 15% but < 35% channers
Very Channery	VCN	CNV	≥ 35% but < 60% channers
Extremely Channery	XCN	CNX	≥ 60% but < 90% channers
Flaggy	FL	FL	≥ 15% but < 35% flagstones
Very Flaggy	VFL	FLV	≥ 35% but < 60% flagstones
Extremely Flaggy	XFL	FLX	≥ 60% but < 90% flagstones
PARAROCK FRAGMENTS (> 2 mm; < Strongly Cemented) [2, 3]			
Parabouldery	PBY	PBY	(same criteria as bouldery)
Very Parabouldery	VPBY	PBYV	(same criteria as very bouldery)
Extr. Parabouldery	XPBY	PBYX	(same criteria as ext. bouldery)
etc.	etc.	etc.	(same criteria as non-para)

[1] The "Quantity" modifier (e.g., *very*) is based on the total rock fragment content. The "Size" modifier (e.g., *cobbly*) is independently based on the largest, dominant fragment size. For a mixture of sizes (e.g., *gravel and stones*), a smaller size–class is named only if its quantity (%) sufficiently exceeds that of a larger size–class. For field texture determination, a smaller size-class must exceed 2 times the quantity (vol. %) of a larger size class before it is named (e.g., 30% gravel and 14% stones = *very gravelly*, but 20% gravel and 14% stones = *stony*). For more explicit naming criteria see NSSH-Part 618, Exhibit 618.11(Soil Survey Staff, 2001b).

J. *Effervescence* – The degree of effervescence relates to the quantity and surface area of carbonate compounds in the soil. Apply a few drops of 1M HCl to the fine soil fraction, and use Table 7 to determine the effervescence class. More bubbles indicate higher amounts of carbonate compounds in the soil.

Table 7. NRCS effervescence classes determined by dropping 1M HCl on the fine soil fraction (Schoeneberger et al. 2002)

Effervescence Class	Code		Criteria
	PDP	NASIS	
Noneffervescent	4	NE	No bubbles form.
Very Slightly Effervescent	0	VS	Few bubbles form.
Slightly Effervescent	1	SL	Numerous bubbles form.
Strongly Effervescent	2	ST	Bubbles form a low foam.
Violently Effervescent	3	VE	Bubbles form a thick foam.

K. *Depth class* – Estimate the soil depth class based on your observations of bedrock exposures or naturally occurring soil profile exposures in the area. Use Table 8 to determine the approximate depth class or classes, and circle your choice(s) on the data sheet. **Do not dig to determine the actual depth.** NPS requires that an archeologist be present during any digging to make sure the area is free of sensitive cultural artifacts.

Table 8. Depth to root restricting layer in centimeters (cm) and inches (in) for depth classes (Soil Survey Staff 1993).

Root restricting depth		
Depth class	Cm	In
Very shallow	< 25	< 10
Shallow	25 - 50	10 - 20
Moderately deep	50 - 100	20 - 40
Deep	100 - 150	40 - 60
Very deep	>= 150	> = 60

L. *Dominant vegetation* – Identify dominant plant species at the site and record this information on the data sheet using the full Latin name. Use vegetation identification keys if necessary, but avoid spending too much time on this. Examine “Potential vegetation” and “Dynamics” columns on the ecological site tables. Look specifically for evidence of vegetation listed as “Potential vegetation” for the ecological site. Familiarize yourself with the range of variation in the plant community due to natural and/or

anthropogenic disturbances. Think about how well the vegetation you see fits the expected vegetation for the ecological site.

3.2 Soil Assessment

Compare the information you collected on the data sheet with the characteristics of the target ecological site on the ecological site table to determine if observed soil and landscape characteristics *reasonably* match those associated with the target soil component and ecological site. Large departures in ecologically significant characteristics such as depth and texture are grounds for answering NO to this question. Use the following examples to help you decide.

Large departures:

- If the target soil is deep, and the observed soil is very shallow or shallow.
- If the target soil is a sandy loam, and the observed soil is a channery clay loam.

Relatively minor departures:

- If the target soil is shallow and the observed soil is very shallow.
- If the target soil is a gravelly sandy loam and the observed soil is a very gravelly loamy sand.
- If the target soil is noneffervescent and the observed soil is strongly effervescent. (Departures from the predicted effervescence are not enough to reject a plot.)

Use the information you collected on the data sheet and the ecological site table to determine the probable soil component at the centroid. Write this on the data sheet (or write "unknown" if the soil component cannot be determined) and decide whether this matches the target soil component(s). If you suspect several soil components are present on the plot but the most dominant component matches the target component, indicate a positive match by circling yes, but note the probable occurrence of other components in the Additional comments field. You can also record comments about any deviations from the predicted soil characteristics in this field. If the soil component does not match the target ecological site or if non-target components are dominant, circle "no" and explain your choice in the additional comments field.

3.3 Vegetation Assessment

Does the observed vegetation *reasonably* match expected vegetation associated with the target ecological site? Soil, landscape, and climate characteristics are primary determinants of ecological sites. Existing vegetation *should only be used with great caution* as a clue in determining whether you are on the target ecological site. Observed vegetation may differ from expected vegetation due to effects of land use, natural disturbances such as fire, or climate. In answering this question, it is important to consider the full range of potential vegetation dynamics on a site – including natural post-disturbance successional processes, typical fluctuations in relation to climate, and possible degradational changes associated with invasive species, overgrazing, and/or major soil loss or redistribution. If observed vegetation is within this range of potential dynamics (natural and anthropogenic) for this ecological site,

then the answer should be YES. However, if observed vegetation appears to be beyond the realm of potential dynamics, then the answer should be NO. Use the following examples to help you decide.

Departures within the range of potential dynamics:

- In reference condition, potential vegetation for the target ecological site is co-dominated by sagebrush and native perennial grasses, but the observed vegetation is dominated by invasive annuals (e.g., cheatgrass) or juniper with evidence of past sagebrush presence.
- Potential vegetation for the target ecological site is a mixed conifer forest but the observed vegetation is an aspen forest. The aspen forest may be a post-fire successional stage.

Departures beyond the range of potential dynamics:

- Potential vegetation for the target ecological site is a desert grassland dominated by Indian ricegrass and observed vegetation is a montane shrubland dominated by Gambel oak and serviceberry.

If a mixture of vegetation communities is present on the plot but the dominant community matches the target ecological site, then circle 'yes', but indicate in the Additional comments field the presence of other types. Also record comments about any other deviations from the predicted dominant vegetation in this field. If the dominant community differs from the target ecological site, circle "no" and add narrative explaining your choice in the additional comments field.

3.4 Ecological Site Assessment

Responses to the soil and vegetation assessments are used to determine if the site matches the target ecological site. Fill in the name of the ecological site that you characterized and estimate of the percent of the plot area comprised of this site type.

For plots with more than one ecological site type, indicate the second-most common ecological site and estimate the percent area. If bedrock, a wash with non-target vegetation, or other nontarget feature makes up part of the plot, include this on your data sheet and estimate the percent area. Write "unknown" if you are unable to determine the ecological site from the information you have. Estimate the total length of transect (in meters) that falls outside the primary or target ecological site and write this on the data sheet. Remember that each grassland/shrubland, woodland, and forest plot has three 50-m transects separated by 25 m (Fig. 7) for a total of 150 meters of transect. Oak plots have three 20-m transects separated by 10 m for a total of 60 meters of transect. Enter the ecological site number and name recorded on the dichotomous key for the respective park unit (e.g., 212-Semidesert Sand (Four-wing Saltbush)). When in doubt, enter "other".

3.5 Site Selection

Plots will be rejected if they do not match the target ecological site (e.g., wrong slope, landform, soil texture, soil depth, or vegetation), or if >30% of the total transect length crosses into another ecological site. Remember that plots will also be rejected if you discover any of the conditions listed in section 2.2.

If both soils and vegetation are characteristic of the target ecological site, and at least 70% of all 3 transects appear to have suitable soil and vegetation characteristics, then select accepted on the data sheet and set up the monitoring plot (see SOP #6).

If the vegetation or soil does not match the expected characteristics for the ecological site, select rejected on the data sheet and describe your rationale in the comments field.

4. References

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. Volume II: Design, supplementary methods and interpretation. USDA-ARS Jornada Experimental Range, Las Cruces, NM. 200 pp.

Schoeneberger, P.J., Wysocki, D.A., Benham, E.C., and Broderson, W.D. (editors), 2002. Field Book for Describing and Sampling Soils, Version 2.0. Natural Resource Conservation Service, National Soil Survey Center Lincoln, NE.

Soil Survey Staff. 1993. Soil survey manual. USDA, Soil Conservation Service, Agricultural Handbook No. 18, U.S. Gov. Print. Office, Washington, D.C. 503 pp.

Site Characterization

Data entered by: Data verified by: **p.1**

NCPN Upland Monitoring

1. GENERAL PLOT INFO.

Park code: _____ Plot ID: _____ Date: _____ Recorder: _____

Vegetation type:_____ Grazed: yes no

Soil survey area: _____ Soil map unit: _____

Photo #:_____ Direction:____ Datum:_____ Zone:_____

_____ ____ Centroid Coordinates (UTM):

_____ ____ __ __ __ __ __ __ __ m N

_____ ____ __ __ __ __ __ __ m E

2. SOIL AND VEGETATION CHARCTERIZATION

A. Parent Material: _____

B. Landform: _____

C. Hillslope position: summit - shoulder - backslope - footslope - toeslope - low level

D. Slope complexity: complex - simple

E. Slope shape - down slope: linear - concave - convex

across slope: linear - concave - convex

F. Percent slope: _____

G. Soil texture: _____

H. Sand modifier: very fine - fine - medium coarse - very course n/a

I. Rock fragment modifiers --- quantity adjective:

n/a (<15%) - none (15 to <35%) - very (35 to <60%) - extremely (60 to <90%) - >90%

--- size:

none - gravelly - cobbly - stony - bouldery - channery - flaggy - gravel - cobble - stone - boulder

J. Effervescence: none - very slight - slight - strong - violent

K. Depth: very shallow - shallow - moderately deep - deep - very deep - unknown

L. Dominant vegetation: _____

_____

_____

_____

p.2

3. SOIL ASSESSMENT **target match:** yes - no

Probable soil component: _____

Additional comments:_____
_____
_____
_____
_____

4. VEGETATION ASSESSMENT **target match:** yes - no

Additional comments:_____
_____
_____
_____
_____

5. ECOLOGICAL SITE ASSESSMENT

Primary Ecological site: _____ **% Area:** _____

Other Ecological site: _____ **% Area:** _____

Estimated transect length outside of target ecological site: _____ **m**

6. SITE SELECTION: accepted - rejected

Comments:_____
_____
_____
_____
_____
_____
_____

Soil Texture, Depth, and Effervescence

Root restricting depth		
Depth class	Cm	In
Very shallow	< 25	< 10
Shallow	25 - 50	10 - 20
Moderately deep	50 - 100	20 - 40
Deep	100 - 150	40 - 60
Very deep	>= 150	> = 60

Effervescence Class	Code		Criteria
	PDP	NASIS	
Noneffervescent	4	NE	No bubbles form.
Very Slightly Effervescent	0	VS	Few bubbles form.
Slightly Effervescent	1	SL	Numerous bubbles form.
Strongly Effervescent	2	ST	Bubbles form a low foam.
Violently Effervescent	3	VE	Bubbles form a thick foam.

TEXTURE MODIFIERS - Conventions for using "Rock Fragment Texture Modifiers" and for using textural adjectives that convey the "% volume" ranges for **Rock Fragments - Size and Quantity**.

Fragment Content % By Volume	Rock Fragment Modifier Usage
< 15	No texture adjective is used (noun only; e.g., *loam*).
15 to < 35	Use adjective for appropriate size; e.g., *gravelly*.
35 to < 60	Use "very" with the appropriate size adjective; e.g., *very gravelly*.
60 to < 90	Use "extremely" with the appropriate size adjective; e.g., *extremely gravelly*.
≥ 90	No adjective or modifier. If ≤ 10% fine earth, use the appropriate noun for the dominant size class; e.g., *gravel*. Use **Terms in Lieu of Texture**.

SIMPLIFIED KEY TO SOIL TEXTURE

Add water to hand-full of soil and knead to break down aggregates. Soil is at proper consistency when plastic and moldable like moist putty.

1. Soil does not remain in a ball when squeezed.....**Sand (Sa)**
1. Soil remains in a ball when squeezed.....2

Squeeze ball between thumb and forefinger, attempting to make a ribbon that you push up over finger.

2. Soil does not form ribbon.....**Loamy Sand (LSa)**
2. Soil does form ribbon; may be very short.....3

3. Ribbon extends < 1 inch before breaking.....4
3. Ribbon extends > 1 inch before breaking.....5

4. *Add excess water to small amount of soil*; soil feels very gritty.....**Sandy Loam (SaL),** or slightly gritty.....**Loam (L)**
4. Soil feels very smooth.....**Silt Loam (SiL)**

5. Soil makes ribbon that breaks when 1-2 inches long; cracks if bent into ring.....6
5. Soil makes ribbon > 2 inches long; doesn't crack if bent into ring.....7

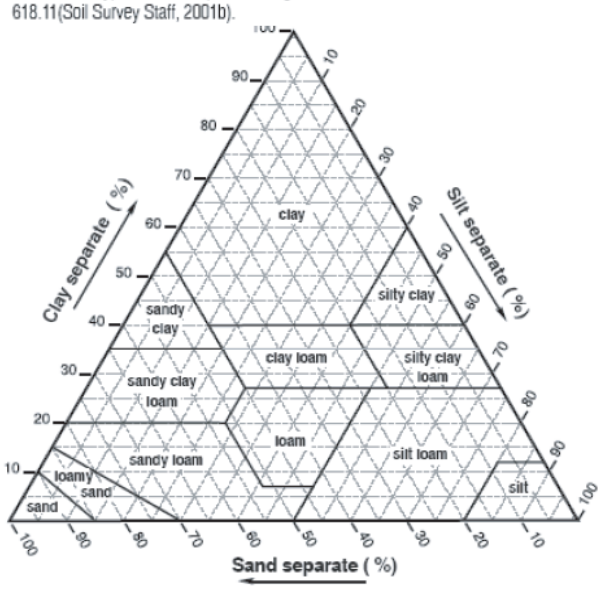
6. *Add excess water to small amount of soil;* soil feels at least slightly gritty.....**Sandy Clay Loam (SaCL) or Clay Loam (CL)**
6. Soil feels smooth.....**Silt (Si) or Silty Clay Loam (SiCL)**

7. *Add excess water to small amount of soil;* soil feels at least slightly gritty.....**Sandy Clay (SaC) or Clay (C)**
7. Soil feels smooth.....**Silty Clay (SiC)**

TEXTURE MODIFIERS - *(adjectives)*

ROCK FRAGMENTS: Size & Quantity [1]	Code		Criteria: Percent (By Volume) of Total Rock Fragments and Dominated By (*name size*): [1]
	Conv.	PDP/ NASIS	
ROCK FRAGMENTS (> 2 mm; ≥ Strongly Cemented)			
Gravelly	GR	GR	≥ 15% but < 35% gravel
Fine Gravelly	FGR	GRF	≥15% but < 35% fine gravel
Medium Gravelly	MGR	GRM	≥15% but < 35% med. gravel
Coarse Gravelly	CGR	GRC	≥ 15% but < 35% coarse gravel
Very Gravelly	VGR	GRV	≥ 35% but < 60% gravel
Extremely Gravelly	XGR	GRX	≥ 60% but < 90% gravel
Cobbly	CB	CB	≥ 15% but < 35% cobbles
Very Cobbly	VCB	CBV	≥ 35% but < 60% cobbles
Extremely Cobbly	XCB	CBX	≥ 60% but < 90% cobbles
Stony	ST	ST	≥ 15% but < 35% stones
Very Stony	VST	STV	≥ 35% but < 60% stones
Extremely Stony	XST	STX	≥ 60% but < 90% stones
Bouldery	BY	BY	≥ 15% but < 35% boulders
Very Bouldery	VBY	BYV	≥ 35% but < 60% boulders
Extremely Bouldery	XBY	BYX	≥ 60% but < 90% boulders
Channery	CN	CN	≥ 15% but < 35% channers
Very Channery	VCN	CNV	≥ 35% but < 60% channers
Extremely Channery	XCN	CNX	≥ 60% but < 90% channers
Flaggy	FL	FL	≥ 15% but < 35% flagstones
Very Flaggy	VFL	FLV	≥ 35% but < 60% flagstones
Extremely Flaggy	XFL	FLX	≥ 60% but < 90% flagstones
PARAROCK FRAGMENTS (> 2 mm; < Strongly Cemented) [2, 3]			
Parabouldery	PBY	PBY	(same criteria as bouldery)
Very Parabouldery	VPBY	PBYV	(same criteria as very bouldery)
Extr. Parabouldery	XPBY	PBYX	(same criteria as ext. bouldery)
etc.	etc.	etc.	(same criteria as non-para)

[1] The "Quantity" modifier (e.g., *very*) is based on the total rock fragment content. The "Size" modifier (e.g., *cobbly*) is independently based on the largest, dominant fragment size. For a mixture of sizes (e.g., *gravel and stones*), a smaller size–class is named only if its quantity (%) sufficiently exceeds that of a larger size–class. For field texture determination, a smaller size-class must exceed 2 times the quantity (vol. %) of a larger size class before it is named (e.g., 30% gravel and 14% stones = *very gravelly*, but 20% gravel and 14% stones = *stony*). For more explicit naming criteria see NSSH-Part 618, Exhibit 618.11(Soil Survey Staff, 2001b).



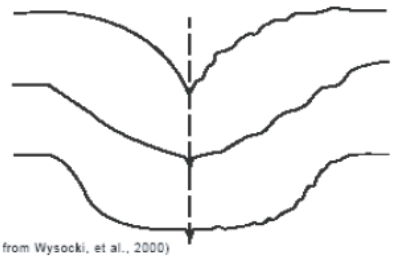
FINE EARTH									ROCK FRAGMENTS 150 380 600 mm					
									channers			flagst.	stones	boulders
Clay [2]		Silt		Sand					Gravel			Cob-bles	Stones	Boulders
fine	co.	fine	co.	v.fi.	fi.	med.	co.	v. co.	fine	medium	coarse			
0.0002	.002 mm		.02	.05	.1	.25	.5	1	2 mm 5		20	76	250	600 mm

Hillslope Descriptors & Cover / Volume Estimation

Slope angle	
Deg	Pct
1	1.7
2	3.5
3	5.2
4	7.0
5	8.7
6	10.5
7	12.3
8	14.1
9	15.8
10	17.6
11	19.4
12	21.3
13	23.1
14	24.9
15	26.8
16	28.7
17	30.6
18	32.5
19	34.4
20	36.4
21	38.4
22	40.4
23	42.4
24	44.5
25	46.6
26	48.8
27	51.0
28	53.2
29	55.4
30	57.7
31	60.1
32	62.5
33	64.9
34	67.5
35	70.0
36	72.7
37	75.4
38	78.1
39	81.0
40	83.9
41	86.9
42	90.0
43	93.3
44	96.6
45	100.0

Slope Complexity - Describe the relative uniformity (smooth linear or curvilinear = *simple* or *S*) or irregularity (*complex* or *C*) of the ground surface leading downslope through the point of interest; e.g., *simple* or *S*.

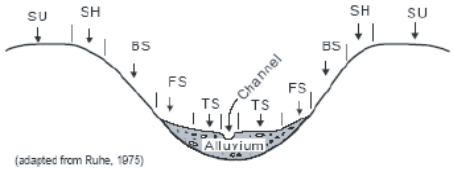
Simple vs. Complex



(adapted from Wysocki, et al., 2000)

Hillslope - Profile Position (Hillslope Position in PDP) - Two-dimensional descriptors of parts or line segments (i.e., slope position) along a transect that runs up and down the slope; e.g., *backslope* or *BS*. This is best applied to transects or points, not areas.

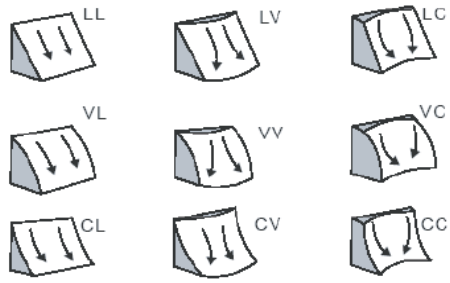
Position	Code
summit	SU
shoulder	SH
backslope	BS
footslope	FS
toeslope	TS



(adapted from Ruhe, 1975)

Slope Classes	Pct. Gradient
Level	< 1
Nearly level	1-3
Gently sloping	4-6
Strongly sloping	7-10
Moderately steep	11-20
Steep1	21-45
Steep2	46-75
Steep3	76-100
Very steep	> 100

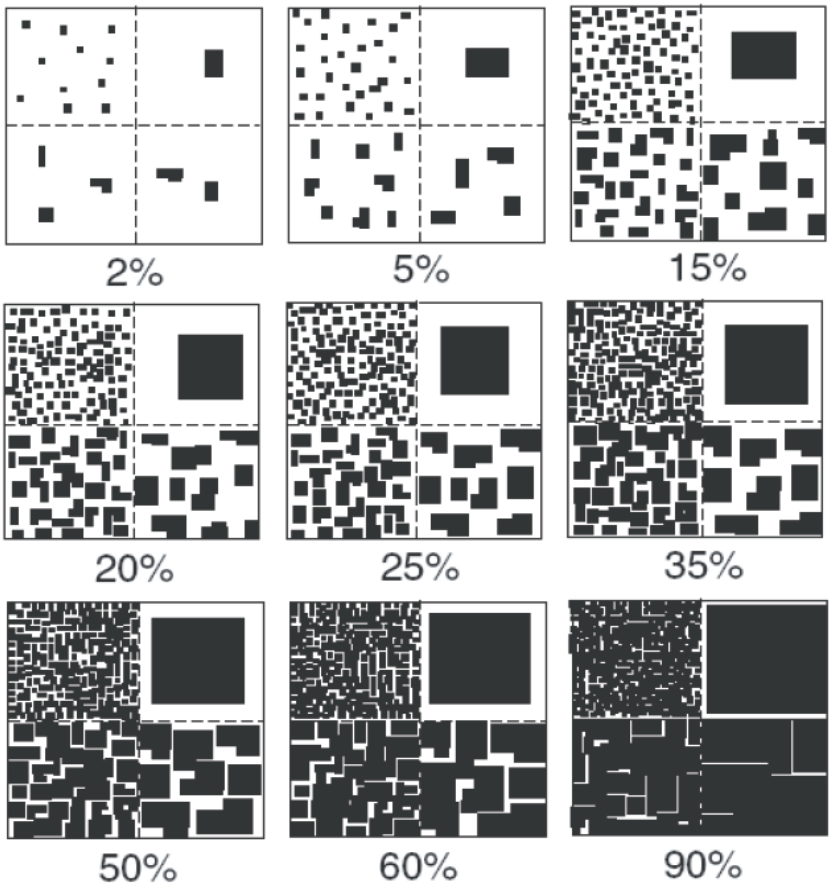
Slope Shape - Slope shape is described in two directions: up-and-down slope (perpendicular to the contour), and across slope (along the horizontal contour); e.g., *Linear, Convex* or *LV*.



(adapted from Wysocki, et al., 2000)

L = Linear
V = Convex
C = Concave

Surface flow pathway



Foliar cover classes	
Class	Cover %
1	< 1
2	1 - 5
3	5 - 10
4	10 - 25
5	25 - 50
6	50 - 75
7	75 - 100

Upland Vegetation and Soils Monitoring Protocol for Park Units in the Northern Colorado Plateau Network

Standard Operating Procedure (SOP) # 6

Establishing Plots and Setting Up Transects

Version 1.25 (December 2017)

Revision History Log:

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #
1.00	3/1/2007	S. Garman	1) Added specific reference to SOP #4 2) Add instructions for recording re-visit comments	1) To emphasize minimizing site impacts 2) Addition of revisit data sheet	1.10
1.10	4/2008	R. Weissinger	Formatting only	To improve useability	1.10
1.10	7/2008	R. Weissinger	Added procedures and equipment for woodland sampling	Expanded sampling frame to include forest ecosites	1.20
1.20	7/2009	D. Witwicki	Added procedures for forest and woodland; revise establishment procedures for transects 1 & 3; remove DRC from data sheets; pre-numbered tree tags; orange stakes	Need to record slope of plot sides; clean up	1.21
1.21	4/2011	D. Witwicki, S. Topp	Change size of rebar for monuments, reorder for work flow, change SOP title	Compliance, usability	1.22
1.22	4/2015	S. Karinen, D. Witwicki	Added instructions to check compass declination and write tape stringing directions, edited data sheets	Needed more instructions, needed room for transect 2 monument trees	1.23
1.23	4/2016	D. Witwicki	Minor updates	Wording clarification	1.24
1.24	12/2017	D. Witwicki, A. Wondrak-Biel	Updated plot figures	For publication	1.25

This SOP provides instructions for establishing permanent monitoring plots in grassland, shrubland, woodland, and forest vegetation types. This SOP includes instructions for setting up plots, recording changes in permanent markers, and recording general comments while revisiting an existing monitoring plot. A list of necessary equipment for these procedures can be found in SOP #1. SOP #4 (Crust-Friendly Field Procedures) should be reviewed before plot establishment. SOP #15 details modifications to the plot set-up for oak plots.

1. Plot Establishment

1.1 Navigate to the plot centroid and log the point on the GPS.

- Use a GPS unit, a topographic map, and the UTM coordinates to locate the point.
- Approach from downslope to avoid trampling the sampling area.
- Place a pinflag at the plot centroid.
- Record the location of the centroid on your GPS (see SOP #3).

1.2 Measure slope and aspect.

A. Stand at the centroid and face downhill.
- If it is difficult to determine which direction is downhill, aim towards the nearest drainage.

B. Aim the clinometer at a point at eye level roughly 25 m downslope. Note the percent slope.

C. Set the compass to true north using the correct declination for the park unit (see SOP #1 for list of current declinations). Aim the compass downslope, level the compass, close one eye, and record the aspect of the slope in degrees. It's very important to have the compass level and to keep metal objects (i.e., rings, watches, chaining pins, transect tape ends) away from it to get an accurate reading.

D. Face uphill and aim the clinometer at a point at eye level roughly 25 m upslope. Note the percent slope.

E. Average the two percent slope measures and record this number. If the plot is truly flat, make a note in the visit comments so it does not look like the crew forgot to record this measure.

1.3 Determine the azimuth of the center transect.

A. Subtract 90˚ from the slope aspect. Record this number as the transect azimuth.
- If the plot is truly level, arbitrarily choose a transect azimuth.

1.4 Establish the center transect.

An upland plot consists of three parallel 50-m long transects running across the slope at intervals of 25 m (Figures 1-3).

A. Have one crew member stand over the centroid pin flag holding the reel of the transect tape and a compass.

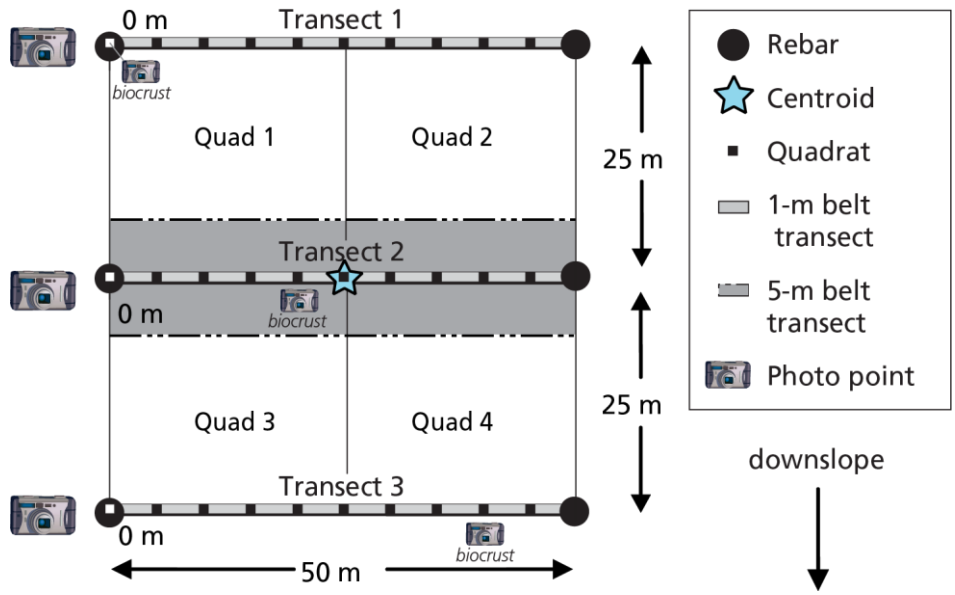


Figure 1. Locations of transects and monitoring measurements at grassland/shrubland plots, including repeat photos, 1-m^2 quadrats for sampling frequency of exotics, one-meter belt transects for measuring shrubs and seedlings, a five-meter belt transect for measuring saplings, and Quad 1 for measuring overstory trees. Soil stability is also collected at six randomized locations along each transect.

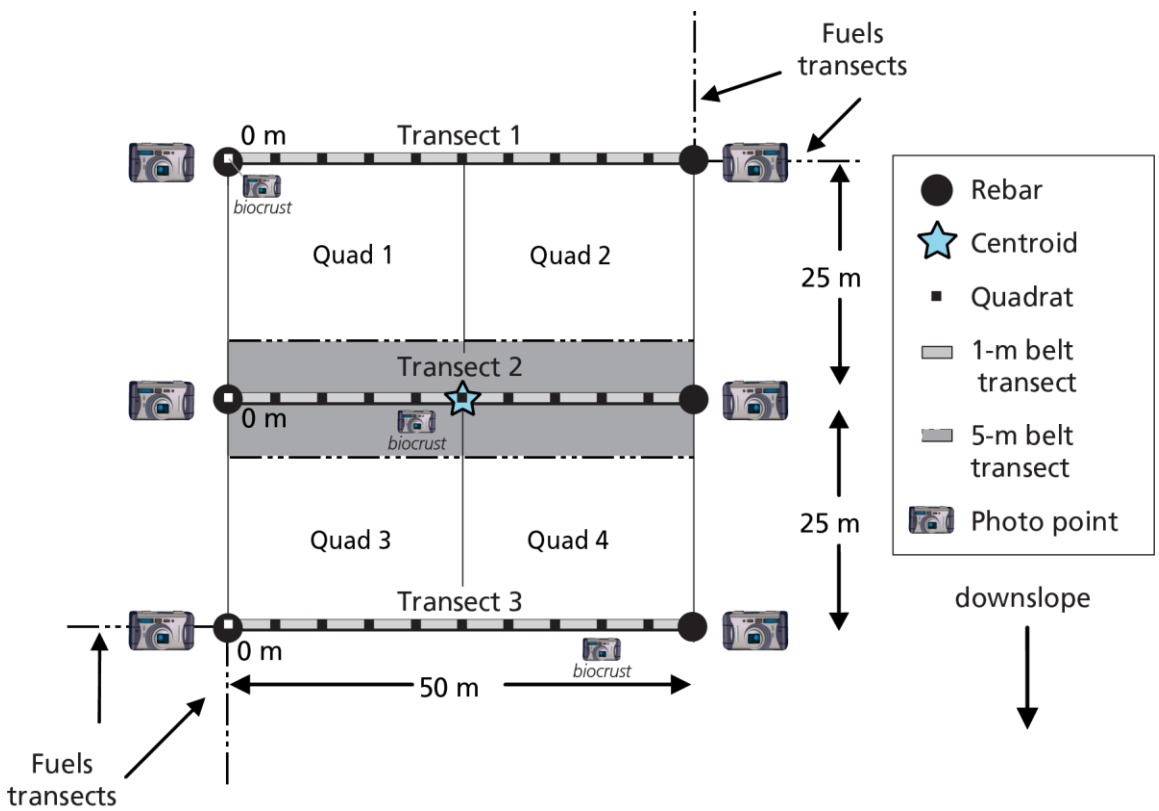


Figure 2. Locations of transects and monitoring measurements at woodland plots, including repeat photos, 1-m^2 quadrats for sampling frequency of exotics, one-meter belt transects for

measuring shrubs and seedlings, a five-meter belt transect for measuring saplings, Quad 1 for measuring overstory trees, and four fuels transects (not drawn to scale). Soil stability is also collected at six randomized locations along each transect.

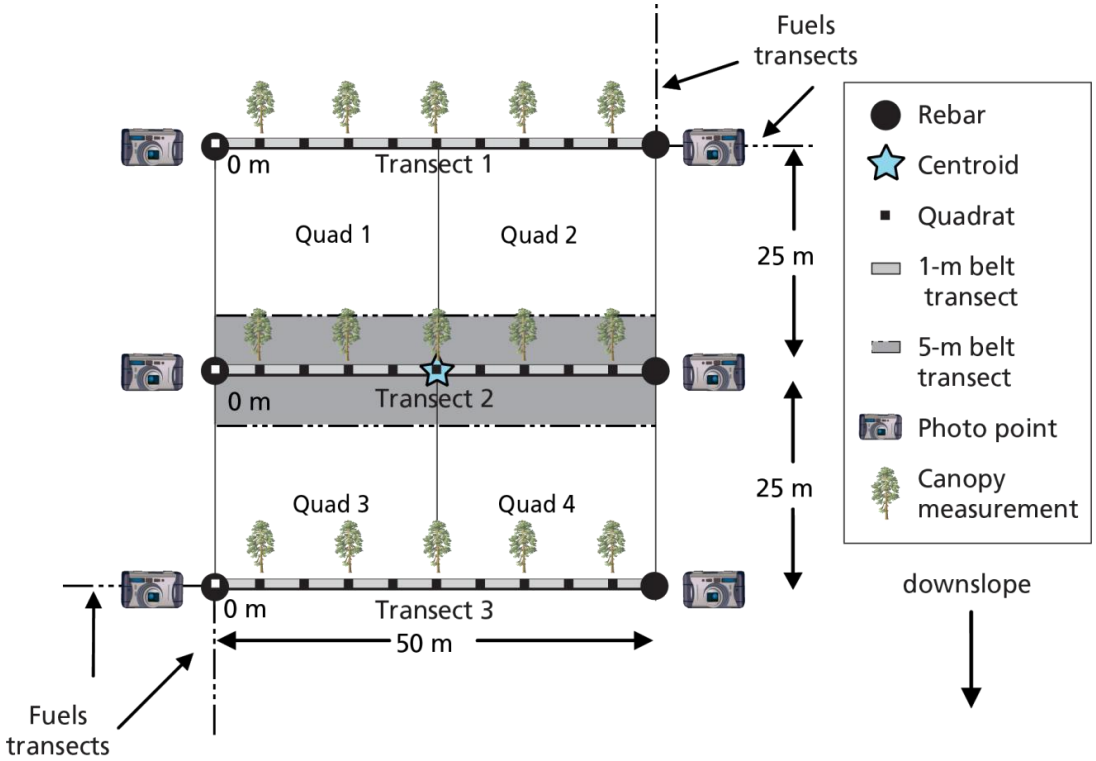


Figure 3. Locations of transects and monitoring measurements at forest plots, including 1-m^2 quadrats for sampling frequency of exotics, one-meter belt transects for measuring shrubs and seedlings, a five-meter belt transect for measuring saplings, Quad 1 for measuring overstory trees, canopy measurements, and four fuels transects (not drawn to scale).

B. The second crew member takes the end of the tape and walks toward the transect origin (left when facing upslope). Continue until the tape is at 25 m over the centroid pin flag.

- Walk downslope of the transect with the tape in your right hand to avoid trampling the sampling area.
- Have the crew member with the compass guide the person with the tape to ensure the correct transect azimuth.
- The line should be taut and as close to the ground as possible to avoid curvature in the line. Thread the tape through tall shrubs and trees to avoid curvature.
- In shrublands with many shrubs of similar height, the tape is strung overtop of the shrubs in order to keep the tape straight.

C. Drive a 3/8” diameter rebar stake into the ground at the origin of the transect, leaving less than 30 cm exposed. Record the distance along the transect where the rebar is placed (e.g., at the origin, the rebar is generally installed at 0 m).

- If bedrock exposure prevents sinking the rebar in at the origin or at the end, locate the closest possible point along the transect and drive the rebar stake in there. Note this location on the data sheet (e.g., 1 m).
- If a piece of rebar is easily visible from a road or trail, only leave about 10 cm of rebar above ground or sink it to ground level. Note this in the plot directions.
- Although transect ends should always be marked with rebar, orange flagging tape or plastic stakes may additionally be used to help relocate rebar in some plots with dense undergrowth. This requires prior permission from each park, and is not permitted in wilderness areas.

D. Stamp the plot information on a metal tag (Fig. 4). Tags should be prepared beforehand in the office or in camp.

Line 1: "NCPN" and the year
Line 2: PlotID number, transect number (i.e., 1 = upper, 2 = center or 3 = lower), and transect location (i.e., O = origin, E = end).

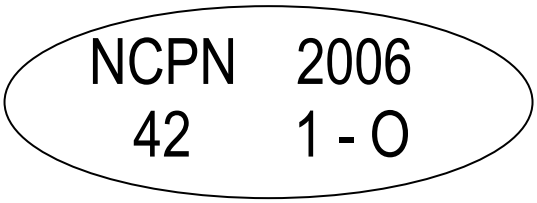


Figure 4. Format of information stamped on metal tags that are attached to rebar.

E. Attach the metal tag to the rebar by threading the tag with a piece of wire and wrapping the wire around the exposed rebar a couple inches below the top.

F. Use the GPS to record the location of the rebar marking the transect origin (see SOP #3).

G. Use a chaining pin to attach the transect tape so that the 0-m mark is lined up with the origin rebar. Secure the transect tape with additional chaining pins as necessary as you walk back towards the centroid.

H. From the centroid, walk with the tape reel along the appropriate azimuth to the 50 m mark, placing chaining pins as necessary to secure the tape. Follow the guidelines in 1.4 step B to avoid trampling the sampling area.

I. At the end of the transect, install rebar with a marked tag. Use a GPS unit to log a point for the rebar at the end of the transect.

J. Align the 50-m mark of the transect with the end rebar, and secure the end of the tape with a chaining pin. Wrap the transect tape around the chaining pin, and place the reel off to the side so that the sign board can lean against the rebar for photos.

K. Move all packs and loose gear to an area near the transect origin.

Establishing Monument Trees (optional)

In some forests and woodlands, plots may be difficult to relocate due to thick vegetation cover and poor satellite reception. In such areas, monument trees should be established for any rebar that might be difficult to relocate.

1) Up to three monument trees are established for each rebar (Fig. 5). Each monument tree should be located within 5 meters of the plot corner. Each tree should be a long-lived species that is healthy and free of major defects that could reduce longevity. If possible, select monument trees from a variety of species so that they will not all be susceptible to the same diseases or insects.
2) Fill in the appropriate data. Monument tree codes are the transect number and location, followed by a, b, or c (e.g. T1-Oa, T3-Ec, etc.).
3) Record the tree's species and diameter at breast height (DBH). See SOP #13 for details on how to measure tree diameter.
4) Determine the bearing from the monument tree to the rebar and the distance from the center point of the monument tree to the rebar, and record these on the data sheet. Be sure your compass is set to the correct declination for the park before recording this bearing.
5) Tag the tree using a pre-numbered round aluminum tree tag. Align the nail so that it enters the tree at breast height (1.37 m). Drive the nail into the tree at an angle, so that the tag hangs down and away from the tree. Leave several centimeters of nail exposed so the tree has ample space for growth.

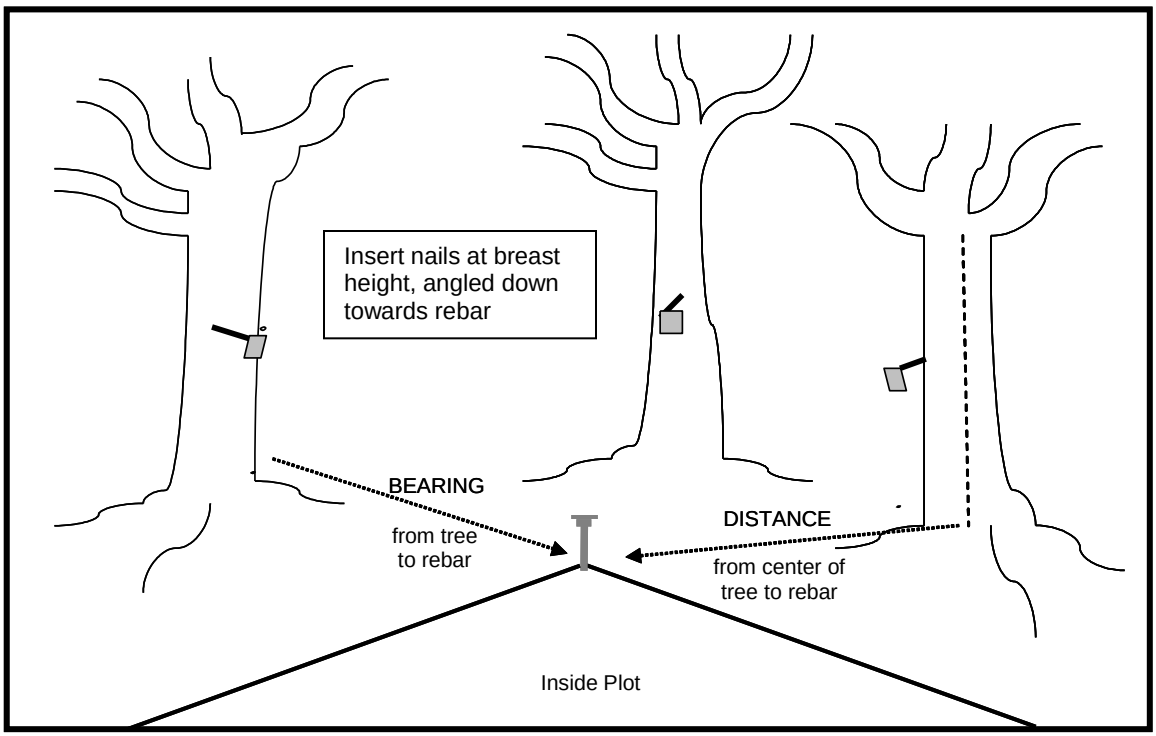


Figure 5. A plot corner with three monument trees (modified from USDI 2003).

1.5 Record general plot information.
While one person begins recording plot establishment data, the other person can take transect photos and log the location of rebar on the GPS if this still needs to be completed.

A. Record directions to the plot.

Write directions assuming that they will be used to relocate the plot by someone who has never been to the plot before. Begin with road travel from an obvious location such as the park visitor center, and describe where to park your vehicle and the details of the route, including any landmarks used in navigating. It may also be useful to photograph landmarks for plots with particularly difficult route-finding. Note specific obstacles or hazards to be avoided at and en route to the plot. Use specific language such as "southwest" and "downslope" rather than ambiguous terms such as "left" or "below."

B. Record locations of the rebar. This is especially important if the position differs from the 0-m or 50-m mark on the transect. UTM coordinates of each rebar location are also recorded on paper data sheets.

C. Record the slope and aspect for the plot and the transect azimuth.

D. Write tape stringing directions for each transect at woodland and forest plots. Include any information that would help someone set up the transects in the exact same locations on a revisit. Describe where the rebar is located, whether the tape should go upslope or downslope of woody vegetation along the transect, at what meter mark along the transect

this vegetation is located, and whether the tape goes under or over vegetation. Make sure to use specific language such as "upslope" and "downslope" and include six letter species codes of vegetation.

1.6 Photograph the transect (see SOP #7).

1.7 Collect all data along the transect (see SOPs #7-14).

1.8 Establish and collect data on the remaining transects.

A. Measure the distance to the upper and lower transect origins from the center transect origin. Have one crew member hold the tape end and compass while the other crew member takes the tape reel and walks either upslope to transect 1 origin or downhill to transect 3 origin in the direction of the plot aspect.

B. Walk until the tape is at 25 m.

C. Install the correct rebar at the new location. This point becomes the origin of Transect 1 if uphill of the center transect, or the origin of Transect 3 if downhill of the center transect.

D. Have one crew member stand over the rebar at the transect origin holding the 0-m end of the transect tape and a compass.

E. The second crew member takes the reel of the transect tape and walks toward the transect end with the reel in the left hand so that he or she is walking on the downslope side of the tape. Walk until the tape is at 50 m, and install the end rebar.

You may also set up all of the transects before collecting data. Immediately after setting up the center transect, have the person standing at the 25 m mark on the center transect shoot the plot aspect uphill or downhill (for transect 1 or 3) while the other crew member walks the tape out to 25 m and places a pin flag there. The 1st crew member then joins the 2nd one at the new pin flag and lays out that transect following the same procedures outlined for the center transect.

1.9 Record slope of plot sides (forest and woodland plots only).

In order to scale up canopy measurements, the slope of all plot sides is recorded in forests and woodlands.

A. Figure 6 illustrates the naming convention for slope sides and the direction of slope side measurements.

B. For sides A and C, stand at the origin of the transect and aim the clinometer at the point roughly eye level above the transect end.

C. For side B, stand at the origin of transect 1 and aim the clinometer at the point roughly eye level above the origin of transect 3.

D. For side D, stand at the end of transect 1 and aim the clinometer at the point roughly eye level above the end of transect 3.

E. Record the percent slope of each plot side. Record whether the slope is going uphill or downhill by circling "up" or "down" on the data sheet.

F. In densely vegetated plots, you may not be able to see the rebar at the other end. To help locate it, hang flagging from a tree branch over the rebar or have your partner stand over it.

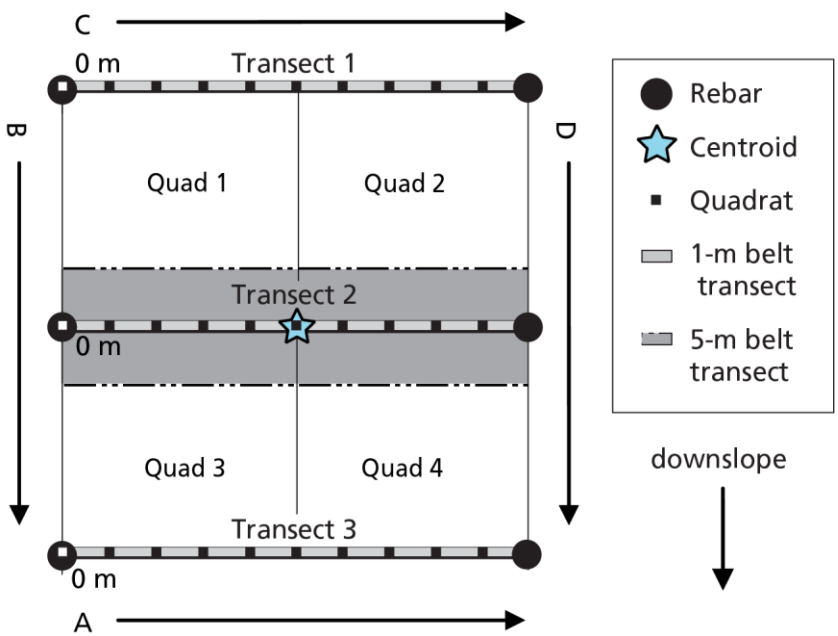


Figure 6. Naming convention (A, B, C, D) and direction of slope measurements for woodland and forest plots.

1.10 Check to make sure that all data fields have been completed.

If slope, aspect, azimuth, directions, rebar locations, or side slopes are missing, be sure to record this data. Check the map on your GPS to make sure that all 7 points were recorded and that the plot shape looks reasonable. Check all pages of monitoring data before leaving the plot to be sure all fields are filled out and all measurements were taken.

2. Revisiting an Existing Monitoring Plot

Make sure to read important notes on plot revisit data sheets before you leave for the field (i.e., missing GPS points, rebar and tags to replace, missing side slopes, etc.). Pack enough equipment to address these issues (i.e., extra tags, rebar, etc.).

2.1 Navigate to a plot corner using a GPS unit, a topographic map, and the UTM coordinates on the Plot Revisit data sheet.

- Be careful not to walk through the plot. It helps to display a map of the transect endpoints on the GPS or approach from the downhill side to avoid trampling the plot.

2.2 Set up the first transect.

A. Use a GPS, witness trees, and photos from the previous plot visit to find rebar marking the ends of the transect.

B. Check the code on the metal tag to confirm the location of the transect origin and end.

- If the monuments of the transect ends have been altered or removed due to disturbances and can not simply be replaced at the same locations, they should be relocated.

a. After determining a suitable location along the transect for a rebar monument, use the GPS to record the new UTM coordinates.

b. If you are using paper data sheets, cross off the old coordinates and rebar location on the Plot Revisit form, and record the new information below. In the field laptop, these and any other changes to plot establishment data are made in "Change Plot Coordinates".

C. Use a chaining pin to attach the transect tape so that the 0-m mark is lined up with the origin rebar.

D. Walk towards the other end of the transect while pulling out the tape.

- Walk downslope of the transect to avoid trampling the sampling area.

E. Align the 50-m mark of the transect with the end rebar, and secure the end of the tape with a chaining pin. Wrap the transect tape around the chaining pin, and place the reel off to the side so that the sign board can lean against the rebar for photos.

F. Adjust the alignment of the tape so that it does not bend around vegetation. Use additional chaining pins to secure the tape in place where necessary. This is important for repeatability, especially during windy visits.

2.3 Photograph the transect and collect all data (SOPs #7-14).

2.4 Set up and collect data at the other transects.

2.5 Check to make sure that all data fields have been completed.

If slope, aspect, azimuth, directions, rebar locations, side slopes, or GPS points are missing, be sure to record this data. Check all pages of monitoring data before leaving the plot to be sure all fields are filled out and all measurements were taken.

References

USDI National Park Service. 2003. Fire Monitoring Handbook. Boise (ID): Fire Management Program Center, National Interagency Fire Center, 274p.

Plot Establishment

Data entered by: Data verified by:

NCPN Upland Monitoring

Park Code: _____ Plot ID: _____ Date: _____

Observers: _____

Centroid UTMs: Zone _____ _____ E _____ N

Ave. Slope (%) _____ Aspect (°) _____ Centroid Transect Azimuth (°) _____

Plot side	Slope (%)
A	_____ up down
B	_____ up down
C	_____ up down
D	_____ up down

Transect Location

Transect	Rebar at origin		Location (m)	Rebar at end		Location (m)
	UTM Easting	UTM Northing		UTM Easting	UTM Northing	
1 (upper) - upslope						
2 (center)						
3 (lower) - downslope						

Monument Trees

Monument (e.g., T1 – Oa, T3 – Ea,…)	Tag #	Species	DBH (cm)	Bearing (°)	Distance to rebar (m)

Directions to plot:

Visit comments:

** Most information in this data sheet is pre-filled by the upland database.*

Plot Revisit

Data entered by: Data verified by:

NCPN Upland Monitoring

Park Code: _____ Plot ID: _____ Date: _____

Observers: _____

Centroid UTMs: Zone _____ _____ E _____ N

Ave. Slope (%) _____ Aspect (°) _____ Centroid Transect Azimuth (°) _____

Plot side	Slope (%)
A	_____ up down
B	_____ up down
C	_____ up down
D	_____ up down

Transect Location

Transect	Rebar at origin		Location (m)	Rebar at end		Location (m)
	UTM Easting	UTM Northing		UTM Easting	UTM Northing	
1 (upper) - upslope						
2 (center)						
3 (lower) - downslope						

Monument Trees

Monument (e.g., T1 – Oa, T3 – Ea,…)	Tag #	Species	DBH (cm)	Bearing (°)	Distance to rebar (m)

Directions to plot:

Visit comments:

Upland Vegetation and Soils Monitoring Protocol for Park Units in the Northern Colorado Plateau Network

Standard Operating Procedure (SOP) # 7

Repeat Photos

Version 1.33 (February 2013)

Revision History Log:

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #
1.00	3/1/2007	S. Garman	Added additional photo points	To provide a more comprehensive photo record of plot conditions	1.10
1.10	2/5/2008	D. Witwicki	1) Clarified orientation of camera in transect photos 2) Added specific instructions for avoiding body parts in photos.	1) Not specified in previous version 2) Field crew in transect photos from previous years	1.20
1.20	4/2008	R. Weissinger	Formatting only	To improve useability	1.20
1.20	7/2008	R. Weissinger	Added woodland procedures	New ecosites	1.30
1.30	3/2009	D. Witwicki	Clarify photos taken for each vegetation type; photo labeling; other photo instructions	Made consistent with database	1.31
1.31	4/2011	D. Witwicki, S. Topp	Clarify instructions	Made consistent with database	1.32
1.32	2/2013	D. Witwicki	Clarify instructions for crust photos	Found photo taken incorrectly	1.33

This SOP provides instructions for taking digital photos of each upland monitoring plot. For grassland/shrubland plots, one photo of each transect and one photo of biological soil crust (BSC) along each transect are required. For forest and oak plots, two photos of each transect are required- one from each end. For woodland sites, all three types of photos are required for each transect. A list of necessary equipment for this procedure can be found in SOP #1.

1. Transect Origin Photos – All Plots

Take photos of the origin end of each transect while the meter tape is stretched out along the transect.

A. Label the sign board with the information below and lean it next to the rebar marking the origin of a transect.

Site – Park code and Plot ID number (e.g., CANY 143)
Date – mm/dd/yyyy, e.g., 08/22/2010
Transect photo ID - T1-O, T2-O, or T3-O

- If you are having difficulty propping up the sign board, use additional objects behind or

underneath it rather than including field crew members or their body parts in the photos. If vegetation or other natural features are blocking the rebar, position the signboard either along the transect or in front of or on top of the obstruction.

B. Stand 3 meters back from the end of a transect, set the camera body on top of a folding engineer ruler extended to 1.5-m in height, and point the camera down the transect.

C. Orient the camera so that it is rotated 90˚ to take a vertical (portrait) format photo.

D. Aim the camera to ensure that the sign board is visible at the bottom right of the field of view and the 50-m tape is visible on the right side.

E. Take a photo. Check the quality of the photo by setting the camera to "play" mode to view the photo. If the photo is blurry or otherwise not acceptable, delete it and take another one.

F. Record the digital file name, photographer, and location along the transect (i.e., -3 m). If you cannot see the transect tape due to an obstruction, take a second photo at some other distance along the transect where you can see more of it. Be sure to record information for this photo, especially the location along the transect.

Recording the Digital File Name

a. While the camera is in "play" mode, you will be able to view the number assigned to the photo. *Do not record this number.* This number changes when the photos are downloaded from the camera. Instead, use the following instructions to record the digital file name in the database or on a paper data sheet.
b. The last 4 digits of the number displayed on the camera (those following the dash) represent a unique photo number.
c. The template for the number you will record is P*mdd9999*, where P=photos, *m* = month (Jan – Sept are coded 1-9, Oct = A, Nov = B, Dec = C); *dd* = day (01-31); and *9999* = the unique number of the photo. For example, photo 0300 taken on October 1 would be recorded as PA010300.

2. Transect End Photos – Forest, Woodland, and Oak Plots

In vegetation types where one photo may not be sufficient to show the characteristics of a transect, an additional photo is taken at the end of each transect. Transect end photos are required for forest, woodland, and oak plots, and may be taken at grassland or shrubland plots when necessary.

A. Label the board with an "E" at the end of the transect number (e.g., T3 – E).

B. Follow the instructions above, standing at 53 m along the transect. For this photo, position the sign board on the bottom left hand corner of the frame with the transect tape visible along the left side. This ensures that the sampled area is in the photo.

3. Biological Soil Crust Photos – Grassland, Shrubland, and Woodland Plots

BSC photos are taken at 0 m on transect 1, 20 m on transect 2, and 40 m on transect 3.

A. Open a folding ruler to 1 m and align it perpendicular to the tape at the correct meter mark (0, 20, or 40) on the uphill side of the tape. The area included in the photo is a 1-m by 1-m square to the right of the folding ruler.

B. Stand on the downhill side of the tape centered on the area that will be included in the photo (e.g., stand at 0.5 m for the BSC photo on transect 1). Orient the camera to take a horizontal (i.e., landscape) format photo and looking directly down at the soil surface. Align the photo so that the transect tape just shows on the bottom of the frame, the folding ruler just shows on the left side of the frame, and an area approximately 1 m by 1 m fills the screen.

C. Take a photo and record the digital file name, photographer, and location along the transect. Take a crust photo even if biological soil crust is not present or vegetation is blocking the view of the soil.

4. Other Photos

Record any additional photos on the bottom of the photo data sheet. Include the digital file name, date, photographer, and a description of the photo content (i.e. scenery, field crew working, artifact, rare plant, etc.).

Photos

Data entered by: Data verified by:

NCPN Upland Monitoring

Park Code: **Plot ID:** **Date:**

Transect Photos (portrait)

Location	Digital file name	Photographer	Location along transect (meters)	Comments
T1 - origin			Default = -3 m	
T2 - origin			Default = -3 m	
T3 - origin			Default = -3 m	
T1 - end			Default = 53 m	
T2 - end			Default = 53 m	
T3 - end			Default = 53 m	

Biological Soil Crust Photos (landscape)

Location	Digital file name	Photographer	Location along transect (meters)	Comments
T1 - 0 m			Default = 0 m	
T2 - 20 m			Default = 20 m	
T3 - 40 m			Default = 40 m	

Other photos (plants, disturbance, etc.)

Photo type	Digital file name	Photographer	Description

Type = archeology, disturbance, fauna, fieldwork, flora, scenic, other

Upland Vegetation and Soils Monitoring Protocol for Park Units in the Northern Colorado Plateau Network

Standard Operating Procedure (SOP) # 8

Measuring Vegetation and Surface Cover

Version 1.07 (November 2017)

Revision History Log:

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #
1.00	7/2009	D. Witwicki	Updated rules for recording live/dead species and litter/woody debris; added instructions for recording tall PJ or other species hits; formatting	To make it consistent with live/dead cover recorded in quadrats; improved PJ cover methods.	1.01
1.01	4/2011	D. Witwicki	Edited method for tall shrub hits	Upward laser too difficult to see	1.02
1.02	11/2013	D. Witwicki	Correction to code on data sheet and in Table 2	Incorrect	1.03
1.03	5/2014	D. Witwicki	Clarified how to sample with laser and densitometer	Needed additional clarification	1.04
1.04	3/2015	D. Witwicki	Clarified definition of litter and woody debris	Unclear which to call at 2.5 cm	1.05
1.05	4/2016	D. Witwicki	Added that multiple hits can occur with the densitometer	unclear	1.06
1.06	11/2017	A. Wondrak-Biel	Updated Figure 1	For publication	1.07

This SOP details methods for estimating cover of vegetation and soil surface features using point-intercept sampling. All vegetation types are sampled using this method. A list of necessary equipment for this procedure can be found in SOP #1. SOP #15 details modifications to the method for oak plots.

Point-Intercept Cover

Point intercept is used to sample vegetation on three 50-m transects at 0.5 m intervals.

1. **Fill out the information at the top of the Point Intercept data sheet.**
   If you are recording data directly into the database, make sure you are on the page of the correct transect.

2. **Record point-intercept data for understory, tall shrub, and woodland species.**

   In grassland/shrubland, woodland, and oak plots, record plant species encountered at any height.

   In forest plots, record all plant species encountered, except those in the overstory canopy.

   - The sampled height includes all understory species, tall shrubs, pinyon pine, Utah juniper, and Gambel oak at any height.
   - Trees with cover below 2 m are also included in point-intercept sampling.

- Trees with cover above 2 m are considered overstory canopy, and are not sampled by point intercept.

A. Stand on the downhill side of the transect and work from the origin to the end.

B. Start at 0.5 m on the tape and move forward 0.5 m for each consecutive point. You will sample 100 points on each transect ending at 50.0 m.

C. If there is a canopy layer taller than 1.5 m above the ground surface (i.e., above the height of laser on the fully extended monopod), use a densitometer to record the top canopy layer at the correct point on the tape.

   a) Position a fully extended monopod (1.5 m tall) on the downhill side of the tape at the correct point. Extend the laser out perpendicular to the tape so that you are sampling on the uphill side.
   b) Use the bubble on the monopod to level the laser.
   c) Position the densitometer on the monopod just above the laser.
   d) Use the bubbles inside the densitometer to level it in both directions.
   e) With both the monopod and the densitometer leveled, determine what species of vegetation, if any, is located at the crosshairs of the densitometer.
   f) Record the species as top canopy (see section F below).
   g) If multiple species are hit, or live and dead parts of plants are hit, record the upper-most intersection as top canopy and any lower hits as lower canopy (see section F below).

D. Sample vegetation less than 1.5 m tall and the ground surface.

   a) Position the monopod on the downhill side of the tape at the correct point. Extend the laser out perpendicular to the tape so that you are sampling on the uphill side.
   b) Use the bubble on the monopod to level the laser. With the laser leveled, push the button to sample the point. **Be careful not to point the laser at anyone's eyes. It can cause serious damage.**

E. Once you have recorded a point, move the uppermost vegetation away so that you can take subsequent hits for lower canopy and surface layers. If it is difficult to keep the monopod level and record hits, have one person hold the monopod level while a second person reads and records hits. On a windy day, it is important to turn the laser on for just a second to record a hit.

F. With the laser leveled, record every plant species it intercepts. Record each canopy species no more than twice, a maximum of one live hit and one dead hit, even if it is intercepted several times. Record the following information for each point:

   I. Top Canopy - Record the species of the top plant intercepted in the "Top canopy" column using a six-letter code composed of the first three letters of the genus and specific epithet (Table 1 & Fig. 1). If a plant is not intercepted, leave this column blank. If the part of the plant intercepted by the laser is dead, write "-D" after the species code on your paper data sheet, or select "N" in the "Alive?" column in the database. Unknown plant species should be recorded according to the procedure in SOP #16.

Table 1. Sample data sheet for examples illustrated below in Figure 1. Points 0.5 and 1 show the first two points on a transect. In Point 0.5, the laser is touching dead fescue (*Festuca octoflora*), bluegrass (*Poa secunda*), clover (*Trifolium gymnocarpon*), live fescue, and a small rock at the surface. Record fescue twice, once as dead and once as live. In Point 1, the laser touches dead fescue then the dead fescue plant base. The table below shows how to record these two points on the data sheet. Notice that all plants are recorded using six-character abbreviations.

Point	Top canopy	Lower canopy			Soil surface	Disturbance
		1	2	3		
0.5	FESOCT - D	POASEC	TRIGYM	FESOCT	SR	
1	FESOCT - D				FESOCT-D	
1.5	ATRCAN	FESOCT			S	Ant
etc.						

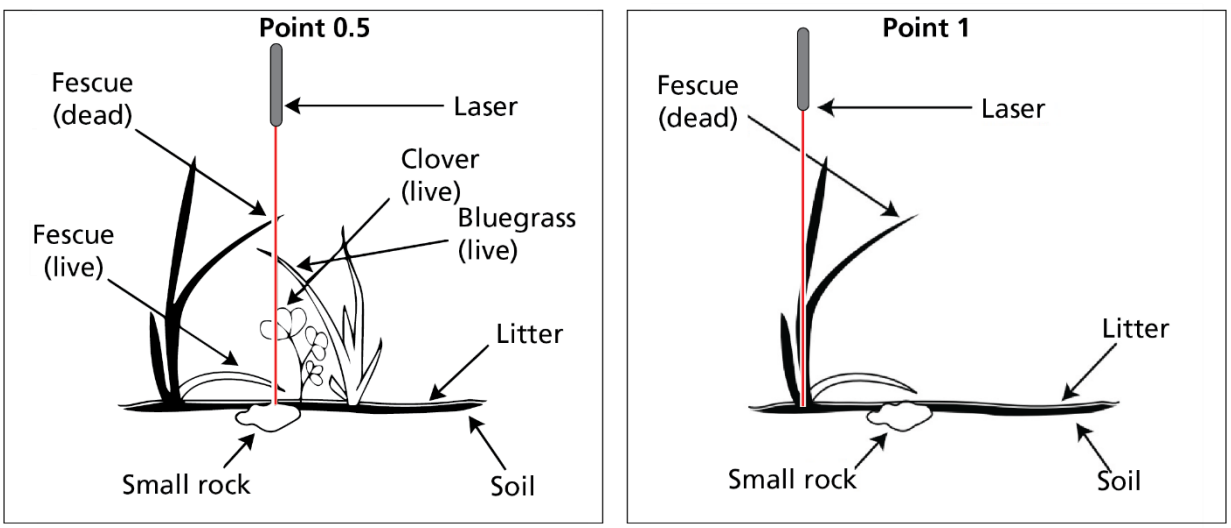


Figure 1. Points along a transect associated with the example in Table 1 (adapted from Herrick et al. 2005).

II. **Lower Canopy Layers**- From the top canopy species, move down the laser and record species intercepted in the order that they occur. Use the "Lower canopy" columns (Table 1 & Fig. 1) to record all additional species intercepted by the laser. Record the plant as dead following the guidelines above. You may also intercept litter or woody debris, but it must be elevated above the soil surface to be considered a lower canopy layer (Table 2). Use the diameter where laser hits to distinguish between litter and woody debris, even if it's connected to something of a different size. If you hit more lower canopy layers than the number of columns available, be sure to record them in the additional lower canopy layers section of the data sheet or database. If you do not encounter lower canopy layers leave these columns blank.

III. **Soil Surface** - In the "Soil surface" column record whether the laser intercepts a plant base (Fig. 2) or a soil surface feature (Table 3). Use the appropriate six-letter code to identify plant bases. Follow the guidelines above to record dead plant bases. Use the abbreviations of soil surface features defined in Table 3 to record all other soil surface features. All points must have a code entered in the "Soil surface" column (Table 1 & Fig. 1). Use Figure 3 to help distinguish between undifferentiated crust and dark cyanobacteria.

IV. **Disturbance** - Record whether the laser intercepts a disturbance on the soil surface in the "Disturbance" column (Table 1 & Fig. 1). Use only abbreviations from Table 4 to label the type of disturbance. Leave this column blank if there is no disturbance.

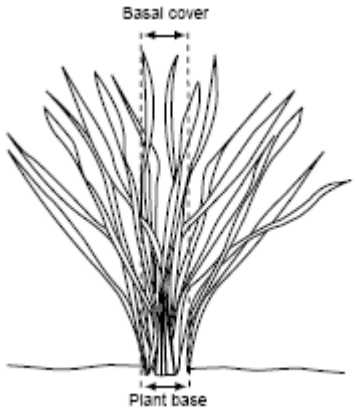


Figure 2. Area defined as plant base and included as basal cover (from Herrick et al. 2005).

Table 2 Abbreviations and definitions of litter and woody debris as lower canopy layer classes for point-intercept sampling.

Code	Lower canopy cover type	Definition
L	Litter	Detached dead plant material less than 2.5 cm in diameter elevated above the soil surface
WD	Woody debris	Detached woody plant material 2.5 cm or greater in diameter elevated above the soil surface

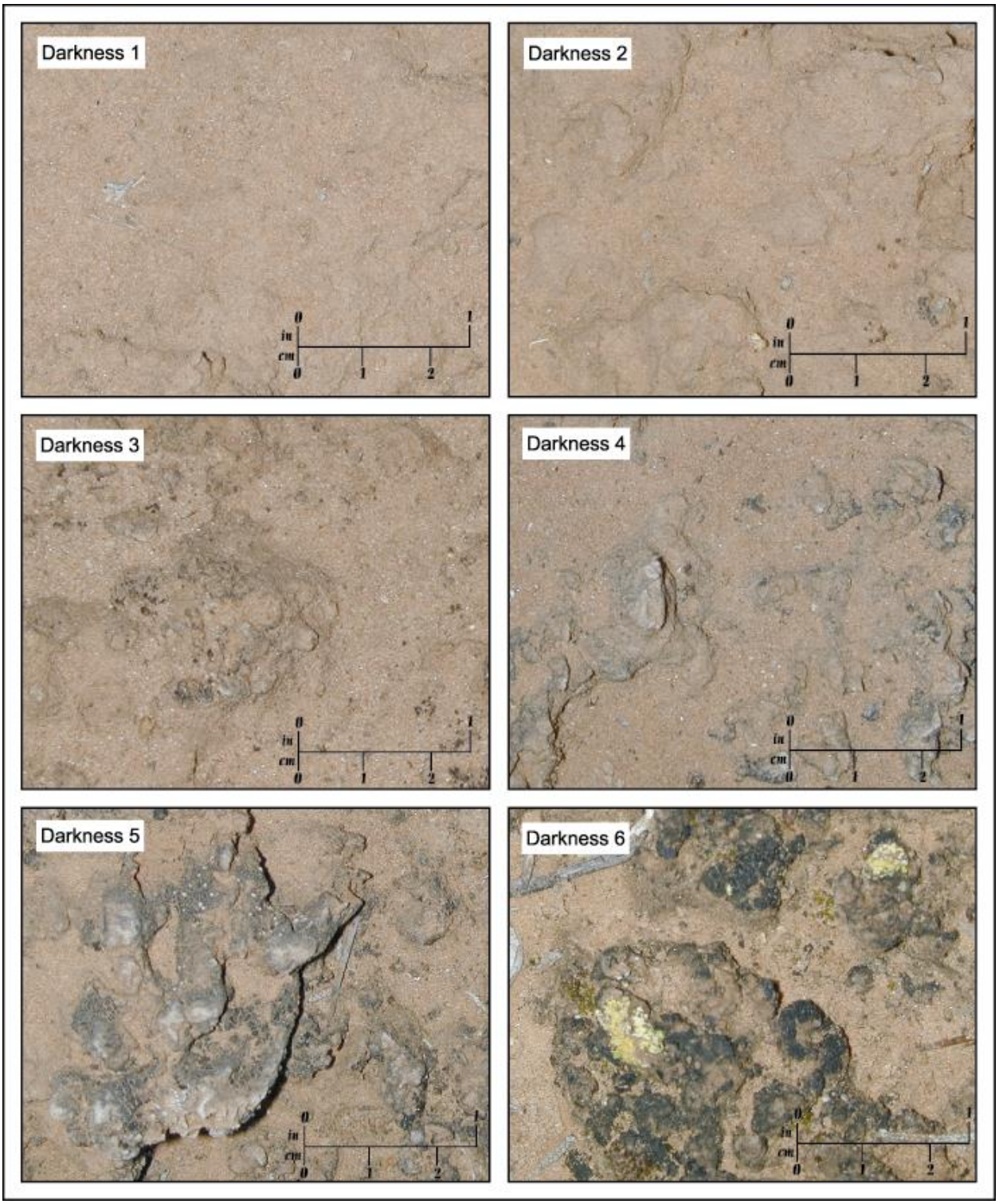


Figure 3. Photographic key to a six-class scheme for describing degrees of biological soil crust development (from Belnap et al. 2008). Darkness 1-3 show mainly undifferentiated crust while Darkness 4-6 contain substantial areas of dark cyanobacteria. Darkness 6 also includes lichens and moss.

Table 3 Abbreviations and definitions of soil surface feature classes for point-intercept sampling.

Code	Soil surface type	Definition
S	Bare soil	Loose soil particles (0-2 mm diameter) not protected from wind erosion by any type of crust or any other soil surface feature
U	Crust, undifferentiated	Anything from physical crust to weak biological crust (weak cyanobacteria) but NOT including dark cyanobacteria, lichen, or moss (Fig 3. #1-3)
CY	Cyanobacteria	Darkened cyanobacterial soil crust, typically black in color (Fig. 3. #4-6)
LC	Lichen	Lichen crust on soil (lichen on rock is recorded as the appropriate rock type)
M	Moss	Moss on soil (moss on rock is recorded as the appropriate rock type)
L	Litter	Detached dead plant material less than 2.5 cm in diameter
WA	Water	Flowing or pooled water
WD	Woody debris	Detached woody plant material 2.5 cm or greater in diameter
SR	Small rock	Rock fragments 2 mm-10 cm in diameter
LR	Large rock	Rock fragments >10 cm in diameter on any axis
BR	Bedrock	Exposed bedrock
SL	Scat, livestock	Any type of livestock scat
SW	Scat, wildlife	Any type of wildlife scat

Table 4. Abbreviations and definitions of soil-surface disturbance classes for point-intercept sampling.

Code	Disturbance type	Definition
Ant	Ant mound	Holes and mounds created by ants
Auto	Motor vehicle	Disturbances caused by any motorized vehicle or old roads
Bike	Bicycle	Disturbances caused by non-motorized bicycles
Exc	Wildlife excavation	Holes and mounds created by wildlife
HT	Human track/trail	Tracks or trails created by humans
LT	Livestock track/trail	Tracks, marks, or trails created by livestock
Oth	Other anthropogenic	Any human disturbance other than tracks and trails
Und	Undifferentiated	Any disturbance of indeterminate origin or not classified as one of the other categories
Wash	Drainage area	Small to large eroded areas caused by temporarily flowing water
WT	Wildlife track	Tracks, marks, or trails created by wildlife

References

Belnap, J., S. L. Phillips, D. L. Witwicki, and M. E. Miller. 2008. Visually assessing the level of development and soil surface stability of cyanobacterially dominated biological soil crusts. Journal of Arid Environments 72: 1257-1264.

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. Volume I: Quick start*. USDA-ARS Jornada Experimental Range, Las Cruces, NM. 36 pp.

Point Intercept

Data entered by: Data verified by: p.1

NCPN Upland Monitoring

Park Code: **PlotID:** **Date:**

Observer: **Recorder:** **Transect:** 1 2 3

Point (m)	Top Canopy	Lower canopy 1	Lower canopy 2	Soil Surface	Disturb-ance	Point (m)	Top Canopy	Lower canopy 1	Lower canopy 2	Soil Surface	Disturb-ance
0.5						13					
1						13.5					
1.5						14					
2						14.5					
2.5						15					
3						15.5					
3.5						16					
4						16.5					
4.5						17					
5						17.5					
5.5						18					
6						18.5					
6.5						19					
7						19.5					
7.5						20					
8						20.5					
8.5						21					
9						21.5					
9.5						22					
10						22.5					
10.5						23					
11						23.5					
11.5						24					
12						24.5					
12.5						25					

Additional canopy layers can be added on the other side

Top canopy
Species code

Lower canopy layers
Species code
L = Litter
WD = Woody debris

Use "-D" for dead parts of species

Soil Surface

S = Bare soil	SR = Small rock
U = Crust, undiff.	LR = Large rock
CY = Cyanobacteria	BR = Bedrock
LC = Lichen	SL = Scat, livestock
M = Moss	SW = Scat, wildlife
L = Litter	WA = water

WD = Woody debris
Species code (for basal hit)

Disturbance

Ant =	Ant mound
Auto =	Motor vehicle
Bike =	Bicycle
Exc =	Wildlife excavation
HT =	Human track/trail
LT =	Livestock track/trail
WT =	Wildlife track
Wash =	Wash
Oth =	Other anthropogenic
Und. =	Undifferentiated

p.2

Point (m)	Top Canopy	Lower canopy		Soil Surface	Disturb-ance
		1	2		
25.5					
26					
26.5					
27					
27.5					
28					
28.5					
29					
29.5					
30					
30.5					
31					
31.5					
32					
32.5					
33					
33.5					
34					
34.5					
35					
35.5					
36					
36.5					
37					
37.5					

Point (m)	Top Canopy	Lower canopy		Soil Surface	Disturb-ance
		1	2		
38					
38.5					
39					
39.5					
40					
40.5					
41					
41.5					
42					
42.5					
43					
43.5					
44					
44.5					
45					
45.5					
46					
46.5					
47					
47.5					
48					
48.5					
49					
49.5					
50					

Additional canopy layers

Point (m)	Lower Canopy		
	3	4	5

Point (m)	Lower Canopy		
	3	4	5

Upland Vegetation and Soils Monitoring Protocol for Park Units in the Northern Colorado Plateau Network

Standard Operating Procedure (SOP) # 9

Measuring Canopy and Basal Gaps

Version 1.13 (April 2013)

Revision History Log:

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #
1.00	3/1/2007	S. Garman	Enhanced instructions for integrating this SOP with SOP#8	To ensure that procedures are conducted in concert with other SOPs	1.10
1.10	4/2008	R. Weissinger	Formatting only	To improve useability	1.10
1.10	3/2009	D. Witwicki	Clarify shrubs for canopy gaps; formatting	Consistency	1.11
1.11	4/2011	D. Witwicki, S. Topp	Modify canopy gap methods to same method as basal gaps	Vegetation cover not used & more time consuming in dense shrublands	1.12
1.12	4/2013	D. Witwicki	Explicitly state to record canopy gaps before basal gaps	Measuring basal gaps can compress some plant canopies	1.13

This SOP provides instructions for measuring gaps between plant canopies and between plant bases of perennial species. This SOP is implemented in grassland and shrubland vegetation types. Record canopy gaps before basal gaps because some plant canopies may become temporarily compressed while determining basal gaps. A list of necessary equipment for this procedure can be found in SOP #1.

1. Canopy gaps

Stand on the downhill side of the transect at the 0-m end and work from left to right towards the 50-m end. Look straight down on the tape and use a meter stick or other stiff stick to project a line vertically to the ground on the uphill side of the tape. Record the start and end of each canopy gap to the nearest centimeter.

***Follow these rules*:**

- A canopy gap occurs any time there is at least 20 cm of gap between plant canopies of perennial species. Therefore, canopy gaps are always at least 20 cm long (Figs. 1 & 2, Tables 1 & 2).
- Canopy occurs any time 50% of any 3-cm segment of tape edge intercepts live or dead perennial plant canopy based on a vertical projection from canopy to ground (Fig. 3).
- If a space <20 cm occurs on either end of the transect, do not count this as a gap.

2. Basal gaps

Immediately after you finish recording canopy gaps, begin sampling basal gaps from the 50-m end of the tape working back towards the 0-m end of the tape. Remain on the downhill side of the transect, and use the same technique as for canopy gaps to project vertically down to the ground. Record the start and end of each gap to the nearest centimeter (Figs. 1 & 2, Tables 1 & 2). Notice that the start of the gap is a higher number than the end because you are working backwards along the transect.

Follow these rules:

- A plant base is any perennial plant stem emerging from the soil surface along the uphill edge of the tape that would force an ant walking along the line on the soil to step off the line to get around it (minimum diameter = 1 mm).
- A basal gap occurs any time there is at least 20 cm of intercept without a plant base. Therefore, there should always be at least 20 cm between basal gap starts and basal gap ends.
- A plant base can stop a gap whether live or dead.
- Plant bases must be anchored in the ground. Litter is not a plant base.
- If a space <20 cm occurs on either end of the transect, do not count this as a gap.

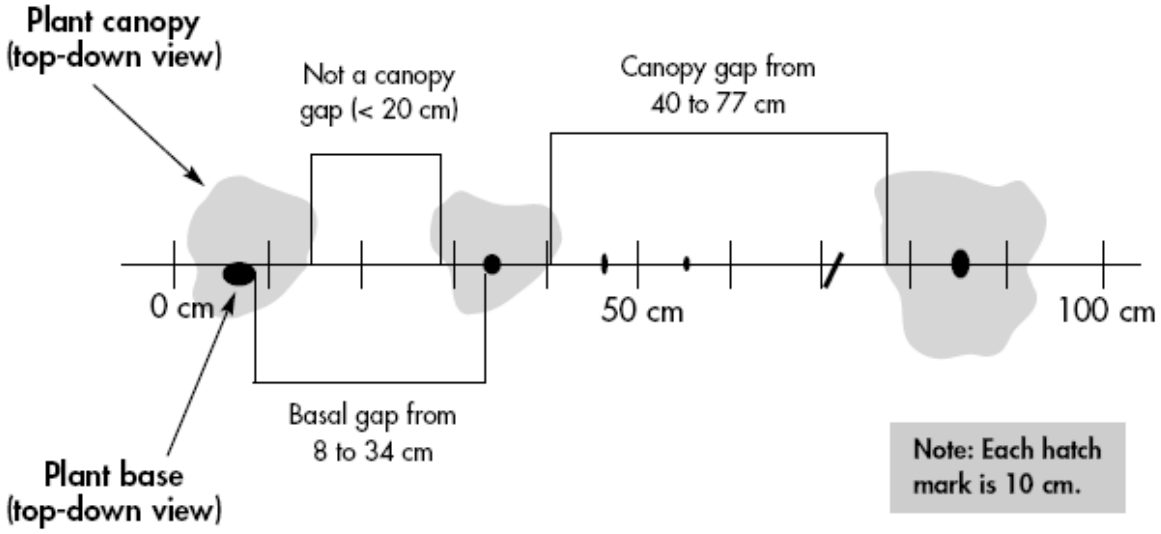


Figure 1. Example of canopy gap intercepts (above the line) and basal gap intercepts (below the line) for 100 cm of a 50-m transect.

Canopy gaps: There is a gap between 40 and 77 cm because the plant canopies present do not cover more than 50% of any 3-cm segment.

Basal gaps: There is a basal gap between 8 and 34 cm. Because the three small plant bases between 34 cm and 86 cm are all within 20 cm of an adjacent plant base, there are no basal gaps even though there is a canopy gap. (from Herrick et al. 2005)

Table 1. Gap intercept data sheet example associated with Figure 1.

Canopy Gaps

Start *(cm)*	End *(cm)*	Start *(cm)*	End *(cm)*
40	77		

Basal Gaps

Start *(cm)*	End *(cm)*	Start *(cm)*	End *(cm)*
34	8		

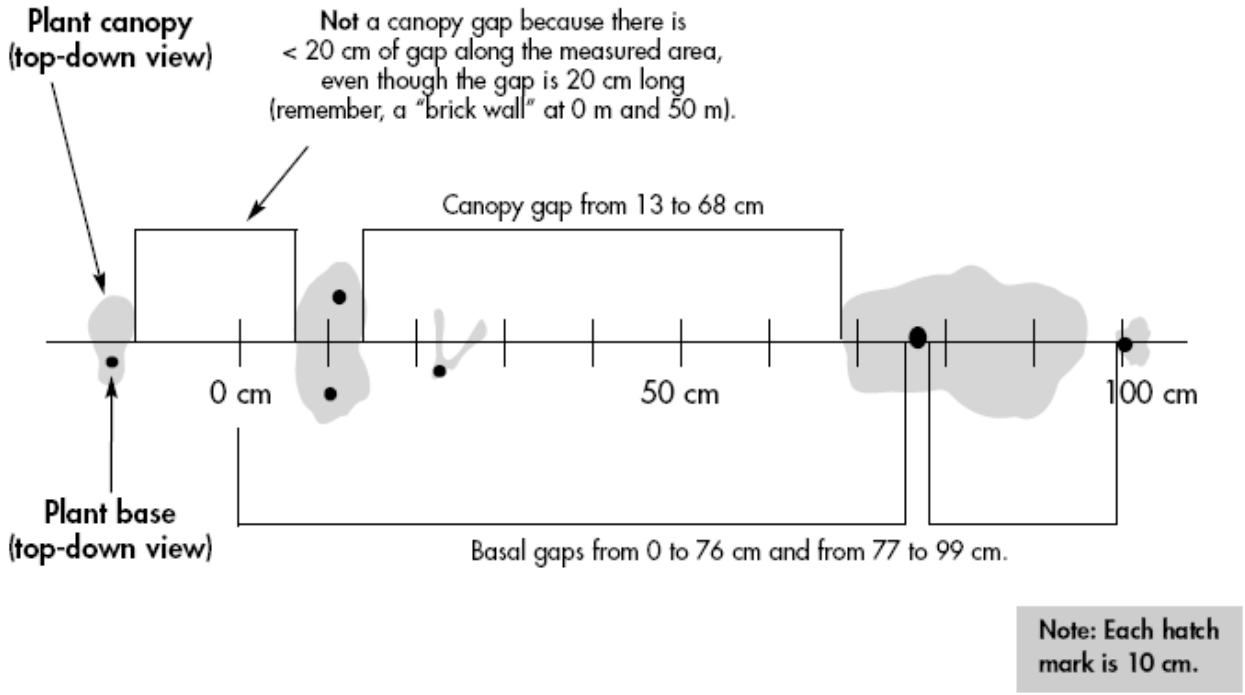


Figure 2. Example of canopy gap intercepts (above the line) and basal gap intercepts (below the line) for 100 cm of a 50-m transect.

Canopy gaps: Look at the plant canopy intercept between the 20 and 30 cm marks on the transect. Because each canopy intercept covers less than 50 percent of a 3-cm segment of the line, it does not count as canopy. (from Herrick et al. 2005)

Table 2. Gap intercept data sheet example associated with Figure 2.

Canopy Gaps

Start *(cm)*	End *(cm)*
13	68

Start *(cm)*	End *(cm)*

Basal Gaps

Start *(cm)*	End *(cm)*
99	77
76	0

Start *(cm)*	End *(cm)*

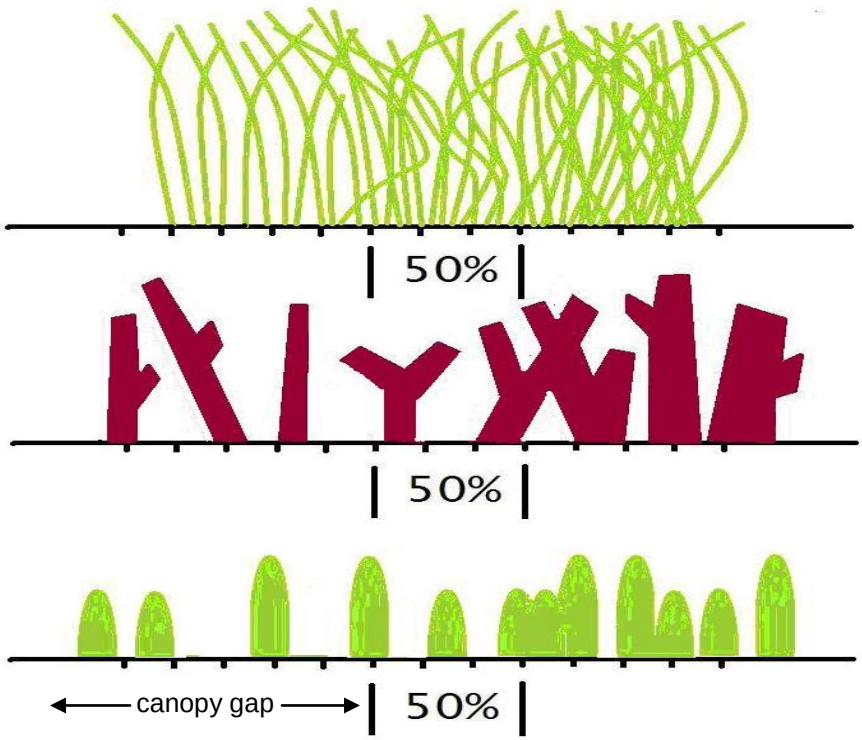


Figure 3. Example of 50% canopy cover over a 3-cm segment of the transect (not to scale).

References

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. Volume I: Quick start. USDA-ARS Jornada Experimental Range, Las Cruces, NM. 36 pp.

p.1

Canopy and Basal Gaps

Data entered by: Data verified by:

NCPN Upland Monitoring

Park Code: _____ **PlotID:** _____ **Date:** _____

Observer: _____ **Recorder:** _____ **Transect:** 1 2 3

Canopy Gaps

Start	Stop	Start	Stop	Start	Stop	Start	Stop	Start	Stop

p.2

Entered by: Date:

Verified by: Date:

Basal Gaps

Start	Stop	Start	Stop	Start	Stop	Start	Stop	Start	Stop

Upland Vegetation and Soils Monitoring Protocol for Park Units in the Northern Colorado Plateau Network

Standard Operating Procedure (SOP) # 10

Measuring Shrub and Tree Seedling Density, Exotic Frequency, Species Richness, and Canopy Closure

Version 1.20 (November 2017)

Revision History Log:

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #
1.00	07/2008	R. Weissinger	Added procedures for tree seedlings and saplings	New ecosite types	1.10
1.10	3/2009	D. Witwicki	Added introductory paragraph; edited instructions to record only live individuals; instructions for exotic perennials; increased box size on data sheet.	Clarified procedures.	1.11
1.11	7/2009	D. Witwicki	Added species richness	For subalpine plots	1.12
1.12	3/2010	D. Witwicki	Reworded spherical densiometer instructions and added details for trunk and branch obstructions.	Clarified procedures	1.13
1.13	5/2011	D. Witwicki	Deleted exotic perennial density and added exotic frequency; updated format	Improve exotic species data; more rare species data	1.14
1.14	1/2012	D. Witwicki	Updated species richness methods	Reflects methods used in 2011	1.15
1.15	4/2012	D. Witwicki	Added species that are not counted in the shrub belt	More sprawling shrubs that are difficult to count	1.16
1.16	11/2013	D. Witwicki	Updated data sheet for shrub and tree seedling density	Incorrect and missing information	1.17
1.17	2/2016	S. Karinen	Added tree seedling density to oak and class #s to shrub density, classes updated so numbers do not overlap	Methods added, classes informally used but not in SOP	1.18
1.18	8/2016	D. Witwicki	Pinyon pine and Utah juniper now sampled as trees at grassland/ shrubland plots (added seedling density & removed from shrub density).	To be more consistent with other monitoring protocols.	1.19
1.19	11/2017	A. Wondrak-Biel	Improved quality of text in Figure 1	For publication	1.20

This SOP details methods to conduct numerous types of vegetation sampling. Density of tree seedlings is recorded in all plot types, and density of live shrubs is recorded in all plot types except oak. Frequency of exotic species is recorded for all plot types, although the frequency method is modified slightly for oak plots (see SOP #15). Canopy closure is measured in forest plots using a spherical densiometer. Species richness is additionally recorded at all subalpine meadow plots. A list of necessary equipment for these procedures can be found in SOP #1.

It is important to measure point-intercept cover before the vegetation measures in this SOP because the area just upslope of the transect is most susceptible to accidental trampling.

1. Shrub and tree seedling density

Fill out the top of the data sheet, and make sure you are on the correct transect if you are entering data directly into the database.

Sample shrub and seedling density in a 1-m belt uphill of the point-intercept transect. Seedling density is sampled in all plot types, and shrub density is recorded in all plot types except oak.

A. Unfold a ruler to 1 m in length and use the ruler and the transect tape to determine whether shrubs and tree seedlings are rooted at least 50% within the belt transect.

B. Record the entire Latin name of each live shrub and tree seedling species encountered on the belt transect. Dead individuals are not recorded.

C. Keep a running total for each species.

D. At sites with high levels of density, estimate density of the transect using the following categories: 101-250, 251-500, 501-1000, and >1000 individuals. Record the midpoint for the appropriate category.

1.1 Shrubs

Record shrubs in six height classes: 0-10 cm, >10-25 cm, >25-50 cm, >50-100 cm, >1-2 m, and >2 m (Table 1). Shrub height is determined by the tallest, live branch on the plant, including the inflorescence, and regardless if the branch is in or outside the plot. The following dwarf shrubs and multi-stem shrubs are not counted:

cactus sp.	*Symphoricarpos sp.*	*Ribes montigenum*
Yucca sp.	*Quercus sp.*	*Prunus virginiana*
Gutierrezia sp.	*Amelanchier utahensis*	*Rosa* sp.
Arctostaphylos sp.	*Mahonia repens*	
Ephedra viridis (in ARCH & CANY grassland plots)		

In cases where individuals are sometimes difficult to distinguish in a species (e.g., *Coleogyne ramosissima*), the counting rule is that stems separated by >0.5 m are separate counting units. Individuals of these same species that can be easily distinguished at distances <0.5 m should be counted separately.

Table 1. Shrub height classes

Class	Height
1	0-10 cm
2	>10-25 cm
3	>25-50 cm
4	>50-100 cm
5	>1-2 m
6	>2 m

1.2 Tree seedlings

Record all tree seedlings that are less than 2.5 cm in diameter.

- Measure the diameter at root crown (DRC) for pinyon pine and Utah juniper, and diameter at breast height (DBH) for all other tree species. Follow the rules for measuring diameter provided in SOP #13.

-For juniper and other species with multi-stem growth forms, only count individual young trees as seedlings and not branches that fall into this size class.

For all species except pinyon pine and Utah juniper, also record tree seedlings that are shorter than 1.37 m (breast height).

2. Exotic Frequency

Record the presence of all exotic plant species rooted in 1-m x 1-m quadrats placed every 5 meters along each transect beginning at 0 m. See SOP #15 for modifications to this sampling method for oak plots.

A. Use engineering rulers to delineate the quadrat starting at the 0-m mark on the transect tape and ending on the 1-m mark.

B. Record the full Latin name and mark an “X” in the box for presence of each exotic species rooted in the quadrat. All live annual and perennial exotic species, or those that were alive earlier in the growing season, are recorded. For any plant rooted underneath the sampling frame, count ones that are rooted at least 50% within the quadrat.

C. Sample exotic frequency in quadrats beginning at 0 m, 5 m, 10 m, 15 m, and every 5 m thereafter for the entire length of the transect (up to 45 m).

3. Species richness **(subalpine meadow only)**

Species richness is recorded in the same 1-m belt as density at all plots at Cedar Breaks National Monument (NM) and the subalpine meadow plot at Timpanogos Cave NM. Record the full Latin

name of all live species or species that were alive earlier in the growing season that are rooted within the 1-m belt.

4. Canopy closure

In forest plots (e.g., aspen, mixed conifer, etc.), take a modified concave spherical densiometer reading every 10 m, starting at the 5-m mark (i.e., 5 m, 15 m, 25 m, etc.). It is best to record overstory canopy cover early or late in the day so that the sun is not directly reflected in the densiometer.

a. Hold the densiometer 12” in front of you at elbow height with your elbows steadied against your torso. Level the densiometer using the bubble level. Position your body so that your forehead is visible at the top of the mirror as you make the reading (Fig. 1).

b. Count the number of point intersections covered by live or dead vegetation above the V (maximum is 17).

c. Four measurements are made, (1) facing downhill; (2) facing the transect end; (3) facing uphill and, (4) facing the transect origin. Keep the densiometer in the same place as you rotate it and yourself for each reading.

Occasionally, you may not be able to take the measurement at one of the standard locations because a tree trunk is blocking that location. If this occurs, move down the transect 0.5 m (i.e., move to 5.5 m) until you can hold the densiometer in the correct location. Do not move the location of the densiometer along the transect for branch obstructions. You should be able to move the densiometer up or down a centimeter or so in order to take the measurement.

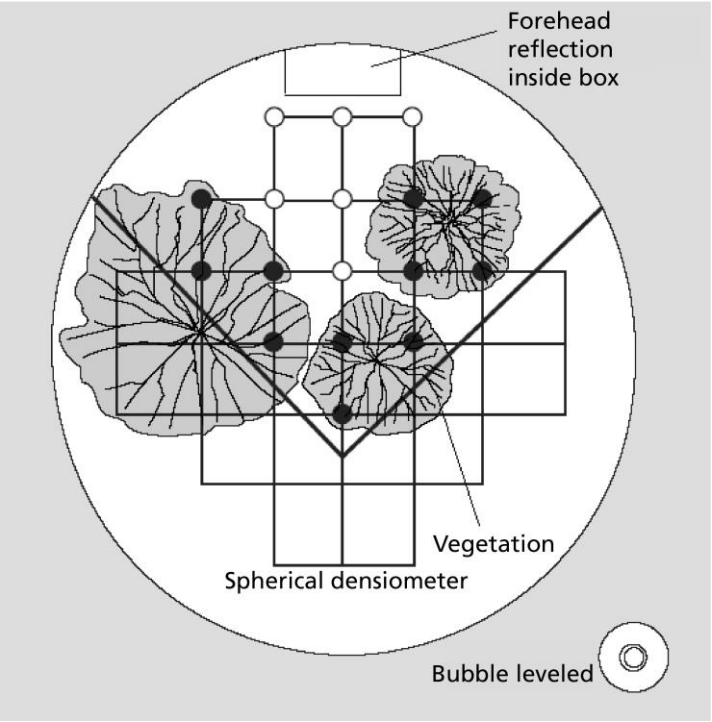


Figure 1. A modified concave spherical densiometer. Note the bubble level, the right angle marking the area sampled, and the 17 points of intersection. Closed circles represent line intersections where vegetation is present and consequently counted in measurement of canopy closure (example shows 11 out of 17 points) (from Fitzpatrick at el. 1998).

References

Fitzpatrick, F.A., I.R. Waite, P.J. D'Arconte, M.R. Meador, M.A. Maupin, and M.E. Gurtz. 1998. Revised methods for characterizing stream habitat in the National Water-Quality Assessment Program: U.S. Geological Survey Open-File Report 98-4052, 67 p.

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. Volume I: Quick start. USDA-ARS Jornada Experimental Range, Las Cruces, NM. 36 pp.

Shrub and Tree Seedling Density

Data entered by: Data verified by:

NCPN Upland Monitoring

Park Code: **PlotID:** **Transect:** 1 2 3

Observer: **Recorder:** **Date:**

Shrub Species	**Height Classes**					
	0 - 10 cm	10.1 - 25 cm	25.1 - 50 cm	50.1-100 cm	1.01 - 2 m	>2.01 m
Tally Total						
Tally Total						
Tally Total						
Tally Total						
Tally Total						
Tally Total						
Tally Total						

Shrub density counts do not include: *Amelanchier utahensis, Arctostaphylos* sp., cactus sp., *Ephedra viridis* (in ARCH/CANY grasslands), *Gutierrezia* sp., *Mahonia repens, Prunus viginiana, Quercus* sp., *Ribes montigenum, Rosa* sp., *Symphoricarpos* sp., *Yucca* sp.

Tree seedlings (<2.5 cm diameter or <1.37 m tall for all species measured at DBH)

Species	Tally	Total	Species	Tally	Total

Exotic Frequency, Species Richness, and Canopy Closure

Data entered by: Data verified by:

NCPN Upland Monitoring

Park Code: **PlotID:** **Transect:** 1 2 3

Observer: **Recorder:** **Date:**

Exotic Frequency – 1-m x 1-m quadrats

	Meter									
Species	0	5	10	15	20	25	30	35	40	45

Species in 1-m belt (subalpine meadow only)

Spherical Densiometer (forest only)

5 m	_____	_____	_____	_____
15 m	_____	_____	_____	_____
25 m	_____	_____	_____	_____
35 m	_____	_____	_____	_____
45 m	_____	_____	_____	_____

Upland Vegetation and Soils Monitoring Protocol for Park Units in the Northern Colorado Plateau Network

Standard Operating Procedure (SOP) # 11

Soil Aggregate Stability

Version 1.25 (August 2016)

Revision History Log:

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #
1.00	3/1/2007	S. Garman	Enhanced instructions for integrating this SOP with SOP#8	To ensure that procedures are conducted in concert with other SOPs	1.10
1.10	2/5/2008	D. Witwicki	Clarified category for dwarf shrub	Unclear in previous version	1.20
1.20	4/2008	R. Weissinger	Formatting only	To improve useability	1.20
1.20	9/2009	D. Witwicki	Replace position & hydrophobic soil indicator on data sheet; decrease distance to resample if protected by rock or litter; formatting; clean up; revise stability class table; remove subsurface sampling	Consistency; table not consistent with sample kits; no subsurface sampling	1.21
1.21	4/2011	D. Witwicki	Updated figure references and format, text for testing samples		1.22
1.22	2/2013	D. Witwicki	Added instructions for moving sampling points	Needed clarification	1.23
1.23	11/2013	D. Witwicki	Updated data sheet	Recorder was missing and a symbol was incorrect	1.24
1.24	8/2016	D. Witwicki	Updated random number methods to select sample locations	To reflect actual method used	1.25

This SOP provides instructions for using a field kit to estimate soil aggregate stability when exposed to rapid wetting. Soil aggregate stability is sampled in grassland/shrubland and woodland plots. A list of necessary equipment for this procedure can be found in SOP #1.

Soil samples are usually collected after vegetation is sampled along each transect. If the soil surface is moist from precipitation, collect the soil samples first so they have time to dry out.

1. **Select 18 sample points (6 points on each transect).**
   A. Use the random number provided by the project manager (between 1 and 800) to determine the sampling locations along each transect. The first sample on each transect is

collected at the random number (in cm). The remaining 5 sample locations are determined by consecutively adding 800 to this number (e.g., using the random number 131, samples are collected at 131, 931, 1731, 2531, 3331, and 4131).

B. Locate the first sampling location along the transect and record it to the nearest centimeter under "Pos" on the data sheet.

C. Collect the sample 5 cm upslope from the transect.

D. Move the sample point only if it has been disturbed during previous measurements, it is covered by a plant base, or the soil surface is protected by a rock or litter.

- Move the sample point down the transect in 5 cm intervals until you have a suitable collection location, and record the new position.
- If a sample point is moved, make sure that the sample is collected at least 1 m away from any other soil aggregate stability samples.
- Make sure to collect all 6 samples on each transect, even if you need to move many of the sample points.

2. Determine the dominant cover class.

Determine the dominant cover class over the random point and enter this into the "Veg" column on the data sheet. The area to be classified is effectively as large as the sample area (6-8 mm in diameter). Record the dominant cover class in the "Veg" column:

NC = no moss, perennial grass, forb, shrub, or tree canopy cover
M = moss
G = perennial grass canopy and grass/shrub canopy mixture
F = perennial forb
Sh = shrub/dwarf shrub canopy
T = tree canopy (includes PJ)

3. Collect a surface sample.

A. Excavate a small trench (10-15 mm deep) in front of the area to be sampled (Fig. 1).

B. Lift out a soil fragment and trim it (if necessary) to the correct size. The soil fragment should be 2-3 mm thick and 6-8 mm in diameter (Figs. 2 and 3). This is about the diameter of a wood pencil eraser. Try to fit sample in dot below (6-8 mm diameter).

C. Minimize shattering by: a) slicing the soil around the sample before lifting; b) lifting out a larger sample than required, and trimming it to size in the palm of your hand; or c) misting the sample area before collection.

- If the soil sample is too weakly structured to sample (falls through the sieve), mist it lightly with deionized water (use an atomizer or equivalent) and then take a sample. Perfume and plastic hair spray bottles work well for this.
- If the sample still will not hold together, record a "1" on the data sheet.
- If the soil surface is covered by a lichen or cyanobacterial crust, include the crust in the sample.
- If the sample is covered by moss, do not collect the sample. Record "6" for the soil stability rating.

D. Gently place the sample in a dry sieve (Fig. 4); place sieve in the appropriate cell of a dry box.

4. Make sure the samples are dry.
Samples must be dry before testing.

- If samples are not dry after collecting, allow to air dry with the lid off.
- Do not leave lid closed on samples for more than 1 minute on hot or sunny days. Excessive heat can artificially increase or decrease stability.

5. Fill the empty (no sieves) box with deionized or distilled water (Fig. 5).
Fill each compartment with water. The water should be approximately the same temperature as the soil.

6. Test the samples.

A. Lower the first sieve with the sample into the respective water-filled compartment—upper left corner of sample box to upper left corner of water box (Fig. 6). From the time the sieve screen touches the water surface to the time it rests on the bottom of the box, 1 second should elapse.

B. Start the stopwatch when the first sample touches the water. Use Table 1 to assign samples to stability classes (also see Fig. 7).

C. Follow the sequence of immersions on the data sheet, adding one sample every 15 seconds. The typical sequence is to immerse the first sample, watch it for 5 seconds, immerse the second sample, and then check the previous 2 samples until it is time to immerse the third sample. This pattern is repeated until all samples have been immersed. When you observe the samples, look for how much structural integrity has been lost.

Beginners may want to immerse a sample every 30 seconds. This allows nine samples to be run in 10 minutes, so it takes 20 minutes to test one box of 18 samples.

D. Continue to observe the samples and look for lost structural integrity until the samples have been immersed for 5 minutes (300 seconds). Record a stability class based on Table 1.

E. After 5 minutes, raise the sieve completely out of the water and then lower it to the bottom without touching the bottom of the tray.

F. Repeat this immersion a total of five times. Do this even if you have already rated the sample a 1, 2, or 3 (you are allowed to change your rating if after sieving > 10% of soil remains on sieve). It should take 1 second for each sieve to clear the water's surface and 1 second to return to near the bottom of the box. Hydrophobic samples (float in water after pushed under) are rated 6, and this number is circled on the data sheet.

G. Record the stability class on the data sheet under 'Rating".

References

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. Volume I: Quick start. USDA-ARS Jornada Experimental Range, Las Cruces, NM. 36 pp.

Figure 1. Excavate small trench.

Figure 2. Collect surface sample.

Figure 3. Ensure correct sample size.

Figure 4. Place sample in sieve.

Figure 5. Complete soil stability kit with water and samples.

Figure 6. Place first sample in water.

(Figures 1-6 are from Herrick et al. 2005)

Table 1. Stability class ratings.

Stability Class	Criteria for assignment to stability class
1	**50%** of structural integrity lost (melts) within **5 seconds** of immersion in water **AND** <10% remains after 5 dipping cycles, **OR** soil too unstable to sample (falls through sieve).
2	**50%** of structural integrity lost within **5-30 seconds** of immersion **AND** <10% remains after 5 dipping cycles.
3	**50%** of structural integrity lost within **30-300 seconds** (5 minutes) of immersion, **OR** <10% remains after 5 dipping cycles.
4	**10-25%** of soil remains on sieve after 5 dipping cycles.
5	**25-75%** of soil remains on sieve after 5 dipping cycles.
6	**75-100%** of soil remains on sieve after 5 dipping cycles.

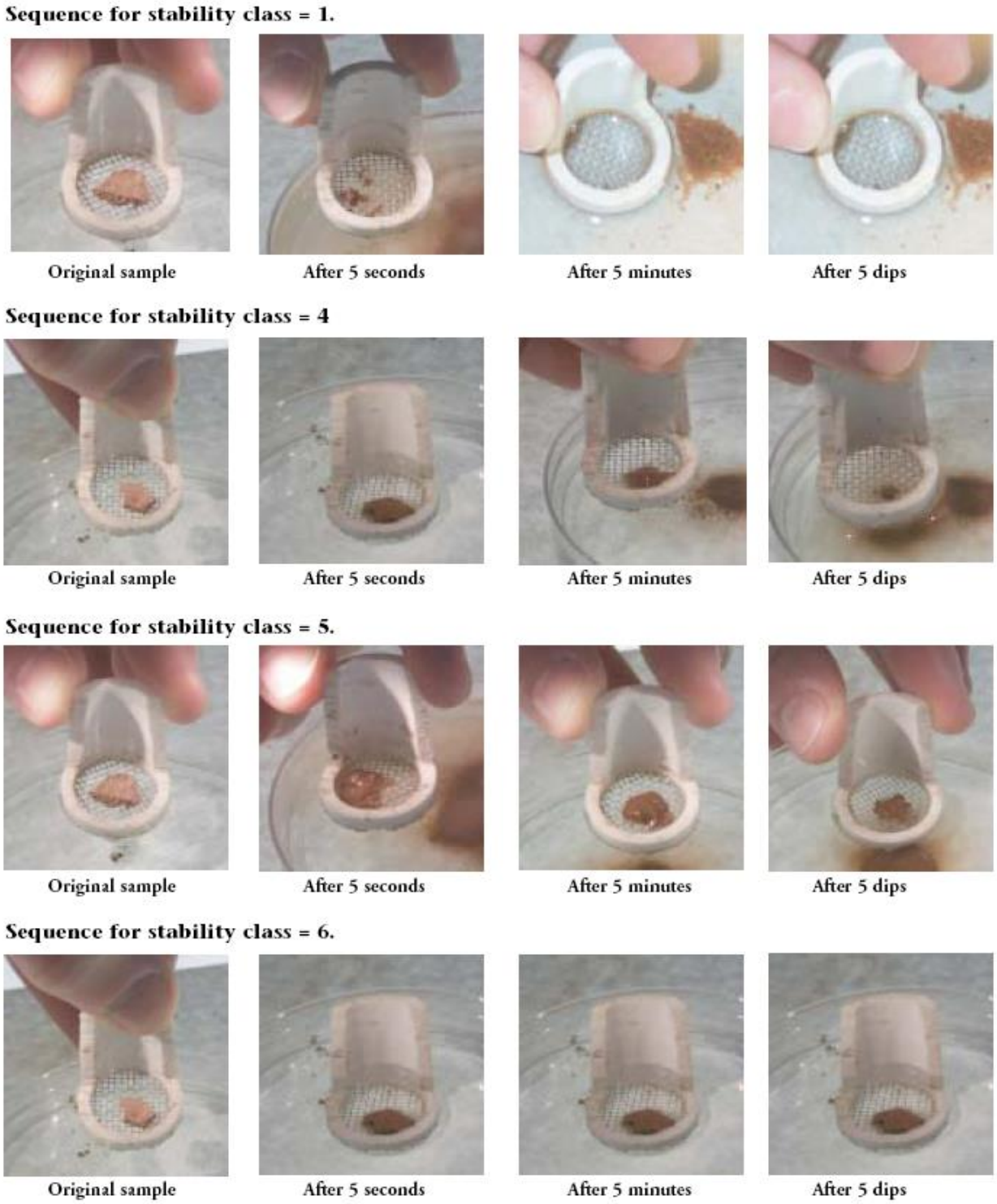


Figure 7. The photos above illustrate the key steps of testing a soil sample for four different stability rankings. Some of the fragments shown in these samples may appear large. They are for illustration only. Be sure to follow the size guidelines (6-8 mm) in step 4 (from Herrick et al. 2005).

Soil Stability Test

Data entered by: Data verified by:

NCPN Upland Monitoring

Park Code: _____ **Plot ID:** _____ **Observer:** _____ **Recorder:** _____ **Date:** _____

Veg = **NC** (no perennial canopy), **M** (moss), **G** (grass or grass/shrub mix), **F** (forb), **Sh** (shrub), **T** (tree) **No.** = stability class 1-6 (see below).

Circle rating number if sample is hydrophobic; moss and hydrophobic samples are rated "6"

	Sample 1					Sample 2				Sample 3				Sample 4				Sample 5				Sample 6			
	Pos	Time In	Dip Time	Veg	No.	Time In	Dip Time	Veg	No.	Time In	Dip Time	Veg	No.	Time In	Dip Time	Veg	No.	Time In	Dip Time	Veg	No.	Time In	Dip Time	Veg	No.
Transect 1		0:00	5:00			0:15	5:15			0:30	5:30			0:45	5:45			1:00	6:00			1:15	6:15		
Transect 2		1:30	6:30			1:45	6:45			2:00	7:00			2:15	7:15			2:30	7:30			2:45	7:45		
Transect 3		3:00	8:00			3:15	8:15			3:30	8:30			3:45	8:45			4:00	9:00			4:15	9:15		

Stability Class	Criteria for assignment to stability class
1	**50%** of structural integrity lost (melts) within **5 seconds** of immersion in water **AND** <10% remains after 5 dipping cycles, **OR** soil too unstable to sample (falls through sieve).
2	**50%** of structural integrity lost within **5-30 seconds** of immersion **AND** <10% remains after 5 dipping cycles.
3	**50%** of structural integrity lost within **30-300 seconds** (5 minutes) of immersion, **OR** <10% remains after 5 dipping cycles.
4	**10-25%** of soil remains on sieve after 5 dipping cycles.
5	**25-75%** of soil remains on sieve after 5 dipping cycles.
6	**75-100%** of soil remains on sieve after 5 dipping cycles.

Upland Vegetation and Soils Monitoring Protocol for Park Units in the Northern Colorado Plateau Network

Standard Operating Procedure (SOP) # 12

Site Impact Assessment

Version 1.23 (August 2017)

Revision History Log:

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #
1.00	3/1/2007	S. Garman	Added instructions for conducting impact assessment around a macroplot	Expanded site impact assessment from just upslope to all area around a macroplot	1.10
1.10	2/5/2008	D. Witwicki	1) Added instructions to complete data form each plot visit 2) Clarified areal extent of disturbance in text & on data form 3) Removed specific lines on data form to hypothesize disturbance effects of fire and erosion.	1) Unclear in previous version 2) Unclear in previous version 3) Beyond the scope of our field crew	1.20
1.20	4/2008	R. Weissinger	Formatting only	To improve useability	1.20
1.20	3/2009	D. Witwicki	Formatting; clean up	Consistency	1.21
1.21	3/2011	D. Witwicki	Added exotic plant walk, combined disturbances into one category	More information for resource managers, 3 categories not necessary	1.22
1.22	8/2017	D. Witwicki	Added instructions for entering data in database	For clarity	1.23

This SOP provides instructions for qualitatively detecting and describing disturbances and exotic plant species at a plot. This assessment is conducted every time vegetation is sampled. A list of necessary equipment for this procedure can be found in SOP #1.

1. Disturbances

Look for disturbances in the area sampled by transects and in the 25-m zone bordering all sides of the transects (Fig. 1).

- A list of common disturbances can be found in Table 1. The list of disturbances is not comprehensive. If a significant disturbance not found on the list is present, it should be recorded. If there is no disturbance to report, write “none” for disturbance type on your paper data sheet, or select “No Disturbances Found” in the database.
- If the area around the plot is visible from a transect, then record the information without additional walking around the plot. If the area is not visible, walk around the transects

in the 25-m zone bordering the sides of all transects and note any disturbances. Walk on the downhill side of the transects and do not trample the areas sampled by point intercept and belt transects.

- At sites with physical and/or biological soil crusts, it is important not to impact soil stability any more than is absolutely necessary. Do not create additional tracks and paths to assess site disturbance.

For each disturbance encountered, record:

Disturbance Type: type of disturbance; examples are in Table 1
Size of area affected (m^2): approximate the aerial extent of the disturbed area (e.g., 10 x 10 m)
Position relative to transects: distance and direction relative to one of the transects
Description: Include severity, potential effects on fire or erosion processes, etc.

Additionally, you may use the figure at the bottom of the data sheet to sketch the approximate size and location of the disturbance.

2. Exotic plant species

Perform a timed walk through the plot (not to exceed 10 minutes) and record all annual and perennial exotic plant species present. Make sure to record any species that were not detected during vegetation sampling. Estimate the number of plants detected and the size of the invasion, and describe the approximate location within the plot.

It is the park's responsibility to remove invasive exotics, but the crew may decide to pull exotics if only a few plants are present and if the time needed to hike to the plot is great. Record if plants were pulled by the crew and their general location in the visit comments.

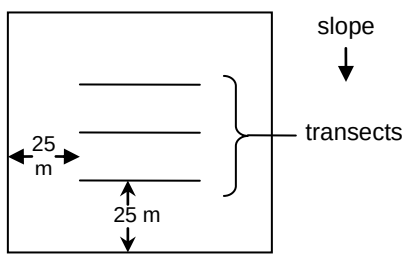


Figure 1. Diagram of area evaluated for disturbances.

Table 1. Common disturbance types in Colorado Plateau uplands.

Disturbance Type	**Description**
Dirt road	
Paved road	
OHV activity	Noticeable off-road tracks
Foot/bike path	
Campsite	
Livestock trailing	Scat and/or trampled vegetation
Livestock grazing	Scat and/or grazed vegetation
Livestock watering point	
Fire	Old or recent burn scars
Water	Recent flooding or inundation denoted by debris piles, scour marks, flattened vegetation, etc.
Wind	Uprooted trees and broken tops
Small rodents	Presence of burrows
Other large mammal activity	Trampling, grazing, browsing, or scat
Insects	Dead trees from insect

Site Impact Assessment

Data entered by: Data verified by:

NCPN Upland Monitoring

Park Code: **Plot ID:** **Date:** **Page _____ of _____**

Observer: **Recorder:**

Disturbances

Disturbance type: _____

Size of disturbance (m^2): _____

Position of disturbance relative to transects: _____

Description (including potential effects on fire or erosion processes): _____

_____

_____

_____

_____

Disturbance type: _____

Size of disturbance (m^2): _____

Position of disturbance relative to transects: _____

Description (including potential effects on fire or erosion processes): _____

_____

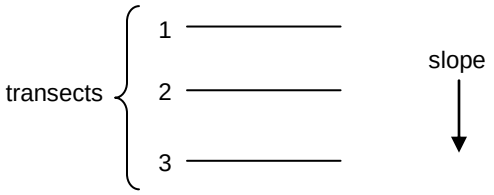
_____

_____

_____

Example disturbance types:

dirt road	fire	livestock trailing
paved road	water	livestock grazing
OHV activity	wind	livestock watering point
foot/bikepath	small rodents	Insects
campsite	other large mammal activity	



Exotic Plant Species Present: (number of plants/size of the invasion, location, note if pulled)

Other Notes:

Upland Vegetation and Soils Monitoring Protocol for the Park Units in the Northern Colorado Plateau Network

Standard Operating Procedure (SOP) # 13

Measuring Overstory Trees

Version 1.12 (December 2017)

Revision History Log:

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #
1.00	3/2009	D. Witwicki	Formatting; clean up	Consistency	1.01
1.01	7/2009	D. Witwicki	Sample overstory trees in quadrat 1 only	Census of entire plot was too much	1.02
1.02	3/2010	D. Witwicki	Added methods to track downed and decaying trees	To ensure data is not missing	1.03
1.03	4/2011	D. Witwicki	Woodland species measured at root crown instead of breast height; clarify tree tag wording	More repeatable; unclear	1.04
1.04	1/2012	D. Witwicki	Gambel oak measured at dbh instead of root crown	Method used in 2011 field season	1.05
1.05	2/2012	D. Witwicki	Make sure no duplicate tree tag numbers at a plot		1.06
1.06	2/2013	D. Witwicki	Added Latin names, clarified when to tag stumps	Crew not familiar with common names; unclear	1.07
1.07	11/2013	D. Witwicki	Updated data sheet, clarified height of saplings and measuring oak in forests and woodlands	Unclear directions and data sheet needed edits	1.08
1.08	3/2015	S. Karinen, D. Witwicki	Clarified instructions for measuring saplings and leaning trees. Added instructions to check for overstory trees on revisit form and for measuring trees when a bulge develops at the nail.	Unclear directions	1.09
1.09	2/2016	S. Karinen	Added sapling density to oak plots, class size to sapling belt, and clarification on indentations near DRC.	Methods added, classes informally used but not in SOP	1.10
1.10	8/2016	D. Witwicki	Pinyon pine and Utah juniper now sampled as trees at grassland/ shrubland plots (added to sapling density & overstory census); clarified that all trees >15 cm are included in overstory census	To be more consistent with other monitoring protocols; needed clarification	1.11
1.11	12/2017	A. Wondrak-Biel	Updated plot figures	For publication	1.12

This SOP details methods for measuring sapling and overstory trees in forest and woodland plots using a 5-m belt transect and a census. Any trees found in grassland/shrubland plots should also be recorded using these procedures. Sampling is performed in oak plots as well, but with slightly modified methods. This protocol covers how to measure the diameter at root crown for pinyon pine (*Pinus edulis* or *P. monophylla*) and Utah juniper (*Juniperus osteosperma*), and diameter at breast height for all other tree species. A list of necessary equipment for this procedure can be found in SOP #1. SOP #15 details modifications to the method for oak plots.

It is important to measure understory vegetation before saplings and overstory trees since the understory is more susceptible to trampling.

1. Tree Saplings Density

In all vegetation types, record live and dead tree saplings (2.5 – 15 cm diameter) in a 5-m belt centered on transect 2.

A. Delineate a 5-m belt transect centered on Transect 2 using a folding ruler (Figures 1-3). You will be sampling 2.5 m on either side of the transect. Carefully measure the distance for any individuals that are close to the outside edge of the belt.

B. Record the full Latin name of all tree species with individuals between 2.5 and 15 cm diameter.

C. Tally the sapling trees using the following diameter classes: 2.5 - 5.0 cm (class 1), 5.1 - 10.0 cm (class 2), and 10.1 – 15.0 cm (class 3).

-Measure the diameter at root crown (DRC) for pinyon pine (*P. edulis* or *P. monophylla*) and Utah juniper (*J. osteosperma*), and diameter at breast height (DBH) for all other tree species (see additional instructions below). Pinyon pine and Utah juniper of any height are considered saplings as long as they fall into the sapling diameter size class at DRC.

-For juniper and other species with multi-stem growth forms, only count young trees as saplings and not branches that fall into this size class.

-When it is difficult to distinguish individuals from branches, do not count stems that lean more than 45 degrees. Use this rule to help distinguish individuals from branches for saplings that are buried underground.

D. Record dead individuals in a separate tally from live individuals. Indicate the density of dead individuals by writing “-D” on paper data sheets or entering “No” in the “Alive?” column in the database.

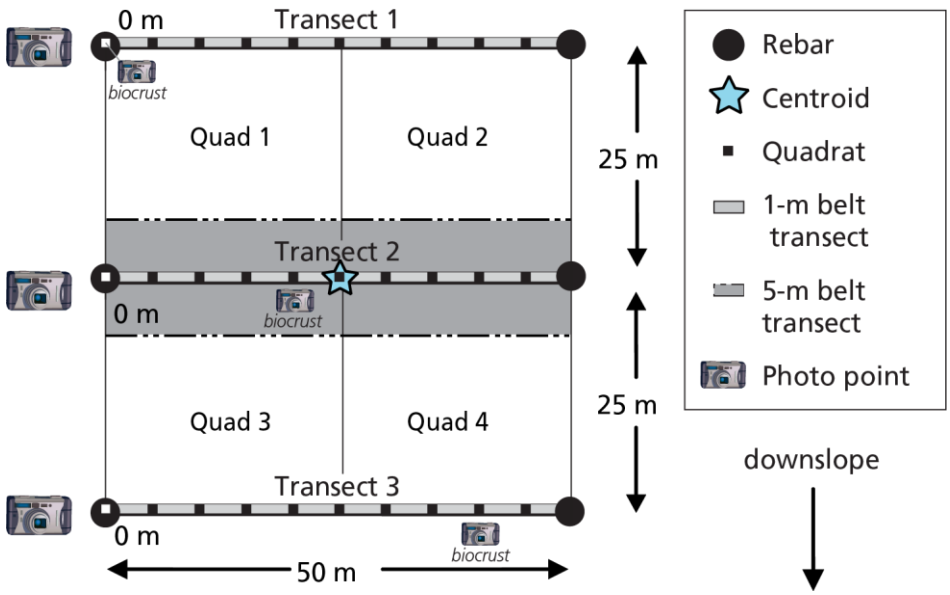


Figure 1. Locations of measurements for sapling density and overstory census in grassland/shrubland plots.

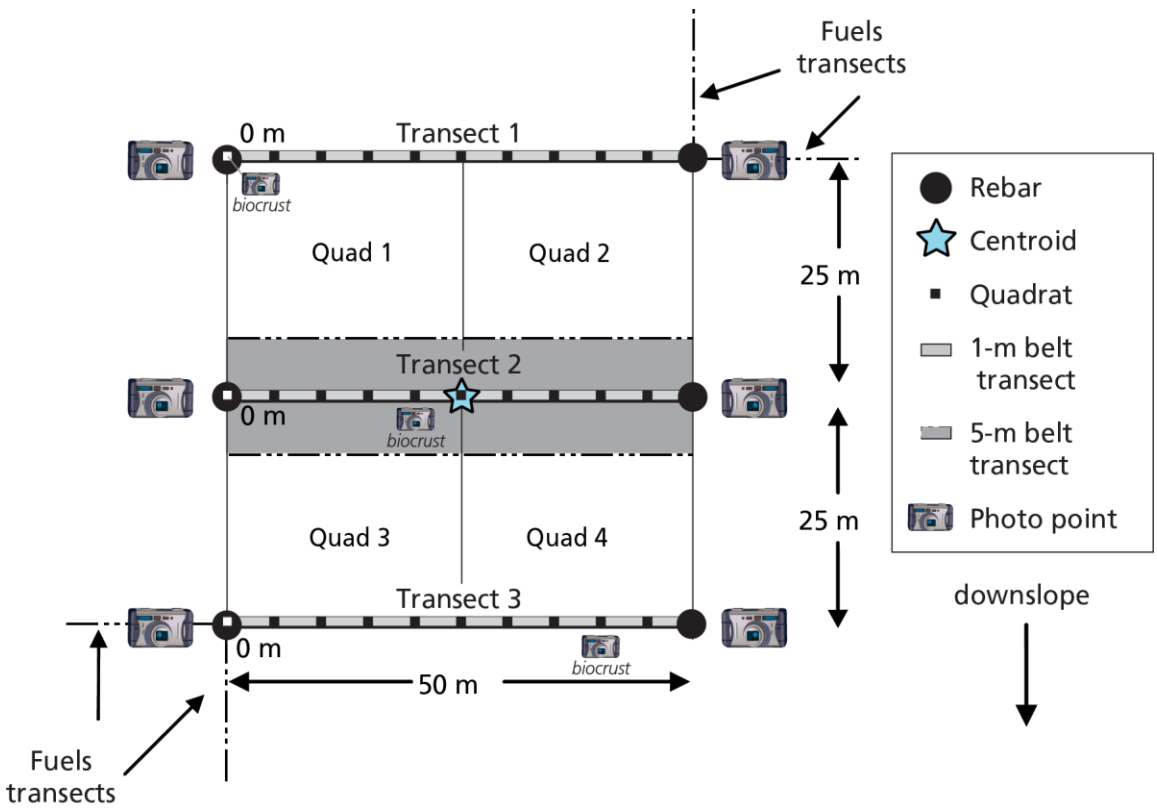


Figure 2. Locations of measurements for sapling density and overstory census in woodland plots.

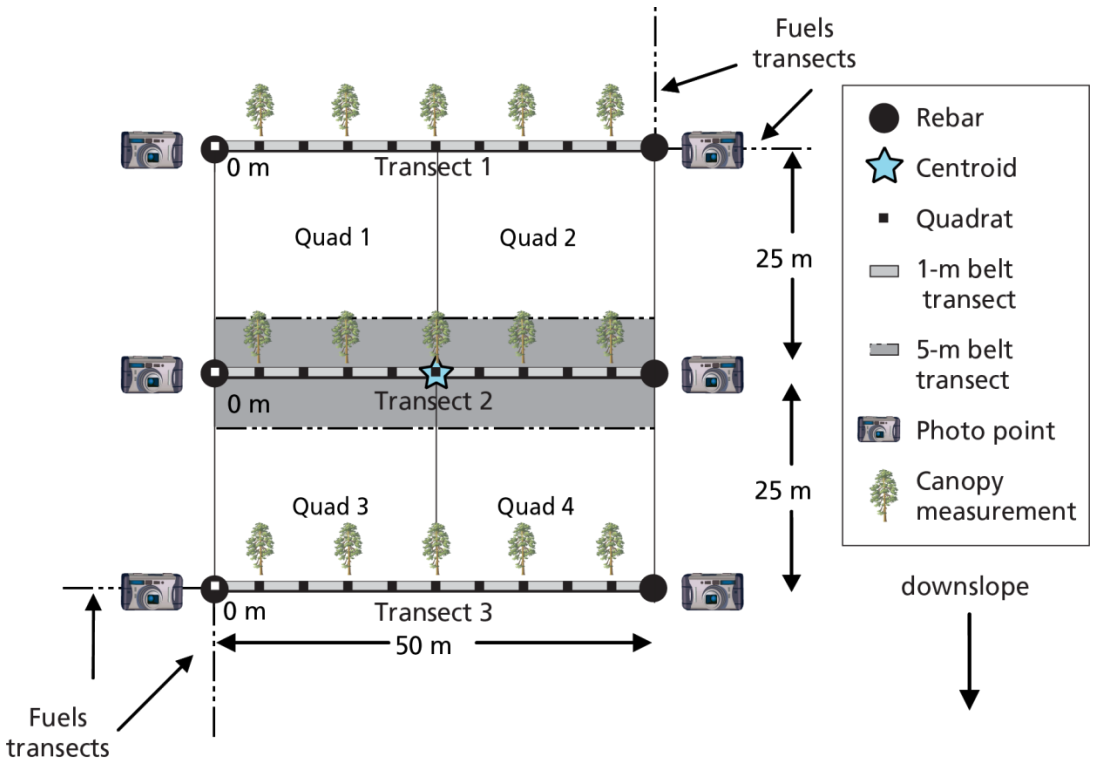


Figure 3. Locations of measurements for sapling density and overstory census in forest plots.

2. Plot Census of Overstory Trees

Tag and measure all live and dead overstory trees (>15 cm diameter) in quadrant 1 of the plot. Gambel oaks (*Quercus gambelii*) are considered overstory trees in forest and woodland plots when the diameter is >15 cm. All live and dead woody stems with a diameter greater than 15 cm are included in the overstory census, regardless of how much they are leaning. See SOP #15 for modifications to this sampling method for oak plots.

A. Divide the plot into quadrants (Figures 1-3), either by marking the centroid with flagging tape or by running two transect tapes to physically divide the plot. If necessary, use additional flagging to help delineate quadrant 1.

B. Census trees in quadrant 1 only. Begin at one corner of a quadrant and systematically sample all trees >15 cm in diameter that are at least 50% rooted within the quadrant.

C. If an overstory tree is not tagged, affix a pre-numbered tag to the **uphill side of the tree** using a 3" nail. *Make sure to attach a tag with a number that has not already been used at the plot*.

   a. Align the nail so that it enters the tree at breast height (1.37 m) for forest species or root crown for woodland species. See instructions below for when to tag at each location. Drive the nail into the tree at an angle, so that the tag hangs down

and away from the tree. Leave several centimeters of nail exposed so the tree has ample space for growth.

b. If the tree forks below breast height (or root crown for woodland species), both forks should be tagged.

c. New tree tags should be attached as needed on plot revisits to saplings that have grown into mature trees with a diameter greater than 15 cm.

D. Record the quadrant, tag number, and species of the tree.

a. Record the full Latin name the first time a species is encountered, and record subsequent occurrences using a six-letter code comprised of the first three letters of the genus and specific epithet.

b. If the species is unknown, record it as UNKT.

E. Measure diameter at breast height (DBH) or root crown (DRC). See instructions below on when and how to use each measurement.

a. Measure just above the nail so that the bottom edge of the tape is touching the top of the nail.

b. Using a diameter tape, measure to the nearest 0.1 cm, making sure to read the correct side of the tape.

c. The only time that a measurement is not taken just above the nail is when a swollen scar has developed at the site of the nail that changes the DBH of the tree (e.g., in some aspens). In this case, the DBH measurement should be taken just above the swollen area so that the DBH is representative of the trunk. Make a note any time that the DBH is not measured just above the nail.

Do not tag or record the diameter (DBH or DRC) of stumps in the tree census. Stumps are defined as trees cut or broken below DBH. Describe this disturbance in the site impact assessment.

F. Record crown health for each tree in forest plots. Also record all dead trees in grassland/shrubland, oak, and woodland plots using this attribute.

Crown Health: Evaluate the density of each tree's crown in relation to crowns of the same species located in a similar position within the canopy. Crown health codes are defined in Table 1. Classes 1 through 4 refer to the estimated amount of the foliage that is intact, expressed as a percent. Class 5 is used to designate standing dead trees with a lean of 45 degrees or less and an overall height greater than 1.37 meters that are still rooted to the ground.

Class 6 should only be used to record trees that were previously tagged and standing but have fallen down since the last plot visit. This class is used in order to not confuse fallen trees with missing data. After a tree has been recorded once as class 6, it does not need to be recorded on the data sheet in subsequent plot visits.

Standing dead trees whose diameters fall below 15 cm since the last plot visit (usually due to decay) should be recorded as class 5. A comment should also be included in the

Notes/Conditions field explaining why a tree < 15 cm diameter was recorded on the data sheet. After a tree has been recorded once as class 5 and < 15 cm diameter, it does not need to be recorded on the data sheet in subsequent plot visits.

G. Record crown class for each live tree in forest plots. Do not record crown class for trees in grassland/shrubland, oak, or woodland plots.

Crown Class: Determine the most appropriate crown class for each live tree according to its canopy position. Use Table 1 and Fig. 4 to determine crown classes for all tree species. Crown class codes are listed at the bottom of the tree data sheet.

H. Record Conditions/Notes. Any significant damage to a living tree should also be recorded on the Overstory Census data sheet. Scan each tree carefully for signs of damage, including but not limited to recent fire scars, lighting strike scars, mistletoe infestation, bark beetles, brooming, cankers, stem decay, wood-boring insects, tent caterpillars, or broken or dead top. Be aware that pathogens other than mistletoe can cause brooming. Only list mistletoe if you see live mistletoe on the tree.

I. At a revisit, check that all trees on the overstory plot revisit sheet have been located and recorded. If a tree cannot be located, it should be recorded on the data sheet and a comment should be included in the Notes/Conditions field.

Table 1. Crown health classes for forest species

Crown Health Class	Description
1	90-100% live foliage
2	50-89% live foliage
3	16-49% live foliage
4	0.1 – 15% live foliage
5	standing dead
6	dead and down

Table 2. Crown classes for forest plots

Crown Class	Description
Dominant	Trees have crowns extending above the general level of the main canopy of adjacent trees and receive full light from above and partly from the sides.
Codominant	Trees have crowns forming the general level of the main canopy of adjacent trees and receive full light from above and comparatively little from the sides.
Intermediate	Trees have crowns extending into the lower portion of the main canopy of adjacent trees, but are shorter in height than the codominants. They receive little direct light from above and none from the sides. Usually intermediate crown-classed trees have small crowns that are crowded on the sides.
Suppressed/ Overtopped	Trees have crowns entirely below the general level of the canopy of adjacent trees, and receive no direct light from above or from the sides.

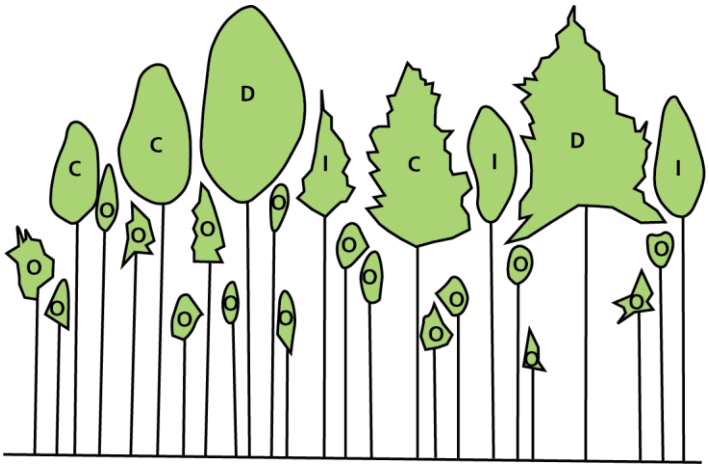


Figure 4. The relative positions of trees using four classes for crown classification. D =Dominant, C = Codominant, I = Intermediate, and O = Overtopped/Suppressed.

Measuring diameter

Using the diameter tape, always measure diameter just above the nail. If this is the first time you are measuring diameter on a tree, measure diameter after you nail the tag to the tree.

1. For species with rough bark, press the hook at the end of the tape into the bark, then run the tape around the trunk, ensuring that the tape is straight and pulled perpendicular to the axis of the trunk. Tapes that are not aligned straight will give an overestimate for the trunk diameter.
2. For tree species with smooth bark (e.g., aspen), do not press the hook into the bark or damage the tree. Instead, hold the hook in place while you extend the tape around the trunk.
3. If the tree is very large, or on a steep slope, have your partner help you wrap the tape.
4. For smaller trees, hold the tape reel in one hand and wrap your arms around the tree, grabbing the hook end with your other hand. Pull the tape back and forth a couple of times to ensure it is straight and perpendicular to the tree axis. Make sure the tape is not twisted. Have your partner check your accuracy for the first few trees.
5. Wrap the tape tightly around the tree and read the number where the tape crosses the zero mark at the beginning (hook end) of the tape (see Fig. 5). Measure diameter to the nearest 0.1 cm.
6. Make sure that you are reading the correct side of the diameter tape. Often one side has standard centimeters and the other side has units calibrated to give the diameter in centimeters when wrapped around the circumference of the tree. Read off of the calibrated side of the tape.

Figure 5. The method for securing a diameter tape to a tree with rough bark.

Measuring DBH

The diameter of most forest species (i.e., aspen, pines (except pinyon), spruce, firs, and Rocky Mountain juniper) and Gambel oak is measured 1.37 m above the ground (Fig. 6A), which is also referred to as breast height. Follow these rules for measuring the DBH of trees exhibiting various growth and bole characteristics.

1. When on a slope, determine the height of the diameter measurement on the uphill side of the tree (Fig. 6B).
2. If trees have a lean, measure diameter 1.37 m up along the bole axis, starting from the uphill side (Fig. 6C). Remember that diameter is measured on live trees with any amount of lean.
3. The location of a fork is defined as the point on the trunk where the **centers** of two trunks diverge. The trunks of a tree forking below 1.37 m are measured separately at 1.37 m above the ground (Fig. 6D).
4. When irregularities occur at DBH, including swellings, bumps, depressions, or branches, diameter is measured **immediately above** the irregularity where the stem takes on a normal form (Fig. 6E).

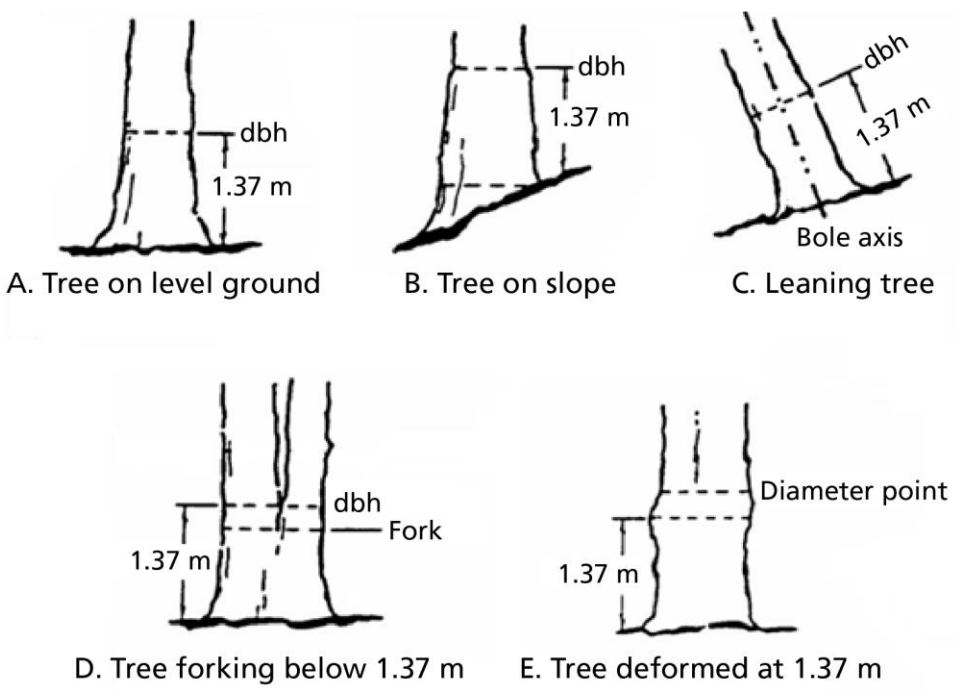


Figure 6. Locations of diameter at breast height (DBH) measurements for a variety of bole form situations (modified from USDA Forest Service 1985).

Measuring DRC

The diameter of highly forked woodland tree species (i.e., Utah juniper and pinyon pine) is measured at the root crown. Do not use this method for unusual individuals of forest tree species that have many boles. Follow these rules for measuring DRC:

1. Measure DRC at the ground line (Fig. 7A) or stem root collar (Fig. 7B), whichever is higher. DRC should be taken just above any swells or flaring present at the base of the trunk, and in a location such that the diameter measurements reflect the volume of the above stems. Make sure to avoid swellings near small side branches.
2. Always measure the bole perpendicular to its axis.
3. If the tree is located on a slope, measure DRC on the uphill side.
4. A single diameter of the root crown should be measured if branching occurs above ground and the single diameter accurately reflects the cumulative volume of the stems it supports. Measure DRC below the fork and above any swells at the base (Fig. 7C).
5. If the stems fork below ground level (Fig. 7D), or the base is deformed and its diameter would grossly overestimate the volume of the individual stems (Fig. 7E), the DRC should be calculated from the individual stem diameters. Measure each stem at the lowest location that represents the bole diameter.
6. Forked trunks are recorded as separate trees on the data sheet and a bracket is placed in the left hand margin to group trunks arising from a shared base. Do not group stems together if you are unsure whether or not they belong to the same individual.
7. Using the guidelines above, mark the location of the DRC measurement with a nail and tree tag. Remember that the diameter will be measured just above the nail. Although nails and tags are generally affixed on the uphill side of a tree, they should be attached to the outside of the trunk on individuals with multiple stems.
8. Include dead stems but not those that are missing or have been cut (Fig. 7F). Avoid indentations that would alter the DRC when cut stems are present near the base.

References

USDA Forest Service. 1985. Field Instructions for the Southeast. Southeastern Forest Experiment Station, Asheville, N.C. (In-house manual).

USDA Forest Service. 2005. Forest Inventory and Analysis National Core Field Guide, Vol. 1: Field Data Collection Procedures for Phase 2 Plots, Version 3.0.

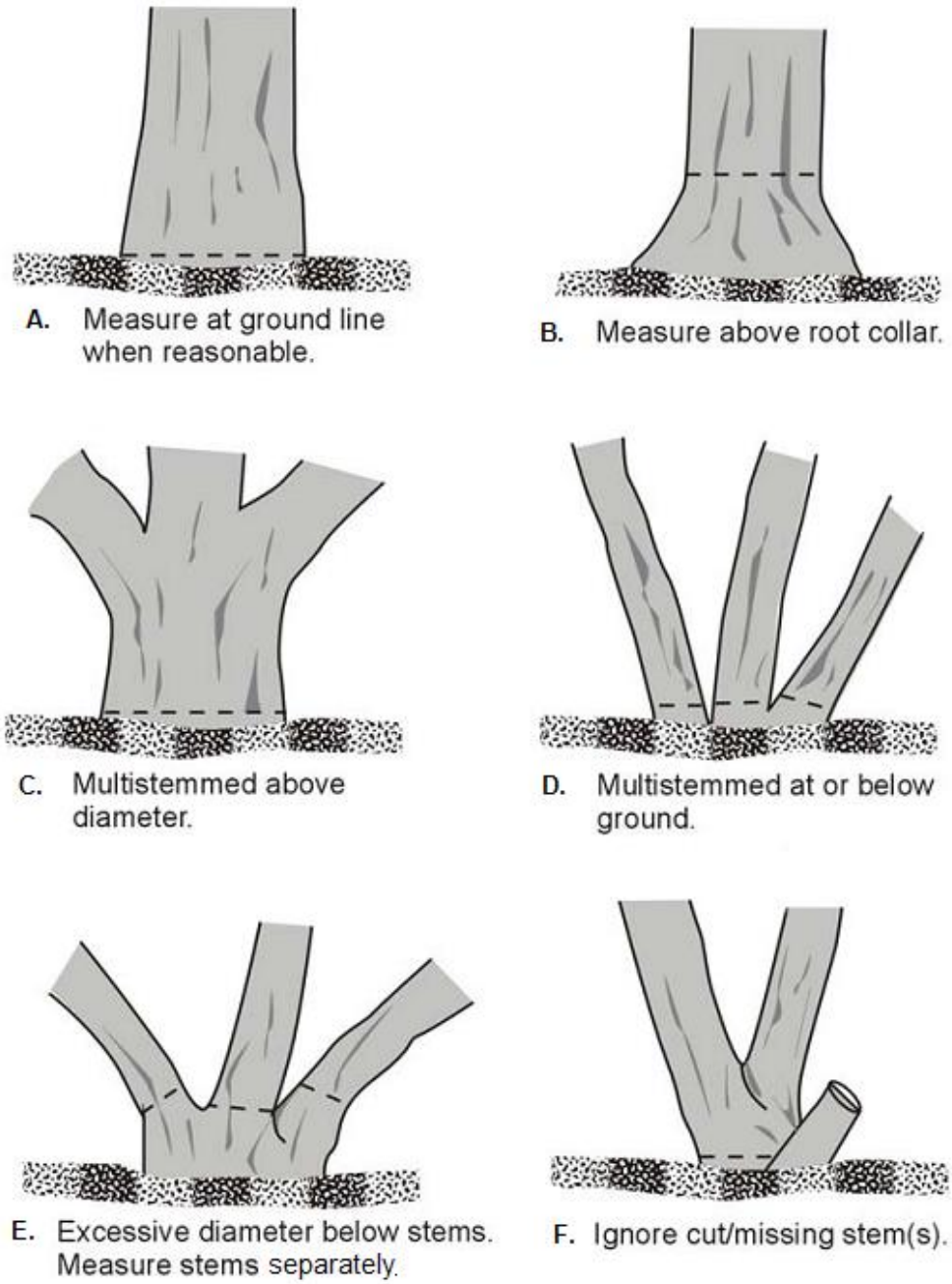


Figure 7. Locations of diameter at root crown (DRC) for a variety of bole form situations (adapted from USDA Forest Service 2005).

Sapling Density (5-m Belt) - Transect 2 only

Data entered by: Data verified by:

NCPN Upland Monitoring

Park Code: **Plot ID:** **Date:**

Observer: **Recorder:**

Record live and dead in separate tallies

	2.5 - 5.0 cm		5.1 - 10.0 cm		10.1 - 15.0 cm	
Species	Tally	Total	Tally	Total	Tally	Total

Overstory Census

Data entered by: Data verified by:

NCPN Upland Monitoring

Park Code: **PlotID:** **Date:** **Page _____ of _____**

Observer: **Recorder:**

Quad	Tag #	Species	Diameter (cm)	DBH or DRC	Crown Health	Crown Class	Notes/Conditions

Crown Health
0 none
1 90-100%
2 50-89%
3 16-49%
4 0.1-15%
5 Standing dead
6 Dead and down

Crown Class
D Dominant
C Codominant
I Intermediate
S Suppressed

Some Possible Tree Conditions

fire scars	broken top
lightning strike scars	dead top
mistletoe infection	stem decay
bark beetles	wood-boring insects

Upland Vegetation and Soils Monitoring Protocol for Park Units in the Northern Colorado Plateau Network

Standard Operating Procedure (SOP) #14

Measuring Fuels

Version 1.07 (November 2017)

Revision History Log:

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #
1.00	7/2009	D. Witwicki	Removed community type from data sheet; clarified definition of litter; formatting	Not necessary	1.01
1.01	6/2011	D. Witwicki	Rewording, clarifications	Consistency and clarity	1.02
1.02	1/2012	D. Witwicki, A. Wondrak Biel	Update Fig. 2	Clarified illustration of transect	1.03
1.03	4/2012	D. Witwicki	Clarified how to deal with moss over litter/duff	Unclear	1.04
1.04	3/2015	S. Karinen, D. Witwicki	Added no fuels at TICA1, clarified definition of woody fuels, updated 10- and 100-hr fuel sizes on data sheet	Missing from protocol	1.05
1.05	3/2017	D. Witwicki	Clarified procedure for sampling woody fuels near transect ends and wording for sampling suspended woody fuels	Unclear	1.06
1.06	11/2017	A. Wondrak Biel	Updated plot figures	For publication	1.07

This SOP details methods for monitoring fuels using a modified Brown's transect. This SOP is implemented in all forest and woodland vegetation types, except for plot 1 at Timpanogos Cave National Monument. A list of necessary equipment for this procedure can be found in SOP #1.

Fuels sampled in this protocol are divided into three categories:

Woody fuels are defined as dead branches, stems, and twigs (but not cones, bark, needles, and leaves) of woody plants that have fallen or broken off and lie on or above the ground.

Litter is defined as undecomposed or partially decomposed organic material that can be readily identified (e.g., leaves, bark, cones, and other non-woody plant material).

Duff is defined as the layer of decomposing organic material below the leaf litter and above the mineral soil. This layer is distinguished from litter by its degree of decomposition -

within duff the origin of the organic matter can no longer be identified (e.g., as leaves, twigs, etc.). The material in the duff layer is typically held together by fungal mycelia.

Woody fuels are measured in English units in order to make the data compatible and comparable with other regional data sets and fuels models.

1. Establishing fuels transects

Fuels are sampled on four transects that extend out 50 feet (15.24 m) from the plot (Fig. 1). Two fuels transects originate at the end of transect 1 while the other two fuels transects originate at the origin of transect 3. Fuels transects are not permanently marked. Determine the bearing and slope of each fuels transect at the first plot visit.

Bearing: Use the information below to determine the bearing for each fuels transect. Record these bearings in the appropriate boxes on the data sheet.

Fuel transect	Bearing
A	Bearing of the plot aspect + 180
B	Same as transect azimuth
C	Bearing of transect azimuth + 180
D	Bearing of the plot aspect

Slope: Measure percent slope of each fuels transect (from end to end) to the nearest one percent. The observer with a clinometer should stand over the rebar at transect origin and sight to the observer's eye height on the second person located at the 50 feet (15.24 m) mark.

2. Setting up the transects

Read the metal tag on the rebar to locate the end of transect 1 and the origin of transect 3. Use a chaining pin to fasten the "0" end of the meter tape to the appropriate position. Use a compass and the fuels transect bearing to run the transect in the appropriate direction. Use another chaining pin to fasten the tape at the 50 feet (15.24 m) mark. Avoid trampling the sampling area on the right side of the fuels transects (Fig. 1).

3. Woody Fuels

From the origin at the plot corner, sample along the right edge of the tape (Fig. 1). Any dead and down woody material intersected by the tape is tallied in the columns under the corresponding size class (Fig. 2). Do not count dead stems and branches attached to rooted shrubs or trees. Make sure to count dead stems and branches of down woody material suspended above the ground (e.g., branches of a fallen pinyon tree that cross the tape at any height).

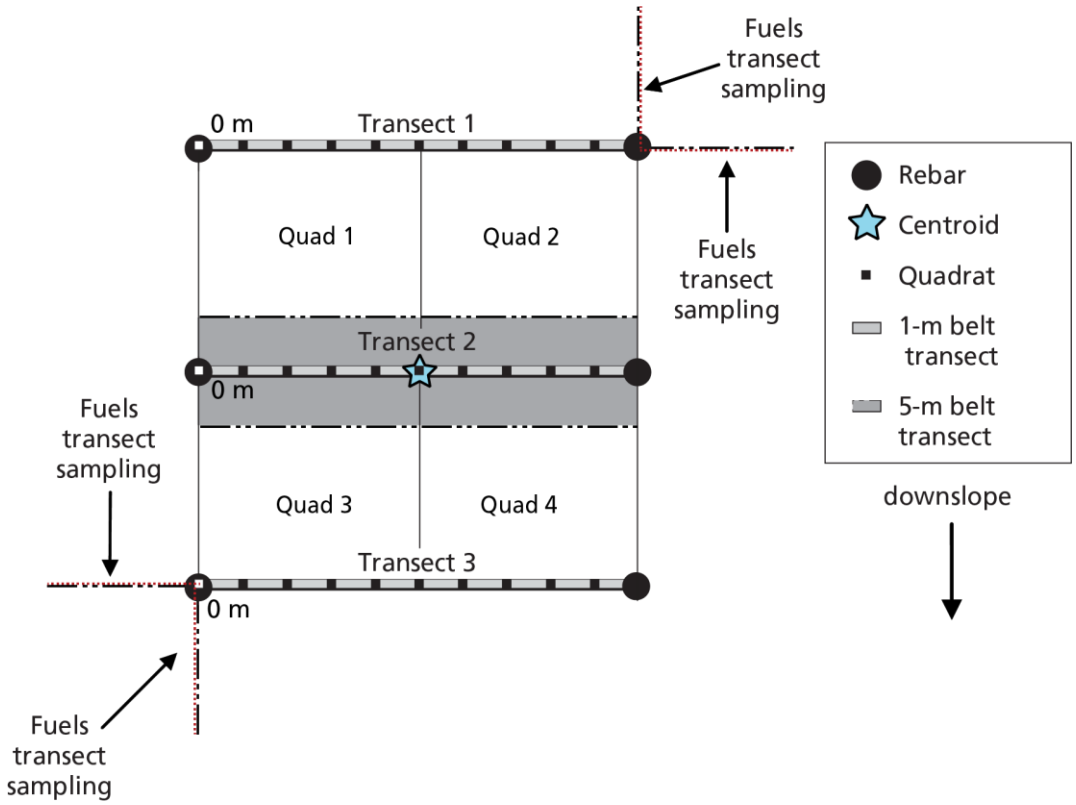


Figure 1. Layout of fuels transects on woodland and forest plots. Transects are sampled on the side indicated by the red dashed line.

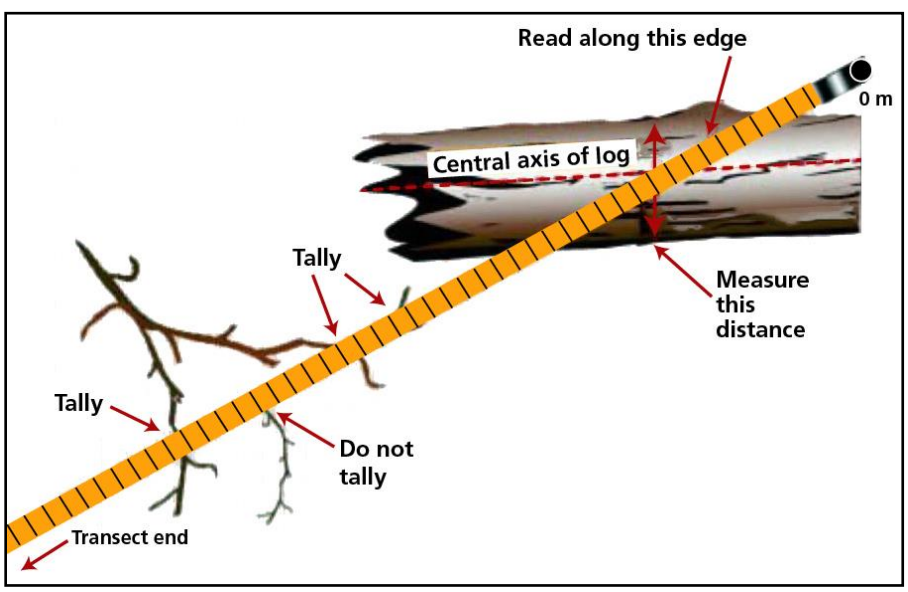


Figure 2. Tally rules for dead and down fuel (modified from USDI 2003). Count all intersections including each individual intersection of a curved piece. All intersections must include the central axis in order to be tallied.

There are four size classes of woody fuels:

0.0 inches < **1-hour fuels** ≤ 0.25 inches

0.25 inches < **10-hour fuels** ≤1.0 inches

1.0 inches < **100-hour fuels** ≤ 3.0 inches

1000-hour fuels > 3.0 inches

Use the Go-No-Go gauge with openings of 0.25, 1, and 3 inches to easily determine the appropriate size class of material encountered along the transect (Fig. 3). You will tally the 1-hour, 10-hour, and 100-hour size classes for the distances listed in Table 1.

Diameters of 1000-hour fuels are measured at the point where they are intersected along the sampling plane. Measurement of all 1000-hour fuels is taken perpendicular to its central axis at the point where the tape crosses (Fig. 2). Only record 1000-hr fuels that cross the end of the tape when the central axis intersects the sampled length of the tape. Fill in the following information for each 1000-hour fuel encountered on the transect:

Transect: Fill in the correct transect (A, B, C, or D).

Diameter: Measure the diameter to the nearest 0.5 inch. If the piece of wood is not resting on the ground and is within reach, use a diameter tape to ascertain the diameter. Otherwise, measure the diameter by holding a ruler or tape measure above the log. To avoid parallax error, position your eyes directly over each end of the tape in sequence. If the portion of the bole intersected by the sampling plane is out of reach overhead, estimate the diameter. Visually assess rotten logs as a cylinder and estimate the diameter. This reconstructed diameter should reflect the existing wood mass, not the original sound diameter.

Decay Class: Record whether the log is sound or rotten. Consider a piece of fuel rotten when it is obviously punky or can be easily kicked apart at the intersection point.

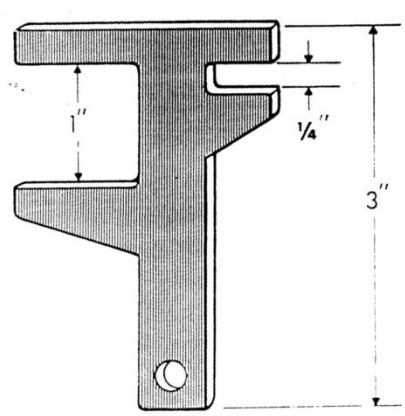


Figure 3. Example of a Go-No-Go Gauge.
(Brown, 1974)

Table 1. Transect lengths for fuel classes.

Fuel Class	Transect Length
1 hour	0-6 ft. (1.83 m)
10 hour	0-6 ft. (1.83 m)
100 hour	0-12 ft. (3.66 m)
1,000 hour	0-50 ft. (15.24 m)

4. Litter and Duff

Take depth measurements for litter and duff at 2, 4, 6, 8, 10, 12, and 14 m along each fuel transect. Sample on the same side of the transect tape as for woody fuels measurements. Record the depth the nearest tenth of a centimeter. Do not take measurements near rebar because it is an unnatural structure that traps materials.

At each sampling point, gently insert a trowel into the ground until you hit mineral soil, then carefully pull it away exposing the litter/duff profile. Locate the boundary between the litter and duff layers. Use a ruler to vertically measure the litter and duff to the nearest tenth of an centimeter. Refill holes created by this monitoring technique. Do not include twigs and larger stems in litter depth measurements. Record duff and litter depth for each point.

- If you hit a rock, root, or buried log below litter or duff instead of mineral soil, record the depth of litter and duff above the buried object.
- If moss is present, measure the duff from the base of the green portion of the moss.
- If you encounter deep litter and duff, make sure to measure the entire depth until you reach mineral soil. This may require digging a bigger hole but is necessary for accurate estimates of fuel volume.
- If you encounter an ash layer in the litter or duff, do not include this in your measurement of duff or litter depth. Record depth of duff and litter down to mineral soil excluding the ash from your measurement.

5. References

Brown, J. K. 1974. Handbook for Inventorying Downed Woody Materials. USDA Forest Service, General Technical Report INT-16.

USDI National Park Service. 2003. Fire Monitoring Handbook. Boise (ID): Fire Management Program Center, National Interagency Fire Center, 274p.

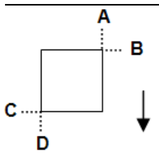
Fuels Data Sheet (p.1)

Data entered by: Data verified by:

NCPN Upland Monitoring

Park Code: **PlotID:** **Date:** **Page _____ of _____**

Observer: **Recorder:**



fuels transect

	A	B	C	D
bearing (˚)				
slope (%)				

# of intercepts

transect	1-hr (0-0.25 in.)	10-hr (>0.25-1 in.)	100-hr (>1-3 in.)
A			
Totals:			

B			
Totals			

C			
Totals			

D			
Totals			
transect length	0-6 feet (1.83 m)	0-6 feet (1.83 m)	0-12 feet (3.66 m)

1000-hr fuels (> 3 in.)

Transect	Diameter (in.)	Decay Class (sound or rotten)

0-50 feet (15.24 m)

Fuels Data Sheet (p.2) Data entered by: Data verified by:

NCPN Upland Monitoring

Park Code: **PlotID:** **Date:** **Page _____ of _____**

Observer: **Recorder:**

Litter and Duff Depth

	depth (cm)							
point on transect (m)	**A**		**B**		**C**		**D**	
	litter	**duff**	**litter**	**duff**	**litter**	**duff**	**litter**	**duff**
2								
4								
6								
8								
10								
12								
14								

Upland Vegetation and Soils Monitoring Protocol for Park Units in the Northern Colorado Plateau Network

Standard Operating Procedure (SOP) # 15

Sampling Gambel Oak/Mixed Montane Shrub Plots

Version 1.08 (December 2017)

Revision History Log:

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #
1.00	7/2009	D. Witwicki	Clarified instructions for tagging large dbh oak; formatting; added oak point-intercept data sheet	consistency	1.01
1.01	3/2010	D. Witwicki	Removed shrub line-intercept	Repetitive data with point-intercept cover.	1.02
1.02	3/2011	D. Witwicki	Fuels no longer sampled in oak; cover of top kill no longer estimated	Measurements not ecologically relevant for oak, not repeatable	1.03
1.03	1/2012	D. Witwicki	Gambel oak measured at dbh instead of root crown; species richness not measured	Methods used in 2011 field season	1.04
1.04	11/2013	D. Witwicki	Updated point-intercept data sheet	Incorrect code	1.05
1.05	12/2014	S. Karinen	Added repeat photos and details to recording crown health	For consistency	1.06
1.06	2/2016	S. Karinen	Added tree seedling and sapling sampling	Added methods	1.07
1.07	12/2017	A. Wondrak-Biel, D. Witwicki	Updated Figure 1	For publication	1.08

This SOP outlines procedures for collecting and recording data for Gambel oak/mixed montane shrub plots, including numerous modifications to other SOPs.

1. Plot establishment and revisit

Plots should be set up according to SOP #6 with the following exceptions (Fig. 1):

-Transects are 20 m long.
-Transects are separated by 10 m.

In the database, make sure to record the position along the transect where rebar is installed. At a minimum, you will need to change the end default of 50 m to 20 m.

2. Repeat photos

Follow SOP #7 to take photos of the origins and ends of each transect.

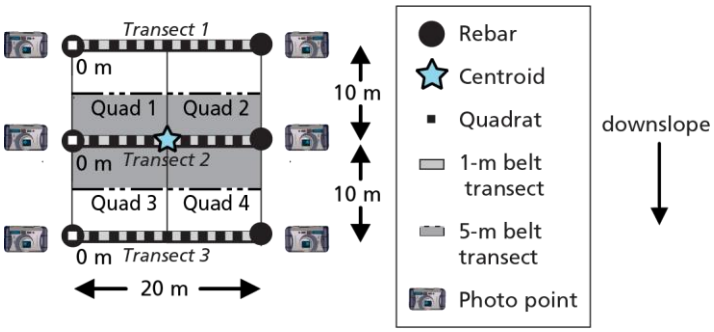


Figure 1. Locations of transects and monitoring measurements at oak plots, including repeat photos, 1-m2 quadrats for sampling frequency of exotics, 1-m belt transects for measuring seedlings, a 5-m belt transect for measuring saplings, and overstory trees censused in Quads 1–4.

3. Point intercept

Follow SOP #8 to sample cover with the laser. Start at 0.25 m and collect a point every 0.25 m for a total of 80 points sampled on each transect. Use the Point Intercept (Oak) data sheet.

4. Exotic frequency

Follow SOP #10 to sample exotic frequency in 1-m^2 quadrats. Record frequency every 2 m along each transect starting at the 0-m mark. Use the Exotic Frequency (Oak) data sheet.

5. Tree seedling density

Follow SOP #10 to record tree seedlings in the 1-m belt upslope of each transect.

6. Tree sapling density

Follow SOP #13 to record live and dead tree saplings (2.5 – 15 cm diameter) in a 5-m belt centered on transect 2.

7. Measuring overstory trees

Follow SOP #13 to record and permanently mark any trees in the 20 m x 20 m plot. Unlike forest and woodland plots, record trees in all four quadrants. Use a crown health of 5 to designate dead trees and a crown health of 6 to designate previously tagged trees as dead and down, but do not otherwise record this measure for live trees. Do not record crown class for trees in oak scrub/mixed montane shrub plots. In addition to trees, record and permanently mark any Gambel oak greater than 10 cm in diameter at breast height following the procedures in SOP #13.

8. Site impact assessment

Follow SOP #12 to record disturbances at each site. In addition, take photos of any Gambel oak mortality or top kill that you find. Top kill is defined as dead branches or parts of branches on the upper part of an otherwise healthy shrub. Top kill does not include dead branches remaining after fire (usually charred) that are located above regrowth.

Point Intercept (Oak)

Data entered by: Data verified by: p.1

NCPN Upland Monitoring

Park Code: **PlotID:** **Date:**

Observer: **Recorder:** **Transect:** 1 2 3

Point (m)	Top Canopy	Lower canopy 1	Lower canopy 2	Soil Surface	Disturb-ance	Point (m)	Top Canopy	Lower canopy 1	Lower canopy 2	Soil Surface	Disturb-ance
0.25						6.5					
0.5						6.75					
0.75						7.0					
1.0						7.25					
1.25						7.5					
1.5						7.75					
1.75						8.0					
2.0						8.25					
2.25						8.5					
2.5						8.75					
2.75						9.0					
3.0						9.25					
3.25						9.5					
3.5						9.75					
3.75						10.0					
4.0						10.25					
4.25						10.5					
4.5						10.75					
4.75						11.0					
5.0						11.25					
5.25						11.5					
5.5						11.75					
5.75						12.0					
6.0						12.25					
6.25						12.5					

Additional canopy layers can be added on the other side

Top canopy
Species code

Lower canopy layers
Species code
L = Litter
WD = Woody debris

Use "-D" for dead parts of species

Soil Surface

S = Bare soil	SR = Small rock
U = Crust, undiff.	LR = Large rock
CY = Cyanobacteria	BR = Bedrock
LC = Lichen	SL = Scat, livestock
M = Moss	SW = Scat, wildlife
L = Litter	WA = Water

WD = Woody debris
Species code (for basal hit)

Disturbance

Ant =	Ant mound
Auto =	Motor vehicle
Bike =	Bicycle
Exc =	Wildlife excavation
HT =	Human track/trail
LT =	Livestock track/trail
WT =	Wildlife track
Wash =	Wash
Oth =	Other anthropogenic
Und. =	Undifferentiated

p.2

Point (m)	Top Canopy	Lower canopy		Soil Surface	Disturb-ance
		1	2		
12.75					
13.0					
13.25					
13.5					
13.75					
14.0					
14.25					
14.5					
14.75					
15.0					
15.25					
15.5					
15.75					
16.0					
16.25					

Point (m)	Top Canopy	Lower canopy		Soil Surface	Disturb-ance
		1	2		
16.5					
16.75					
17.0					
17.25					
17.5					
17.75					
18.0					
18.25					
18.5					
18.75					
19.0					
19.25					
19.5					
19.75					
20.0					

Additional canopy layers

Point (m)	Lower Canopy		
	3	4	5

Point (m)	Lower Canopy		
	3	4	5

Exotic Frequency (Oak)

Data entered by: Data verified by:

NCPN Upland Monitoring

Park Code: **PlotID:** **Date:**

Observer: **Recorder:**

Transect: 1 2 3

Exotic Frequency – Quadrats

Species	Meter									
	0	2	4	6	8	10	12	14	16	18

Transect: 1 2 3

Exotic Frequency – Quadrats

Species	Meter									
	0	2	4	6	8	10	12	14	16	18

Upland Vegetation and Soils Monitoring Protocol for Park Units in the Northern Colorado Plateau Network

Standard Operating Procedure (SOP) # 16

Unknown Plant Species

Version 1.03 (March 2013)

Revision History Log:

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #
1.00	3/2009	D. Witwicki	Updated unknown species codes; formatting; clean up	Consistency	1.01
1.01	3/2011	D. Witwicki	Rewording for clarity		1.02
1.02	3/2013	D. Witwicki	Added sampling method to data sheet	To be consistent with edits to the database	1.03

Sometimes it may be difficult or impossible to determine the specific identity of individual plants encountered during sampling. Crews may be unfamiliar with a plant or unable to distinguish one species from other similar species at the time of sampling. Before sampling, review the field herbarium for that park and any previously collected unknown species and use existing unknown names whenever possible. A list of necessary equipment for this procedure can be found in SOP #1.

1. When an unknown plant is encountered

Follow the procedures below when you encounter a species that you cannot identify.

1. Search the immediate area surrounding the point or transect, looking for specimens of the unknown plant that could help you identify the species (i.e., due to the presence of flowers or fruits).

   Do not spend excessive time attempting to identify a specimen. It is more important to complete a minimum of one plot per day. Figure out unknowns at camp or in the office, rather than attempting to identify unknowns while at the plot.

2. Determine if the plant is identifiable. Some plant specimens may not be identifiable because they are dead and falling apart, are grazed to the ground, or have no identifying features other than life form. In these cases, use the most appropriate general unknown plant code.

Code	Unknown plant type
UNK	unknown species (unknown life form)
UNKAF	unknown annual forb
UNKAG	unknown annual graminoid
UNKF	unknown forb
UNKG	unknown graminoid
UNKH	unknown herb (forb or grass)
UNKPF	unknown perennial forb
UNKPG	unknown perennial graminoid
UNKS	unknown shrub
UNKT	unknown tree

If you think the unknown species could be identified, follow the directions below. Remember, NCPN botanists have extensive experience identifying plants in the region, and may be able to identify dead plants or those lacking flowers or fruits, so when in doubt, make a collection.

3. Create an unknown species code. If you cannot identify the species, create a unique code using the following system. It is especially important for specimens that do not have identifiable characteristics in this sampling year, but may be identified in future years. *Whenever a species identity is questionable, use the unknown species protocol. Do not guess!*

   Unknown Code = unk + 4 letter park code + plot number + your initials + collection number for the plot (e.g., unkCANY137-ST1)

   On paper data sheets, record this code in the appropriate column instead of the species name. In the database, use the Unknown Species tab to add a new record to the species picklist.

4. Select the required plant type information. For forbs and grasses, it is especially important to note whether it is annual or perennial (to the best of your ability), and for perennial grasses, whether it is rhizomatous or a bunchgrass.
5. Give a very brief general description of the plant species. This should be a few words that you will remember if you encounter the same unknown species somewhere else on the plot or on another plot (e.g., opposite hairy round leaves).
6. Fill in the sampling method, transect number, and position on the transect where the unknown plant was encountered. This is particularly important if the specimen was encountered on a measurement other than point intercept.
7. Take a photograph of the unknown plant if you think important features of the plant may be difficult to see after it is collected or if it is the only one you can find.
8. Record if the specimen was collected, photographed, and your best guess if you have one.
9. Fill in any remaining fields that might be helpful, including the following:

Leaf Characteristics- leaf type, leaf margin, leaf surface, petiole, etc.

Stem Characteristics- shape, pubescence, markings, and color of the stem, bud characteristics.

Flower Characteristics- floral formula, location (axillary or terminal), habit (indeterminate or determinate), pubescence, and color.

Microhabitat Characteristics- relevant habitat characteristics, especially if it is different from the rest of the plot (e.g., wash bottom, clayey soil in depression, etc.).

These fields are mostly used when you cannot collect a specimen or you think that some of these plant parts may be damaged during transport.

10. Continue looking for identifiable specimens of unknowns as you sample the rest of the plot.

11. Use the same unknown code each time you encounter the unknown species. In the database, your unknown code will now be included in the species picklist, along with the brief description you gave it. It can be selected like any other species codes.

12. Identify to genus only when appropriate. It is permissible to identify a plant only to the genus level if no identifiable parts are present for keying, or if hybridization makes species delineation difficult (e.g., *Opuntia* sp., *Yucca* sp., etc.). Try to avoid identifying to genus, since these records have limited use in data analysis.

2. Collecting unknown plants

After it becomes apparent that you will not be able to identify the plant to species in a timely manner at the plot, make a collection.

1. Collect specimens from outside of the monitoring plots whenever possible. Do not collect the plant if there is the only one on the plot. Do not collect specimens from the sampling area above the tape.

2. If you must collect from inside a monitoring plot, remove only a minimal amount of plant material. Do not remove roots of perennial species that are collected within the plot.

3. Attempt to collect as many identifiable parts as possible, including flowers, fruits, and leaves. It is important to collect roots of forbs and grasses when you are uncertain if it is annual vs. perennial or rhizomatous vs. bunchgrass. You may need to collect from more than one plant to get enough identifiable material, but don’t be excessive.

4. Wrap a piece of masking tape around the plant and use a fine-point permanent marker to label it with the unknown species code.

5. Carefully place the specimen inside a resealable plastic bag and label with the unknown species code, date, and collector.

6. Place the specimen in a protected place in your backpack and in a shady spot until you get back to camp. With assistance from the lead botanist, attempt to identify the plant when you are back at camp.

7. If the specimen cannot be identified right away, preserve the bag in a cooler as soon as possible. Make sure the specimen does not get wet. If a cooler is not available, press the plant between two sheets of newspaper. Make sure to label the paper that the specimen is pressed between with the unknown species code.

8. After returning to the office, check to make sure that the field crew leader received all unknown specimens stored in plastic bags.

Although everyone is encouraged to learn new plants while in the field, please do not make excessive collections of plants. Remember, we are working in national parks, and the vegetation is protected.

Unknown Plant Species

Data entered by: Data verified by:

NCPN Upland Monitoring

Park Code:	**Plot ID:**	**Date:**	**Collected by:**
Method:	**Transect:** 1 2 3	**Position on transect (m):**	**Photos:**

Unknown species code: _____

Plant Type & General Description: *tree* *shrub* *grass* *forb* *other*_____

Forbs and grasses: *annual* *perennial*

Perennial Grasses: *bunchgrass* *rhizomatous*

Most salient feature:

Leaf Characteristics (optional):

Leaf Type: (compound/simple, arrangement, etc.)

Margin:

Other: (pubescence, sap, stipules, etc)

Stem Characteristics (optional): (shape, pubescence, bud)

Flower Characteristics (optional): (color, location, floral formula)

Microhabitat Characteristics:

Collected: *Yes* *No*

Best Guess:

Confirmed to be:

Identified by: Date:

Upland Vegetation and Soils Monitoring Protocol for Park Units in the Northern Colorado Plateau Network

Standard Operating Procedure (SOP) # 17

After each Field Visit and after the Field Season

Version 1.02 (August 2016)

Revision History Log:

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #
1.00	3/2011	S. Topp, D. Witwicki	Added detail, including section on after each field visit	Increase usability	1.01
1.01	8/2016	D. Witwicki	Minor updates to match current procedures		1.02

This SOP details procedures performed after each field visit and at the end of the field season, including equipment maintenance and data management.

1. After each Field Visit

1. Follow check-out procedures with Glen Canyon dispatch detailed in the NCPN Field Safety SOP.

2. Make sure that all cameras, lasers, satellite phones, and GPS units are returned to the office.

3. Complete any data entry and verification. Resolve any questions with the crew members who collected the data.

4. Organize and file any data sheets.

5. Download photos and organize by park code and plot number.

6. Charge camera, satellite phone, and vehicle jump starter batteries.

7. Return GPS units to the GIS technician for downloading and charging.

8. Return field laptops and all accessories to the data manager's office.

9. Report all broken or missing equipment to the field crew coordinator. Repair equipment if possible or indicate if new equipment needs to be purchased before the next field hitch. Clean stoves and any other equipment that are dirty.

10. Remove any plant collections from the cooler, verify the identity if possible, or place them in the plant press.

11. Clean the insides of vehicles. Especially dirty or muddy vehicles may be washed as often as monthly when needed. Report vehicle repair needs to the field crew coordinator.

12. Be sure any seeds that have attached themselves to your clothing, pack, or shoes have been removed prior to going back out to the field. This is to prevent the spread of weeds between parks.

13. Organize monitoring boxes for the next hitch. Also, clean up the conference room before leaving for multiple days off.

14. Fill out and submit any necessary administrative paperwork (i.e., travel vouchers, timesheets, extra work authorizations, leave requests).

15. Complete a trip report detailing the location and dates of field work, crew members participating, work completed, travel and housing availability, safety concerns and how they were accommodated, weather conditions, any equipment problems or needs, and any other pertinent information. Also note any interesting or unusual findings, observations of disturbance, human or animal activity, deviations from the SOP, or access issues.

16. The crew leader should brief the crew on what to expect for the next field hitch (where they will be going, who will be working with whom, etc.).

2. After the Field Season

1. Equipment maintenance. Inspect all equipment for damage and note any missing equipment. Clean and repair all equipment prior to returning it to the project leader.

2. Equipment inventory. Ensure that adequate supplies are on hand for the next field season and create a list of supplies that need to be ordered.

3. Complete identification of unknown plants. The field crew leader is responsible for ensuring complete resolution of all unknown plants. Plants are identified to species, family, or at least life form. Where appropriate, annotate the data sheets with the correct identifications and ensure that species are entered correctly in the database.

4. New species follow-up. The field crew leader is responsible for ensuring that plant species not on current park lists are submitted for NPSpecies updates. The field crew leader is also responsible for mounting, labeling, and preparing voucher specimens for any new species collected in a park unit. Update park plant species lists and the species list in the database.

5. Field herbaria. The field crew leader mounts and labels appropriate specimens for the field herbarium.

6. Data management. The field crew leader is responsible for ensuring that all data sheets are completed properly.

7. Data entry. The field crew leader is responsible for ensuring that all data are entered and verified according to procedures outlined in SOP #18. Also make sure that all photos are downloaded to the X:\ drive and correctly labeled.

8. Field season review procedures. Prior to the departure of the field crew, the project manager will query the field crew for issues with existing monitoring protocols and field logistics and will seek recommendations for improvements.

9. Logistics. The field crew leader updates access documents with new or revised logistical information, such as road closures, park personnel turnover, etc.

10. Organization. Organize all maps and paperwork from the previous field season. Clean and organize the conference room. Clean out and prepare plant presses for the next field season.

Upland Vegetation and Soils Monitoring Protocol for the Park Units in the Northern Colorado Plateau Network

Standard Operating Procedure (SOP) # 18

Data Management

Version 1.15 (March 2016)

Revision History Log:

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #
1.00	8/1/2008	H. Thomas	Changes associated with 2008 protocol.	To document database and data management procedure changes related to 2008 protocol changes, e.g., new field methods.	1.10
1.10	9/2009	H. Thomas & D. Witwicki	Changes associated with 2009 protocol.	To document database and data management procedure changes related to 2009 protocol changes, e.g., new forest/woodland methods.	1.11
1.11	8/2011	H. Thomas	Updates due to protocol changes in 2010 and 2011.	To document database and data management procedure changes related to protocol changes made in 2010 and 2011.	1.12
1.12	12/2012	H. Thomas	Updates due to protocol changes in 2012.	To document database and data management procedure changes related to protocol changes made in 2012.	1.13
1.13	12/2013	H. Thomas	Updates due to protocol changes in 2013.	To document database and data management procedure changes related to protocol changes made in 2013.	1.14
1.14	3/2016	H. Thomas	Added the *NoDataCollected* table to appendix A, and made minor edits throughout the document.	To document database modifications for the 2016 field season and to reflect current data management practices.	1.15

This Standard Operating Procedure (SOP) describes data management procedures for all data derived from upland monitoring in Northern Colorado Plateau Network (NCPN) park units. The procedures for data management given in this SOP follow guidelines and standards that are described in the NCPN Data Management Plan (Beer et al 2005).

Definitions and Acronyms

FGDC	Federal Geographic Data Committee. The interagency committee that promotes the coordinated development, use, sharing, and dissemination of geographic data.
GIS	Geographic Information Systems
GPS	Global Positioning System
I&M	Inventory & Monitoring Program of the National Park Service
NCPN	Northern Colorado Plateau Network
NPS	National Park Service
PDF	Portable Document Format
PDLC	Project Data Life Cycle
SOP	Standard Operating Procedure
Accepted data	Data that have undergone all QA and QC procedures as defined in the published protocol and associated SOPs.
Data products	Information that is derived from accepted project data.
Data Store	The NPS-wide repository for documents, publications, and datasets related to NPS natural and cultural resources (https://irma.nps.gov/DataStore).
Master database	Project-specific database that stores the full project dataset and is used for viewing, summarizing, and analysis. Contains only accepted data.
Primary dataset	The dataset that is the most comprehensive and representative of the data associated with a project. This dataset can normally be used independently of other project datasets and is often distributed to external users. The primary dataset can be tabular or spatial. For most NCPN monitoring projects, the primary dataset will be either a Microsoft (MS) Access database or a geodatabase.
Project level metadata	A metadata record associated with the primary project dataset that contains cross references to all project data products and is uploaded to the Data Store.
Quality assurance (QA) procedures	Procedures used to ensure collection of data with minimal errors.
Quality control (QC) procedures	Procedures used to flag or modify data to ensure that data meet established data quality standards.
Raw data	Data that have not been subjected to either quality control or documentation procedures; includes data recorded by hand on hard-copy forms, digital files from handheld devices, GPS receivers, telemetry data loggers, etc.
Spatial dataset	A dataset that is natively read by mapping software; often produced by mapping software, such as ESRI ArcMap and ArcInfo; also includes georeferenced imagery, geodatabases, as well as hardcopy aerial photographs, satellite imagery and maps.
Tabular dataset	A dataset organized in a table or group of tables where each column and row has a specific interpretation; often produced by MS Excel, MS Access, database, or

	statistical software, and managed as text, spreadsheet, or relational databases.
Working database	A project-specific database for entering and processing data for the current season (or other logical period of time).

1 Database Design

The primary dataset associated with the NCPN upland monitoring project is a tabular dataset stored in a Microsoft (MS) Access database, referred to subsequently as the upland database. The upland database is compatible with Access 2007 and 2010, and has a frontend/backend file structure:

- *Upland.accdb*: This frontend file contains all queries, forms, reports, and associated Visual Basic (VB) application code.
- *Upland_be.accdb*: This backend file contains the database tables.

The frontend/backend file structure allows multiple users to enter data in a network environment, and allows for easy backup and transfer of the data tables. Users typically launch the frontend file, and a utility will prompt them to establish a link to the backend file.

The upland database was developed following the NPS Natural Resource Database Template (NRDT), which is based on a location record, one or more related event records, and observation data elements linked to each event. Figure 1 shows the relationships between the primary upland database tables (all tables are not shown).

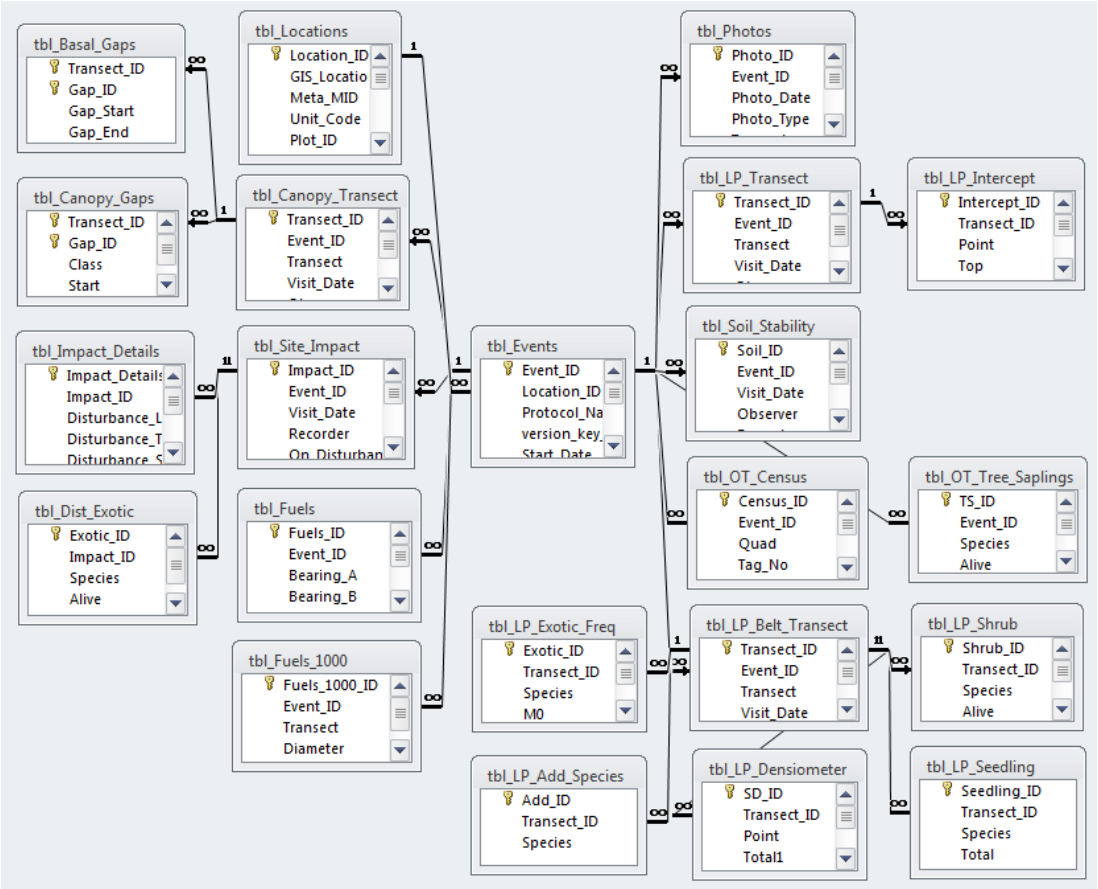


Figure 1 Data Model for Upland Database

Each upland monitoring site or plot has a record in *tbl_Locations*, which stores basic location information as well as soil and vegetation characteristics that are recorded during site characterization and plot establishment. Each plot can have many site visits, which are recorded in *tbl_Events*. During each site visit, several different types of observations are recorded. The observations recorded during a site visit vary depending upon the Vegetation Type of the plot (forest, grassland/shrubland, oak scrub, or woodland; refer to SOPs 7-15 for details about which observations are recorded for each of these types). The main types of observations recorded during a plot visit are described briefly below:

- For each of the three transects associated with a plot:
    - Cover of vegetation and soil surface features is measured using the line-point intercept sampling technique and recorded in *tbl_LP_Transect* and *tbl_LP_Intercept.*
    - Gap intercept estimates between plant canopies are obtained and recorded in *tbl_Canopy_Transect* and *tbl_Canopy_Gaps*.
    - Gap intercept estimates between plant bases are obtained and recorded in *tbl_Canopy_Transect* and *tbl_Basal_Gaps*.
    - Several measures are recorded in a 1-meter belt transect:
        - Density of live shrubs and tree seedlings is recorded in tables *tbl_LP_Belt_Transect*, *tbl_LP_Seedling*, and *tbl_LP_Shrub*.

    - Additional species detected in the 1-meter belt are recorded in tables *tbl_LP_Belt_Transect* and *tbl_LP_Add_Species*.
    - Estimates of overstory canopy cover are recorded in *tbl_LP_Belt_Transect* and *tbl_LP_Densiometer*
    - The presence of exotic plant species within quadrats is recorded in tables *tbl_LP_Belt_Transect* and *tbl_LP_Exotic_Freq*.
- Density of tree saplings is measured in a 5-m belt transect and recorded in *tbl_OT_Tree_Saplings*.
- Attributes of overstory trees are measured in Quadrant 1 and recorded in *tbl_OT_Census*.
- Fuels are measured in four separate transects and recorded in *tbl_Fuels* and *tbl_Fuels_1000*.
- Estimates of soil aggregate stability are obtained and recorded in *tbl_Soil_Stability*.
- Several photos are taken during each site visit and recorded in *tbl_Photos*.
- Site impacts are assessed and recorded in tables *tbl_Site_Impact* and *tbl_Impact_Details*. Exotic plant species observed during a timed plant walk are recorded in tables *tbl_Site_Impact* and *tbl_Dist_Exotic*.

Each site visit is linked to tables *tbl_master_verison* and *tbl_SOP_version*, which together define the narrative and suite of SOP versions in effect at the time of the site visit. Documentation of all tables and fields in the upland database is provided in Appendix A.

2 Populating the Upland Database

Prior to each field season, the working database for the upland monitoring protocol is prepared for the upcoming field season's data entry. The working database is initially an "empty" database, i.e., it contains no observation data, just populated lookup tables and certain "static" plot information (e.g., location, site characterization information). The working database is used for data entry, verification, and validation for a given field season. After the dataset in the working database is quality checked, it is merged into the master upland database.

The upland field crew records data electronically using ruggedized field laptops or tablets that run the upland database. Paper data sheets are used as a backup data collection method. Separate copies of the working database are loaded onto each of the field laptops prior to a field trip. These database copies are initially empty. At some point after the field trip, the data in these copies are merged into the working database. For the remainder of this document, the term "upland database" refers to either the working database or one of its copies that resides on a field laptop.

The upland database is populated via a combination of data import and data entry, using the procedures described below:

- Prior to each field trip, data management staff ensures that all plots expected to be visited and/or established are loaded into the working database. This plot

information is obtained from the project manager. For new plots, only the required fields (Unit Code, Plot ID, and Vegetation Type) are populated.

- The working database is then used to create an empty database that is loaded onto the field laptops. Each empty database contains no observation data, just populated lookup tables and plot location information.
- For each plot that is visited and/or established, plot visit and establishment data are entered in the database on the field laptops. If a field laptop is unavailable, the data are recorded on paper and then entered into the working database at a later time (as soon as possible after the plot visit). For newly established plots, location information is recorded using GPS units.
- After each field trip, a merging tool is used to merge the data on the field laptops into the working database. This tool appends all plot visit data and updates *tbl_Locations* with any plot establishment data. Also after each field trip, GPS data are downloaded, corrected, and visually reviewed.
- At the end of the field season, after more comprehensive data quality checking is performed, the corrected GPS data are uploaded to *tbl_Locations* in the working database. Table 1 lists the fields that are either imported or derived from GPS data (see Appendix A for field descriptions).

Table 1 Fields Imported/Derived from GPS Data into tbl_Locations

T1_Elevation	T2_Elevation	T3_Elevation	E_Coord	Datum
T1O_UTME	T2O_UTME	T3O_UTME	N_Coord	UTM_Zone
T1O_UTMN	T2O_UTMN	T3O_UTMN	Elevation	Max_PDOP
T1E_UTME	T2E_UTME	T3E_UTME	Coord_Units	Rcvr_Type
T1E_UTMN	T2E_UTMN	T3E_UTMN	Coord_System	

Plot location data is expected to be relatively static over time. Thus, GPS data is normally only imported when a plot is initially established. If the location information for a given plot changes for some reason (e.g., a rebar gets lost and it's not possible to establish the new rebar at the same location), it will need to be re-imported from the GPS files.

The majority of data in the upland database will be populated via data entry. Data entry should occur as soon as possible after data collection is completed and by the person who collected the data or someone who is familiar with the project and data. The primary goal of data entry is *to record data in digital form with 100% accuracy, whether transcribing the data from paper records or keying the data into a field laptop as a crew member dictates.*

The Upland Database User's Guide (NCPN-NPS 2016a) provides data entry instructions and identifies differences between office and field data entry procedures. The project manager makes certain that persons performing data entry are familiar with the user's guide, understand how to enter data and follow the protocols, and understand how to operate field laptops. Data entry technicians are responsible for becoming familiar with the field data forms, field laptops, database software, database structure, and any standard codes for data entry. The data manager, in conjunction with the project manager, will

ensure that the user's guide is kept current as new features are implemented in the database and/or as data entry procedures change.

QA/QC measures for data entry are built into the database forms to automatically validate data where possible. Data entry forms maximize the use of auto-filled fields, range limits, pick lists, and spelling checks. Error messages alert the operator to correct mistakes. Any errors or omissions that become apparent during data entry should be resolved as soon as possible. In such cases, the data entry technician should contact the person who collected the data for clarification. The appropriate modifications should then be made to the paper field sheets following the instructions provided in Section 3.

3 Data Verification and Validation

To ensure that upland monitoring data are of the highest possible quality, verification and validation of upland monitoring data will be performed according to the procedures described in the NCPN Quality Assurance and Quality Control Guidance Document (NCPN-NPS 2008a). *Data verification* checks that data entered into a secondary (i.e., electronic) format match the source data, while *data validation* checks that the data make sense. Note that the data verification procedures described in the next section apply primarily to data recorded using hard copy data sheets.

3.1 Data Verification

Data verification immediately follows data entry and involves checking the accuracy and completeness of the computerized records against the hard copy field records and identifying and correcting any errors. The following verification methods will be used to verify upland data:

1. **Visual review at data entry**. The person doing data entry verifies each and every record after input and immediately corrects any errors.
2. **Visual review after data entry**. All records are compared to the original data source. Each data field on the corresponding electronic data entry form is compared with the original values from the hard copy, preferably by a second person who did not perform the data entry. Any errors that are discovered are corrected in the database as soon after data entry as possible.
3. **Summary queries and tallies**. Queries are run that detect broad errors such as duplicate or omitted records. Examples of such queries for upland data are given below.
    a. Listing and count of the monitoring plots established by park by year.
    b. Listing and count of the monitoring plots visited by park by year.
    c. For each year/park/plot combination, a listing and count of the transects having shrub density observations recorded.
    d. For each year/park/plot combination, a count of the number of photo points recorded.

4. **Visual review of spatial data**. Using GIS, upland monitoring plot data are visually inspected for accuracy. This review takes place at the end of the field season.

Detailed verification procedures are provided in Upland Monitoring Quality Assurance and Quality Control Procedures (NCPN-NPS 2016b).

3.2 Data Validation

While many errors are prevented by including validation routines that function during data entry, additional review of the data by the project manager is needed to detect generic and specific errors that fall outside the scope of automated validation.

Invalid data commonly consist of slightly misspelled names, the wrong date, or out-of-range errors in parameters with well-defined limits (e.g., elevation). Other errors consist of unreasonable metrics or associations. For example, suppose a species was dominant on a plot during the current year's visit, but there was no observation recorded during the previous year's visit. Such data seem questionable and might indicate a species identification error. These types of logic errors (or potential errors) can be challenging to resolve, and in some cases it may not be possible to resolve them during the current year. Such questionable data will be flagged for future resolution.

Validation queries will be of two types: one type will present tabular data in ways that records can be reviewed for content and context; the other type will perform specific calculations or routines to detect logic or range errors. Corrections to errors detected during validation require notations in the *original paper field records* about how and why the data were changed. Modifications to paper field records should be clear and concise while preserving the original data entries or notes. Validation efforts should also include a check for the completeness of a dataset since field sheets or other sources of data could be overlooked.

Detailed validation procedures are provided in Upland Monitoring Quality Assurance and Quality Control Procedures (NCPN-NPS 2016b).

3.3 Data Quality Review and Communication

The project manager and any personnel involved in data collection or entry will meet several times during the field season to discuss data quality problems and issues. Procedures may need revision if verification and validation processes reveal an unacceptable level of data quality. Quality checks may also reveal the need to modify field or computer forms if data transcription or entry errors are frequent.

Once validation has been completed, metadata will be created for the upland dataset. An important part of this metadata is data quality documentation, which consists of the verification and validation results. This data quality documentation, along with the data quality assessment form, will be used to notify end users and other project personnel of project data quality. For example, any questionable data that have been flagged will be identified. The data quality assessment form will be completed jointly by the project manager and data manager to indicate that the data have undergone all QA/QC

procedures and are documented and ready for archiving, posting and distribution. The data quality assessment form can be found in the NCPN Project Data Life Cycle Guidance Document (NCPN-NPS 2007a). The data quality documentation and assessment form will be stored in the upland project archive folder.

4 Version Control

Version control is the process of managing copies of changing files over the course of a project. Change includes any alteration to the structure or content of the files, which should not be made without the ability to fully recover a dataset as it existed before changes were made. NCPN uses several techniques to help ensure proper version control: data archiving (refer to Section 5 for data archiving details), directory structure conventions, backup procedures (refer to the user's guide (NCPN-NPS 2016a)), and database versioning.

4.1 Directory Structure Conventions

NCPN has adopted directory structure conventions for I&M project folders (NCPN-NPS 2007b). Based on these conventions, each project has an active folder for storing all current or working project files and an archive folder for storing archived project files. In general, the active project folder stores only the most recent project files (e.g., data and reports from current year, current protocol version). All active project folders are stored on the NCPN shared drive (X:). The active upland project folder is in the following location:

X:\Active_Monitoring_Projects\Upland

The structure of the active project folder is as follows (all folders are not shown):

- **Data**:
  - **Database**: Contains the working and master databases.
  - **Field_Forms**: Contains any scanned field forms for current year.
  - **GPS_Downloads**: Contains corrected GPS data for current year.
  - **Plot_Summary_Data**: Contains plot data summaries.
- **Field_Crews**: Contains files used by field crews, such as plant lists and trip reports.
- **NCPN_Working_Files**: Contains miscellaneous files used internally, such as database requirements documentation.
- **Project_Life_Cycle**: Contains files related to project data life cycle tracking, e.g., data quality assessment form, data quality documentation.
- **Protocol**:
  - **Native_Format**: Contains source files for current version of protocol.
  - **PDF**: Contains PDF of current version of protocol.
- **Protocol_Review**: Contains current documents associated with protocol reviews.
- **Reports**:
  - **Native_Format**: Contains source files used to create current year reports.
  - **PDF**: Contains PDF versions of reports produced during current year.
- **Sampling_Design**: Contains files related to sampling design.

For additional details on NCPN directory structure conventions, refer to the NCPN Directory Structure Guidance Document (NCPN-NPS 2007b).

4.2 Database Versioning

Database versioning refers to the process of tracking modifications to the database structure or application code, which can occur independently of modifications to the data. NCPN uses a version numbering scheme to track database modifications, in which modifications are grouped into software releases. Major releases are those involving significant changes to the database and are designated with the next whole number (e.g., version 2.0, 3.0, 4.0 …). For releases with only minor database changes (e.g., bug fixes), version numbers increase incrementally by hundredths (e.g., version 1.01, version 1.02, etc). Database version information is maintained within the database, and can be viewed by choosing the **About** tab on the upland main menu page, and then choosing **View release history**. Whenever a database version change occurs, copies of the database files are placed in the appropriate archive location (refer to Section 5).

5 Data Archiving

Archiving is a critical step in ensuring the long-term preservation of data. Upland data will be archived on an annual basis, after the current year's data have been quality checked and analysis and reporting have been completed. Archiving of certain data may occur more frequently, e.g., if a protocol version change occurs. Archiving will be done for both digital and hard copy data.

5.1 Digital Data Archiving

All digital upland data will be archived on the NCPN read-only shared drive (R:) in the upland archive folder (R:\Monitoring_Archive\Upland). Table 2 lists the upland monitoring digital data files that require archiving, along with their respective archive folder locations. The digital files listed in Table 2 will also be burned onto an archival-standard CD or DVD and sent to the Western Archeological and Conservation Center (WACC) according to the procedures outlined in the NCPN Archiving Guidance Document (NCPN-NPS 2010).

Table 2 Upland Digital Data Archiving Summary

Data Product(s)/ File(s)	Archive Location[1]	Comments
Database	Data\<*year*>\Database\	• Contains archived database files for a given year
Field crew files	Field_Crews\<*year*>\	• Contains archived field crew files for a given year
Field forms	Data\<*year*>\Field_Forms\	• Contains archived digital field forms (PDF) for a given year
GPS data	Data\<*year*>\GIS_Data\ GPS_Data\	• Contains archived GPS data files for a given year
Original photos	R:\NCPN_Photos_Archive\ Raw_Photo_Data_Archive\	• Archive location is an absolute path

[1] Archive location is relative to R:\Monitoring_Archive\Upland unless stated otherwise.

Data Product(s)/ File(s)	Archive Location[1]	Comments
	Monitoring\Upland\<*year*>	• Contains original, unedited (e.g., not rotated) photo files
Photos	R:\NCPN_Photos_Archive\ NCPN Photos\Upland	• Archive location is an absolute path • Renamed photo files archived as part of NCPN photo database processing - refer to NCPN Photo Management Guidance Document (NCPN-NPS 2008b) for details
Project data life cycle files	Project_Life_Cycle\<*year*>\	• Contains archived files related to project data life cycle tracking for a given year
Protocol	Protocol\<*version*[2]>\	• Contains archived protocol files for a given version
Protocol review	Protocol_Review\<*year*>\	• Contains archived protocol review documents for a given year
Reports	Reports\<*year*>\	• Contains archived report files for a given year
Sampling design files	Sampling_Design\<*year*>\	• Contains archived files related to sampling design for a given year.

5.2 Hard Copy Data Archiving

All hard copy upland data will be archived at WACC according to the procedures outlined in the NCPN Archiving Guidance Document (NCPN-NPS 2010). Table 3 lists the upland monitoring hard copy data files that require archiving, along with a summary of archiving procedures.

Table 3 Upland Hard Copy Data Archiving Summary

Data Product(s)/File(s)	Comments
Field Forms	• Original field forms stored in NCPN archives at WACC. • Digital copies retained in NCPN office.
Reports	• Archival copies stored in NCPN archives at WACC. • Hard copies retained in NCPN office.
Protocol	• Archival copies stored in NCPN archives at WACC. • Hard copies retained in NCPN office.
Protocol Review	• Archival copies stored in NCPN archives at WACC. • Digital copies retained in NCPN office.
Photos	• Slides or selected prints stored in NCPN archives at WACC. • Digital copies retained in NCPN office.
Data/Metadata Printouts	• Archival copies of project-level metadata stored in NCPN archives at WACC. • Hard copies retained in NCPN office. • Above applies to any other data/metadata printouts deemed critical to long-term upland monitoring.
Project Data Life Cycle Files	• Archival copies stored in NCPN archives at WACC. • Digital copies retained in NCPN office.

[2] <*version*> indicates protocol version key number, e.g., Version_Key_1

6 Metadata

Metadata, which is defined as structured information about the content, quality, condition, and other characteristics of data, is a critical step toward ensuring that datasets are usable for their intended purposes well into the future. Metadata can take many different forms, including formal FGDC-compliant metadata, Data Store References, and protocol version information.

To comply with NPS metadata requirements, metadata for upland datasets will be created following NCPN metadata procedures (NCPN-NPS 2007c):

- A metadata record will be created for the upland database (since it is considered the *primary dataset* for the upland monitoring project) and uploaded to the Data Store. The Data Store metadata record, also referred to as the project level metadata, will be updated annually.
- All other upland datasets and data products will be documented as cross-reference citations in the project level metadata record.

Another type of metadata specific to NCPN is the Project Data Life Cycle (PDLC) checklist, which helps to ensure that all data management activities (e.g., data verification/validation, metadata, archiving) are completed each year for monitoring projects. In accordance with this requirement, a PDLC checklist will be completed each year for upland monitoring data. For further details related to the PDLC checklist, refer to the NCPN Project Data Life Cycle Guidance Document (NCPN-NPS 2007a).

Table 4 summarizes the metadata tasks required for upland monitoring datasets and data products, and

Table 5 describes the tasks and provides references where more detailed procedures are described.

Table 4 Summary of Metadata Tasks for Upland Monitoring Data

Dataset/ Data Product	Data Store	X-Ref Citation	PDLC Check-list	MVT	Photo DB	DB Doc
Database	X		X			X
GIS Data		X	X			
Reports	X	X	X			
Protocol	X	X	X	X		
Photos		X	X		X	
Field Forms		X	X			

Table 5 Metadata Task Descriptions

Metadata Task	Metadata Task Description	Reference(s)
Data Store	A Data Store Reference is created for the upland database and then updated annually. References are also created for each report and for the protocol. The Reference for the protocol is versioned as needed.	Metadata Guidance Document (NCPN-NPS 2007c), https://irma.nps.gov/Content/DataStore/Help/
X-Ref Citation	A cross reference citation is added to the project level metadata record.	Metadata Guidance Document (NCPN-NPS 2007c)
PDLC Checklist	The PDLC checklist is completed, which includes adding product records to the NCPN Project Tracking Database.	Project Data Life Cycle Guidance Document (NCPN-NPS 2007a), Project Tracking Guidance Document (NCPN-NPS 2008c, in development)
MVT	The Master Version Table is updated as needed.	Protocol Versioning Guidance Document (NCPN-NPS 2009)
Photo DB	Photo records are added to the NCPN Photo Database.	Photo Management Guidance Document (NCPN-NPS 2008b)
DB Doc	Database table and field documentation is updated as needed.	Appendix A

The complete protocol for this project (Protocol Narrative and all SOPs) is an integral component of the project metadata. All narrative and SOP version changes are noted in a Master Version Table (MVT), which is maintained in SOP #20. Any time the narrative or an SOP version change occurs, a new Version Key number (VK#) must be created and recorded in the MVT, along with the date of the change and the versions of the narrative and SOPs in effect. The Version Key number is essential for project information to be properly interpreted and analyzed. *The protocol narrative, SOPs, and data should not be distributed independently of this table.* Refer to the NCPN Protocol Versioning Guidance Document (NCPN-NPS 2009) for detailed protocol versioning procedures.

7 References

- Beer, M., E. Nance, A. Wight, M. Powell, and R. DenBleyker. 2005. Northern Colorado Plateau Network, data management plan. National Park Service, Inventory and Monitoring Program, Northern Colorado Plateau Network, Moab, UT. 86 pp plus appendices.
- NCPN-NPS 2007a. Project Data Life Cycle Guidance Document, Version 1.0. National Park Service, Inventory and Monitoring Program, Northern Colorado Plateau Network, Moab, UT.
- NCPN-NPS 2007b. Directory Structure Guidance Document, Version 1.0. National Park Service, Inventory and Monitoring Program, Northern Colorado Plateau Network, Moab, UT.

- NCPN-NPS 2007c. Metadata Guidance Document, Version 1.0. National Park Service, Inventory and Monitoring Program, Northern Colorado Plateau Network, Moab, UT.
- NCPN-NPS 2008a. Quality Assurance and Quality Control Guidance Document, Version 1.0. National Park Service, Inventory and Monitoring Program, Northern Colorado Plateau Network, Moab, UT.
- NCPN-NPS 2008b. Photo Management Guidance Document, Version 1.0. National Park Service, Inventory and Monitoring Program, Northern Colorado Plateau Network, Moab, UT.
- NCPN-NPS 2008c. Project Tracking Guidance Document, Version 1.0, Draft. National Park Service, Inventory and Monitoring Program, Northern Colorado Plateau Network, Moab, UT.
- NCPN-NPS 2009. Protocol Versioning Guidance Document, Version 1.0. National Park Service, Inventory and Monitoring Program, Northern Colorado Plateau Network, Moab, UT.
- NCPN-NPS 2010. Archiving Guidance Document, Version 2.00. National Park Service, Inventory and Monitoring Program, Northern Colorado Plateau Network, Moab, UT.
- NCPN-NPS 2016a. Upland Database User's Guide. National Park Service, Inventory and Monitoring Program, Northern Colorado Plateau Network, Moab, UT.
- NCPN-NPS 2016b. Upland Monitoring Quality Assurance and Quality Control Procedures. National Park Service, Inventory and Monitoring Program, Northern Colorado Plateau Network, Moab, UT.

Appendix A Documentation of Database Tables

The table and field definitions in this appendix correspond to version 5.18 of the upland database (the version used during the 2016 field season). The database consists of three types of tables: data tables, lookup tables, and metadata tables. Tables appear in alphabetical order within each of these three categories.

Data Tables

Table Name: NoDataCollected
Description: Identifies sampling methods where no data were collected for a sampling visit event. Values only present if no data is collected for a sampling method.

Field Name	Field Description	Field Type	Field Width
ID	Event or transect identifier (Event_ID or Transect_ID FK)	dbText	50
SampleLevel	Sampling level (E=Event or T=Transect)	dbText	1
SampleType	Sampling type where no data collected (1mBelt-Shrub, 1mBelt-TreeSeedling, 1mBelt-Exotics, OverstoryTree-Sapling, OverstoryTree-Census, Fuel-1000hr, Fuel-1000hr-A, Fuel-1000hr-B, Fuel-1000hr-C, Fuel-1000hr-D, SiteImpact-Disturbance, SiteImpact-Exotic)	dbText	25

Table Name: tbl_Basal_Gaps
Description: Table of basal gaps by transect

Field Name	Field Description	Field Type	Field Width
Transect_ID	Foreign key to tbl_Canopy_Transect	dbText	50
Gap_ID	Gap ID - Unique record identifier within a transect	dbInteger	2
Gap_Start	Gap start	dbInteger	2
Gap_End	Gap end	dbInteger	2

Table Name: tbl_Canopy_Gaps
Description: Table of canopy gaps by transect

Field Name	Field Description	Field Type	Field Width
Transect_ID	Foreign key to tbl_Canopy_Transect	dbText	50
Gap_ID	Gap ID - unique record identifier within a transect	dbInteger	2
Class	Segment class: g=gap, s=shrub, v=other vegetation [Discontinued use in 2011 with adoption of basal gap format]	dbText	1
Start	Start position of segment in centimeters	dbInteger	2
Gap_End	Gap end [Added in 2011 with adoption of basal gap format]	dbInteger	2

Table Name: tbl_Canopy_Transect
Description: Table of transect information for gap intercepts

Field Name	Field Description	Field Type	Field Width
Transect_ID	Unique record identifier - primary key	dbText	50
Event_ID	Link to tbl_Events	dbText	50
Transect	Transect number - 1, 2, or 3	dbByte	1
Visit_Date	Date of visit.	dbDate	8
Observer	Name of person observing canopy gaps	dbText	50
Recorder	Name of person recording observations	dbText	50
Species	Shrub species on transect	dbMemo	0

Table Name: tbl_Dist_Exotic
Description: Table of exotic species recorded during timed plant walk (part of site impact assessment).

Field Name	Field Description	Field Type	Field Width
Exotic_ID	Unique record identifier - primary key	dbText	50
Impact_ID	Foreign key to tbl_Site_Impact	dbText	50
Species	Exotic species code	dbText	15
Alive	Is species alive?	dbBoolean	1
Notes	Notes on species	dbMemo	0

Table Name: tbl_Events
Description: Table of sampling events (plot visits)

Field Name	Field Description	Field Type	Field Width
Event_ID	Event identifier (Event_ID)	dbText	50
Location_ID	Link to tbl_Locations (Loc_ID)	dbText	50
Protocol_Name	The name or code of the protocol governing the event (Protcl_Nam)	dbText	100
version_key_number	Master protocol version key	dbLong	4
Start_Date	Starting date for the event (Start_Date) - date of plot visit	dbDate	8
Comments	Plot visit comments	dbMemo	0
Observer	Plot visit observer	dbText	50
Fuels_Observer	Fuels observer	dbText	50
Fuels_Recorder	Fuels recorder	dbText	50
Fuels_Date	Date of fuels observation	dbDate	8
Census_Observer	Overstory census observer	dbText	50
Census_Recorder	Overstory census recorder	dbText	50
Census_Date	Date of census observation	dbDate	8
Sapling_Observer	Overstory sapling observer	dbText	50
Sapling_Recorder	Overstory sapling recorder	dbText	50
Sapling_Date	Date of overstory sapling observation	dbDate	8

Table Name: tbl_Fuels
Description: Table of woody fuels (1-hr, 10-hr, 100-hr), litter, and duff measurements

Field Name	Field Description	Field Type	Field Width
Fuels_ID	Unique record identifier - primary key	dbText	50
Event_ID	Foreign key to tbl_Events	dbText	50
Bearing_A	Bearing of the plot slope + 180 in degrees [Discontinued use in 2011. Moved to tbl_Locations]	dbInteger	2
Bearing_B	Bearing of transect 1 in degrees [Discontinued use in 2011. Moved to tbl_Locations]	dbInteger	2
Bearing_C	Bearing of transect 3 + 180 [Discontinued use in 2011. Moved to tbl_Locations]	dbInteger	2
Bearing_D	Bearing of the plot slope [Discontinued use in 2011. Moved to tbl_Locations]	dbInteger	2
Slope_A	Slope of transect A to nearest half percent [Discontinued use in 2011. Moved to tbl_Locations]	dbSingle	4
Slope_B	Slope of transect B to nearest half percent [Discontinued use in 2011. Moved to tbl_Locations]	dbSingle	4
Slope_C	Slope of transect C to nearest half percent [Discontinued use in 2011. Moved to tbl_Locations]	dbSingle	4
Slope_D	Slope of transect D to nearest half percent [Discontinued use in 2011. Moved to tbl_Locations]	dbSingle	4
1HR_A	One hour fuel intercept for transect A	dbInteger	2
1HR_B	One hour fuel intercept for transect B	dbInteger	2

Field Name	Field Description	Field Type	Field Width
1HR_C	One hour fuel intercept for transect C	dbInteger	2
1HR_D	One hour fuel intercept for transect D	dbInteger	2
10HR_A	Ten hour fuel intercept for transect A	dbInteger	2
10HR_B	Ten hour fuel intercept for transect B	dbInteger	2
10HR_C	Ten hour fuel intercept for transect C	dbInteger	2
10HR_D	Ten hour fuel intercept for transect D	dbInteger	2
100HR_A	Hundred hour fuel intercept for transect A	dbInteger	2
100HR_B	Hundred hour fuel intercept for transect B	dbInteger	2
100HR_C	Hundred hour fuel intercept for transect C	dbInteger	2
100HR_D	Hundred hour fuel intercept for transect D	dbInteger	2
2Litter_A	Litter depth at 2 meter point for transect A in centimeters	dbDecimal	16
4Litter_A	Litter depth at 4 meter point for transect A in centimeters	dbDecimal	16
6Litter_A	Litter depth at 6 meter point for transect A in centimeters	dbDecimal	16
8Litter_A	Litter depth at 8 meter point for transect A in centimeters	dbDecimal	16
10Litter_A	Litter depth at 10 meter point for transect A in centimeters	dbDecimal	16
12Litter_A	Litter depth at 12 meter point for transect A in centimeters	dbDecimal	16
14Litter_A	Litter depth at 14 meter point for transect A in centimeters	dbDecimal	16
2Litter_B	Litter depth at 2 meter point for transect B in centimeters	dbDecimal	16
4Litter_B	Litter depth at 4 meter point for transect B in centimeters	dbDecimal	16
6Litter_B	Litter depth at 6 meter point for transect B in centimeters	dbDecimal	16
8Litter_B	Litter depth at 8 meter point for transect B in centimeters	dbDecimal	16
10Litter_B	Litter depth at 10 meter point for transect B in centimeters	dbDecimal	16
12Litter_B	Litter depth at 12 meter point for transect B in centimeters	dbDecimal	16
14Litter_B	Litter depth at 14 meter point for transect B in centimeters	dbDecimal	16
2Litter_C	Litter depth at 2 meter point for transect C in centimeters	dbDecimal	16
4Litter_C	Litter depth at 4 meter point for transect C in centimeters	dbDecimal	16
6Litter_C	Litter depth at 6 meter point for transect C in centimeters	dbDecimal	16
8Litter_C	Litter depth at 8 meter point for transect C in centimeters	dbDecimal	16
10Litter_C	Litter depth at 10 meter point for transect C in centimeters	dbDecimal	16
12Litter_C	Litter depth at 12 meter point for transect C in centimeters	dbDecimal	16
14Litter_C	Litter depth at 14 meter point for transect C in centimeters	dbDecimal	16
2Litter_D	Litter depth at 2 meter point for transect D in centimeters	dbDecimal	16
4Litter_D	Litter depth at 4 meter point for transect D in centimeters	dbDecimal	16
6Litter_D	Litter depth at 6 meter point for transect D in centimeters	dbDecimal	16
8Litter_D	Litter depth at 8 meter point for transect D in centimeters	dbDecimal	16
10Litter_D	Litter depth at 10 meter point for transect D in centimeters	dbDecimal	16
12Litter_D	Litter depth at 12 meter point for transect D in centimeters	dbDecimal	16
14Litter_D	Litter depth at 14 meter point for transect D in centimeters	dbDecimal	16
2Duff_A	Duff depth at 2 meter point for transect A in centimeters	dbDecimal	16
4Duff_A	Duff depth at 4 meter point for transect A in centimeters	dbDecimal	16
6Duff_A	Duff depth at 6 meter point for transect A in centimeters	dbDecimal	16
8Duff_A	Duff depth at 8 meter point for transect A in centimeters	dbDecimal	16
10Duff_A	Duff depth at 10 meter point for transect A in centimeters	dbDecimal	16
12Duff_A	Duff depth at 12 meter point for transect A in centimeters	dbDecimal	16
14Duff_A	Duff depth at 14 meter point for transect A in centimeters	dbDecimal	16
2Duff_B	Duff depth at 2 meter point for transect B in centimeters	dbDecimal	16
4Duff_B	Duff depth at 4 meter point for transect B in centimeters	dbDecimal	16
6Duff_B	Duff depth at 6 meter point for transect B in centimeters	dbDecimal	16
8Duff_B	Duff depth at 8 meter point for transect B in centimeters	dbDecimal	16
10Duff_B	Duff depth at 10 meter point for transect B in centimeters	dbDecimal	16

Field Name	Field Description	Field Type	Field Width
12Duff_B	Duff depth at 12 meter point for transect B in centimeters	dbDecimal	16
14Duff_B	Duff depth at 14 meter point for transect B in centimeters	dbDecimal	16
2Duff_C	Duff depth at 2 meter point for transect C in centimeters	dbDecimal	16
4Duff_C	Duff depth at 4 meter point for transect C in centimeters	dbDecimal	16
6Duff_C	Duff depth at 6 meter point for transect C in centimeters	dbDecimal	16
8Duff_C	Duff depth at 8 meter point for transect C in centimeters	dbDecimal	16
10Duff_C	Duff depth at 10 meter point for transect C in centimeters	dbDecimal	16
12Duff_C	Duff depth at 12 meter point for transect C in centimeters	dbDecimal	16
14Duff_C	Duff depth at 14 meter point for transect C in centimeters	dbDecimal	16
2Duff_D	Duff depth at 2 meter point for transect D in centimeters	dbDecimal	16
4Duff_D	Duff depth at 4 meter point for transect D in centimeters	dbDecimal	16
6Duff_D	Duff depth at 6 meter point for transect D in centimeters	dbDecimal	16
8Duff_D	Duff depth at 8 meter point for transect D in centimeters	dbDecimal	16
10Duff_D	Duff depth at 10 meter point for transect D in centimeters	dbDecimal	16
12Duff_D	Duff depth at 12 meter point for transect D in centimeters	dbDecimal	16
14Duff_D	Duff depth at 14 meter point for transect D in centimeters	dbDecimal	16

Table Name: tbl_Fuels_1000
Description: Table of woody fuels (1000-hr) measurements

Field Name	Field Description	Field Type	Field Width
Fuels_1000_ID	Unique record identifier - primary key	dbText	50
Event_ID	Foreign key to tbl_Events	dbText	50
Transect	Transect associated with 1000-hr fuel measurements	dbText	1
Diameter	Diameter to nearest .5 inch	dbSingle	4
Decay_Class	Decay class: sound, rotten, not recorded	dbText	15

Table Name: tbl_Impact_Details
Description: Table of site impact assessment details [Added in 2008]

Field Name	Field Description	Field Type	Field Width
Impact_Details_ID	Unique record identifier - primary key	dbText	50
Impact_ID	Foreign key to tbl_Site_Impact	dbText	50
Disturbance_Location	Observation-location type: onsite [Other values used were allowed through 2010: “onsite”, “off-site upslope”, and “off-site other than upslope”]	dbText	15
Disturbance_Type	Disturbance type	dbText	50
Disturbance_Size	Size of disturbance	dbText	255
Disturbance_Position	Position of disturbance relative to transects (on-site disturbances only)	dbText	255
Disturbance_Distance	Distance from macroplot (off-site disturbances only)	dbText	255
Disturbance_Direction	Direction from macroplot in degrees azimuth	dbText	50
Disturbance_Description	Description of disturbance including potential effects on fire or erosion processes	dbMemo	0

Table Name: tbl_Location_History
Description: Site and plot definition history table

Field Name	Field Description	Field Type	Field Width
Location_History_ID	M. Location identifier (Loc_ID)	dbText	50
Location_ID	Foreign key to tbl_Location	dbText	50
Unit_Code	Park code	dbText	4

Field Name	Field Description	Field Type	Field Width
Plot_ID	Plot identifier	dbInteger	2
Modify_Date	Date of update	dbDate	8
Recorder	Person modifying data	dbText	50
E_Coord	UTM East of centroid (X_Coord)	dbDouble	8
N_Coord	UTM North of centroid (Y_Coord)	dbDouble	8
Plot_Slope	Plot slope in percent - 1 decimal	dbSingle	4
Plot_Aspect	Plot aspect in degrees - 1 decimal	dbSingle	4
Azimuth	Direction from origin to end of center transect in degrees - 1 decimal	dbSingle	4
T1O_UTME	UTM East of transect 1 origin	dbDouble	8
T1O_UTMN	UTM North of transect 1 origin	dbDouble	8
T1O_Rebar	Distance from transect 1 origin of rebar in meters - 1 decimal	dbSingle	4
T1E_UTME	UTM East of transect 1 end	dbDouble	8
T1E_UTMN	UTM North of transect 1 end	dbDouble	8
T1E_Rebar	Distance from transect 1 end of rebar in meters - 1 decimal	dbSingle	4
T1_Elevation	Elevation in meters of transect 1	dbInteger	2
T2O_UTME	UTM East of transect 2 origin	dbDouble	8
T2O_UTMN	UTM North of transect 2 origin	dbDouble	8
T2O_Rebar	Distance from transect 2 origin of rebar in meters - 1 decimal	dbSingle	4
T2E_UTME	UTM East of transect 2 end	dbDouble	8
T2E_UTMN	UTM North of transect 2 end	dbDouble	8
T2E_Rebar	Distance from transect 2 end of rebar in meters - 1 decimal	dbSingle	4
T2_Elevation	Elevation in meters of transect 2	dbInteger	2
T3O_UTME	UTM East of transect 3 origin	dbDouble	8
T3O_UTMN	UTM North of transect 3 origin	dbDouble	8
T3O_Rebar	Distance from transect 3 origin of rebar in meters - 1 decimal	dbSingle	4
T3E_UTME	UTM East of transect 3 end	dbDouble	8
T3E_UTMN	UTM North of transect 3 end	dbDouble	8
T3E_Rebar	Distance from transect 3 end of rebar in meters - 1 decimal	dbSingle	4
T3_Elevation	Elevation in meters of transect 3	dbInteger	2
Plot_Directions	Directions to plot	dbMemo	0
Bearing_A	Bearing of the plot slope + 180 in degrees for fuels transect [Added in 2011 when field moved to tbl_Locations]	dbInteger	2
Bearing_B	Bearing of fuels transect 1 in degrees [Added in 2011 when field moved to tbl_Locations]	dbInteger	2
Bearing_C	Bearing of fuels transect 3 + 180 [Added in 2011 when field moved to tbl_Locations]	dbInteger	2
Bearing_D	Bearing of the plot slope for fuels transect [Added in 2011 when field moved to tbl_Locations]	dbInteger	2
Slope_A	Slope of fuels transect A to nearest half percent [Added in 2011 when field moved to tbl_Locations]	dbSingle	4
Slope_B	Slope of fuels transect B to nearest half percent [Added in 2011 when field moved to tbl_Locations]	dbSingle	4
Slope_C	Slope of fuels transect C to nearest half percent [Added in 2011 when field moved to tbl_Locations]	dbSingle	4
Slope_D	Slope of fuels transect D to nearest half percent [Added in 2011 when field moved to tbl_Locations]	dbSingle	4
SlopeA	Slope for plot side A in percent	dbSingle	4

Field Name	Field Description	Field Type	Field Width
SlopeAUD	Slope A up or down	dbText	4
SlopeB	Slope for plot side B in percent	dbSingle	4
SlopeBUD	Slope B up or down	dbText	4
SlopeC	Slope for plot side C in percent	dbSingle	4
SlopeCUD	Slope C up or down	dbText	4
SlopeD	Slope for plot side D in percent	dbSingle	4
SlopeDUD	Slope D up or down	dbText	4

Table Name: tbl_Locations
Description: Site and plot definition table

Field Name	Field Description	Field Type	Field Width
Location_ID	Location identifier (Loc_ID)	dbText	50
GIS_Location_ID	Link to GIS feature, equivalent to NPS_Location_ID (GIS_Loc_ID)	dbText	50
Meta_MID	Link to NR-GIS Metadata Database (Meta_MID)	dbText	50
Unit_Code	Park code	dbText	4
Plot_ID	Plot identifier	dbInteger	2
SiteDate	Date site characterized	dbDate	8
Recorder	Person recording data	dbText	50
Soil_Survey_Area	Soil survey corresponding to park unit and plot	dbMemo	0
Soil_Map_Unit	Soil map unit in which the centroid lies	dbText	10
GPS_File_Name	GPS file name for centroid coordinates	dbText	50
Rcvr_Type	GPS unit type	dbText	50
Elevation	Elevation of site origin in meters	dbInteger	2
E_Coord	UTM East of centroid (X_Coord)	dbDouble	8
N_Coord	UTM North of centroid (Y_Coord)	dbDouble	8
Coord_Units	Coordinate distance units (Coord_Unit)	dbText	50
Coord_System	Coordinate system (Coord_Syst)	dbText	50
UTM_Zone	UTM zone (UTM_Zone)	dbInteger	2
Datum	Datum of mapping ellipsoid (Datum)	dbText	5
Max_PDOP	Horizontal accuracy	dbDouble	8
Max_HDOP	Positional accuracy	dbDouble	8
Updated_Date	Date of entry or last change (Upd_Date)	dbText	50
Geologic_Setting	Geologic setting on site	dbText	100
Landform	Landform on site	dbText	100
Hillslope_Position	Hillslope position that describes location - summit, shoulder, backslope, footslope, toeslope, or low level	dbText	10
Slope_Complexity	Relative uniformity of ground surface leading down slope - complex or simple	dbText	7
Slope_Shape_Down	Slope shape down slope - linear, concave, convex	dbText	7
Slope_Shape_Across	Slope shape across slope - linear, concave, convex	dbText	7
Percent_Slope	Percent slope at centroid - tenths	dbSingle	4
Soil_Texture	Particle size distribution of fine earth fraction and clay particles	dbText	50
Sand_Modifier	Predominant size class of sand if sand is a major part of the soil texture - very fine, fine, medium, coarse, very course, n/a	dbText	50
Rock_Fragment_Qty	Rock fragment quantity modifier - n/a, none, very, extremely, >90%	dbText	50
Rock_Fragment_Size	Rock fragment size modifier - none, gravelly, cobbly,	dbText	50

Field Name	Field Description	Field Type	Field Width
	stony, bouldery, channery, flaggy, gravel, cobble, stone, boulder		
Effervescence	Quantity and surface area of carbonate compounds in the soil - none, very slight, slight, strong, violent	dbText	50
Depth	Depth to bedrock - very shallow, shallow, moderately deep, deep, very deep, unknown	dbText	50
Dominant_Vegetation	Dominant vegetation at site. This field is used to help field crew determine correct ecosite. It is not quality checked.	dbMemo	0
Soil_Assessment	Is it a soil assessment target match	dbBoolean	1
Probable_Component	Probable soil component	dbText	50
Soil_Comments	Additional soil comments	dbMemo	0
Veg_Assessment	Is it a vegetation assessment target match	dbBoolean	1
Veg_Comments	Vegetation assessment comments	dbMemo	0
Primary_Eco_Site	Primary ecological site name	dbText	50
Primary_Percent	Percentage of macroplot comprised of primary site type - 1 decimal	dbSingle	4
Other_Eco_Site	Other ecological site name	dbText	50
Other_Percent	Percentage of macroplot comprised of other site type - 1 decimal	dbSingle	4
Transect_Length	Estimated total length of transect in meters that falls outside the target ecological site	dbInteger	2
Site_Selection	Site accepted or rejected	dbBoolean	1
Site_Selection_Comments	Additional site selection comments	dbMemo	0
Soil_Profile_Samples	Number of soil profile samples collected	dbInteger	2
2cm_Samples	Number of 0-2 cm composite samples collected	dbInteger	2
10cm_Samples	Number of 2-10 cm composite samples collected	dbInteger	2
Plot_Date	Date plot established if different from site characterization date	dbDate	8
Plot_E_Coord	UTM East of centroid if plot established on different visit from site characterization. [Discontinued use in 2008]	dbDouble	8
Plot_N_Coord	UTM North of centroid (Y_Coord) if plot established on different visit from site characterization. [Discontinued use in 2008]	dbDouble	8
Observer	Person establishing plot	dbText	50
Plot_Slope	Plot slope in percent - 1 decimal	dbSingle	4
Plot_Aspect	Plot aspect in degrees - 1 decimal	dbSingle	4
Azimuth	Direction from origin to end of center transect in degrees - 1 decimal	dbSingle	4
T1O_UTME	UTM East of transect 1 origin	dbDouble	8
T1O_UTMN	UTM North of transect 1 origin	dbDouble	8
T1O_Rebar	Distance from transect 1 origin of rebar in meters - 1 decimal	dbSingle	4
T1E_UTME	UTM East of transect 1 end	dbDouble	8
T1E_UTMN	UTM North of transect 1 end	dbDouble	8
T1E_Rebar	Distance from transect 1 end of rebar in meters - 1 decimal	dbSingle	4
T1_Elevation	Elevation in meters of transect 1	dbInteger	2
T2O_UTME	UTM East of transect 2 origin	dbDouble	8
T2O_UTMN	UTM North of transect 2 origin	dbDouble	8

Field Name	Field Description	Field Type	Field Width
T2O_Rebar	Distance from transect 2 origin of rebar in meters - 1 decimal	dbSingle	4
T2E_UTME	UTM East of transect 2 end	dbDouble	8
T2E_UTMN	UTM North of transect 2 end	dbDouble	8
T2E_Rebar	Distance from transect 2 end of rebar in meters - 1 decimal	dbSingle	4
T2_Elevation	Elevation in meters of transect 2	dbInteger	2
T3O_UTME	UTM East of transect 3 origin	dbDouble	8
T3O_UTMN	UTM North of transect 3 origin	dbDouble	8
T3O_Rebar	Distance from transect 3 origin of rebar in meters - 1 decimal	dbSingle	4
T3E_UTME	UTM East of transect 3 end	dbDouble	8
T3E_UTMN	UTM North of transect 3 end	dbDouble	8
T3E_Rebar	Distance from transect 3 end of rebar in meters - 1 decimal	dbSingle	4
T3_Elevation	Elevation in meters of transect 3	dbInteger	2
Plot_Directions	Directions to plot	dbMemo	0
Parent_Material	Parent material	dbText	100
Grazed_field	Is plot grazed?	dbBoolean	1
Vegetation_Type	Vegetation type	dbText	50
SlopeA	Slope for plot side A in percent	dbSingle	4
SlopeAUD	Slope A up or down	dbText	4
SlopeB	Slope for plot side B in percent	dbSingle	4
SlopeBUD	Slope B up or down	dbText	4
SlopeC	Slope for plot side C in percent	dbSingle	4
SlopeCUD	Slope C up or down	dbText	4
SlopeD	Slope for plot side D in percent	dbSingle	4
SlopeDUD	Slope D up or down	dbText	4
Master_Stratification	Master stratification for summaries and analysis	dbText	75
Bearing_A	Bearing of the plot slope + 180 in degrees for fuels transect [Added in 2011 when field moved to tbl_Locations]	dbInteger	2
Bearing_B	Bearing of fuels transect 1 in degrees [Added in 2011 when field moved to tbl_Locations]	dbInteger	2
Bearing_C	Bearing of fuels transect 3 + 180 [Added in 2011 when field moved to tbl_Locations]	dbInteger	2
Bearing_D	Bearing of the plot slope for fuels transect [Added in 2011 when field moved to tbl_Locations]	dbInteger	2
Slope_A	Slope of fuels transect A to nearest half percent [Added in 2011 when field moved to tbl_Locations]	dbSingle	4
Slope_B	Slope of fuels transect B to nearest half percent [Added in 2011 when field moved to tbl_Locations]	dbSingle	4
Slope_C	Slope of fuels transect C to nearest half percent [Added in 2011 when field moved to tbl_Locations]	dbSingle	4
Slope_D	Slope of fuels transect D to nearest half percent [Added in 2011 when field moved to tbl_Locations]	dbSingle	4

Table Name: tbl_LP_Add_Species
Description: Table of additional species in 1 meter belt transect

Field Name	Field Description	Field Type	Field Width
Add_ID	Unique record identifier - primary key	dbText	50

Field Name	Field Description	Field Type	Field Width
Transect_ID	Foreign key to tbl_LP_Belt_Transect	dbText	50
Species	Additional species observed	dbText	15

Table Name: tbl_LP_Belt_Transect
Description: Table of transect information for 1 meter belt transect

Field Name	Field Description	Field Type	Field Width
Transect_ID	Unique record identifier - primary key	dbText	50
Event_ID	Foreign key to tbl_Events	dbText	50
Transect	Transect number - 1, 2, or 3	dbByte	1
Visit_Date	Date of visit	dbDate	8
Observer	Name of person observing	dbText	50
Recorder	Name of person recording	dbText	50

Table Name: tbl_LP_Densiometer
Description: Table of spherical densiometer point intersection counts in 1 meter belt transect

Field Name	Field Description	Field Type	Field Width
SD_ID	Unique record identifier - primary key	dbText	50
Transect_ID	Foreign key to tbl_LP_Belt_Transect	dbText	50
Point	Point on transect	dbText	4
Total1	Total count, measurement 1	dbInteger	2
Total2	Total count, measurement 2	dbInteger	2
Total3	Total count, measurement 3	dbInteger	2
Total4	Total count, measurement 4	dbInteger	2

Table Name: tbl_LP_Exotic
Description: Table of exotic species by transect in 1 meter belt transect [Discontinued use in 2011]

Field Name	Field Description	Field Type	Field Width
Exotic_ID	Unique record identifier - primary key	dbText	50
Transect_ID	Foreign key to tbl_LP_Belt_Transect	dbText	50
Species	Exotic species code	dbText	15
Alive	Is species alive?	dbBoolean	1
Total	Total count	dbInteger	2

Table Name: tbl_LP_Exotic_Freq
Description: Table of exotic frequency by quadrat in 1 meter belt transect [Added in 2011]

Field Name	Field Description	Field Type	Field Width
Exotic_ID	Unique record identifier - primary key	dbText	50
Transect_ID	Foreign key to tbl_LP_Belt_Transect	dbText	50
Species	Exotic species observed	dbText	15
M0	Zero point quadrat species detected checkbox	dbBoolean	1
M5	5 meter quadrat species detected checkbox	dbBoolean	1
M10	10 meter quadrat species detected checkbox	dbBoolean	1
M15	15 meter quadrat species detected checkbox	dbBoolean	1
M20	20 meter quadrat species detected checkbox	dbBoolean	1
M25	25 meter quadrat species detected checkbox	dbBoolean	1
M30	30 meter quadrat species detected checkbox	dbBoolean	1
M35	35 meter quadrat species detected checkbox	dbBoolean	1
M40	40 meter quadrat species detected checkbox	dbBoolean	1
M45	45 meter quadrat species detected checkbox	dbBoolean	1
Oak0	Oak plot zero point quadrat species detected	dbBoolean	1
Oak2	Oak plot 2 meter quadrat species detected	dbBoolean	1
Oak4	Oak plot 4 meter quadrat species detected	dbBoolean	1

Field Name	Field Description	Field Type	Field Width
Oak6	Oak plot 6 meter quadrat species detected	dbBoolean	1
Oak8	Oak plot 8 meter quadrat species detected	dbBoolean	1
Oak10	Oak plot 10 meter quadrat species detected	dbBoolean	1
Oak12	Oak plot 12 meter quadrat species detected	dbBoolean	1
Oak14	Oak plot 14 meter quadrat species detected	dbBoolean	1
Oak16	Oak plot 16 meter quadrat species detected	dbBoolean	1
Oak18	Oak plot 18 meter quadrat species detected	dbBoolean	1

Table Name: tbl_LP_Intercept
Description: Table of point intercept measurements by transect

Field Name	Field Description	Field Type	Field Width
Intercept_ID	Unique record identifier - primary key	dbText	50
Transect_ID	Foreign key to tbl_LP_Transect	dbText	50
Point	Intercept point: increments of 0.25m up to 20m for oak plots, 0.5m up to 50m for all other vegetation types	dbDecimal	16
Top	Top canopy species code	dbText	15
Alive	Is top canopy species alive?	dbBoolean	1
Surface	Soil surface code	dbText	15
Surface_Alive	If soil surface is a species, is it alive?	dbBoolean	1
LCS1	Lower canopy species 1 [Lower canopy species/alive fields added in 2009 to accommodate user interface needed for field data entry]	dbText	15
LCA1	Lower canopy alive 1	dbBoolean	1
LCS2	Lower canopy species 2	dbText	15
LCA2	Lower canopy alive 2	dbBoolean	1
LCS3	Lower canopy species 3	dbText	15
LCA3	Lower canopy alive 3	dbBoolean	1
LCS4	Lower canopy species 4	dbText	15
LCA4	Lower canopy alive 4	dbBoolean	1
LCS5	Lower canopy species 5	dbText	15
LCA5	Lower canopy alive 5	dbBoolean	1
LCS6	Lower canopy species 6	dbText	15
LCA6	Lower canopy alive 6	dbBoolean	1
LCS7	Lower canopy species 7	dbText	15
LCA7	Lower canopy alive7	dbBoolean	1
LCS8	Lower canopy species 8	dbText	15
LCA8	Lower canopy alive 8	dbBoolean	1
LCS9	Lower canopy species 9	dbText	15
LCA9	Lower canopy alive 9	dbBoolean	1
LCS10	Lower canopy species 10	dbText	15
LCA10	Lower canopy alive 10	dbBoolean	1
D1	Disturbance code 1 [Disturbance fields added in 2009 to accommodate user interface needed for field data entry]	dbText	15
D2	Disturbance code 2	dbText	15
D3	Disturbance code 3	dbText	15
D4	Disturbance code 4	dbText	15
D5	Disturbance code 5	dbText	15

Table Name: tbl_LP_Seedling
Description: Table of seedling density measurements by transect in 1 meter belt transect

Field Name	Field Description	Field Type	Field Width

Field Name	Field Description	Field Type	Field Width
Seedling_ID	Unique record identifier - primary key	dbText	50
Transect_ID	Foreign key to tbl_LP_Belt_Transect	dbText	50
Species	Seedling species code	dbText	15
Total	Total count	dbInteger	2

Table Name: tbl_LP_Shrub
Description: Table of shrub density measurements by transect in 1 meter belt transect

Field Name	Field Description	Field Type	Field Width
Shrub_ID	Unique record identifier - primary key	dbText	50
Transect_ID	Foreign key to tbl_LP_Belt_Transect	dbText	50
Species	Shrub species code	dbText	15
Alive	Is shrub species alive?	dbBoolean	1
HC10	0-10cm height class total	dbInteger	2
HC25	10.1-25cm height class total	dbInteger	2
HC50	25.1-50cm height class total	dbInteger	2
HC100	50.1-100cm height class total	dbInteger	2
HC2m	1.01-2m height class total	dbInteger	2
HCGT2	>2.01m height class total	dbInteger	2

Table Name: tbl_LP_Transect
Description: Table of transect information for point intercept measurements

Field Name	Field Description	Field Type	Field Width
Transect_ID	Unique record identifier - primary key	dbText	50
Event_ID	Foreign key to tbl_Events	dbText	50
Transect	Transect number - 1, 2, or 3	dbByte	1
Visit_Date	Date of visit	dbDate	8
Observer	Name of person observing	dbText	50
Recorder	Name of person recording	dbText	50

Table Name: tbl_Monument
Description: Table of monument tree information

Field Name	Field Description	Field Type	Field Width
Monument_ID	Unique record identifier - primary key	dbText	50
Location_ID	Foreign key to tbl_Locations	dbText	50
Monument_Code	Corner code	dbText	5
Tag_No	Tag number of monument tree	dbInteger	2
Species	Species code of monument tree	dbText	15
DBH	Diameter at breast height in centimeters	dbSingle	4
Bearing	Bearing from monument tree to plot corner in degrees	dbInteger	2
Rebar_Distance	Distance from center point of monument tree to plot corner in meters	dbSingle	4

Table Name: tbl_OT_Census
Description: Table of overstory tree census information

Field Name	Field Description	Field Type	Field Width
Census_ID	Unique record identifier - primary key	dbText	50
Event_ID	Foreign key to tbl_Events	dbText	50
Quad	Quadrat number	dbInteger	2
Tag_No	Tag number	dbInteger	2
Species	Species code	dbText	15

Field Name	Field Description	Field Type	Field Width
DBH	Diameter at breast height or diameter at root crown in centimeters	dbSingle	4
DType	Diameter type identifying root crown or breast height measurement; NULL if Crown_Health = 6.	dbText	3
Crown_Health	Crown health class	dbInteger	2
Crown_Class	Crown class	dbText	50
Notes	Notes about any significant damage to a living tree	dbText	255

Table Name: tbl_OT_Tree_Saplings
Description: Table of sapling tallies in 5 meter belt transect

Field Name	Field Description	Field Type	Field Width
TS_ID	Unique record identifier - primary key	dbText	50
Event_ID	Foreign key to tbl_Events	dbText	50
Species	Sapling species code	dbText	15
Alive	Is sapling species alive?	dbBoolean	1
D25	2.5 - 5.0 cm diameter class total	dbInteger	2
D51	5.1 - 10.0 cm diameter class total	dbInteger	2
D101	10.1 - 15.0 cm diameter class total	dbInteger	2

Table Name: tbl_Photos
Description: Table of plot visit photos

Field Name	Field Description	Field Type	Field Width
Photo_ID	Unique record identifier - primary key	dbText	50
Event_ID	Foreign key to tbl_Events	dbText	50
Photo_Date	Date photograph taken	dbDate	8
Photo_Type	Type of photo: digital, film, movie, other	dbText	50
Transect	Transect and location of photo (T1 - origin; T2 - origin; T3 - origin;T1 - end; T2 - end; T3 - end; T1 - 0m - crust; T2 - 20m - crust; T3 - 40m - crust)	dbText	25
Roll	Roll for film photos	dbText	10
Frame	Frame for film photos	dbInteger	2
Digital_File	Digital file name	dbText	50
Photographer	Photographer	dbText	50
Direction	Direction of photograph [Discontinued use in 2008]	dbText	3
Location	Location of photo point along transect in meters	dbDecimal	16
Other_Identifier	Other digital photo identifier	dbText	50
Comments	Photo comments	dbMemo	0
NCPN_Image_ID	Digital file name in NCPN Photo Database	dbText	50

Table Name: tbl_Quadrat
Description: Table of quadrat information for 10 m2 quadrats [Discontinued use in 2008]

Field Name	Field Description	Field Type	Field Width
Quadrat_ID	Unique record identifier - primary key	dbText	50
Transect_ID	Foreign key to tbl_Quadrat_Transect	dbText	50
Quadrat	Quadrat number: 1 to 5	dbByte	1
Observer	Name of person observing canopy gaps	dbText	50
Recorder	Name of person recording observations	dbText	50
Crust_Q1	Undifferentiated crust nested quadrat 0.01 m2	dbBoolean	1
Crust_Q2	Undifferentiated crust nested quadrat 0.1 m2	dbBoolean	1

Field Name	Field Description	Field Type	Field Width
Crust_Q3	Undifferentiated crust nested quadrat 1 m2	dbBoolean	1
Crust_Q4	Undifferentiated crust nested quadrat 10 m2	dbBoolean	1
Crust_Cover	Percent undifferentiated crust cover 10 m2 quadrat [Discontinued in 2007 due to method change]	dbText	3
Crust_Cover_1M2	Percent undifferentiated crust cover 1 m2 quadrat [Added in 2007 due to method change]	dbText	3
Cyan_Q1	Cyanobacteria nested quadrat 0.01 m2	dbBoolean	1
Cyan_Q2	Cyanobacteria nested quadrat 0.1 m2	dbBoolean	1
Cyan_Q3	Cyanobacteria nested quadrat 1 m2	dbBoolean	1
Cyan_Q4	Cyanobacteria nested quadrat 10 m2	dbBoolean	1
Cyan_Cover	Percent cyanobacteria cover in 10 m2 quadrat [Discontinued in 2007 due to method change]	dbText	3
Cyan_Cover_1M2	Percent cyanobacteria cover in 1 m2 quadrat [Added in 2007 due to method change]	dbText	3
Lichen_Q1	Lichen nested quadrat 0.01 m2	dbBoolean	1
Lichen_Q2	Lichen nested quadrat 0.1 m2	dbBoolean	1
Lichen_Q3	Lichen nested quadrat 1 m2	dbBoolean	1
Lichen_Q4	Lichen nested quadrat 10 m2	dbBoolean	1
Lichen_Cover	Percent lichen cover in 10 m2 quadrat [Discontinued in 2007 due to method change]	dbText	3
Lichen_Cover_1M2	Percent lichen cover in 1 m2 quadrat [Added in 2007 due to method change]	dbText	3
Moss_Q1	Moss nested quadrat 0.01 m2	dbBoolean	1
Moss_Q2	Moss nested quadrat 0.1 m2	dbBoolean	1
Moss_Q3	Moss nested quadrat 1 m2	dbBoolean	1
Moss_Q4	Moss nested quadrat 10 m2	dbBoolean	1
Moss_Cover	Percent moss cover in 10 m2 quadrat [Discontinued in 2007 due to method change]	dbText	3
Moss_Cover_1M2	Percent moss cover in 1 m2 quadrat [Added in 2007 due to method change]	dbText	3
Lscat_Q1	Livestock scat nested quadrat 0.01 m2	dbBoolean	1
Lscat_Q2	Livestock scat nested quadrat 0.1 m2	dbBoolean	1
Lscat_Q3	Livestock scat nested quadrat 1 m2	dbBoolean	1
Lscat_Q4	Livestock scat nested quadrat 10 m2	dbBoolean	1
Lscat_Cover	Percent livestock scat cover in 10 m2 quadrat	dbText	3
Wscat_Q1	Wildlife scat nested quadrat 0.01 m2	dbBoolean	1
Wscat_Q2	Wildlife scat nested quadrat 0.1 m2	dbBoolean	1
Wscat_Q3	Wildlife scat nested quadrat 1 m2	dbBoolean	1
Wscat_Q4	Wildlife scat nested quadrat 10 m2	dbBoolean	1
Wscat_Cover	Percent wildlife scat cover in 10 m2 quadrat	dbText	3
Ant_Q1	Ant mound nested quadrat 0.01 m2	dbBoolean	1
Ant_Q2	Ant mound nested quadrat 0.1 m2	dbBoolean	1
Ant_Q3	Ant mound nested quadrat 1 m2	dbBoolean	1
Ant_Q4	Ant mound nested quadrat 10 m2	dbBoolean	1
Ant_Cover	Percent ant mound cover in 10 m2 quadrat	dbText	3
Bicycle_Q1	Bicycle disturbance nested quadrat 0.01 m2	dbBoolean	1
Bicycle_Q2	Bicycle disturbance nested quadrat 0.1 m2	dbBoolean	1
Bicycle_Q3	Bicycle disturbance nested quadrat 1 m2	dbBoolean	1
Bicycle_Q4	Bicycle disturbance nested quadrat 10 m2	dbBoolean	1
Bicycle_Cover	Percent bicycle disturbance cover in 10 m2 quadrat	dbText	3
Htrail_Q1	Human track/trail nested quadrat 0.01 m2	dbBoolean	1

Field Name	Field Description	Field Type	Field Width
Htrail_Q2	Human track/trail nested quadrat 0.1 m2	dbBoolean	1
Htrail_Q3	Human track/trail nested quadrat 1 m2	dbBoolean	1
Htrail_Q4	Human track/trail nested quadrat 10 m2	dbBoolean	1
Htrail_Cover	Human track/trail disturbance cover percentage in 10 m2 quadrat	dbText	3
Ltrail_Q1	Livestock track/trail nested quadrat 0.01 m2	dbBoolean	1
Ltrail_Q2	Livestock track/trail nested quadrat 0.1 m2	dbBoolean	1
Ltrail_Q3	Livestock track/trail nested quadrat 1 m2	dbBoolean	1
Ltrail_Q4	Livestock track/trail nested quadrat 10 m2	dbBoolean	1
Ltrail_Cover	Livestock track/trail disturbance cover percentage in 10 m2 quadrat	dbText	3
Vehicle_Q1	Motor vehicle track nested quadrat 0.01 m2	dbBoolean	1
Vehicle_Q2	Motor vehicle track nested quadrat 0.1 m2	dbBoolean	1
Vehicle_Q3	Motor vehicle track nested quadrat 1 m2	dbBoolean	1
Vehicle_Q4	Motor vehicle track nested quadrat 10 m2	dbBoolean	1
Vehicle_Cover	Motor vehicle disturbance cover percentage in 10 m2 quadrat	dbText	3
Wildlife_Ex_Q1	Wildlife excavation nested quadrat 0.01 m2	dbBoolean	1
Wildlife_Ex_Q2	Wildlife excavation nested quadrat 0.1 m2	dbBoolean	1
Wildlife_Ex_Q3	Wildlife excavation nested quadrat 1 m2	dbBoolean	1
Wildlife_Ex_Q4	Wildlife excavation nested quadrat 10 m2	dbBoolean	1
Wildlife_Ex_Cover	Wildlife excavation disturbance cover percentage in 10 m2 quadrat	dbText	3
Wtrail_Q1	Wildlife track/trail nested quadrat 0.01 m2	dbBoolean	1
Wtrail_Q2	Wildlife track/trail nested quadrat 0.1 m2	dbBoolean	1
Wtrail_Q3	Wildlife track/trail nested quadrat 1 m2	dbBoolean	1
Wtrail_Q4	Wildlife track/trail nested quadrat 10 m2	dbBoolean	1
Wtrail_Cover	Wildlife track/trail disturbance cover percentage in 10 m2 quadrat	dbText	3
Other_Q1	Other anthropogenic nested quadrat 0.01 m2	dbBoolean	1
Other_Q2	Other anthropogenic nested quadrat 0.1 m2	dbBoolean	1
Other_Q3	Other anthropogenic nested quadrat 1 m2	dbBoolean	1
Other_Q4	Other anthropogenic nested quadrat 10 m2	dbBoolean	1
Other_Cover	Other anthropogenic disturbance cover percentage in 10 m2 quadrat	dbText	3
Undiff_Q1	Undifferentiated disturbance nested quadrat 0.01 m2	dbBoolean	1
Undiff_Q2	Undifferentiated disturbance nested quadrat 0.1 m2	dbBoolean	1
Undiff_Q3	Undifferentiated disturbance nested quadrat 1 m2	dbBoolean	1
Undiff_Q4	Undifferentiated disturbance nested quadrat 10 m2	dbBoolean	1
Undiff_Cover	Undifferentiated disturbance cover percentage in 10 m2 quadrat	dbText	3
Cover_Tree	Percentage tree cover in 10 m2 quadrat	dbText	3
Cover_Shrub	Percentage shrub & dwarf-shrub cover in 10 m2 quadrat	dbText	3
Cover_Annual	Percentage annual grass cover in 10 m2 quadrat	dbText	3
Cover_Perennial	Percentage perennial grass cover in 10 m2 quadrat	dbText	3
Cover_Forbs	Percentage forbs/herbs cover in 10 m2 quadrat	dbText	3
Cover_Plant_Basal	Percentage plant basal cover in 10 m2 quadrat	dbText	3
Cover_Soil	Percentage bare soil (loose) cover in 10 m2 quadrat	dbText	3
Cover_Litter	Percentage litter cover in 10 m2 quadrat	dbText	3
Cover_Woody	Percentage woody debris (>2.5cm) cover in 10 m2 quadrat	dbText	3
Cover_Small_Rock	Percentage small rock cover (2-20mm) in 10 m2 quadrat	dbText	3

Field Name	Field Description	Field Type	Field Width
Cover_Large_Rock	Percentage large rock (>2cm) cover in 10 m2 quadrat	dbText	3
Cover_Bedrock	Percentage bedrock cover in 10 m2 quadrat	dbText	3
Cover_Biocrust	Percentage biocrust cover in 10 m2 quadrat	dbText	3
Cover_Crust_Undiff	Percentage undifferentiated crust cover in 10 m2 quadrat	dbText	3
Comments	10 m2 quadrat comments	dbMemo	0

Table Name: tbl_Quadrat_Shrubs
Description: Table of shrub counts by quadrat [Discontinued use in 2008]

Field Name	Field Description	Field Type	Field Width
Shrub_ID	Unique record identifier - primary key	dbText	50
Quadrat_ID	Foreign key to tbl_Quadrat_Transect	dbText	50
Plant_Code	Plant code from lookup table	dbText	10
0cm	Number of shrubs 0-10 cm	dbInteger	2
10cm	Number of shrubs 10-25 cm	dbInteger	2
25cm	Number of shrubs 25-50 cm	dbInteger	2
50cm	Number of shrubs 50-100 cm	dbInteger	2
100cm	Number of shrubs 1-2 m	dbInteger	2
200cm	Number of shrubs >2 m	dbInteger	2

Table Name: tbl_Quadrat_Species
Description: Table of plant species by quadrat [Discontinued use in 2008]

Field Name	Field Description	Field Type	Field Width
Species_ID	Unique record identifier - primary key	dbText	50
Quadrat_ID	Foreign key to tbl_Quadrat_Transect	dbText	50
Plant_Code	Plant code from lookup table	dbText	50
Alive	Is plant alive?	dbText	3
Q1	Present in 0.01 m2 quadrat?	dbBoolean	1
Q2	Present in 0.1 m2 quadrat?	dbBoolean	1
Q3	Present in 1 m2 quadrat?	dbBoolean	1
Q4	Present in 10 m2 quadrat?	dbBoolean	1
Percent_Cover	Percent cover in 10 m2 quadrat	dbText	3
Rooted_Outside	Is plant rooted outside quadrat?	dbBoolean	1

Table Name: tbl_Quadrat_Transect
Description: Table of transect information for 10 m2 quadrats [Discontinued use in 2008]

Field Name	Field Description	Field Type	Field Width
Transect_ID	Unique record identifier - primary key	dbText	50
Event_ID	Foreign key to tbl_Events	dbText	50
Transect	Transect number - 1, 2, or 3	dbByte	1
Visit_Date	Date of visit	dbDate	8

Table Name: tbl_Site_Impact
Description: Table of site impact assessment information

Field Name	Field Description	Field Type	Field Width
Impact_ID	Unique record identifier - primary key	dbText	50
Event_ID	Foreign key to tbl_Events	dbText	50
Visit_Date	Date of visit	dbDate	8
Recorder	Person recording site impact information	dbText	50
On_Disturbance	On-site disturbance type [Discontinued use in 2008. Moved to tbl_Impact_Details]	dbText	50

Field Name	Field Description	Field Type	Field Width
On_Size	Size of area affected in m2 [Discontinued use in 2008. Moved to tbl_Impact_Details]	dbInteger	2
On_Position	Position of disturbance relative to transects [Discontinued use in 2008. Moved to tbl_Impact_Details]	dbText	255
On_Effect	Effect of disturbance on erosional processes on macroplot [Discontinued use in 2008. Moved to tbl_Impact_Details]	dbMemo	0
On_Fire	Alteration of fire behavior on macroplot caused by disturbance [Discontinued use in 2008. Moved to tbl_Impact_Details]	dbMemo	0
On_Additional	Additional on-site disturbance description [Discontinued use in 2008. Moved to tbl_Impact_Details]	dbMemo	0
Off_Disturbance	Off-site disturbance type [Discontinued use in 2008. Moved to tbl_Impact_Details]	dbText	50
Off_Size	Size of area affected in m2 [Discontinued use in 2008. Moved to tbl_Impact_Details]	dbInteger	2
Off_Distance	Distance upslope from macroplot in meters [Discontinued use in 2008. Moved to tbl_Impact_Details]	dbInteger	2
Off_Effect	Effect of disturbance on erosional processes on macroplot [Discontinued use in 2008. Moved to tbl_Impact_Details]	dbMemo	0
Off_Fire	Alteration of fire behavior on macroplot caused by disturbance [Discontinued use in 2008. Moved to tbl_Impact_Details]	dbMemo	0
Off_Additional	Additional off-site disturbance description [Discontinued use in 2008. Moved to tbl_Impact_Details]	dbMemo	0
Site_Sketch	BLOB of site sketch or jpg picture of disturbance	dbLongBinary	0
Percent_Top_Kill	Percentage of Gambel oak cover in plot affected by top kill [Added in 2009. Discontinued in 2011]	dbInteger	2
Percent_Dead	Percentage of Gambel oak cover in plot that is completely dead [Added in 2009. Discontinued in 2011]	dbLong	4

Table Name: tbl_SL_Transect
Description: Table of transect information for shrub line-intercept gaps [Added in 2009. Discontinued in 2010]

Field Name	Field Description	Field Type	Field Width
Transect_ID	Unique record identifier - primary key	dbText	50
Event_ID	Foreign key to tbl_Events	dbText	50
Transect	Transect number - 1, 2, or 3	dbByte	1
Visit_Date	Date of visit	dbDate	8
Observer	Name of person observing	dbText	50
Recorder	Name of person recording	dbText	50

Table Name: tbl_SLI_Gaps
Description: Table of Shrub Line-Intercept Gaps [Added in 2009. Discontinued in 2010]

Field Name	Field Description	Field Type	Field Width
SLI_ID	Unique record identifier - primary key	dbText	50
Transect_ID	Foreign key to tbl_SL_Transect	dbText	50
Species	Species code	dbText	50
Shrub_Start	Start of shrub cover to nearest centimeter	dbLong	4
Shrub_End	End of shrub cover to nearest centimeter	dbInteger	2

Table Name: tbl_Soil_Profile
Description: Table of soil profiles for plots

Field Name	Field Description	Field Type	Field Width
Soil_Profile_ID	Unique record identifier	dbText	50
Location_ID	Link to tbl_Locations (Loc_ID)	dbText	50
Depth	Sample depth	dbText	9
Texture	Soil texture	dbText	100
Rock_Fragment_Qty	Rock fragment quantity modifier - n/a, none, very, extremely, >90%	dbText	9
Rock_Fragment_Size	Rock fragment size modifier - none, gravelly, cobbly, stony, bouldery, channery, flaggy, gravel, cobble, stone, boulder	dbText	8
Effervescence	Effervescence	dbText	11

Table Name: tbl_Soil_Stability
Description: Table of soil stability measurements

Field Name	Field Description	Field Type	Field Width
Soil_ID	Unique record identifier - primary key	dbText	50
Event_ID	Foreign key to tbl_Events	dbText	50
Visit_Date	Date of visit	dbDate	8
Observer	Name of person observing	dbText	50
Recorder	Name of person recording observations	dbText	50
Sample_Type	Sample type: 1=surface, 2=subsurface	dbLong	4
T1500_Pos	Transect 1 5:00 minute position	dbDouble	8
T1500_Veg	Transect 1 5:00 minute vegetation: NC, M, G, F, Sh, T, nr	dbText	2
T1500_Rating	Transect 1 5:00 minute rating 1-6	dbLong	4
T1500_Hydro	Is transect 1 5:00 minute rating hydrophobic?	dbBoolean	1
T1545_Pos	Transect 1 5:45 minute position	dbDouble	8
T1545_Veg	Transect 1 5:45 minute vegetation: NC, M, G, F, Sh, T, nr	dbText	2
T1545_Rating	Transect 1 5:45 minute rating 1-6	dbLong	4
T1545_Hydro	Is transect 1 5:45 minute rating hydrophobic?	dbBoolean	1
T2630_Pos	Transect 2 6:30 minute position	dbDouble	8
T2630_Veg	Transect 2 6:30 minute vegetation: NC, M, G, F, Sh, T, nr	dbText	2
T2630_Rating	Transect 2 6:30 minute rating 1-6	dbLong	4
T2630_Hydro	Is transect 2 6:30 minute rating hydrophobic?	dbBoolean	1
T2715_Pos	Transect 2 7:15 minute position	dbDouble	8
T2715_Veg	Transect 2 7:15 minute vegetation: NC, M, G, F, Sh, T, nr	dbText	2
T2715_Rating	Transect 2 7:15 minute rating 1-6	dbLong	4
T2715_Hydro	Is transect 2 7:15 minute rating hydrophobic?	dbBoolean	1
T3800_Pos	Transect 3 8:00 minute position	dbDouble	8
T3800_Veg	Transect 3 8:00 minute vegetation: NC, M, G, F, Sh, T, nr	dbText	2
T3800_Rating	Transect 3 8:00 minute rating 1-6	dbLong	4
T3800_Hydro	Is transect 3 8:00 minute rating hydrophobic?	dbBoolean	1
T3845_Pos	Transect 3 8:45 minute position	dbDouble	8
T3845_Veg	Transect 3 8:45 minute vegetation: NC, M, G, F, Sh, T, nr	dbText	2
T3845_Rating	Transect 3 8:45 minute rating 1-6	dbLong	4
T3845_Hydro	Is transect 3 8:45 minute rating hydrophobic?	dbBoolean	1
T1515_Pos	Transect 1 5:15 minute position	dbDouble	8
T1515_Veg	Transect 1 5:15 minute vegetation: NC, M, G, F, Sh, T, nr	dbText	2
T1515_Rating	Transect 1 5:15 minute rating 1-6	dbLong	4
T1515_Hydro	Is transect 1 5:15 minute rating hydrophobic?	dbBoolean	1
T1600_Pos	Transect 1 6:00 minute position	dbDouble	8
T1600_Veg	Transect 1 6:00 minute vegetation: NC, M, G, F, Sh, T, nr	dbText	2
T1600_Rating	Transect 1 6:00 minute rating 1-6	dbLong	4
T1600_Hydro	Is transect 1 6:00 minute rating hydrophobic?	dbBoolean	1

Field Name	Field Description	Field Type	Field Width
T2645_Pos	Transect 2 6:45 minute position	dbDouble	8
T2645_Veg	Transect 2 6:45 minute vegetation: NC, M, G, F, Sh, T, nr	dbText	2
T2645_Rating	Transect 2 6:45 minute rating 1-6	dbLong	4
T2645_Hydro	Is transect 2 6:45 minute rating hydrophobic?	dbBoolean	1
T2730_Pos	Transect 2 7:30 minute position	dbDouble	8
T2730_Veg	Transect 2 7:30 minute vegetation: NC, M, G, F, Sh, T, nr	dbText	2
T2730_Rating	Transect 2 7:30 minute rating 1-6	dbLong	4
T2730_Hydro	Is transect 2 7:30 minute rating hydrophobic?	dbBoolean	1
T3815_Pos	Transect 3 8:15 minute position	dbDouble	8
T3815_Veg	Transect 3 8:15 minute vegetation: NC, M, G, F, Sh, T, nr	dbText	2
T3815_Rating	Transect 3 8:15 minute rating 1-6	dbLong	4
T3815_Hydro	Is transect 3 8:15 minute rating hydrophobic?	dbBoolean	1
T3900_Pos	Transect 3 9:00 minute position	dbDouble	8
T3900_Veg	Transect 3 9:00 minute vegetation: NC, M, G, F, Sh, T, nr	dbText	2
T3900_Rating	Transect 3 9:00 minute rating 1-6	dbLong	4
T3900_Hydro	Is transect 3 9:00 minute rating hydrophobic?	dbBoolean	1
T1530_Pos	Transect 1 5:30 minute position	dbDouble	8
T1530_Veg	Transect 1 5:30 minute vegetation: NC, M, G, F, Sh, T, nr	dbText	2
T1530_Rating	Transect 1 5:30 minute rating 1-6	dbLong	4
T1530_Hydro	Is transect 1 5:30 minute rating hydrophobic?	dbBoolean	1
T1615_Pos	Transect 1 6:15 minute position	dbDouble	8
T1615_Veg	Transect 1 6:15 minute vegetation: NC, M, G, F, Sh, T, nr	dbText	2
T1615_Rating	Transect 1 6:15 minute rating 1-6	dbLong	4
T1615_Hydro	Is transect 1 6:15 minute rating hydrophobic?	dbBoolean	1
T2700_Pos	Transect 2 7:00 minute position	dbDouble	8
T2700_Veg	Transect 2 7:00 minute vegetation: NC, M, G, F, Sh, T, nr	dbText	2
T2700_Rating	Transect 2 7:00 minute rating 1-6	dbLong	4
T2700_Hydro	Is transect 2 7:00 minute rating hydrophobic?	dbBoolean	1
T2745_Pos	Transect 2 7:45 minute position	dbDouble	8
T2745_Veg	Transect 2 7:45 minute vegetation: NC, M, G, F, Sh, T, nr	dbText	2
T2745_Rating	Transect 2 7:45 minute rating 1-6	dbLong	4
T2745_Hydro	Is transect 2 7:45 minute rating hydrophobic?	dbBoolean	1
T3830_Pos	Transect 3 8:30 minute position	dbDouble	8
T3830_Veg	Transect 3 8:30 minute vegetation: NC, M, G, F, Sh, T, nr	dbText	2
T3830_Rating	Transect 3 8:30 minute rating 1-6	dbLong	4
T3830_Hydro	Is transect 3 8:30 minute rating hydrophobic?	dbBoolean	1
T3915_Pos	Transect 3 9:15 minute position	dbDouble	8
T3915_Veg	Transect 3 9:15 minute vegetation: NC, M, G, F, Sh, T, nr	dbText	2
T3915_Rating	Transect 3 9:15 minute rating 1-6	dbLong	4
T3915_Hydro	Is transect 3 9:15 minute rating hydrophobic?	dbBoolean	1
Comments	Soil stability comments	dbMemo	0

Table Name: tbl_Unknown_Species
Description: Table of unknown plant species

Field Name	Field Description	Field Type	Field Width
Unknown_ID	Unique record identifier - primary key	dbText	50
Species_ID	Foreign key to parent table [Discontinued use in 2009]	dbText	50
Unknown_Code	Temporary code for unknown species	dbText	15
Collected_by	Person collecting specimen	dbText	50
Method	Collection method	dbText	50

Field Name	Field Description	Field Type	Field Width
Transect_Number	Collection transect	dbInteger	2
Plant_Type	Plant type: herb, shrub, tree, grass, sedge, other	dbText	50
Plant_Description	General description	dbMemo	0
Salient_Feature	Most salient feature	dbText	255
Leaf_Type	Leaf type: compound/simple, arrangement	dbText	50
Margin	Leaf margin	dbText	50
Other_Characteristics	Other leaf characteristics: pubescence, sap, stipules	dbText	255
Stem_Characteristics	Stem characteristics: shape, pubescence, bud	dbText	255
Flower_Characteristics	Flower characteristics: color location floral formula	dbText	255
General_Characteristics	General and microhabitat characteristics	dbText	255
Collected	Was plant collected	dbBoolean	1
Best_Guess	Best guess species name	dbText	50
Confirmed_Code	Confirmed species code	dbText	50
Have_Photos	Are there photos?	dbBoolean	1
Forb_Grass_Type	Annual or perennial	dbText	10
Perennial_Grasses	Perennial grass type: bunchgrass or rhizomatous	dbText	15
Identified_by	Person making final identification	dbText	50
Identified_Date	Date of identification	dbDate	8
Position	Position on transect (m)	dbInteger	2

Lookup Tables

Table Name: tlu_Contacts
Description: Contact data for project-related personnel

Field Name	Field Description	Field Type	Field Width
Contact_ID	Contact identifier (Contact_ID)	dbText	50
Last_Name	Last name (Cnt_Last)	dbText	50
First_Name	First name (Cnt_First)	dbText	50
Middle_Init	Middle initial (Cnt_MI)	dbText	4
Organization	Organization or employer (cntorg)	dbText	50
Position_Title	Title or position description (cntpos)	dbText	50
Address_Type	Address (mailing, physical, both) type (addrtype)	dbText	50
Address	Street address (cntaddr)	dbText	50
Address2	Address line 2, suite, apartment number (Cnt_Addr2)	dbText	50
City	City or town (city)	dbText	50
State_Code	State or province (state)	dbText	8
Zip_Code	Zip code (postal)	dbText	50
Country	Country (country)	dbText	50
Email_Address	E-mail address (cntemail)	dbText	50
Work_Phone	Phone number (cntvoice)	dbText	50
Work_Extension	Phone extension (Work_Ext)	dbText	50
Contact_Notes	Contact notes (Cnt_Notes)	dbMemo	0
Active	Active flag for pick list filtering. 1 = active, 2=inactive	dbByte	1

Table Name: tlu_Cover_Class
Description: Lookup table of vegetation cover classes for soil stability

Field Name	Field Description	Field Type	Field Width
Cover_Class	Vegetation cover class	dbText	2
Cover_Description	Cover class description	dbText	25

Table Name: tlu_Crown_Class
Description: Lookup table for crown class

Field Name	Field Description	Field Type	Field Width
Crown_Class	Crown class	dbText	25

Table Name: tlu_Crown_Health_Class
Description: Lookup table of crown health classes

Field Name	Field Description	Field Type	Field Width
Crown_Health_Class	Crown health class	dbInteger	2
Class_Description	Health class description	dbText	50

Table Name: tlu_Densiometer_Point
Description: Lookup table of valid densiometer points

Field Name	Field Description	Field Type	Field Width
Point	Densiometer measurement point	dbText	4
Sort_Seq	Sort sequence	dbInteger	2

Table Name: tlu_Disturbance
Description: Lookup table of disturbance types

Field Name	Field Description	Field Type	Field Width
Disturbance	Disturbance type	dbText	50

Table Name: tlu_Eco_Site
Description: Lookup table for primary ecological site

Field Name	Field Description	Field Type	Field Width
Eco_Site	Primary ecological site type	dbText	50

Table Name: tlu_Effervescence
Description: Lookup table of soil effervescence

Field Name	Field Description	Field Type	Field Width
Effervescence	Soil effervescence	dbText	11

Table Name: tlu_Hillslope_Position
Description: Lookup table of hillslope position

Field Name	Field Description	Field Type	Field Width
Position	Hillslope position	dbText	9

Table Name: tlu_LP_Disturbance
Description: Lookup table of line-point disturbances

Field Name	Field Description	Field Type	Field Width
Dist_Code	Disturbance code	dbText	5
Disturbance	Disturbance description	dbText	50

Table Name: tlu_LP_Soil_Surface
Description: Lookup table of line-point soil surface

Field Name	Field Description	Field Type	Field Width
Surface_Code	Soil surface code	dbText	5
Surface_Description	Soil surface description	dbText	50
LC_Code	Lower canopy code (1 indicates code also applies to lower canopy fields)	dbByte	1

Table Name: tlu_Monument_Code

Description: Lookup table of monument tree corner codes

Field Name	Field Description	Field Type	Field Width
Monument_Code	5 character monument corner code	dbText	5

Table Name: tlu_NCPN_Plants
Description: Contains all NCPN master plant species

Field Name	Field Description	Field Type	Field Width
Master_Family	Master family	dbText	50
Master_PLANT_Code	Master species code; primary key (USDA PLANTS Database)	dbText	20
Master_Species	Master species name (Integrated Taxonomic Information System)	dbText	50
UT_Family	Utah family	dbText	50
CO_Family	Colorado family	dbText	50
WY_Family	Wyoming family	dbText	50
Utah_PLANT_Code	Utah species PLANTS code	dbText	20
Utah_Species	Utah species name (Welsh et al 2003)	dbText	50
Co_PLANT_Code	Colorado species PLANTS code	dbText	20
Co_Species	Colorado species name (Weber & Wittmann 2001)	dbText	50
Wy_PLANT_code	Wyoming species PLANTS code	dbText	20
Wy_Species	Wyoming species name (Dorn 2001)	dbText	50
Add_Synonyms	Additional synonyms	dbMemo	0
Taxonomic_Notes	Taxonomic notes	dbMemo	0
Master_Common_Name	Master common name	dbText	50
ARCH	Park presence descriptor for ARCH	dbText	15
BLCA	Park presence descriptor for BLCA	dbText	15
BRCA	Park presence descriptor for BRCA	dbText	15
CANY	Park presence descriptor for CANY	dbText	15
CARE	Park presence descriptor for CARE	dbText	15
CEBR	Park presence descriptor for CEBR	dbText	15
COLM	Park presence descriptor for COLM	dbText	15
CURE	Park presence descriptor for CURE	dbText	15
DINO (UT)	Park presence descriptor for DINO - Utah	dbText	15
DINO (CO)	Park presence descriptor for DINO - Colorado	dbText	15
FOBU	Park presence descriptor for FOBU	dbText	15
GOSP	Park presence descriptor for GOSP	dbText	15
HOVE (UT)	Park presence descriptor for HOVE - Utah	dbText	15
HOVE (CO)	Park presence descriptor for HOVE - Colorado	dbText	15
NABR	Park presence descriptor for NABR	dbText	15
PISP	Park presence descriptor for PISP	dbText	15
TICA	Park presence descriptor for TICA	dbText	15
ZION	Park presence descriptor for ZION	dbText	15
Lifeform	Lifeform derived from USDA PLANTS	dbText	255
Duration	Duration derived from USDA PLANTS	dbText	255
Nativity	Nativity derived from USDA PLANTS	dbText	255
Trinomial	True if species code represents a trinomial name	dbBoolean	1
Unique_Species	True if species code represents a genus and species designation	dbBoolean	1
New_Record	Is it a new record?	dbBoolean	1
LU_Code	Shorthand (a.k.a. 6-letter) lookup code	dbText	25
Wetland_Code	Code identifying wetland designation (see http://plants.usda.gov/wetinfo.html#categories)	dbText	20

Field Name	Field Description	Field Type	Field Width
Wetland_Code_Info_Source	Information source used to determine wetland classification	dbText	50
Photosynthetic_Pathway	Photosynthetic pathway designation (source: Osborne et al. 2014, doi: 10.1111/nph.12942)	dbText	5

Table Name: tlu_Parks
Description: Look-up table of parks in the Northern Colorado Plateau Network

Field Name	Field Description	Field Type	Field Width
ParkCode	Four-letter abbreviation for park code	dbText	5
ParkName	Full name of park where data were collected	dbText	50
ParkState	State code	dbText	2

Table Name: tlu_Profile_Depth
Description: Lookup table of soil profile depths

Field Name	Field Description	Field Type	Field Width
Depth	Soil profile depth	dbText	9

Table Name: tlu_Rock_Frag_Q
Description: Lookup table of rock fragment quantity modifiers

Field Name	Field Description	Field Type	Field Width
Quantity	Rock fragment quantity modifier	dbText	9
Descriptor	Modifier descriptor	dbText	12

Table Name: tlu_Rock_Frag_Size
Description: Lookup table of rock fragment size modifiers

Field Name	Field Description	Field Type	Field Width
Size	Rock fragment size modifier	dbText	8

Table Name: tlu_Sand_Modifier
Description: Lookup table of sand modifiers

Field Name	Field Description	Field Type	Field Width
Modifier	Sand modifier	dbText	25

Table Name: tlu_Slope_Shape
Description: Lookup table of slope shapes

Field Name	Field Description	Field Type	Field Width
Shape	Slope shape	dbText	7

Table Name: tlu_Soil_Depth
Description: Lookup table of soil depth to bedrock

Field Name	Field Description	Field Type	Field Width
Depth	Soil depth	dbText	50

Table Name: tlu_Soil_Survey_Area
Description: Lookup table for soil survey area

Field Name	Field Description	Field Type	Field Width
Soil_Survey_Area	Soil survey area	dbText	50

Table Name: tlu_Soil_Texture
Description: Lookup table for soil texture

Field Name	Field Description	Field Type	Field Width
Soil_Texture	Particle size distribution of fine earth fraction and clay particles	dbText	50

Table Name: tlu_Veg_Type
Description: Lookup table for vegetation type

Field Name	Field Description	Field Type	Field Width
Vegetation_Type	Vegetation type (forest, grassland/shrubland, oak scrub, woodland)	dbText	50

Table Name: xref_Park_EcoSite
Description: Cross reference of park with associated eco site types

Field Name	Field Description	Field Type	Field Width
Unit_Code	4 letter park code	dbText	50
Eco_Site	Associated ecological site type	dbText	50

Metadata Tables

Table Name: tbl_master_version
Description: Table of protocol version information

Field Name	Field Description	Field Type	Field Width
project_ID	Project ID number to ensure uniqueness across all projects	dbLong	4
version_key_number	Protocol version key number	dbLong	4
version_key_date	Date of protocol version key number	dbDate	8
narrative_version	Version of protocol narrative	dbDecimal	16
version_comments	Comments regarding version, if any	dbMemo	0

Table Name: tbl_SOP_version
Description: Table of SOP version information

Field Name	Field Description	Field Type	Field Width
version_key_number	Protocol version key number	dbLong	4
SOP_number	SOP number	dbLong	4
SOP_version_number	SOP version number	dbDecimal	16
active_flag	Yes indicates SOP is active	dbBoolean	1

Table Name: tlu_projects
Description: Table of NCPN project information

Field Name	Field Description	Field Type	Field Width
project_ID	Project ID number to ensure uniqueness across all projects	dbLong	4
project_name	Project name	dbText	50
project_linkfile	Path and file name of project database	dbText	255
project_include_flag	True indicates project is to be included in query results	dbBoolean	1
project_comments	Comments regarding project, if any	dbMemo	0

Table Name: tsys_App_Releases
Description: Application table - Application release history

Field Name	Field Description	Field Type	Field Width
Release_ID	Unique identifier for the release	dbText	50
Release_date	Date of the release	dbDate	8
Database_title	Title of the database	dbText	100

Field Name	Field Description	Field Type	Field Width
Version_number	Version control number	dbText	20
File_name	Filename, used to identify older versions of the database	dbText	50
Release_by	Person who made the release	dbText	50
Release_notes	Release notes, which may include a summary of revisions	dbMemo	0
Author_phone	Phone number of application author	dbText	50
Author_email	Email address of application author	dbText	50
Author_org	Organization (NPS Unit code) for the author's place of work	dbText	10
Author_org_name	Name of organization for author's place of work	dbText	100

Upland Vegetation and Soils Monitoring Protocol for the Park Units in the Northern Colorado Plateau Network

Standard Operating Procedure (SOP) # 19

Data Analysis and Reporting

Version 1.05 (November 2017)

Revision History Log:

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #
1.00	9/2009	D. Witwicki	Combine dryland and forest instructions, update table formats & variance assessment procedures	Procedures modified since last version	1.01
1.01	10/2011	D. Witwicki	Add basal area and exotic frequency; Remove specific report instructions and tables	Instructions too specific	1.02
1.02	12/2012	D. Witwicki	Revise fuel metrics	Recommended by fire ecologist	1.03
1.03	8/2016	D. Witwicki	Change annual reports to summary reports; refer to survey designs in the appendix		1.04
1.04	11/2017	D. Witwicki	Added reference to narrative appendices	For publication	1.05

This SOP provides an overview of analysis and reporting procedures. After raw data from the field season are quality checked, they are then summarized to the plot level. Additional QAQC is performed comparing these data to previously collected data to catch misidentified species and values that represent unlikely amounts of change between years. Once data quality issues are resolved, analyses can be conducted. Two general types of analyses are performed: 1) summary reporting of the most recent monitoring observations (summary reports and briefs), and 2) comprehensive assessments of the long-term data set (variance estimation of the overall sampling design, evaluation of status and trends, and correlations with other vital signs).

1.0 Data Summary

The sampling unit for all upland analyses is the plot, and sub-samples recorded along transects must be scaled to this level. Summary queries are created in Access to expedite this process.

Richness
Data from the 1-m belt are used to calculate species richness, which is the number of unique species encountered. For each plot, calculate richness of all species, native species, and species by life form (e.g., tree, shrub, etc.). At plots where the species richness is not measured in the 1-m belt, richness of dominant species can be compiled from point-intercept data. It is important that species richness is derived using the same methods and area sampled for all years and plots in an analysis. Otherwise, rarefaction methods will need to be used if the number of sub-samples changes within or among monitoring plots (e.g., Krebs 1989, Ludwig and Reynolds 1988). In addition, a species list for the plot is assembled using all vegetation measures.

Percent Cover
Percent cover is calculated for each species, life form, ground cover attribute, and disturbance using point-intercept data from transects. It is derived by summing the number of points where each species, life form, ground cover attribute, or disturbance is hit, and dividing by the total number of point-intercept readings across all three transects, times 100 (eq. 1, Table 1). Canopy closure is the average of all densiometer readings across a plot expressed as a percent (eq. 1, Table 1).

Exotic frequency
Exotic frequency is derived from the number of detections of each exotic species in the 1-m^2 quadrats, and reported as the percent of detections.

Density
Density is derived for shrubs and tree seedlings in the 1-m belt, saplings in the 5-m belt, and overstory trees in quadrant 1. It is the number of shrubs, tree seedlings, saplings, or overstory trees counted, divided by the total area sampled, scaled to stems per ha (eq. 2, Table 1). This measure is calculated for each species by size class.

Basal Area
Basal area is the cross-sectional area of trees divided by the total area sampled, scaled to m^2 per ha. Basal area and density are correlated and should always be considered together when reviewing data summaries of each (eq. 3, Table 1).

Other overstory tree measures
Overstory tree summaries should also include the distribution of stem diameters, crown health, and crown classes.

Basal and Canopy Gaps
Basal and canopy gaps are summarized by mean gap size and distribution of gap sizes. Mean gap size is derived by simply averaging the gap sizes recorded on all three transects (eq. 4, Table 1). For distribution of gap sizes, calculate the percentage of all three transects covered in gaps <20 cm and canopy, 20-50 cm gaps, 51-100 cm gaps, 101-200 cm gaps, and >200 cm gaps.

Soil Stability

There are three calculations for soil stability: 1) the average stability for all samples is derived by summing all stability values and dividing by the total number of samples; 2) the average stability for protected soil is derived in a similar manner but only using the samples associated with canopy (Veg= G, F, Sh, or T as defined on page 2 of SOP#11); and 3) the average stability for unprotected soil is similarly derived but only using samples associated with moss or no canopy (Veg = M or NC).

Fuel Loading

Fuel loading is derived using formulas from Brown (1974) and Brown and colleagues (1982). Fuel load is calculated separately for each size class: 1-hour, 10-hour, and 100-hour fuels are calculated using Equation 5 (Table 1); 1000-hour sound and 1000-hour rotten fuels are calculated using Equation 6 (Table 1); and litter and duff are calculated using Equation 7 (Table 1). Specific gravity and bulk density values used in the calculations (see Table 2) are weighted by basal area of tree species in each vegetation or ecological site type.

Table 1. Formulas for deriving plot-level measures.

Percent Cover

$$PC = (h / n)*100 \quad (1)$$

where;

PC = percent cover
h = the number of points where each species, ground cover attribute, life form, or overstory is hit
n = the total number of points per plot

Density

$$D = 10{,}000 * t / a \quad (2)$$

where D = density of shrubs or trees in individuals/ha
t = the number of shrubs or tree seedlings in the 1-m belt, saplings in the 5-m belt, or overstory trees in quadrant 1
a = area sampled in m^2

Table 2 (continued). Formulas for deriving plot-level measures.

Basal area

$$BA = \left(\sum_{i=1}^{y} [(DBH_i / [2*100])^2 * \pi]\right) / (a / 10000) \quad (3)$$

where BA = basal area in m^2/ha
DBH_i = diameter at breast height[1] in cm for tree i in the 5-m belt or Quadrant 1
y = the total number of trees with DBH measures
π = 3.142
a = area sampled in m^2

[1]diameter at root crown for Utah juniper and pinyon pine

Mean (canopy or basal gap size)

$$M = \left(\sum_{i=1}^{v} g_i\right) / v \quad (4)$$

where;
M = mean in cm
g_i = gap size in cm for gap i
v = the total number of gap measures

Fuel Loading

1-hr, 10-hr, and 100-hr fuels:

$$F = (11.64 * n * d^2 * s * c) / N_\ell \quad (5)$$

1000-hr fuels:

$$F = (11.64 * \sum d^2 * s * c) / N_\ell \quad (6)$$

Litter and duff:

$$F = (1.815 * B * D) \quad (7)$$

where;
F = fuel load in tons per acre
n = the total number of intersections for each size class (1-hr, 10-hr, 100-hr) per plot
d = diameter in inches
s = specific gravity (use appropriate value(s) from Table 2)
c = slope correction factor

$$c = \sqrt{1 + \left(\frac{\%slope}{100}\right)^2}$$

N_ℓ = total length of transects sampled in feet for each size class
B = bulk density of litter or duff (use appropriate value(s) from Table 2)
D = mean depth of litter or duff per plot in inches

Table 3. Specific gravity of downed woody material (1-hr, 10-hr, 100-hr and 1000-hr fuels) and bulk density of litter and duff for selected tree species.

	Specific gravity					Bulk density (lb/ ft^3)	
				1000-hr			
Tree species	**1-hr**	**10-hr**	**100-hr**	**sound**	**rotten***	**litter**	**duff**
Abies concolor	0.53	0.54	0.57	0.57	0.30	4.9	11.4
Abies lasiocarpa*	0.40	0.40	0.40	0.40	0.30		
Juniperus osteosperma	0.67	0.65	0.62	0.62	0.30	4.4	11.1
Juniperus scopulorum	0.67	0.65	0.62	0.62	0.30	4.4	11.1
Picea engelmannii*	0.34	0.34	0.34	0.34	0.30		
Pinus edulis	0.65	0.64	0.62	0.62	0.30	9.1	14.6
Pinus monophylla	0.65	0.64	0.62	0.62	0.30	9.1	14.6
Pinus ponderosa	0.46	0.46	0.39	0.39	0.30	0.99	9.24
Populus tremuloides	0.42	0.40	0.39	0.39	0.30	0.94	6.0
Pseudotsuga menziesii	0.53	0.53	0.57	0.57	0.30	6.3	9.5
general*	0.48	0.48	0.40	0.40	0.30		

* Values from Brown (1974) for these species and for rotten 1000-hr fuels. All other values are from the NPS fire effects monitoring program based out of Zion National Park.

2.0 Data Quality Assessment

Before data analysis and reporting, plot-level data should be additionally evaluated for reasonable levels of change based on historical conditions at each plot. For instance, a measure may appear to be valid based on the database domain, but represent an unreasonable (and unlikely) change in plot conditions since the last field visit. Summarized attributes should be compared between years, and all suspect values (large increases or decreases) should be flagged and resolved before the data are analyzed. In addition, data should be evaluated for the omission of historically dominant species or the appearance of dominant species not detected in previous years. New occurrences of a species should be compared with the park-level species list and species-range limits.

Suspect measures or species should be evaluated by field crew members and by field verification if possible. Any corrections made to the database should be recorded in the QAQC log. Suspect data that are not resolved should also be flagged in the QAQC log so that it can excluded from analyses, if appropriate. Suspect data that cannot be resolved in the office should be brought to the attention of the field crew at the next monitoring visit so that they may eventually be resolved.

3.0 Summary Reporting

Summary Reports
The primary objectives of the summary report are to 1) document monitoring activities for the period of record, 2) summarize data and describe the current condition of resources, and 3) provide information to park managers in a timely manner that increases data utility and communication. A separate report is completed for each NCPN park unit with upland vegetation and soils monitoring. Existing NCPN reports should be consulted for formatting.

Annual Briefs
Each year, information from summary reports and other analyses is further summarized in 1-2 page briefs that provide resource managers with a concise summary of issues of concern. NCPN produces two types of briefs: vital signs briefs and park briefs. The upland vital signs brief summarizes findings from upland vegetation and soils monitoring in all NCPN parks. Park briefs are produced for each NCPN park unit and contain a section on upland vegetation and soils monitoring. Existing vital signs briefs and park briefs should be consulted for formatting.

4.0 Comprehensive assessments

Comprehensive analyses and reports are completed periodically on the long-term data set. Comprehensive reports should be structured like typical scientific manuscripts (introduction, methods, results, discussion, and literature cited sections) and may include, but are not limited to, any of the analyses described in this section.

Sampling-Design Variance Assessment
The sampling design for upland vegetation and soils monitoring at each park unit is documented in the appendices to the protocol narrative. For park units with pilot monitoring, the initial assessment of variance is performed after three years of data collection. For all park units with upland vegetation and soils monitoring, assumptions of the sampling design should be checked periodically to make sure they are meeting the original monitoring and sampling objectives. Sampling designs are evaluated by calculating variance and power for trend, and assessments are recommended every 5-7 years.

Variance estimates are derived from all years of monitoring data, not just observations from the current field season. Where necessary, alternative survey designs are evaluated to determine appropriate enhancements, such as an increase in sample size or more frequent visits to established plots, to achieve the original sampling objective. Power-for-trend is evaluated with alternative numbers of panels, sample sizes, and revisit schemes. A trend may be reported as a yearly rate or a rate over a set number of years. This conversion is outlined for increasing (eq. 7, Table 3) and decreasing (eq. 8, Table 3) rates of trend. Results are then used to determine which survey designs best meet the

original/desired sampling objectives.

Table 4. Formula for converting a yearly rate of trend to a rate of trend over a set number of years.

Conversion for rate of trend

$$I = e^{rt} \quad (7)$$

$$D = 1 - e^{rt} \quad (8)$$

where;

I = % increase over t years
D =% decrease over t years
e =base of the natural logarithm
r = the yearly rate of increase or decrease
t = the total time period of increase or decrease

Variance components are estimated using a mixed-effects model (Larsen et al. 1995). Use the appropriate SAS code (Table 4) for balanced or unbalanced sampling designs. In the SAS code for generating this estimation (Table 4), site and year are categorical variables coded to indicate the plot and the year of the response. For simplicity, site should be the NCPN PlotID (recorded in the Upland database for each monitoring location) and year should be the calendar year when the observation was recorded. This code generates values of variance for site, year, and year*site (residual variance).

If there is a trend over time (i.e., the year variable is significant), the data will need to be detrended so that year variance is not inflated. Use one of the mixed models in Table 5 to account for time. If time is significant, the year variance should decrease. If time is not significant, then the original model should be sufficient. Alternatively, using inflated year variance in a power-for-trend assessment will favor a more conservative sampling design.

Values of the variance components, the panel structure of the current sampling design, and the desired minimum detectable change level determine the power-for-trend. Power-for-trend is assessed using the Power-for-Trend R code (Attachment A). Comparing the resulting power with the proposed power of the sampling design determines the degree to which the implemented design is achieving the stated sampling objective(s). Using procedures outlined in Attachment A, determine power-for-trend for the key attributes considered in crafting the sampling design. Where necessary, alternative survey designs can be evaluated to determine necessary enhancements to achieve the desired sampling objectives. This involves using the empirically derived variance estimates with alternative numbers of panels, sample sizes, and revisit schemes to determine which survey design best meets the original/desired sampling objectives.

Table 5. SAS code for generating ln-transformed estimates of variance components using a mixed effects model.

4-1. For a balanced sampling design

```
DATA THEKS1;
  INFILE '<pathname\filename>';
    INPUT site year response; LogResp= log(response+1);
RUN;
TITLE "Methods of Moments Estimates";
PROC mixed method= type3 covtest asycorr;
  class year site;
  MODEL LogResp =;
   random site year site*year;
RUN;
```

4-2. For an unbalanced sampling design

```
DATA THEKS1;
  INFILE '<pathname\filename>';
    INPUT site year response; LogResp= log(response+1);
RUN;
TITLE "Methods of Moments Estimates";
PROC mixed method= REML covtest asycorr;
  class year site;
  MODEL LogResp =/DDFM=KENWARDROGER;
   random site year site*year;
RUN;
```

Status and Trends Assessments

The underlying motivation for using survey designs to monitor upland ecosystems is the ability to make inferences to a finite, target population. Alternatively, model-based designs and assessments rely on modeled relationships, and thus tend to have inherent assumptions, and in some cases, limitations in terms of the scope of inference. However, model-based assessments may be useful to help explain reasons for trends observed in survey-design efforts, and information from other vital signs monitoring (e.g., climate, air quality, land use, land condition) or other sources may prove critical to interpreting observed upland trends. Bayesian methods may detect trends earlier than frequentist methods and should be developed over time.

Status and trend analyses are performed after at least 5 years of monitoring data are collected. When significant trends are detected, reasons for these trends should be evaluated by comparison with other NCPN data sets (correlation, covariates, etc.), literature reviews, comparison with other similar data sets, and additional assessments using ancillary information. When unidirectional trends are not detected, correlations may help us understand ecosystem drivers.

Frequentists Methods

Frequentist trend assessments of complex survey designs are performed using mixed-effects models (Larsen et al. 1995). Plot-scale measures are used in the model and are evaluated on the basis of time for each stratum (i.e., ecological site type, vegetation type, or elevation zone) in a park unit and for all relevant response variables. In the mixed-effects model, time is treated as a fixed effect while site and year are random effects. Site refers to the plot and year is the same value as time. Both site and year are treated as categorical variables while time is treated as a continuous variable. Use the appropriate SAS code to evaluate trend (Table 5) for balanced or unbalanced sampling designs. The output from this model is a measure of the intercept and slope, the significance of the slope and intercept being different from zero, and measures of the variance and covariance of the regression parameters. A significant slope indicates a significant trend, at least at the alpha level used to assess significance.

Table 6. SAS code for a mixed-effects model to evaluate significance of trend.

5-1. For a balanced sampling design

```
INFILE '<pathname\filename>';
   INPUT time site response; year=time; LogResp = log(response+1);
RUN;
PROC mixed method=type3;
  class  site year;
  MODEL LogResp = time/cl covb ;
  random site year ;
RUN;
```

5-2. For an unbalanced sampling design

```
INFILE '<pathname\filename>';
   INPUT time site response; year=time; LogResp = log(response+1);
RUN;
PROC mixed method=REML;
  class  site year;
  MODEL LogResp = time/cl covb DDFM=KENWARDROGER;
  random site year ;
RUN;
```

Status is the condition of the attribute and is derived in two ways. If the trend slope is not significantly different from zero, mean and variance of status is simply the mean and variance of all measures of the attribute up to the current time period. If the slope is significant, then status is the solution of the regression model for the latest time period of the data used to generate the trend line (eq. 9 in Table 6). Standard error of status is

derived from the covariance matrix of the regression coefficients (eq. 10 in Table 6), which is output by the SAS model shown in Table 5 (i.e., via the covb option).

Table 7. Formula for deriving status and trend estimates.

Mean Status From a Trend Line

$$ST_t = b_0 + b_1 * t \qquad (9)$$

where;

ST_t = estimate of mean status at time = t
b_0 = the estimated intercept parameter
b_1 = the estimated slope parameter
t = the most recent time period of the data (in the same units used to generate b_0 and b_1)

Standard Error of Status

$$SeSTt = \sqrt{(\sigma^2_{b0} + 2t\,\sigma_{b0b1} + \sigma^2_{b1}t^2)} \qquad (10)$$

where;

$SeST_t$ = the standard error of the mean-status estimate at time = t
σ^2_{b0} = the variance of the intercept parameter
σ_{b0b1} = the covariance of the regression parameters
σ^2_{b1} = the variance of the slope parameter
t = the most recent time period of the data

The calculations in the previous two paragraphs are used to make inferences to each stratum (i.e., ecological site type, vegetation type, or elevation zone) in the survey design for a park unit. If you would like to combine these to make inference to multiple strata or the entire area of the park unit that is monitored, you will need to use the Horvitz-Thompson Estimator (Thompson 1992). The following procedure should only be used for observations from the most recent monitoring event. Refer to Thompson (1992) for specific details on how to perform this calculation using trend line status estimation from multiple years of data. Derivation of the mean, variance, and confidence interval for the Horvitz-Thompson Estimator is shown in Table 7 (eq. 11, 12, and 13). Although the estimator provides an unbiased result, the variance can be large if π_i and y_i are not well related (Thompson 1992). In such case, the Generalized Horvitz-Thompson Estimator should be used (eq. 14 and 15, Table 7).

Table 8. Formula for the variants of the Horvitz-Thompson Estimator.

Horvitz-Thompson Estimator

$$y_\pi = \left(\sum_{i=1}^{v} y_i/\pi_i\right) / N \qquad (11)$$

where;

y_π = estimate of the mean
v = the number of plots in the sample
y_i = observed value for plot i
π_i = the inclusion probability that plot i is in the sample
N = total number of unique monitoring plots (all strata combined)

The inclusion probability, π_i, is derived from the selection probability of a plot, which is generated in the plot-selection process (see survey design reports for each park unit for details):

$$\pi_i = 1 - (1- p_i)^n$$

where;

p_i = the selection probability of plot i
n = number of plots in a sample

The variance of the mean is:

$$\mathrm{var}(y_\pi) = \left[\sum_{i=1}^{v} \left((1/\pi_i^2) - (1/\pi_i) \right) y_i^2 + 2 \sum_{i=1}^{v} \sum_{j>1}^{v} \left[(1/(\pi_i \pi_j)) - (1/\pi_{ij}) \right] y_i\, y_j \right] / N^2 \qquad (12)$$

where;

π_{ij} = the inclusion probability that both plots i and j are in the sample.

where;

$$\pi_{ij} = \pi_i + \pi_j - [1 - (1- p_i - p_j)^n]$$

The confidence interval using a t with v-1 degrees of freedom is:

$$y_\pi \pm t \sqrt{\mathrm{var}(y_\pi)} \qquad (13)$$

Generalized Horvitz-Thompson Estimator

$$y_g = \sum_{i=1}^{v} (y_i/\pi_i) \Big/ \sum_{i=1}^{v} (1/\pi_i) \qquad (14)$$

$$\mathrm{var}(y_g) = \Big[\sum_{i=1}^{v} \left((1-\pi_i)/\pi_i^2 \right) (y_i - y_g)^2 + 2 \sum_{i=1}^{v} \sum_{j>1}^{v} \left[(\pi_{ij} - \pi_i\pi_j)/\pi_i\pi_j \right] \left[((y_i - y_g)(y_j - y_g)) / \pi_{ij} \right] \Big] / N^2 \qquad (15)$$

The confidence interval using a t with v-1 degrees of freedom is given in eq. 13, but y_g should be used instead of y_π.

Multivariate assessments of trends may be performed on plant community measurements. Changes in community composition and structure between time periods can be summarized using average Euclidean distance between resemblance matrices to determine the occurrence of significant changes (Collins 2000). Resemblance matrices consist of lists of species that occur in either of two time periods and percent cover of the species in each time period. If a species only occurred in one of the time periods, a value of zero is used for the other time period. Euclidean distance between two samples is first derived using eq. 16 in Table 8. An average Euclidean distance (eq. 17, Table 8) is then derived, which compensates for increasing distance with increasing number of species.

For each monitoring plot, the average Euclidean distance for all possible pair-wise comparisons of time periods is used in a trend assessment (Table 5). Associated with each pair-wise distance is the time lag, which is simply the time difference between the pair-wise samples. For trend assessments, the square-root of time lag is used to down-weight the smaller number of values for the longer time lags (which characteristically will be fewer than for shorter time lags). For all monitoring plots of a stratum combined, the site, year (categorical form of the square root of time lag), and time (continuous value of square root of time lag) are used in the model in Table 5 to evaluate significance of trend in the average Euclidean distance. A significant trend indicates changes in community composition and structure over time. Where a significant trend occurs, further investigation is required to determine species loss or addition, or changes in the species measure (cover or frequency) resulting in the significant trend.

Trends in size-class distributions also can be evaluated using the average Euclidean distance measure. For canopy and basal gap measures, distribution of canopy and basal gap sizes are generated for each monitoring event and changes in this distribution are evaluated using the same approach outlined above for plant communities. For each attribute, the size-class interval must be constant among all years and the sub-samples of

plot-level measures must be constant (i.e., the same number and length of transects in all years and on all plots). A significant slope indicates a trend in the distribution of canopy or basal gap sizes and further investigation is required to determine which class intervals increased or decreased over time.

Similarity metrics are an additional way to evaluate plant community change over time. A simple but useful measure is the Coefficient of Sorensen (eq. 18, Table 8). This coefficient is based on presence/absence of species, and it more heavily weights matches in species composition than mismatches. When a plot has multiple years of observations, a Sorensen's similarity coefficient is based on all recorded species and the associated time lag is derived for all pair-wise time periods. For all monitoring plots in a stratum, the site, year (categorical form of the square root of time lag), and time (continuous value of square root of time lag) are used in the model in Table 5 to evaluate significance of trend in the similarity. A significant trend indicates changes in community composition. Where a significant trend occurs, further investigation is required to determine species loss or addition resulting in the significant trend.

Table 9. Formula for deriving measures of Euclidean distance and similarity.

Euclidean Distance

$$Euc_{jk} = \sqrt{\Sigma (x_{ij} - x_{ik})^2} \quad (16)$$

where;

Euc_{jk} = the Euclidean distance between samples j and k
x_{ij} = attribute of category i in sample j
x_{ik} = attribute of category i in sample k

NOTE: an attribute could be percent cover or distribution of size classes; a category is either a species or a size class. E.g., if working with percent cover, then x_{ik} is percent cover of species i in sample k, and x_{ij} is percent cover of species i in sample j.

Average Euclidean Distance

$$AEuc_{jk} = \sqrt{Euc^2_{jk} / n)} \quad (17)$$

where;

$AEuc_{jk}$ = the average Euclidean distance between samples j and k
Euc_{jk} = the Euclidean distance between samples j and k (eq. 8)
n = the number of categories in samples

Sorenson's Similarity Coefficient

$$S_s = 2a/(2a+b+c) \quad (18)$$

where;

S_s = Sorensen's similarity coefficient
a = the number of species in both sample 1 and 2
b = the number of species in sample 2 but not in sample 1
c = the number of species in sample 1 but not in sample 2

Model-Based Methods

Model-selection procedures consider a range of potential factors influencing directional change in resource conditions. Even if a significant trend occurs as a function of time, the relationship between other explanatory variables and upland measures should be evaluated to determine potential 'causes' of trends. These other explanatory variables can include biophysical features of the plots as well as measures from other vital signs monitoring (e.g., climatic conditions).

Model selection methods (Burnham and Anderson 1998) evaluate the explanatory power of different models of trends in upland measures. Multiple models are considered, each with different combinations of independent variables and interaction terms. All models should be based on hypothesized, ecologically meaningful relationships. Adjusted AIC (Akaike's Information Criterion) values generated with a mixed-effects model are used to determine the best predictive model as well as the importance of independent variables.

The primary model in this model-selection procedure is the response of interest vs. time (see frequentist methods above). Alternative models can be based on measures of climate, air quality, land use, and land condition, as well as other measures that may be considered important. When evaluating other variables, they are either included in an interaction with time or time is replaced with the variable.

The result of the model-selection procedure is the selection of the model (i.e., set of independent variables) which best predicts the trend of the response variable. This, in turn, aids in explaining reasons for the observed trend. For instance, if alternative models with one or more driver attributes (e.g., drought days) accounted for more variance than just using time, trends may be attributed to these attributes in a correlational relationship, but not necessarily a causal relationship. If alternatives to time account for less variance, other avenues of investigation should be considered to explain reasons for observed trends.

Bayesian Methods

Bayesian methods for trend assessment identify the probability of different slope-parameter values (Gelman et al. 2000, Wade 2000) given the observed data. This differs from frequentist methods which calculate the probability of observing data given a specific value for a parameter, such as the null hypothesis. Assessing the probability of different slope values is potentially important for various reasons. First, sampling designs are largely based on a few key features. The minimum detectable trend at a reasonable power level for many of the other responses will likely be much higher. Estimating the probability of slope values may be the best way to provide insight into trends for these

attributes. Second, even for the key features around which sampling designs were based, Bayesian methods may reveal the potential of declining trends before rejecting the null hypothesis that the regression slope equals 0 with conventional statistics.

Bayesian methods use a likelihood distribution generated from the sample data that provides the probability of observing the data for every possible parameter value. Combining this with a prior distribution produces a posterior distribution which is used to make inference about parameters. The prior distribution reflects previous knowledge about the distribution of parameters. In the absence of such knowledge, a non-informative distribution can be used, which essentially is a uniform distribution across the range of the likelihood distribution. In subsequent analyses, the posterior distribution of previous assessments can be used as the prior distribution. The posterior distribution allows assessments of the probability of user-selected parameter values. The probability of various increasing and decreasing slopes should be evaluated based on the posterior distribution and the consequences of not alerting management of a potential trend. The result of this assessment is the derivation of the probability of different levels of decline/increase. Even though conventional statistics may not reveal a significant trend, relatively high probabilities (e.g., $\geq$0.70) of trends with a Bayesian method may warrant special attention.

Correlations

There will be instances where a monitored attribute fails to exhibit a trend (i.e., a direction change), but instead may have periods of decline followed by recovery. In other words, natural variation may be more evident than a precipitous decline or increase, and it may mirror the variation in a key driver attribute. Discerning this variation and reasons for it can involve many complex procedures. As a first step, however, correlational methods can provide useful insight and are relatively simple.

For attributes that fluctuate between declines and increases, correlations with climate, air quality, land cover/use, land condition, and other potential drivers should be considered. Strong correlations between a response and driver may be sufficient to understand reasons for the observed variation over time (e.g., strong correlation between shrub cover and annual precipitation).

Another form of correlational assessment is path analysis (Lundquist 2000). This method accounts for the inter-correlated structure among factors by decomposing correlations to direct and indirect effects. For instance, changes in grass cover in a shrub-steppe system may be influenced by shrub cover alone or by climate alone or by the influence of climate on shrub cover. A path analysis would decompose the effects of climate and of shrubs on grass cover, while considering the combined influence of climate and shrubs. The result of a path analysis is the indication of the strength of direct and indirect factors on a response, thus providing insight into reasons for the observed changes in a response. Path analysis is based on correlation values and the simultaneous solution of structural equations. Simple examples of the construction and use of path analysis are provided in Lundquist (2000) and Van Bruggen and Arneson (1986); details of path analysis are provided in Pugesek et al. (2003).

5.0 References

Brown, J. K. 1974. Handbook for inventorying downed woody material. USDA Forest Service General Tech. Report INT-16, Intermountain Forest and Range Experiment Station, Ogden, UT.

Brown, J. K., R. D. Oberheu, and C. M. Johnston. 1982. Handbook for inventorying surface fuels and biomass in the Interior West. USDA Forest Service General Tech. Report INT-129, Intermountain Forest and Range Experiment Station, Ogden, UT.

Burnham, K. P. and D. R. Anderson. 1998. Model selection and inference: a practical information-theoretic approach. Springer-Verlag, NY

Collins, S. L. 2000. Disturbance frequency and community stability in native tallgrass prairie. American Naturalist, 155:311-325.

Gelman, A., J. B. Carlin, H. S. Stern, and D. B. Rubin. 2000. Bayesian Data Analysis. Chapman & Hall/CRC, New York.

Krebs, C. J. 1989. Ecological methodology. Harper Collins *Publishers*, New York.

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, 31:117-140.

Lundquist, J. E. 2000. A method of estimating direct and indirect effects of Armillaria root disease and other small-scale forest disturbances on canopy gap size. Forest Science, 46:356-362.

Ludwig, J. A. and J. F. Reynolds. 1988. Statistical ecology. John Wiley & Sons, New York.

Pugesek, B. H., A. Tomer, and A. von Eye. 2003. Structural equation modeling. Cambridge University Press, Cambridge, UK.

Thompson, S. K. 1992. Sampling. John Wiley & Sons, Inc, New York.

Van Bruggen, A. H. C. and P. A. Arneson. 1986. Path coefficient analysis of effects of *Rhizoctonia solani* on growth and development of dry beans. Phytopathology, 76:874-878.

Wade, P. R. 2000. Bayesian methods in conservation biology. Conservation Biology, 14:1308-1316.

Attachment A
Power-for-Trend Procedures

The Power-for-Trend R code written by T. Kincaid (EPA, Corvallis, OR) is used to evaluate power for trend. This code resides as two files on the NCPN server called trendse.R and power.R. The original power.R code was modified to facilitate ease of code modification to evaluate multiple sets of variance estimators. The portion of the code that must be modified occurs at the very top and is shown in Table A-1. User-provided values are inserted in place of < >. Variance components are derived following procedures described in section 4.0 Sampling-design Variance Assessment. The % trend value and alpha level correspond to the sampling objective being evaluated. The ind.mean (indicator mean) is set to 1 when working with variance measures from log-transformed data. Otherwise, this parameter is set to the mean of the indicator.

The nsites attribute specifies the number of panels and plots per panel in the revisit design. In the example below, there are 5 panels (hence, nrow=5) with the number of plots specified for each year out to 10 years (hence, ncol = 10). In the first panel, one plot is visited in year 1, then revisited every 4 years. The same revisit scheme occurs for each panel, but the first year of monitoring increases by a year. The nrow and ncol parameters control how the list of numbers is interpreted. The nrow essentially indicates the number of panels, and ncol indicates the number of years of the panel design. Power-for-trend is derived from year 2 up to year = ncol. Thus, if the sampling objective being examined specifies a minimum detectable change over a 15-yr period, the panel-revisit design in nsites must extend out to 15 years. Values shown in bold in the nsites command are replaced with values specific to the design being examined.

After modifying the necessary parameter values in power.R, cut and paste trendse.R into an R window, then cut and paste the modified power.R code into the same window for immediate execution. The modified power.R code also can be saved for later execution. For instructions on running R or to access the R program, see **The Comprehensive R Archive Network (CRAN)** web site (http://cran.r-project.org/).

Table A-1. Portion of Power-for-Trend R code that is modified.

indicator=	“<name of indicator>”
ind.mean=	1
trend=	<% increase or decrease per year>
site.var=	< site variance >
year.var=	< year variance >
siteyear.var=	0
index.var=	< residual variance >
site.rho=	1
year.rho=	0
alfa=	<alpha value; e.g., 0.05, 0.1 >
plot.ind=	TRUE

```
nsites <- matrix(c(1,0,0,0,1,0,0,0,1,0,
  0,1,0,0,0,1,0,0,0,1,
  0,0,1,0,0,0,1,0,0,0,
  0,0,0,1,0,0,0,1,0,0,
  1,0,0,0,1,0,0,0,1,0), nrow= 5, ncol=  10 ,byrow=TRUE)
```

Successful execution of the power-for-trend code will result in a list at the bottom of the screen indicating the year, power-for-trend, and the standard error of status (e.g., see below). The last entry in the list contains the power-for-trend value used for comparison with the sampling objective.

```
…….
  Year          Power        Standard Error of Status
  1   2        0.10171         0.29905
  2   3        0.10583         0.27777
  3   4        0.11288         0.26163
  4   5        0.12349         0.24823
  5   6        0.13836         0.23656
  6   7        0.18196         0.20541
  7   8        0.24693         0.18830
  8   9        0.32448         0.17866
  9  10        0.40652         0.17277
```

Upland Vegetation and Soils Monitoring Protocol for Park Units in the Northern Colorado Plateau Network

Standard Operating Procedure (SOP) # 20

Revising the Protocol Narrative and SOPs

Version 1.11 (December 2017)

Revision History Log:

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #
1.00	3-1-2007	S. Garman, NCPN Ecologist	Updated MVT	To reflect changes based on 2006 field work	1.01
1.01	3-26-2008	S. Garman, NCPN Ecologist	Updated MVT	To reflect changes based on 2007 field work	1.02
1.02	9-25-2009	H. Thomas, NCPN Data Manager	Updated MVT	To reflect changes based on 2008 field work, new field methods, and updated NCPN protocol versioning procedures.	1.03
1.03	12-15-2010	H. Thomas, NCPN Data Manager	Updated MVT	To reflect changes based on 2010 field work and incorporate peer review comments	1.04
1.04	1-11-2012	H. Thomas, NCPN Data Manager	Updated MVT	To reflect changes based on 2011 field work and incorporate peer review comments	1.05
1.05	6-6-2013	H. Thomas, NCPN Data Manager	Updated MVT	To reflect changes based on 2012 field work	1.06
1.06	3-4-2014	H. Thomas, NCPN Data Manager	Updated MVT	To reflect changes based on 2013 field work	1.07
1.07	4-2-2015	H. Thomas, NCPN Data Manager	Updated MVT	To reflect changes based on 2014 field work	1.08
1.08	3-8-2016	H. Thomas, NCPN Data Manager	Updated MVT	To reflect changes based on 2015 field work	1.09
1.09	8-12-2016	H. Thomas, NCPN Data Manager	Updated MVT	To prepare protocol for publication and reflect changes based on 2016 field work	1.10

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #
1.10	12-6-2017	H. Thomas, NCPN Data Manager	Updated MVT	To prepare protocol for publication and reflect changes based on 2017 field work	1.11

This Standard Operating Procedure (SOP) explains how to make and track changes to the Narrative and Standard Operating Procedures for the Northern Colorado Plateau Network (NCPN) Upland Monitoring Protocol. Individuals editing the Protocol Narrative or any one of the SOPs need to follow these procedures in order to eliminate confusion on how data are collected and analyzed. All observers conducting the monitoring should be familiar with this SOP in order to identify and use the most current methods. The procedures in this SOP are based on the NCPN Protocol Versioning Guidance Document (NCPN-NPS 2009).

Procedures:

1. Modifications must be reviewed for clarity and technical soundness. Small changes or additions to existing methods will be reviewed in-house by NCPN Inventory and Monitoring staff. An outside review is required for substantive changes in methods. Regional and national staff of the National Park Service and experts outside of the Park Service with familiarity in vegetation and soil monitoring and data analysis will be used to review major changes.

2. Record all changes to a protocol document (Protocol Narrative or SOP) in the document's revision history log, even minor edits like fixing typos or formatting changes. It is not necessary to record the specific edits made, rather just the fact that typos were fixed or formatting changes were made. For minor edits, record the same document version number in the revision history log. For actual protocol changes (e.g., changes in methods, equipment), assign a new version number in the revision history log. Depending on the significance of the changes, it may be okay to combine multiple changes in the same entry in the revision history log. Version numbers increase incrementally by hundredths (e.g. version 1.01, version 1.02, etc.) for minor changes. Major revisions should be designated with the next whole number (e.g., version 2.0, 3.0, 4.0 …). Record the previous version number, date of revision, author of the revision, and the reason for the changes along with the new version number (if applicable).

3. Narrative and SOP updates may occur independently. That is, a change in one SOP will not necessarily invoke changes in other SOPs; a narrative update may not require SOP modifications. The NCPN tracks the narrative and SOP version numbers in a Master Version Table (MVT), which is maintained in the master version table database and included in this document (SOP #20).

4. New versions of the protocol narrative and SOPs must be posted on the NCPN website. Older versions of the Protocol Narrative and SOPs must be archived in the NCPN Upland Protocol Library: (R:\Monitoring_Archive\Upland\Protocol).

Upland Monitoring, Northern Colorado Plateau Network
Master Version Table

A dash ("-") in a cell indicates that the narrative or SOP is not applicable during the corresponding time period. An "x" indicates that an SOP has been retired.

Effective Date	Narrative	1-Preparations for the Field Season	2-Hiring & Training Field Technicians	3-Using GPS Units	4-Crust-Friendly Field Procedures	5-Site Characterization	6-Establishing Plots	7-Repeat Photos	8-Measuring Vegetation & Surface Cover	9-Measuring Canopy & Basal Gaps	10-Density, Frequency, & Richness	11-Soil Aggregate Stability	12-Site Impact Assessment	13-Measuring Overstory Trees	14-Measuring Fuels	15-Sampling Oak Plots	16-Unknown Plant Species	17-After Field Visit / Season	18-Data Management	19-Data Analysis & Reporting	20-Revising the Protocol	21-Survey Design & Plot Selection	21-Quadrat-Based Sampling
1/1/2006	-	1.00	1.00	1.00	-	1.00	1.00	1.00	-	1.00	-	1.00	1.00	-	-	-	-	1.00	-	-	1.00	-	1.00
1/1/2007	1.00	1.10	1.10	1.00	1.00	1.10	1.10	1.10	-	1.10	-	1.10	1.10	-	-	-	-	1.00	1.00	1.00	1.01	-	1.10
1/1/2008	1.00	1.20	1.20	1.00	1.00	1.20	1.20	1.30	1.00	1.10	1.10	1.20	1.20	1.00	1.00	1.00	1.00	1.00	1.10	1.00	1.02	-	1.20
1/1/2009	1.01	1.21	1.21	1.00	1.01	1.22	1.21	1.31	1.01	1.11	1.12	1.21	1.21	1.02	1.01	1.01	1.01	1.01	1.11	1.01	1.03	1.00	x
1/1/2010	1.01	1.22	1.30	1.00	1.02	1.23	1.22	1.31	1.02	1.12	1.14	1.22	1.22	1.04	1.02	1.03	1.01	1.01	1.11	1.01	1.04	1.00	x
1/1/2011	1.02	1.23	1.30	1.01	1.03	1.24	1.22	1.32	1.02	1.12	1.15	1.22	1.22	1.05	1.03	1.04	1.02	1.01	1.12	1.02	1.05	1.00	x
1/1/2012	1.03	1.23	1.30	1.01	1.03	1.24	1.22	1.32	1.02	1.12	1.16	1.22	1.22	1.06	1.04	1.04	1.02	1.01	1.13	1.02	1.06	1.00	x
1/1/2013	1.04	1.23	1.30	1.03	1.03	1.24	1.22	1.33	1.02	1.13	1.16	1.23	1.22	1.07	1.04	1.04	1.03	1.01	1.14	1.03	1.07	1.00	x
1/1/2014	1.05	1.23	1.30	1.03	1.03	1.24	1.22	1.33	1.04	1.13	1.17	1.24	1.22	1.08	1.04	1.05	1.03	1.01	1.14	1.03	1.08	1.00	x
1/1/2015	1.05	1.24	1.31	1.03	1.03	1.24	1.23	1.33	1.05	1.13	1.17	1.24	1.22	1.09	1.05	1.06	1.03	1.01	1.14	1.03	1.09	1.00	x
1/1/2016	1.06	1.25	1.31	1.04	1.03	1.24	1.24	1.33	1.06	1.13	1.19	1.25	1.22	1.11	1.05	1.07	1.03	1.02	1.15	1.04	1.10	1.01	x
1/1/2017	1.07	1.26	1.32	1.04	1.03	1.25	1.25	1.33	1.07	1.13	1.20	1.25	1.23	1.12	1.07	1.08	1.03	1.02	1.15	1.05	1.11	1.02	x

References

NCPN-NPS 2009. Protocol Versioning Guidance Document, Version 1.0. National Park Service, Inventory and Monitoring Program, Northern Colorado Plateau Network, Moab, UT.

Upland Vegetation and Soils Monitoring Protocol for the Park Units in the Northern Colorado Plateau Network

Standard Operating Procedure (SOP) # 21

Survey Design and Plot Selection

Version 1.02 (November 2017)

Revision History Log:

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #
1.00	8/2016	D. Witwicki	Added references 1) to appendix with park survey designs and, 2) for R and spsurvey; updated attribute names in Table 5	Added park survey design appendices for NRR publication and other missing references	1.01
1.01	11/2017	D. Witwicki	Minor updates	For publication	1.02

This SOP details the procedures for creating survey designs appropriate for each NCPN park unit and selecting monitoring plots. This SOP provides general instructions for creating robust survey designs that provide defensible long-term monitoring data and answer management questions to the greatest extent possible. This includes guidelines for the rationale behind selecting target upland areas, procedures used to define the target population for monitoring, and procedures used to select monitoring locations. The specific survey design and site selection procedures used for each park unit are documented in the appendices to the protocol narrative.

1.0 Defining the Upland Vegetation and Soils Resources for Monitoring

Since budget limitations do not allow for monitoring all upland resources in a park unit, priority areas and issues for upland monitoring need to be defined by park resource management staff and NCPN ecologists. The project manager should meet with park resource management staff to discuss the following:

1) Park resource management issues (e.g., livestock grazing, social trailing, climate change),
2) Vegetation, soil, and/or ecological site types of concern,
3) Geographic areas of the park unit of particular concern, and
4) Questions and concerns about potential future change of these systems.

These issues should be prioritized so that they can be addressed according to available monitoring resources. The yearly monitoring effort at large park units may be as a great as 2 pay periods of field work for 3 monitoring crews while it may be as little as less than a pay period of work for one monitoring crew at some of the smallest park units. These estimates, along with estimates of the variability of the resource being monitored, should

be used to estimate the number of monitoring questions that can be addressed at each park.

The project manager should also introduce park staff to the NCPN upland vegetation and soils response design during the initial meeting and help them understand the benefits and limitations of using this response design. Management issues should be addressed to the greatest extent possible without losing the quality and robustness of the long-term monitoring effort that I&M standards require. The initial meeting should occur well before the initiation of upland vegetation and soils monitoring at a park unit (at least 6 months to 1 year for most parks). Follow up meetings or other forms of communication will be necessary to refine proposed survey designs.

2.0 Accessibility

Before looking at possible target areas for monitoring, accessibility of the park unit is delineated, and inaccessible areas are eliminated from the potential sampling frame. Numerous NCPN park units contain private in-holdings, steep slopes (>40 or 50%), and areas that are surrounded by steep slopes (e.g., mesa tops) that are deemed inaccessible for NCPN upland vegetation and soils monitoring. In addition, areas only accessible by river travel may be eliminated due to costs and complicated logistics of access.

Accessibility is derived using the NCPN Landscape Accessibility Model tool (Garman unpublished). This model uses roads and trails to determine access to park areas and derives an estimate of hiking distance to every parcel of the landscape. The model also uses slope and aspect to identify areas deemed too steep to traverse and areas such as mesa tops isolated by steep slopes. Rivers and private property may also be masked out of the model. The result of this model is a spatial data layer delineating inaccessible areas and hiking distances to all accessible areas of the park unit.

3.0 Delineating the Target Population

Defining the target population is a multi-step procedure. The initial emphasis is to determine the ecological site types (SRM 1989, 1995) that correspond to the resource of interest. NCPN preferentially uses ecological sites to delineate target upland monitoring areas because they incorporate soil, geologic, and climate characteristics in addition to the potential vegetation. In park units where recent soil surveys and ecological site descriptions are not available, alternative procedures are used for delineating target monitoring areas. Depending on the affordable sampling effort, a number of ecological sites or vegetation types are then selected for monitoring, and collectively define the strata of the sampling frame.

3.1 Ecological Sites

Recent Natural Resources Conservation Service (NRCS) soil survey maps and corresponding ecological site descriptions are used to identify the ecological sites which potentially support vegetation of interest. For example, in a park where grasslands have the greatest management concern, all ecological sites that support grasslands would be identified. Based on perceived costs and goals of upland vegetation and soils monitoring, ecological sites supporting grassland communities are selected for further consideration (Table 1).

Soil map units corresponding to the selected ecological sites are evaluated based on the reported percentages of each site within a soil map unit and the spatial extent of soil map units. Based on this evaluation, ecological sites with small spatial extent may be eliminated from the sampling frame (Table 2). After the initial filtering of inaccessible areas and unsuitable soil map units, the remaining area (example shown in Fig. 1) is included in spatial-data and field-based investigations of ecological sites.

Table 1. Ecological sites supporting grassland communities in accessible areas of Needles and Island in the Sky districts of Canyonlands National Park.

Ecological site #	Ecological site name	Estimated area (ha)	% of total park area	% of total herbaceous park area
R035XY118UT	Desert Sandy Loam (Four-wing Saltbush)	2618.0	4.3	19.6
…	…	…	…	…
Total land area (ha) = 61048.19530		Total herbaceous land (ha) = 13377.38670		

Table 2. List of soil map units by selected ecological site. Bold, italicized map units were deleted from consideration due to limited amounts of target ecological sites within the map unit or the limited spatial extent of the map unit.

Vegetation community – target ecological site number & name	Soil map units with ≥35% of target ecological site	Soil map units with <35% of target ecological site
SHRUBS – 133 Desert Shallow Sandy Loam (blackbrush)	1, 56, 57	11, ***20, 40,*** 51, ***58***, 71, 73, ***75***, 76, 80, 99
…	…	…

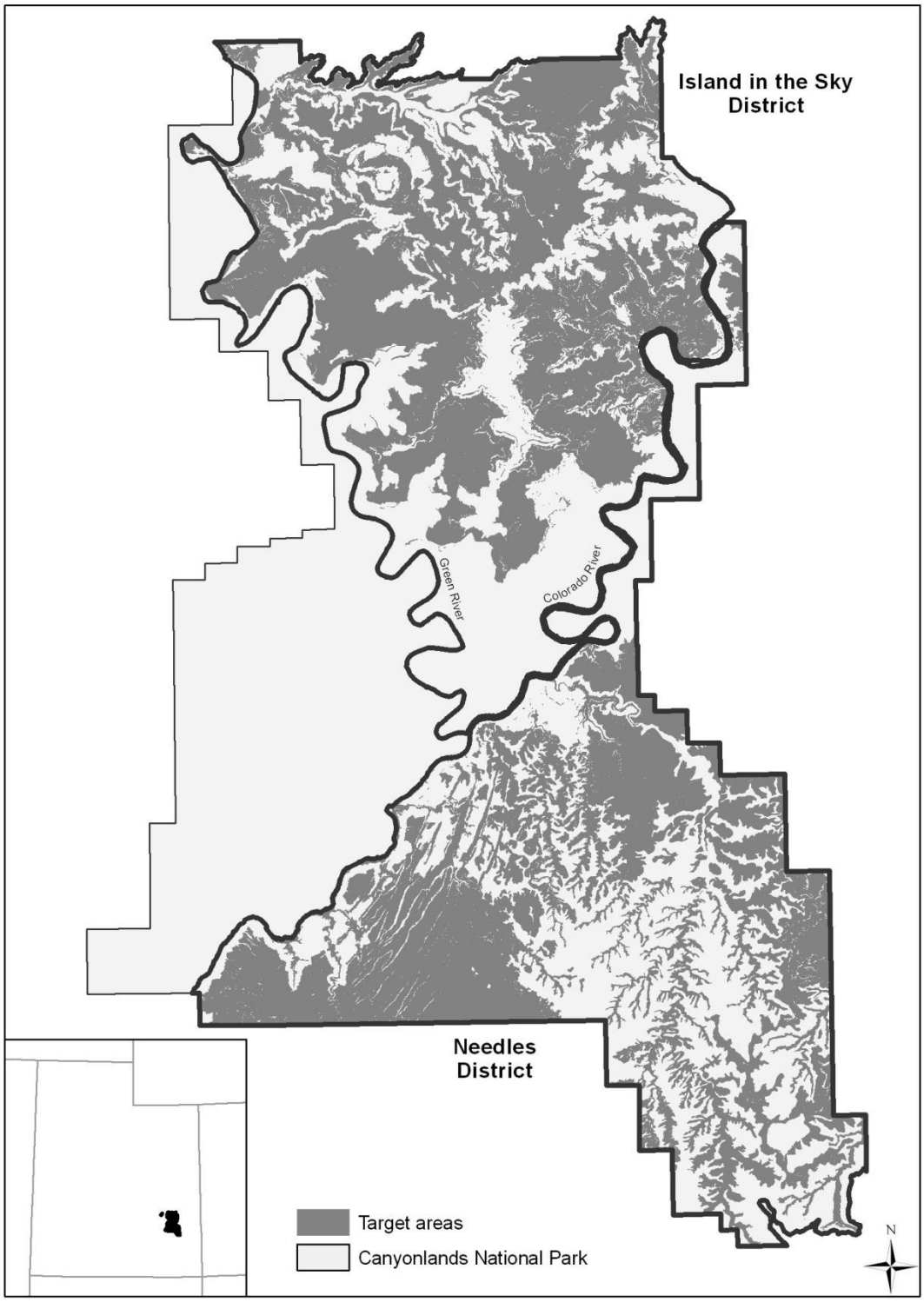


Figure 1. Location of accessible areas containing potential target ecological sites for upland vegetation and soils monitoring in Canyonlands National Park.

3.2 Mapping the Sampling Frame

Soil components which define ecological sites are not explicitly mapped in soil surveys, and depending on the soil survey and the goals of upland vegetation and soils monitoring, it may be useful to explicitly map target ecological sites. Similar ecological sites may be mapped together in groups referred to as ecological site types. Finer mapping of similar ecological sites was found by NCPN to not be a worthwhile exercise, especially when all of the similar ecological sites are deemed as target areas for monitoring.

Advanced methods of predictive mapping may be used to create ecological site maps when you have complete coverage of soil maps and other spatial data layers such as elevation, slope, vegetation, geology, etc. Some possible methods include feature extraction modeling and Classification and Regression Tree (CART) models. Specifics on how to use each method are outlined in Garman et al. (2010) and in Appendix A of the protocol narrative (see survey designs for Canyonlands and Capitol Reef national parks). Both methods require an extensive field reconnaissance (recon) effort to determine ecological sites of random points in the potential target sampling frame. The sections below provide an overview of a few techniques for mapping strata of the sampling frame, including alternative methods for dealing with incomplete and old spatial data sets.

3.2.1 Feature Extraction Modeling

Feature extraction modeling can be used for predictive mapping of ecological sites through packages such as Feature Analyst (VLS 2002). This software uses information from field recon points and spatial data layers (soil map unit, vegetation map unit, elevation, geology, etc.) to develop rules for where each ecological site occurs on aerial photos. It then uses these rules to characterize the entire area of interest and produce a predicted map of target ecological sites (Figure 2). After field verification, the program can use new data to “learn” and improve the initial version of the map.

Feature extraction modeling is a good tool for delineating areas that appear distinct on aerial photos. It is not recommended for distinguishing ecological sites with similar species or life form composition. For example, areas dominated by different species of perennial bunchgrasses are not easily distinguished using this method. Feature extraction modeling may also be useful for simply eliminating non-target areas such as rock outcrops from soil map units.

3.2.2 CART

CART uses ecological site and biophysical attributes (soil map unit, vegetation map unit, geology, elevation, percent slope, and slope position) of random locations visited in the field to develop ‘rules’ for classifying the landscape to ecological site. The model with the most heterogeneity in groupings is selected statistically, and decision tree rules are based on this model. This model is then applied to the landscape to predict areas where each ecological site occurs.

CART models are a good tool when quality spatial data sets are available for the entire area of a park unit.

3.2.3 Other Methods of Determining Target Monitoring Areas

Although feature extraction modeling and CART provide excellent tools to create high-quality ecological site maps, the time and money required to use these methods is high. Other methods may be used to lower costs or to deal with incomplete/poor quality data sets.

For soil surveys that have few ecological sites per soil map unit, you may be able to create an ecological site map based mainly on soil map units. For example, in a park unit that has sagebrush as a target vegetation type, you can create a map using all soil map units that have a high percentage of sagebrush ecological site predicted (>70%). Soil map units that have 35-70% sagebrush ecological site should also be considered for the map, but you may want to visit polygons of these soil map units and eliminate polygons that contain little to no target ecological site area. If a vegetation map of the park unit is available, this may also be used to help identify and eliminate additional non-target ecological site area within the soil map units. Maps should be conservative estimates of ecological site area since it is better to leave areas in the sampling frame and reject specific non-target plots than to eliminate potential target area from the sampling frame.

If recent soil surveys and ecological sites are not available for a park unit, other types of data may be used to delineate target sampling areas. Target sampling areas for survey designs should be delineated using features that are not expected to change over the period of long-term monitoring, such as geology, elevation, and aspect. Target populations should not be delineated using current vegetation maps since vegetation is expected to change over relatively short time periods.

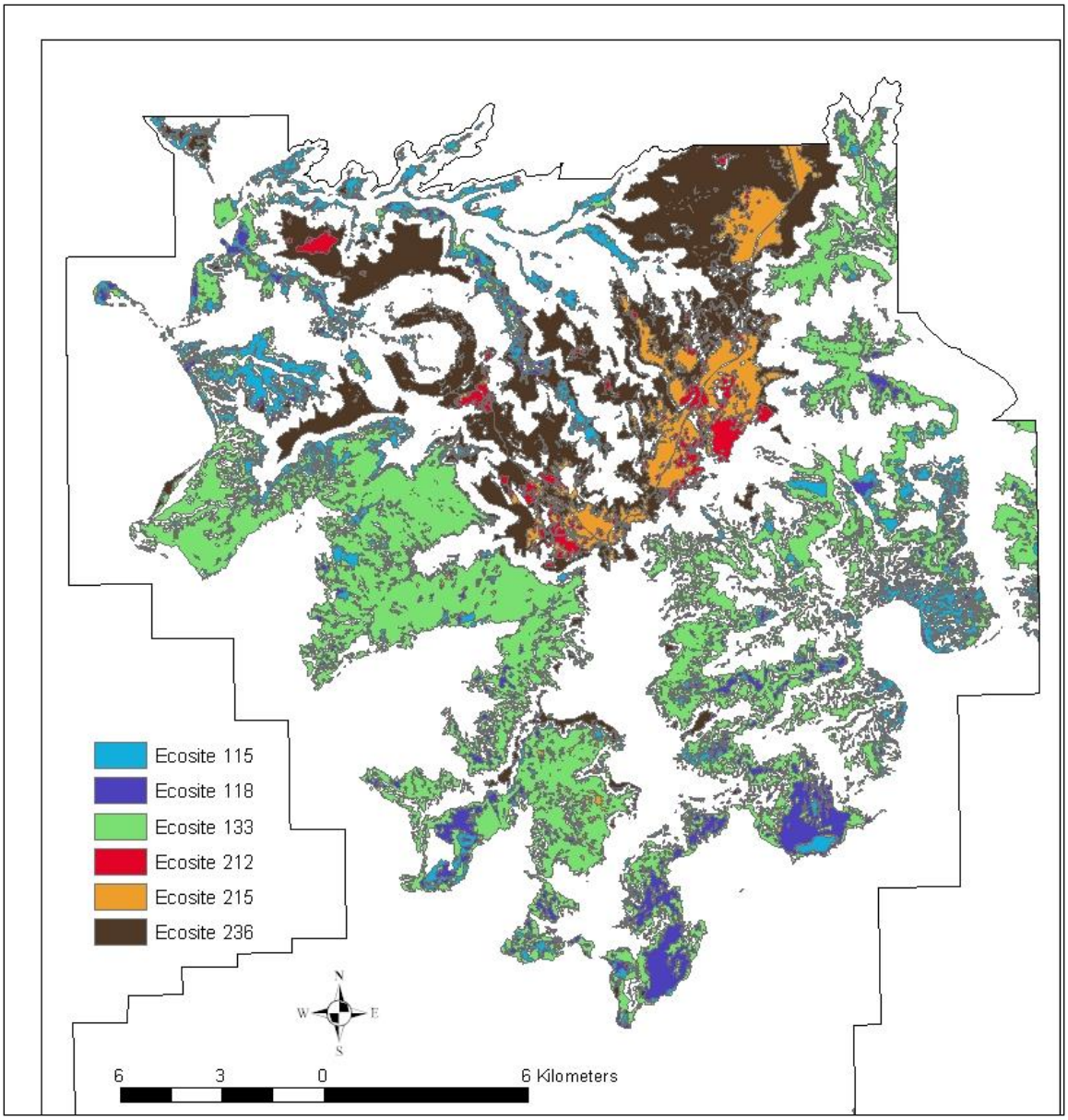


Figure 2. Predicted target ecological sites for the Island in the Sky district of Canyonlands National Park using feature extraction modeling.

3.3 Preparation of the Sampling Frame for Monitoring Plot Selection

Obvious non-target areas should be filtered out of the sampling frame. This may include wash bottoms, bodies of water, roads, developed areas in parks, or specific areas that the park would like to exclude from the sampling frame (archeological sites or other areas of special concern).

To avoid selection of plots too close to roads, trails, park boundaries, and strata boundaries, polygons of predicted site types should also be buffered. The buffer distance depends on the vegetation type to be sampled since different size areas are sampled for different vegetation types (Table 3; see section 3.2 in the upland vegetation and soils narrative for detailed definitions of vegetation types). Consider using a larger buffer in small parks dissected by numerous roads and trails since it is likely that plots will be selected near these non-target features. Otherwise, you may end up spending a lot of time in the field rejecting plots that are too close to roads, trails, boundary fences, etc.

Table 3. Buffer size by vegetation type.

Vegetation type	**Buffer size**
Grassland/Shrubland	25-35 m
Forest/Woodland	45-65 m
Oak	10-15 m

4.0 Monitoring Plot Selection

After the sampling frame has been finalized, a spatially-balanced random sample of monitoring plots is selected. Plots may be selected over the entire sampling frame and then clipped to the area of each stratum or plots may be selected initially by stratum. You will need to think about the overall monitoring goals when deciding which method to use. NCPN uses one of two procedures to select plots: Generalized Random Tessellation Stratified (GRTS; Stevens and Olsen 2004) or Reversed Randomized Quadrant Recursive Raster (RRQRR; Theobold et al. 2007). Both methods generate a spatially-balanced random sample based on the requested number of monitoring locations, and sequentially order the selected locations (i.e., points) in an output shape file. Although both methods perform virtually the same task, there are a few advantages and disadvantages to either method. These are listed in the individual sections below.

4.1 Plot Selection Methods

4.1.1 GRTS

The R-GRTS version of GRTS operates in the R statistical software environment (R Core Team 2006). The sampling frame is a polygon shape file that includes all strata. The following section provides basic instructions for running R-GRTS:

1) To run R-GTRS, you need the statistical program R. Download the latest version from http://cran.r-project.org/.
2) You will also need a couple of additional packages to run GRTS. Go to http://www.epa.gov/NHEERL/arm/analysispages/software.htm and download sp_0.9-25.zip and spsurvey_2.0.zip. Do not unzip these files.

3) Open R and select Packages→Install Package(s). Select a nearby mirror, then select sp and spsurvey (Kincaid and Olsen 2006), and click OK. This step only needs to be performed once during the initial installation of the R packages.

4) Each time you want to run GRTS, you will need to select Packages→Load Package, then select sp and spsurvey. You will also need to go to File→Change Dir… and browse to the location of the sampling frame shape file. If the survey design has multiple strata, make sure that your shape file has unique coding for each one.

5) Create R code for GRTS using the basic design in Table 4 as an example. This script may be edited using any package as long as it is saved as a non-document file (i.e., .R, .txt, etc.). The convention is to use a suffix of .R when saving the file containing the R code, but this is not a requirement. Specific instructions for manipulating the code to your design specifications are provided below:

    a. Lines beginning with # are simply comment fields so you can include whatever you want.

    b. Scripts operate on shape files. In this script, replace each place you see "CEBR_frame" with the name of the shape file of your sampling frame.

    c. Inside the shape file, you need to include codes indicating areas to be considered in the GRTS selection. You can have multiple codes (e.g., different ecological sites or elevation gradients), or a single code. In this example, there is an attribute called Gridcode in the CEBR_frame shapefile, and it is set to 1 for areas above the rim and 2 for areas below the rim. In this script, every place you see "Gridcode" you would replace it with the name of the code attribute you used in the shapefile of your sampling frame.

    d. The following PaneldsgnUN command indicates the selection of 20 points in polygons where Gridcode=1 and 8 points in polygons where Gridcode=2. The number following PanelOne= must be equal to the sum of values specified in caty.n=c(). In this example, we are interested in selecting 20 pts from Gridcode=1 and 8 points from Gridcode=2; thus PanelOne=28 and caty.n=c('1'=20,'2'=8). If we wanted a total of 40 pts, then PanelOne=40, caty.n=c('1'=10,'2'=30) OR caty.n=c('1'=20,'2'=20) OR any other combination as long as the sum of numbers inside caty.n=c() equals 40.

```
PaneldsgnUn <- list(None=list(panel=c(PanelOne=28), seltype='Unequal',
            caty.n=c('1'=20,'2'=8),over=50) )
```

    e. The over=50 part of the PaneldsgnUN command indicates the number of oversample points you would like from GRTS. It will disperse the oversample points over the entire area of the sampling frame including all strata. You can not specify the probability of oversample points. Make

sure you have a large enough oversample to account for all possible rejections.

f. The name of the output shapefile is substituted for “CEBR_sites” in the following section of code:

out.shape='CEBR_sites'.

6) Cut and paste the script into the bottom of the R Console window. As soon as you perform the pasting, the GRTS code is activated. As each line of the GRTS script is executed, it is written to the primary R window. Errors are also written to this window. After you see "Final number of levels: [then a number]", the program is done. You can then look at the resulting point shape file in the directory that you provided to R.

Table 4. Basic script for R-GRTS

```
## Unequal Probability GRTS (and panels) with area shapefile (CEBR upland)   ##

# Load sp package
# Load spsurvey package
# Change dir to where shapefiles are located

# Read dbf file
# attribute table from shapefile
att <- read.dbf("CEBR_frame")
#header
head(att)

##### Unequal probability GRTS survey design with panels with oversample

# What is the column that identifies the target population polygons?
levels(att$Gridcode)

# Create design

PaneldsgnUn <- list(None=list(panel=c(PanelOne=28), seltype='Unequal',
        caty.n=c('1'=20,'2'=8),over=50) )

# run to get random seed
sample(100000000,1)
# or use set.seed for repeatable design
# set.seed(4447864)

Panelsites <- grts (design=PaneldsgnUn,src.frame='shapefile',in.shape='CEBR_frame',
att.frame=att,type.frame='area',mdcaty='Gridcode',DesignID='frpoints',
shapefile=TRUE, prj='CEBR_frame', out.shape='CEBR_sites')

# summarize sites selected
# addmargins( table(Panelsites$mdcaty,Panelsites$panel) )
```

The output from R-GRTS is a shape file which indicates the selected plots and their sequential order. When a plot is rejected (due to prediction error, overlap with existing monitoring plots, etc.), the next sequential plot is used. The selection probability of plots is provided in the output shape file, however, as plots are rejected the selection probability must be manually re-calculated.

Advantages to using GRTS are that the selection probability of points is calculated for you and that programming language can be used to create complex survey designs with numerous panels. The main disadvantage to using GRTS is that you must initially select an appropriate oversample so that you have enough plots to account for rejection. Adding points after the initial plot selection run is not possible in GRTS.

4.1.2 RRQRR

RRQRR operates as a tool within ArcGIS. This tool uses raster files of the sampling frame. The following section provides instruction for running RRQRR:

1) Open a new project in ArcMap. Click on Window→ArcToolbox so that the ArcToolbox opens on your screen. Left click on the word ArcToolbox and then right click on AddTool. Go to the directory where RRQRR is stored (usually C:\Temp) and select it. Make sure to use the correct version of RRQRR for the version of ArcGIS installed on the computer. RRQRR93 is compatible with ArcGIS9.3.
2) Add your shape file containing the sampling frame to the project and rasterize to a 5-m grid. A 5-m grid is recommended to ensure complete coverage of the landscape. If you plan to select points separately for each stratification, make sure you include this attribute in your shape file before you rasterize it. This will allow you to modify the raster in Spatial Analyst→ Reclassify so that you can select points for each stratum separately. Code the target area for each stratum with a unique positive integer, and code all other areas -9999.
3) Move the raster(s) to C:\Temp, then add the raster(s) to your project.
4) Click on the tool RRQRR 200712221→Reversed Randomized Quadrat-Recursive Raster (RRQRR) Tools→1. Generate RRQRR Sequence Raster. Select your sampling frame raster under Reference Frame Raster. If you have existing monitoring points that you would like to include in the survey design, direct RRQRR to the shape file containing these points. Click OK.
5) The output is a folder in C:\Temp named RRQRR with the year, date, and time attached. Within this folder is a file named rrqrr_ras. Add this to your project.
6) Within the RRQRR tool, click on 2. Filter RRQRR Sequence Raster. Select your sampling frame raster under Inclusion Probability Raster. Select rrqrr_ras under RRQRR Sequence Raster. Click OK.
7) The output is a folder in C:\Temp named RRQRR_filter with the year, date, and time attached. Within this folder is a file named rrqrr_filter. Add this to your project.

8) Within the tool, click on 3. Generate RRQRR Sample Points. Select your sampling frame raster under Inclusion Probability Raster. Select rrqrr_filter under RRQRR Filtered Sequence Raster. Request the number of sample points that you would like from RRQRR. Click OK.
9) The output is a folder in C:\Temp named RRQRR_smp with the year, date, and time attached. Within this folder are two files of interest: sample_pts.shp is an ordered list containing the number of sample points you requested, and smpts.shp contains an ordered list of all possible points. Smpts.shp contains your oversample and should be used to continue working down the ordered list of points if you run out of points from sample_pts.

In RRQRR, plots should be established following the "order_" attribute. Assign ascending PlotID numbers in this order. When a plot is rejected (due to prediction error, overlap with existing monitoring sites, etc.), the next sequential plot is used. The selection probability of plots must be calculated manually once the final operational survey design is in place. Also, the number of monitoring plots must be tracked during plot establishment to ensure a balanced number of plots for each stratum.

Advantages to using RRQRR are that it gives you an ordered file of all possible monitoring plots. Therefore, you have an unlimited number of possible monitoring plots in your sampling frame should there be a high number of plot rejections. Another advantage is the option to include a few established monitoring plot locations in your sampling design. This feature could be especially useful if you run out of oversample points in a GRTS run and need to add points to an existing design. The main disadvantage to RRQRR is that it does not calculate selection probabilities, therefore, you must complete these calculations manually.

5.0 Tracking Monitoring Plots

A sequential list of potential plot locations for each ecological site type or other stratum is stored in a shape file. The list indicates acceptance or rejections of plots, reasons for rejection, the date of plot establishment, and other important information related to the survey design (Table 5). The list provides a way to track pre-monitoring evaluation of sites and plot establishment, and for the eventual derivation of selection probabilities.

Table 5. Attributes of upland monitoring plot shape file for each park unit.

Field	Description
order_	Sequential ordering of plots provided by RRQRR
PlotID	The plot ID number- created manually based on the SiteID in R-GRTS or using the order provided by RRQRR
EcoType/Ecosite	The ecological site type predicted by the map
musym/Soil_MU	The NRCS soil map unit number of the plot

Grazing	Indicates whether the plot is grazed or ungrazed in designs where this stratification is used
Estab_Date	Month, day, and year when the plot was established
EvalStatus	estab = established; recon = not visited; accept = visited and deemed to be acceptable as a monitoring site; reject = rejected
EvalReason	Describes why a site was rejected and other comments
Panel	Panel number assigned to plot once full monitoring design is implemented
X	UTM E (NAD83) of the selected location
Y	UTM N (NAD83) of the selected location
Hike_km	Hiking distance to the plot in km
AreaDescr	In large parks, this indicates the area of the park where the plot is located.

6.0 Modifications After Pilot Implementation

During the first few years of monitoring, the accuracy of the sampling frame should be assessed by visiting as many sites as possible. This effort also doubles as site clearing ahead of the monitoring crew. If a map is found to be overstratified (such as what happened when trying to delineate all of the grassland ecological sites in Canyonlands National Park), then it may be beneficial to combine the sampling frame for all of the similar ecological sites and accept any grassland ecological site that falls within this larger sampling frame. Other minor modifications to the sampling frame may prove beneficial based on individual circumstances of the sampling design for each park unit.

After 3 years of pilot monitoring, a variance assessment and power analysis is performed on the initial data (see SOP #19). These results are used to create a long-term operational sampling design and revisit schedule. After each additional 5-7 years of monitoring, survey designs are evaluated to make sure they continue to meet the goals of long-term monitoring, and necessary adjustments are made at this time.

7.0 References

Garman, S. L., D. Witwicki, and A. Wight. 2010. Mapping ecological sites for long-term monitoring in national parks. *In* van Riper III, C., B. F. Wakeling, and T. D. Sisk, eds., The Colorado Plateau IV: Shaping conservation through science and management. Tucson: The University of Arizona Press.

Kincaid, T. M., and A. R. Olsen. 2006. spsurvey: Spatial Survey Design and Analysis. R package version 1.1.

R Core Team. 2006. R: A language and environment for statistical computing. R, R Foundation for Statistical Computing, Vienna, Austria.

SRM (Society for Range Management). 1989. Glossary of terms used in range management. 3rd edition, Society for Range Management, Denver.

SRM (Society for Range Management). 1995. New concepts for assessment of rangeland condition. Journal of Range Management 48:271-282.

Stevens, D. L. and A. R. Olsen. 2004. Spatially balanced sampling of natural resources. Journal of the American Statistical Association 99:262-278.

Theobald, D. M., D. L. Stevens Jr., D. White, S. Urquhart, A. R. Olsen, and J. B. Norman. 2007. Using GIS to generate spatially balanced random survey designs for natural resource applications. Environmental Management 40:134-146.

VSL (Visual Learning Systems). 2002. User Manual, Feature Analyst Extension for ArcView 3.2, Visual Learning Systems, Inc. Missoula, MT.