Arches National Park
Survey Design and Site Selection Report

Defining the Upland Resources for Monitoring

Discussion with Southeast Utah Group (SEUG) resource management staff identified grasslands and shrublands as the highest priority for long-term monitoring. Both NCPN and SEUG staff agreed that it was best to monitor the same vegetation types (blackbrush, Pinyon-juniper [PJ], and grasslands) in ARCH as are currently monitored by NCPN in Canyonlands National Park (CANY). For ecological sites that occur in both parks, this will provide a larger dataset that could help detect trends more quickly. The goal of upland monitoring at ARCH is to provide information on the natural variability of upland resources as well as early warning of system degradation.

Accessibility

An accessibility map was created for ARCH based on road and trail access using the NCPN Landscape Accessibility Model tool. Steep slopes ($\geq$ 50%) and areas isolated due to steep slopes (e.g. mesa tops) were considered inaccessible. The resulting map (Figure 1) deemed 86.6% of the park as accessible.

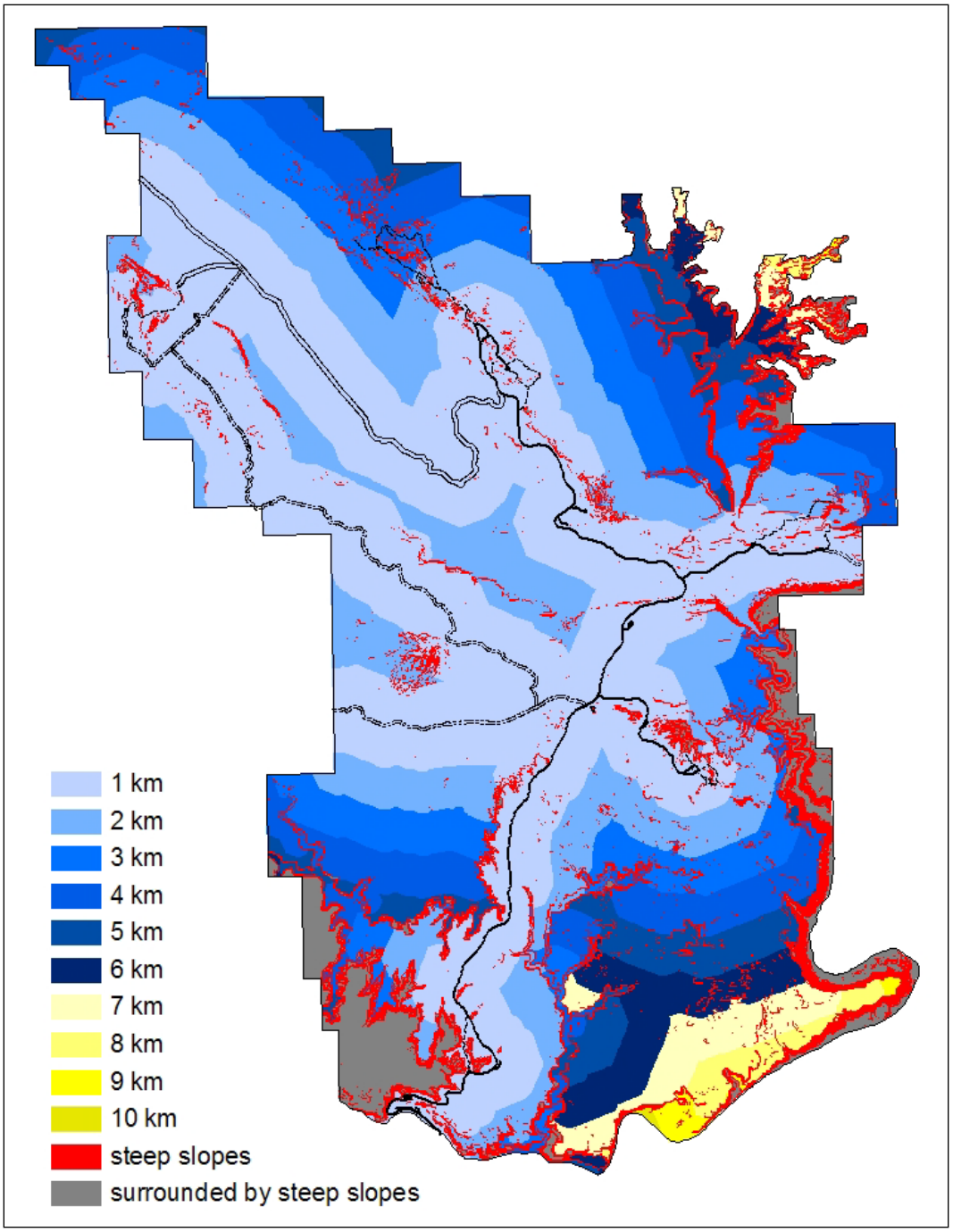


Figure 1. Accessible areas and hiking distances for Arches National Park.

Defining Target Vegetation Communities

Inspection of the ARCH vegetation map (Coles et al. 2009) and field visits to the park determined the vegetation associations corresponding to the target communities for monitoring. Blackbrush and PJ woodlands are the dominant shrubland vegetation types in ARCH, and substantial areas of grassland exist on valley bottoms. The map units and area for all vegetation associations in the park are listed in Table 1.

Defining Target Soils and Ecological Sites

Although the vegetation map is used to determine dominant vegetation associations in a park, it is not used to create the sampling frame. A more robust survey design can be created using factors such as soil properties or elevation that are not expected to change over longer time frames.

A draft soil survey for ARCH was recently provided to NCPN (USDA NRCS unpublished). The soil survey contains soil map units that are explicitly mapped across the landscape. Soil map units typically have multiple soil components, and it is the soil component that is directly associated with a specific ecological site. Using the draft Arches Soil Survey, ecological sites associated with blackbrush, PJ, and grasslands were summarized in Table 2.

At CANY and other NCPN parks, ecological sites have been lumped into broader groups with similar vegetation, precipitation, and soil depth that we are calling ecological site types. Ecological site types were also used at ARCH to group similar ecological sites in the soil survey (see Table 2). After further discussion with SEUG resource staff, three ecological site types were selected for monitoring at ARCH: deep blackbrush, PJ/blackbrush, and grassland.

Deep Blackbrush

Deep blackbrush was selected as a priority ecological site type at ARCH due to the large spatial extent and because NCPN is currently not monitoring it at CANY. Although a substantial area of this ecological site type exists in CANY, it was not recognized in the old soil survey, and was therefore not included in the CANY upland monitoring design. In ARCH, the deep blackbrush ecological site type contains 2 ecological sites (see Table 2).

PJ/Blackbrush

At both CANY and ARCH, there is one target ecological site, 236-Semidesert Shallow Sandy Loam (Utah juniper/blackbrush), in the PJ/blackbrush ecological site type. Although a second ecological site, 19-Shallow Sand Rock Pocket, was mapped in the draft Arches Soil Survey, it contains too much bedrock for our monitoring criteria. Additionally, it was not included in the old CANY soil survey, which was used to develop the NCPN upland monitoring design at that park.

Grassland

The two grassland ecological sites at ARCH are the same ecological sites that NCPN monitors at CANY (see Table 2). Two additional grassland ecological sites (115-Desert Sand and 118-Desert Sandy Loam) were included in the CANY sampling design, but it is expected that these will be combined with the semidesert grassland ecological sites in the

new version of the Canyonlands Soil Survey, which should be completed within the next few years.

Although the shallow blackbrush ecological site type has substantial area in ARCH, it was not selected for monitoring due to the limitations of our affordable effort. This ecological site type is currently being monitored at CANY.

The estimated area of target ecological sites in ARCH is 6921.9 ha (see Table 2). The area of each ecological site in the park is calculated using the estimated percentage of that ecological site within each of the soil map units where it is predicted to occur, and therefore, is often substantially less than the area of the soil map unit. The target ecological sites for monitoring are described in detail in Table 3 and are illustrated in Figure 2.

Predictive Mapping of Ecological Sites on the Landscape

Since the draft Arches Soil Survey provided a good estimate of locations of target ecological sites, we did not explicitly map ecological sites for ARCH like we did for CANY. Instead a predictive map of deep blackbrush, PJ/blackbrush, and grassland ecological site types was developed using the soil map units associated with the target ecological sites (Figure 3). All soil map units that contained >10% of a soil component associated with a target ecological site were included in the sampling frame. Notice that the area of the sampling frame (Table 4) is larger than the predicted area of each ecological site (Table 2) because all soil map units used to make the map contain some nontarget areas. The sampling frame area represents 34.7% of the total park area and 40.1% of accessible area.

Before site selection, the sampling frame was buffered by 25 m to prevent plots from crossing roads, trails, the park boundary, non-target vegetation, or inaccessible areas.

Table 1. Area (ha) of vegetation types in Arches National Park.

map unit #	Vegetation map unit name	area (ha)
Blackbrush shrublands		
10	Blackbrush Shrublands	5988.6
Woodlands		
20	Pinyon - Juniper / Blackbrush Woodlands	500.2
25	Sand Dune Woodlands	2091.9
31	Moab Tongue Slickrock Woodlands	4395.6
32	Pothole and Jointed Sandstone Woodlands	3776.4
33	Sandstone Ledges Woodlands	3056.0
341	Entrada Fin / Swale Woodland Mosaic	803.3
Grasslands/shrublands		
11	Sandsheet Shrublands	1023.3
14	Mormon Tea - Mixed Grass Shrublands	1277.6
17	Weedy Herbaceous Vegetation	908.5
18	High Terrace Shrub Herbaceous Complex	722.1
71	Winterfat Shrublands	335.1
Desert Scrub		
5	Badlands Sparse Vegetation	134.2
15	Shale Barrens Desert Scrub	1217.2
26	Mat Saltbush Sparse Vegetation	27.1
27	Salina Lyme Grass Sparse Vegetation	34.2
35	Gypsum Badlands Sparse Vegetation	163.5
Riparian/Wash		
1	Tamarisk River Corridor Shrubland	34.4
2	Riverine Sandbar Sparse Willow Shrubland	6.5
4	Gambel Oak Terrace Shrubland	5.4
6	Greasewood Flats	456.8
7	Pinyon - Juniper Intermittently Flooded Woodlands	461.4
8	Basin Big Sagebrush Terrace Shrubland	145.1
9	Tributary Tamarisk and Salix Shrubland Mosaic	129.7
90	Dry Wash Shrublands	91.2
92	Tributary Mesic Herbaceous Complex	8.5
93	Tributary Woodland Complex	284.0
Sparse Vegetation		
13	Dune Complex	131.3
30	Talus Sparse Vegetation Complex	1385.2
97	Cliff and Alcove Complex	86.8
111	Colorado River	8.3
130	Entrada Sandstone	1060.3
136	Wingate Sandstone	57.4
Developed areas		
210	Residential	0.6
223	Government buildings	1.3
226	Transportation corridors	167.7
	Total	30976.6

Table 2. Estimated area (ha) and associated soil map units for ecological sites supporting grassland, blackbrush, and pinyon-juniper communities in Arches National Park. Estimates of spatial extent include inaccessible areas. Bold type indicates ecological sites that were selected for monitoring.

Ecological Site Type	Ecological site #	Ecological site name	Estimated area (ha)	% of total land area	Associated soil map units (>10% area)
Blackbrush (shallow)	R035XY133UT	Desert Shallow Sandy Loam (Blackbrush)	212.6	0.7	119
	R035XY233UT	Semidesert Shallow Sandy Loam (Blackbrush)	1910.2	6.2	80, 126, 127
Blackbrush (deep)	**R035XY210UT**	**Semidesert Sand (Blackbrush)**	**2081.5**	**6.8**	**91,103**
	R035XY218UT	**Semidesert Sandy Loam (Blackbrush)**	**73.5**	**0.2**	**129**
PJ / Blackbrush	R035XY019UT	Shallow Sand Rock Pocket (Utah Juniper-Pinyon)	6277.2	20.3	81, 83, 85, 86, 100, 117, 126
	R035XY236UT	**Semidesert Shallow Sandy Loam (Utah juniper-blackbrush)**	**2406.6**	**7.8**	**81, 87, 88, 89**
Grassland	**R035XY212UT**	**Semidesert Sand (Fourwing saltbush)**	**508.6**	**1.6**	**108**
	R035XY215UT	**Semidesert Sandy Loam (Fourwing saltbush)**	**1851.6**	**6.0**	**108, 116**
Total ARCH area =			30976.6		

Table 3. Description of ecological sites selected for upland monitoring in Arches National Park.

Physiognomic type	Ecological Site Type	Ecological Site Name **Notation / No.**	Soil properties	Geological properties	Vegetative properties	Disturbance-mediated alternative states
shrubland	Blackbrush (deep)	Semidesert Sand (blackbrush) **SDS210 / 210**	deep sands on dunes and sand sheets	eolian deposits derived from sandstone	dominated by blackbrush	*Description currently N/A*
		Semidesert Sandy Loam (blackbrush) **SDSL218 / 218**	deep sandy loams on mesas and hills	alluvium and eolian deposits derived from sandstone	dominated by blackbrush	*Description currently N/A*
	PJ / Blackbrush	Semidesert Shallow Sandy Loam (Utah juniper/ blackbrush) **SDSSL236 / 236**	shallow sandy loams on benches and mesas	residuum and/or eolian deposits from sandstone	dominated by blackbrush, juniper, and pinyon pine	Decreased bunchgrass and increased juniper, blackbrush, and prickly pear. Cheatgrass and annual forbs may invade.
herbaceous	Grassland	Semidesert Sand (four-wing saltbush) **SDS212 / 212**	deep sands on dunes and sand sheets	eolian deposits derived from sandstone	dominated by Indian ricegrass, four-wing saltbush, and Mormon tea	Decreased bunchgrass and saltbush and increased snakeweed, prickly pear, juniper, and sand sage. Russian thistle may invade.
		Semidesert Sandy Loam (four -wing saltbush) **SDSL215 / 215**	deep sandy loams on mesas and valleys	alluvium and eolian deposits derived mainly from sandstone	dominated by Indian ricegrass, needle and thread, four-wing saltbush, and Mormon tea	Decreased bunchgrass and increased snakeweed, Mormon tea, and prickly pear. Cheatgrass and Russian thistle may invade.

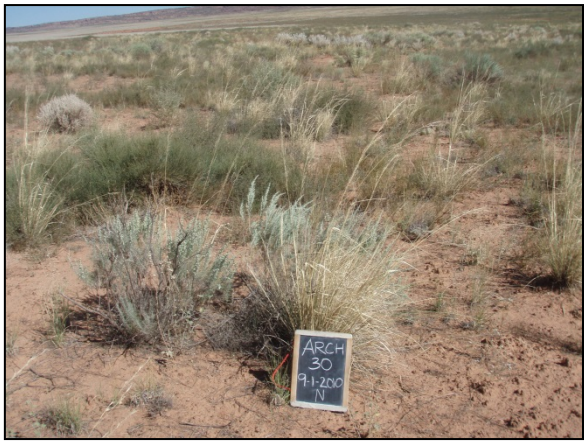
Figure 2. Examples of the ecological sites selected for upland monitoring at Arches National Park. See Table 3 for descriptions.

Semidesert Sand
(Blackbrush)

Semidesert Sandy Loam
(Blackbrush)

Semidesert Shallow Sandy Loam
(Utah juniper/blackbrush)

Semidesert Sand
(Fourwing saltbush)



Semidesert Sandy Loam
(Fourwing saltbush)

Table 4. Area (ha) of each ecological site type included in the sampling frame for upland monitoring at Arches National Park.

Ecological site type	Area (ha)*	Predicted target area**
Deep blackbrush	4375	49.3%
PJ/blackbrush	3871	62.2%
Grassland	2509	94.1%
Total sampling frame	10755	64.4%

* Based on the accessible area within a 10 km hiking distance.

**Predicted amount of target ecological site in the sampling frame

Monitoring Site Selection

Monitoring sites were selected using Reversed Randomized Quadrant Recursive Raster (RRQRR - Theobald et al. 2007). The sampling frame was converted to a 10-m grid to ensure complete coverage of the landscape. Sites were selected for the entire buffered sampling frame (Figure 3) producing the following files. All locations listed in these shape files have a selection probability of 1.

ARCH_smp_pts- ordered list of all possible monitoring points selected through RRQRR.
ARCH_sample_pts- ordered list of 250 initial monitoring points selected through RRQRR.

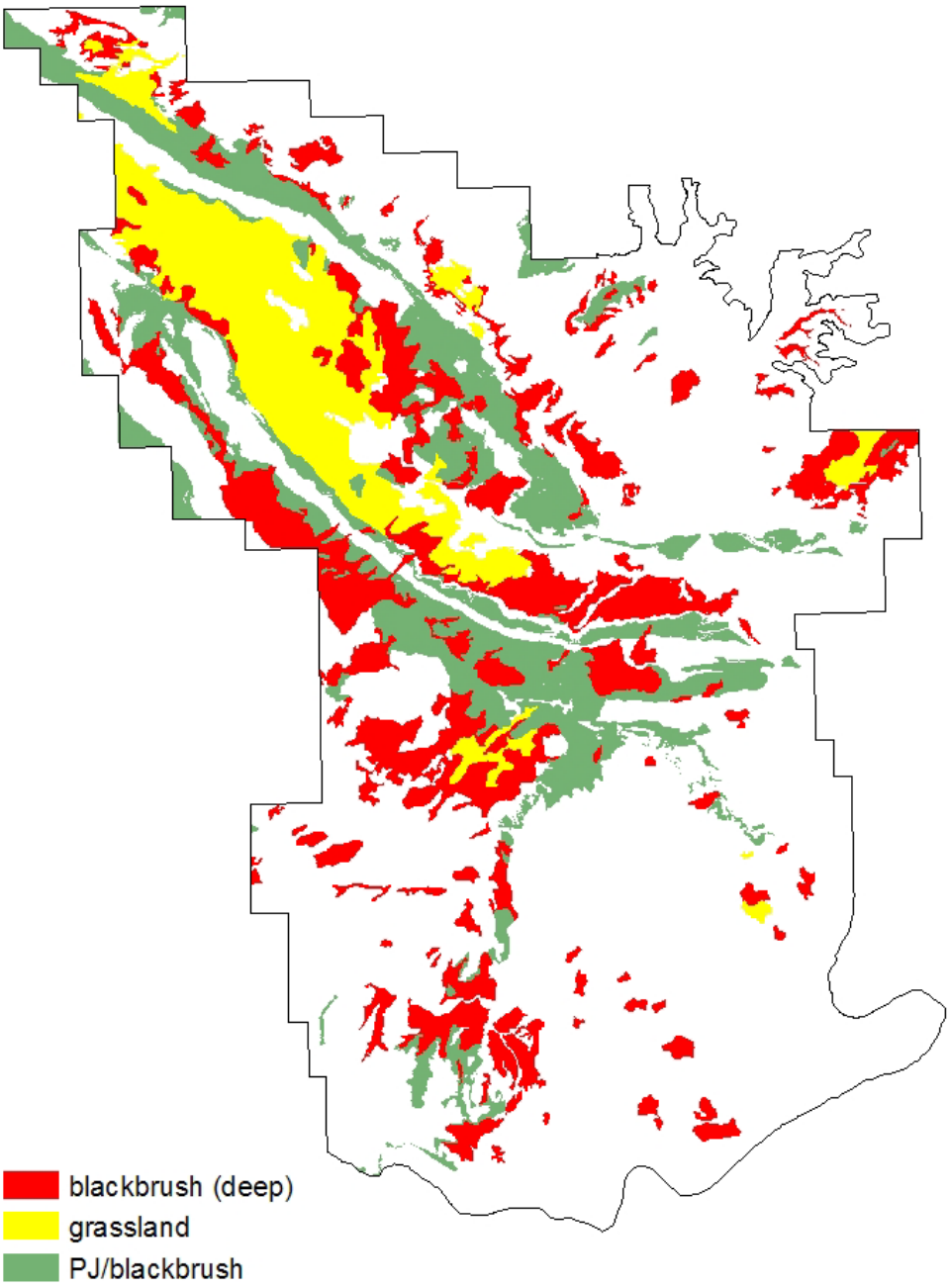


Figure 3. Sampling frame for Arches National Park. Deep blackbrush consists of ecological sites 210 and 218; Grassland consists of ecological sites 212 and 215; PJ/blackbrush consists of ecological site 236.

Tracking Monitoring Sites

ARCH_upland_master.shp, derived from ARCH_sample_pts.shp, contains the first 250 potential monitoring plots and any relevant tracking information (Table 5). The attributes include acceptance or rejections of plots, reasons for rejection, and date of plot establishment. It is used to schedule pre-monitoring evaluation of sites and for the eventual derivation of selection probabilities. In this file, the "order_" attribute was renamed "RQorder" for consistency among parks.

Table 5. Attributes of ARCH_upland_master.shp for tracking upland monitoring locations in Arches National Park.

Field	Description
Veg_Type	Vegetation type for upland sampling methods (grassland/shrubland)
EcoType	Predicted vegetation type based on sampling frame (deep blackbrush =210 or 218, grassland = 212 or 215, PJ = 236)
MasterStra	Indicates groups for analyzing data (deep blackbrush, grassland, PJ)
PlotID	The plot number, based on ascending order of the RQorder field, renumbered to give unique plot numbers for each point on the list.
Panel	Panel that plot is associated with in the revisit design (1-7, panel=0 for rejected plots)
PanelYear	Year(s) that panel is sampled (1-7)
EvalStatus	Ultimate status of a plot (estab = established; NotEval = not visited; accept = visited and deemed to be acceptable as a monitoring site; reject = rejected)
S_Action	Status of plot determined in the field and recorded on GPS (accept or reject)
EvalReason	Describes why a site was accepted or rejected
Estab_Date	Month, day, and year of plot establishment
Soil_MU	Soil map unit from Arches Soil Survey associated with the monitoring plot
X	UTM E (NAD83, Zone 12)
Y	UTM N (NAD83, Zone 12)
Hike_km	Hiking distance to plot in kilometers
AreaDescr	General area of the park where the plot is located
Comments	Miscellaneous
ActualEco	Actual ecological site number (210, 212, 215, 218, or 236)
RQorder	Sequence number produced by RRQRR that doesn't start at 1 or increment by 1 (=order_ in sample_pts shape files and =GRID_CODE in smpts shape files)
inc_prob	inclusion probability; 1 indicates equal probability of selection for all points from the sample_pts shape file

Survey Design

We decided that there was no need for pilot monitoring in ARCH because estimates of variability were made using data from CANY.

Plots are sampled following a rotating-panel design that samples 8 plots each year and a total of 28 plots over 7 years for each of the 3 priority ecological site types. A total of 84 plots are sampled between all ecological site types. Plots are sampled 2 years in a row (in order to detect year-to-year differences due to temperature, precipitation, etc.) and rested for 5 years. Every 7 years, the sampling scheme repeats itself. The number of plots in each vegetation type should approximately represent the area of each vegetation type in the sampling frame.

	Year									
panel	1	2	3	4	5	6	7	8	9	10
1	4	4						4	4	
2		4	4						4	4
3			4	4						4
4				4	4					
5					4	4				
6						4	4			
7	4						4	4		

Figure 4. Number of plots sampled each year per ecological site type based on 7-year rotating panel revisit design for long-term upland monitoring at Arches National Park.

Response Design

The response design for ARCH is based on NCPN upland monitoring protocols for grasslands and shrublands. Table 6 outlines specific methods used.

Table 6. Response design for vegetation monitored in Arches National Park.

Method	Grassland/Shrubland
Transects	3 – 50 m transects
Plot establishment	Rebar at transect ends
Photos	Transect origin, BSCs
Point-intercept	X
Gap intercept	X
Soil stability	X
1-m belt (shrubs, seedlings, and exotic frequency)	X
5-m belt (saplings)	if trees are present
Tree census	if trees are present
Site Impact	X

Literature Cited

Coles, J., A. Tendick, G. Manis, A. Wight, G. Wakefield, J. Von Loh, and A. Evenden. 2009. Vegetation classification and mapping project report, Arches National Park. Natural Resource Technical Report NPS/NCPN/NRTR-2009/253. National Park Service, Fort Collins, Colorado.

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.

USDA NRCS. draft. Soil Survey of Arches National Park. Richfield, UT.