Volume I: Quick Start

Monitoring Manual

for Grassland, Shrubland and Savanna Ecosystems

by

Jeffrey E. Herrick, Justin W. Van Zee,
Kris M. Havstad, Laura M. Burkett and Walter G. Whitford

with contributions from

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Mike Pellant, David A. Pyke, Marta D. Remmenga, Patrick Shaver,
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USDA - ARS Jornada Experimental Range
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Cover illustration:
Collecting Line-point intercept data
in a south-central New Mexico desert grassland.

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USDA-NRCS Soil Quality Institute
USDA-NRCS National Soil Survey Center
U.S. Forest Service (Colorado, New Mexico)
U.S. Geological Survey, Biological Resources Division (Colorado, Utah)
U.S. National Park Service
(California, Nevada, Utah)

This is Volume I of a two-part document. The second volume includes guidance on monitoring program design and interpretation, as well as additional methods. For updates, electronic copies of data forms and a user-friendly Access database and field (touchscreen) data entry system, please visit the USDA-ARS Jornada Experimental Range web site (http://usda-ars.nmsu.edu).

[1]This list does not necessarily imply endorsement by these organizations.

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Introduction

This manual describes how to monitor three rangeland attributes: **soil and site stability**, **watershed function** and **biotic integrity**. Nearly everything we value about rangelands depends on these attributes. Monitoring these three attributes is like monitoring the foundation of our rangeland ecosystems. The measurements used to monitor these attributes also can be used to generate indicators relevant to specific management objectives, such as maintaining wildlife habitat, biodiversity conservation or producing forage.

Monitoring the key attributes:

Soil and site stability
Hydrologic function
Biotic integrity

Do I have to read the whole thing?

No. Even the *Quick Start* volume, which includes only the basics, probably includes some things you don't need. Start with photos for long-term monitoring. Record short-term observations and data on the appropriate Short-Term Monitoring Data Form. You can add quantitative measurements as you have time available. In some cases, you may need to refer to Volume II (see the questions below).

Units

Both English and metric units are included. For simplicity, many of these conversions are approximate. For example, the rough equivalent for a 50 m line is listed as 150 ft instead of 164 ft. This is because it is easier to select 50 points along a 150 ft transect (every 3 ft). For precise conversions. please see Volume II, Appendix B.

Is *Quick Start* All I Need?

***Quick Start* is the only volume needed if all of the following are "true."**

What to ask yourself:	True	False	If false, then see Volume II . . .
My management objectives are fairly well described (Table 1).			Chapter 1
I already know where I want to monitor.			Chapters 5-6
The basic monitoring strategy (Table 1) sounds reasonable, and I am either not aware of compaction or other problems not covered by the basic methods or I have decided not to monitor these problems.			Chapter 4
I'm comfortable with a standard number of measurements (page 5) that will allow me to document large changes but may miss smaller changes.			Chapter 4
I am not planning to monitor riparian areas.			Chapter 4
I already know how to interpret the indicators.			Chapter 17*

*For information about how to calculate additional indicators and interpret your results, please see Volume II, Chapters 16 and 17.

How To Establish a Monitoring Program

Long- and short-term monitoring

We recommend a combination of short-term and long-term monitoring (Table 1). Long-term monitoring (pages 6-33) is designed to document changes in the condition of the land, such as changes in soil structure and plant basal cover, and is normally repeated every one to five years. Short-term monitoring (pages 34-36) may be repeated at any time interval and is designed to check whether or not the management system is being followed (how much residual cover remains, or how much biomass is removed). Long-term monitoring is used to generate a "trend record," while short-term monitoring is used to establish an "annual-use record."

Figure 1. Monitoring invasive species in a belt transect.

Table 1. Examples of long- and short-term management objectives and the associated monitoring strategies described in Volume I. For other objectives and strategies, please refer to Volume II. Levels I-III refer to increasing monitoring intensity. Level II is the semiquantitative alternative to the standard methods (Level III). Both options are described in the following pages.

	Long-term monitoring	**Short-term monitoring**
Management objectives	Sustainability: Maintain or increase land productivity* and the number of land use options. Minimize risk of land degradation.	Maintain adequate cover to limit soil erosion and promote water infiltration. Maintain or increase cover of one or more species that persist through catastrophic disturbances (drought, fire). Limit invasive species.
Monitoring strategy	**Monitoring Intensity Level I** Photo points **Monitoring Intensity Levels II and III** Photo points and one or more of the following measurements: 1. Line-point intercept (III) or step point (II) (for cover and composition) 2. Gap intercept (III) or step gap (II) (for size of bare patches) 3. Soil stability test (III) or bottle cap test (II) (for soil erosion resistance) 4. Belt transects (III) (for invasive species)	**Monitoring Intensity Level I** Daily to monthly observations **Monitoring Intensity Level II** Daily to monthly observations *and* 1. Step-point (percent cover only) 2. Step-gap (percent steps completely in bare patches)

*Productivity includes all services that the land provides, not just forage production.

Monitoring and Management Flow Chart

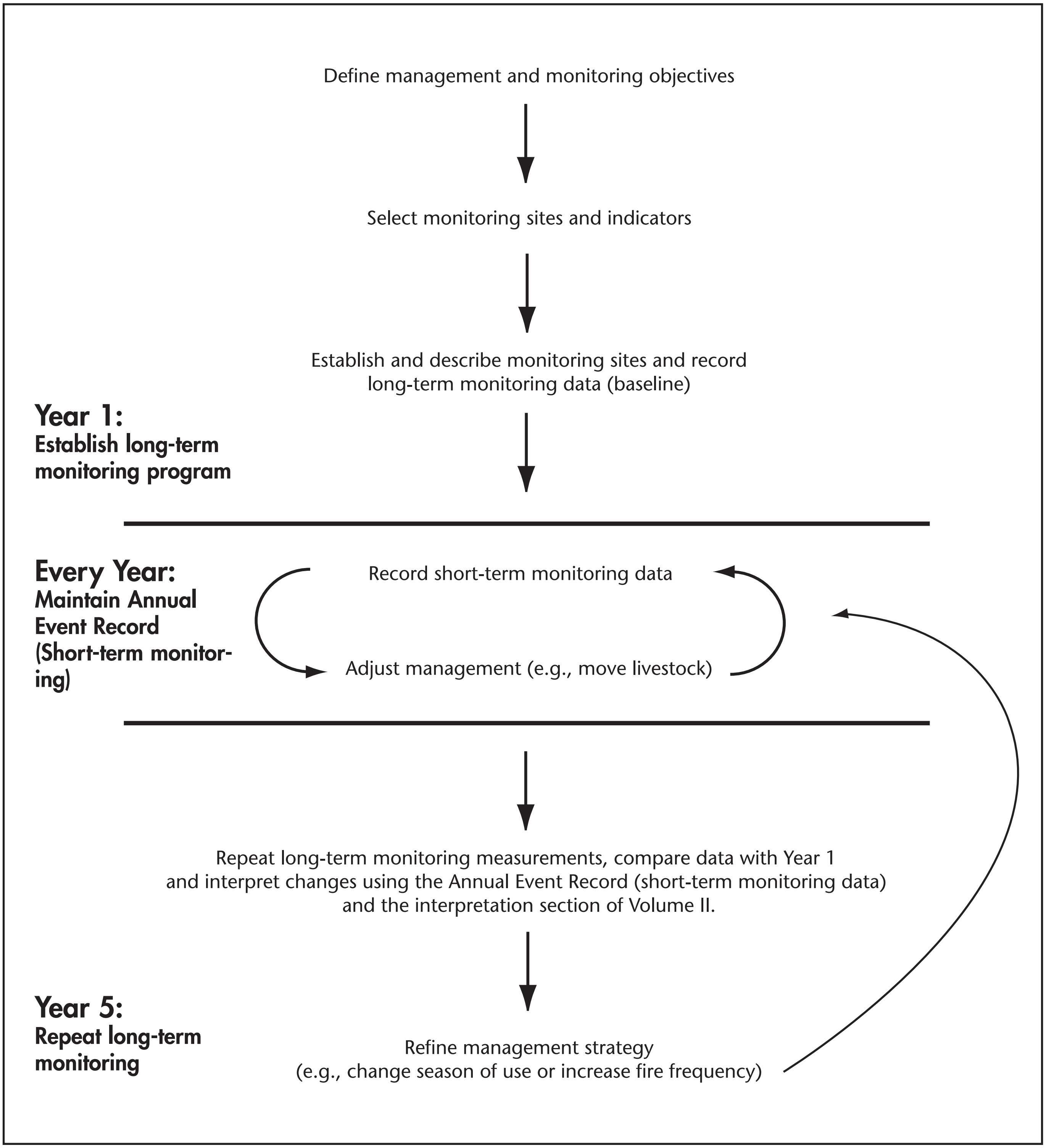


Figure 2. Quick Start monitoring program design, implementation and integration with management. For more detail on monitoring program design, see chapters 1-6 in Volume II.

How To Establish a Monitoring Program

Quick Start Monitoring program checklist*

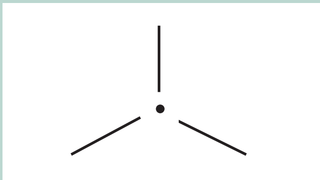
Step	Done?
Define monitoring objectives.	_____
Assemble background information (maps, photos) and select general areas you would like to monitor.	_____
Select monitoring sites. This may involve preliminary evaluations of risk or opportunity for change.	_____
Select indicators.	_____
Describe each monitoring site's management, slope, soil texture and depth.	_____
Establish permanent transects and begin monitoring.	_____

*For a more detailed checklist, see the Introduction of Volume II, Section I.

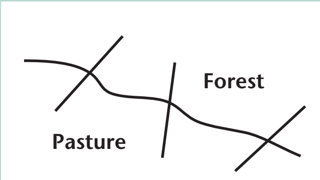
Measurement options

Standard transect layout

- Standard transect length is 50 m (150 ft); a multiple single transect design is often used to maximize replication at landscape scale.
- 50 m spoke design covers a 1-hectare (~2.5 acres) plot. 25 m spoke design covers ~0.3-hectare (~0.7 acres). Transects begin 5 m (15 ft) from the plot's center to focus trampling around center stake and minimize disturbance effects on transects.



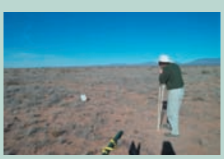
- Parallel transect design is best for crossing boundaries (forest-pasture) and other linear features, such as riparian zones.



Paper data collection forms are included for each method. Each data form includes calculations for standard indicators. For updates, electronic versions of the data forms and automated indicator calculations please visit the USDA-ARS Jornada Experimental Range web site (http://usda-ars.nmsu.edu).

Estimated time requirements for *Quick Start* long-term measurement options.

Method–page	No.*	Time** (hours)	No. of people	Indicators generated
Photos (for visual record of data), page 6	3	0.1	2	None
Line-point intercept (for plant cover and composition), page 9	150 pts. (50/line)	0.5	2	Foliar cover (%) Plant basal cover (%) Bare ground (%)
Canopy gap intercept (to monitor areas that are susceptible to wind erosion and/or weed invasion), page 16	3 lines	0.4	2	Proportion of line covered by large gaps between plant canopies
Basal gap intercept page 16	3 lines	0.4	2	Proportion of line covered by large gaps between plant bases
Soil stability test (for soil susceptibility to water erosion), page 23	18 samples	0.5	1	Average surface stability: • total • under canopy • not under canopy
Belt transect (for invasive species), page 30	3 belts	0.2	2	Number of invasive plants per hectare



Photos

Line-point intercept

Canopy and basal gap intercept

Soil stability test

Belt transect

* No. = Total number needed for three 50 m transects.

** Total hours for a team of two people, except for Soil stability, which only requires one person. Estimates are based on averages for an experienced team working in a variety of desert plant communities. Time requirements are extremely variable. One person can complete all methods, but we have found it most efficient to have a data recorder and an observer (except for Soil stability). Allow for an additional half hour when first establishing the permanent transects.

Long-Term Methods

Photo points

Use Photo points to qualitatively monitor how vegetation changes over time. Permanent photographs of a landscape are useful for detecting changes in vegetation structure and for visually documenting measured changes. Take at least one photo of each transect. If you take digital photos, be sure to print and store photos in plastic photo storage sheets. Slide the photo card (page 8) behind the photo in the plastic storage sheet. For more information on photo point monitoring, see the USFS Photo Point Monitoring Handbook (www.fs.fed.us/pnw/pubs/gtr526/).

Materials

- **Tape measure (5 m (15 ft) minimum)**
- **Four 60 cm (2 ft) rebar stakes**
- **Four 60 cm (2 ft) 3/4-in PVC pipe**
- **Compass**
- **35 mm or digital camera with a 50 mm-equivalent lens (1:1 ratio). If a wide angle, telephoto or zoom is used, be sure to record lens and camera information.**
- **Photo point (ID) board (chalk or whiteboard) or Photo point (ID) card (page 8) on a clipboard**
- **Thick marking pen**
- **One 1.5m (5 ft) long, 3/4-in diameter PVC pipe.**

Standard methods (rule set)

1. Establish photo point

Rules

1.1 Drive center stake into ground, leaving less than 30 cm (1 ft) exposed.

1.2 Drive transect stakes into ground 5 m (15 ft) from center stake at 120° intervals to mark beginning of the three transects.

1.3 Cover stakes with 60 cm (3/4-in) PVC (optional for safety and visibility).

1.4 Mark the far end (50 m) of each transect with a stake if the location will be used for vegetation and/or soil measurements. Use same procedure described in 1.2 and 1.3.

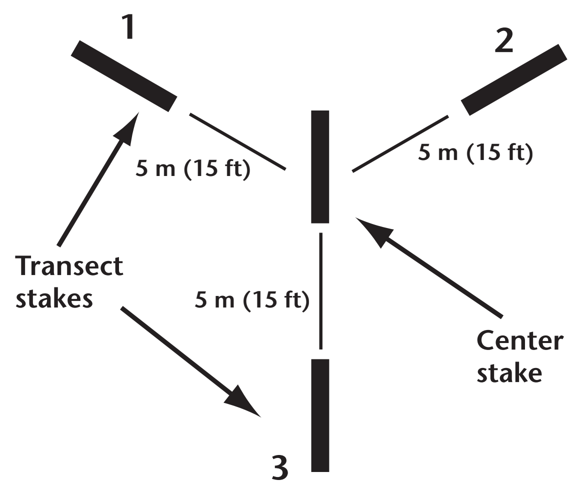


Figure 3. Transect stake locations for spoke design. Stakes mark beginnings of each transect. Base of stake located at bottom center of photo.

Ground cover photo option

Use each of the three transect stakes as one corner of a permanent plot (usually 1x1 m or 3x3 ft) and mark the other three corners with small stakes. Before taking the photo, mark the perimeter with a piece of rope or meter/yard sticks. Place the camera over the center of the plot at a standard height and take the photo.

Figure 4. Photographer is at plot center and Photo point ID board marks beginning of one of the three transects.

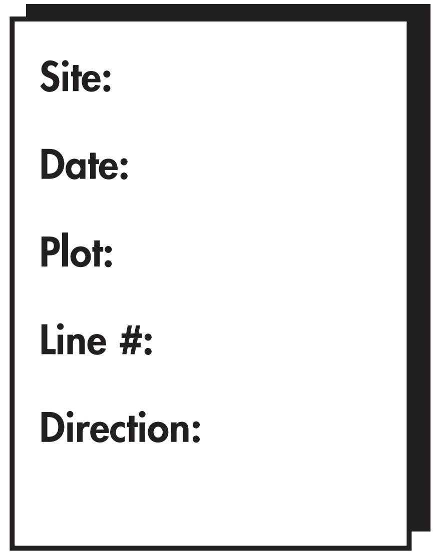


Figure 5. Photo point ID board.

2. Record photo information

Rules

2.1 Record date, location, precipitation and management history since the last photos were taken on a 7.5x12.5 cm (3x5 in) card or on one of the Short-Term Monitoring data forms (page 35 or 36).

3. Set up first photo

Rules

3.1 Remove PVC sleeve from center stake and replace with 1.5 m (5 ft) PVC pipe. Be sure that the pipe rests on the ground.

3.2 Label photo point ID board and lean it next to or hang it on the stake, marking the beginning of the first transect.

4. Take first photo (Fig. 4).

Rules

4.1 Set camera body on top of (1.5 m) center pole and point it down the first line.

4.2 Place bottom of nearest transect pole at the photo's bottom center.

4.3 Take photo.

5. Repeat Steps 3 and 4 for the other two photos.

Riparian note: At riparian sites, take two additional photos. Stand in mid-channel, hold camera 1.5 m (5 ft) above the ground and position bottom of viewfinder on a point located 5 m (15 ft) away. Take one photo facing upstream and one downstream.

Site:

Date:

Plot:

Line #:

Direction:

Photo point ID card

Line-point intercept

Line-point intercept is a rapid, accurate method for quantifying soil cover, including vegetation, litter, rocks and biotic crusts. These measurements are related to wind and water erosion, water infiltration and the ability of the site to resist and recover from degradation. For a detailed discussion of this and other methods for measuring plant cover and/or composition, see Elzinga et al. 2001[2]. For alternative Line-point intercept methods (including height measurements) see Volume II.

Materials

- **Measuring tape (length of transect)—if using a tape measure in feet, use one marked in tenths of feet.**
- **Two steel pins for anchoring tape**
- **One pointer—a straight piece of wire or rod, such as a long pin flag, at least 75 cm (2.5 ft) long and less than 1 mm (1/25 in) in diameter**
- **Clipboard, Line-Point Intercept Data Form (page 12) and pencil(s)**

Standard methods (rule set)

1. Pull out the tape and anchor each end with a steel pin (Fig. 6).

Rules

1.1 Line should be taut.

1.2 Line should be as close to the ground as possible (thread under shrubs using a steel pin as a needle).

2. Begin at the "0" end of the line.

3. Working from left to right, move to the first point on the line. Always stand on the same side of the line.

4. Drop a pin flag to the ground from a standard height (__ cm (__in)) next to the tape (Fig. 7).

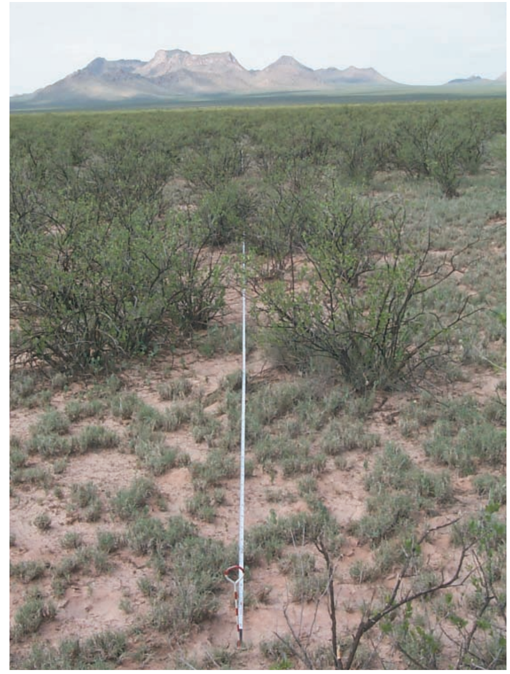


Figure 6. Transect line pulled taut.

Rules

4.1 The pin should be vertical.

4.2 The pin should be dropped from the same height each time. A low drop height minimizes "bounces" off of vegetation but increases the possibility for bias.

4.3 Do not guide the pin all the way to the ground. It is more important for the pin to fall freely to the ground than to fall precisely on the mark.

4.4 A pair of lasers with a bubble level can be used instead of the pin. This tool is useful in savannas where plant layers may be above eye level. See Appendix A (Monitoring tools) in Volume II for suppliers.

Step-point or pace transect with pin (Semiquantitative alternative)

Use a pin flag dropped in front of your boot instead of the points on the tape. Record first hit or all hits, as for standard method. This method is less accurate because it is difficult to walk a straight line, especially through shrubs. Using the toe of a boot instead of a pin creates additional errors because the boot often pushes plant canopies into interspaces. This leads to overestimates of foliar cover.

[2]Elzinga, C.L., D.W. Salzer, J.W. Willoughby and J.P. Gibbs. 2001. *Monitoring Plant and Animal Populations*, Blackwell Publishing. 368 pp.

5. Once the pin flag is flush with the ground, record every plant species it intercepts.

Rules

5.1 Record the species of the first stem, leaf or plant base intercepted in the "Top layer" column using the PLANTS database species code (http://plants.usda.gov/), a four-letter code based on the first two letters of the genus and species, or the common name.

5.2 If no leaf, stem or plant base is intercepted, record "NONE" in the "Top layer" column.

5.3 Record all additional species intercepted by the pin.

5.4 Record herbaceous litter as "L," if present. Litter is defined as detached dead stems and leaves that are part of a layer that comes in contact with the ground. Record "WL" for detached woody litter that is greater than 5 mm (or ~1/4 in) in diameter and in direct contact with soil.

5.5 Record each plant species only once, even if it is intercepted several times.

5.6 If you can identify the genus, but not the species either use the PLANTS database genus code (http://plants.usda.gov) or record a number for each new species of that genus. ALWAYS define the genus portion of the code and the functional group at the bottom of the data form (*Artemisia* species = AR01).

5.7 If you *cannot* identify the genus, use the following codes:

AF# = Annual forb (also includes biennials)
PF# = Perennial forb
AG# = Annual graminoid
PG# = Perennial graminoid
SH# = Shrub
TR# = Tree

If necessary, collect a sample of the unknown off the transect for later identification.

5.8 Foliage can be live or dead but only record each species once. If both live and dead canopy for the same species is hit on the same point, record the live canopy. Be sure to record all species intercepted.

Figure 7. Point falling on bare soil (NONE/S).

6. Record whether the pin flag intercepts a plant base (Fig. 8) or one of the following in the "Soil surface" column.

R = Rock (> 5 mm or ~1/4 inch in diameter)
BR = Bedrock
EL = Embedded litter
D = Duff
M = Moss
LC = Visible biotic crust on soil
S = Soil that is visibly unprotected by any of the above

Rules

6.1 For unidentified plant bases, use the codes listed under 5.7.

6.2 Record embedded litter as "EL" where removal of the litter would leave an indentation in the soil surface or would disturb the soil surface. Record duff as "D" where there is no clear boundary between litter and soil and litter is not removed during typical storms (occurring annually).

6.3 Additional categories may be added, such as "CYN" = dark cyanobacterial crust.

Recording dead vs. live:

Distinguishing dead vs. live plants or plant parts is important for many objectives. Points where only dead plants or plant parts are intercepted can be recorded by either circling the species on the paper data form, or by using the optional checkbox in the Access database form (http://usda-ars.nmsu.edu/monit_assess/monitoring.php). Be sure to note whether a check means that the plant part (recommended) or entire plant is dead, and remember that many desert plants only appear to be dead.

Table 2. Sample data form for examples illustrated below. Points 1 and 2 show the first two points on a line. In Point 1, the pin flag is touching dead fescue, live bluegrass, clover, live fescue, litter and a rock. Record fescue only once, even though it intercepts the pin twice. In Point 2, the flag touches fescue, then touches litter and finally the fescue plant base. Table 2 shows how to record these two points on the data form.

Pt.	Top layer	Lower layers			Soil surface
		Code 1	Code 2	Code 3	
1	Fescue	Bluegrass	Clover	L	R
2	Fescue	L			Fescue
3	Fescue	L			S
etc.					

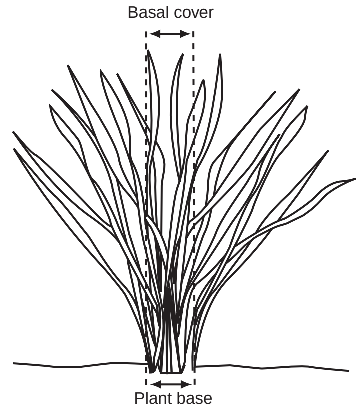
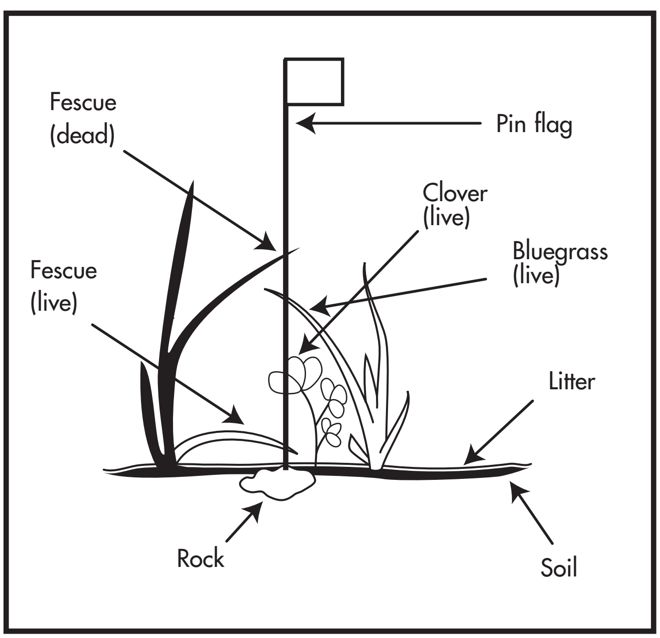
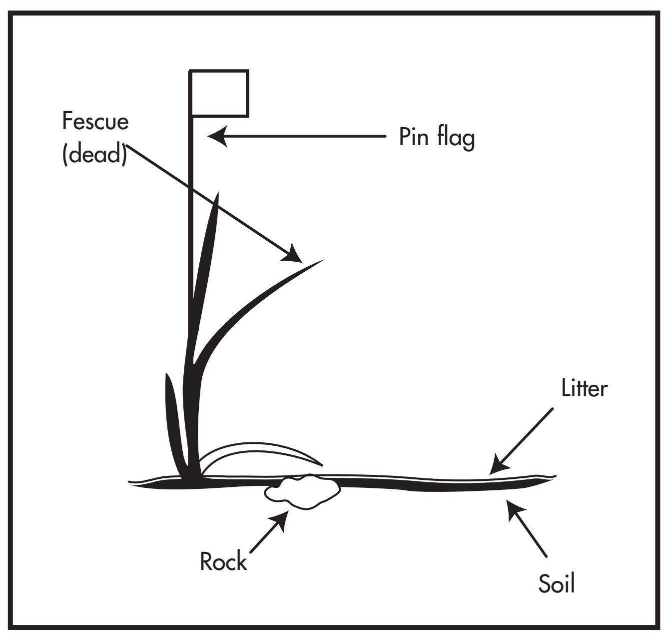


Figure 8. Area defined as plant base and included as basal cover.



Point 1



Point 2

Riparian note: Line-point intercept collected perpendicular to the channel is often used to monitor riparian zone width. A modified point intercept method is used to monitor "greenline" vegetation along the channel's edge (Vol. II, Chapter 13).

Line-point Intercept Data Form

Page ______ of ______

Shaded cells for calculations

Plot: ______ Line #: ______ Observer: ______ Recorder: ______

Direction: ______ Date: ______ Intercept (Point) Spacing Interval = ______ cm (___ in)

Pt.	Top layer	Lower layers			Soil surface	Pt.	Top layer	Lower layers			Soil surface
		Code 1	Code 2	Code 3				Code 1	Code 2	Code 3	
1						26					
2						27					
3						28					
4						29					
5						30					
6						31					
7						32					
8						33					
9						34					
10						35					
11						36					
12						37					
13						38					
14						39					
15						40					
16						41					
17						42					
18						43					
19						44					
20						45					
21						46					
22						47					
23						48					
24						49					
25						50					

% foliar cover = ____ top layer pts (1st col) x 2 = ____ %

% bare ground* = ____ pts (w/NONE over S) x 2 = ____ %

% basal cover = ____ plant base pts (last col) x 2 = ____ %

Top layer codes: Species code, common name, or NONE (no cover).

Lower layers codes: Species code, common name, L (herbaceous litter), WL (woody litter, >5 mm (~1/4 in) diameter).

Unknown Species Codes:

AF# = annual forb
PF# = perennial forb
AG# = annual graminoid
PG# = perennial graminoid
SH# = shrub
TR# = tree

Soil Surface (do not use litter):

Species Code (for basal intercept)
R = rock fragment (>5 mm (~1/4 in) diameter)
BR = bedrock, M = moss
LC = visible biotic crust on soil
S = soil without any other soil surface code
EL = embedded litter (see page 10)
D = duff

**Bare ground occurs ONLY when Top layer = NONE, Lower layers are empty (no L), and Soil surface = S.*

Line-point intercept indicator calculations

Foliar cover (as calculated here) does not include bare spaces within a plant's foliage.

1. Percent foliar cover

Rules

1.1 Count the total number of plant intercepts in the "Top layer" column and record this number in the blank provided.

1.2 Plant intercepts include all points where a plant is recorded in the "Top layer" column. Do not include points that have a "NONE" in the "Top layer" column.

1.3 Multiply the number of plant intercepts (from 1.1) by 2* and record your "% foliar cover" in the blank provided.

2. Percent bare ground

Rules

2.1 Count the total number of points along the line that have bare ground and record this number in the blank provided.

2.2 Bare ground occurs **only** when:

A. There are no plant intercepts (NONE is recorded in the "Top layer" column).

B. There are no litter intercepts ("Lower layers" columns are empty).

C. The pin only intercepts bare soil ("S" recorded in the "Soil surface" column).

2.3 Multiply the number of bare ground hits (from 2.1) by 2* and record your "% bare ground" in the blank provided.

3. Percent basal cover

Rules

3.1 Count the total number of plant basal intercepts in the "Soil surface" column and record this number in the blank provided.

3.2 Plant basal intercepts occur anytime the pin intercepts a live or dead plant base (Species code recorded in "Soil surface" column).

3.3 Multiply the number of basal intercepts (from 3.1) by 2* and record your "% basal cover" in the blank provided.

---

*For 50 points per line. Multiply by 1 for 100 points per line. Multiply by 4 for 25 points per line.

Table 3. Line-point intercept data form example showing a 50-point line and associated indicator calculations.

Page 1 **of** 1 — **Shaded cells for calculations**

Plot: 3 **Line #:** 2 **Observer:** Jane Smith **Recorder:** David Patrick

Direction: 120° **Date:** 10/15/2002 **Intercept (Point) Spacing Interval =** 100 **cm (___ in)**

Pt.	Top layer	Lower layers			Soil surface	Pt.	Top layer	Lower layers			Soil surface
		Code 1	Code 2	Code 3				Code 1	Code 2	Code 3	
1	BOER				BOER	26	PRGL	BOER			S
2	BOER				S	27	NONE	L			S
3	SP01	BOER			S	28	BOER				LC
4	BOER				S	29	SP01	BOER			S
5	NONE				S	30	YUEL	L			S
6	BOER				S	31	BOER				S
7	NONE	L			S	32	NONE				R
8	NONE				S	33	BOER				S
9	BOER				S	34	NONE	L			S
10	BOER	L			S	35	BOER				S
11	BOER	L			S	36	BOER	L			BOER
12	BOER				S	37	BOER	L			S
13	NONE				S	38	BOER	L			S
14	BOER				S	39	NONE				S
15	NONE	L			S	40	NONE	L			S
16	NONE				R	41	BOER				S
17	BOER				S	42	PRGL	SP01			S
18	BOER				BOER	43	PRGL				S
19	NONE				R	44	SP01				S
20	BOER				S	45	NONE				S
21	BOER				S	46	BOER				S
22	SP01				S	47	BOER				BOER
23	BOER	L			S	48	BOER	L			S
24	NONE	L			S	49	NONE	L			S
25	NONE	L			S	50	BOER	GUSA			S

% foliar cover = 34 top layer pts (1st col) x 2 = 68 %

% bare ground* = 5 pts (w/NONE over S) x 2 = 10 %

% basal cover = 4 plant base pts (last col) x 2 = 8 %

Top layer codes: Species code, common name, or NONE (no cover).

Lower layers codes: Species code, common name, L (herbaceous litter), WL (woody litter, >5 mm (~1/4 in) diameter).

Unknown Species Codes:

AF# = annual forb
PF# = perennial forb
AG# = annual graminoid
PG# = perennial graminoid
SH# = shrub
TR# = tree

Soil Surface (do not use litter):

Species Code (for basal intercept)
R = rock fragment (>5 mm (~1/4 in) diameter)
BR = bedrock, M = moss
LC = visible biotic crust on soil
S = soil without any other soil surface code
EL = embedded litter (see page 10)
D = duff

**Bare ground occurs ONLY when Top layer = NONE, Lower layers are empty (no L), and Soil surface = S.*

Line-point intercept basic interpretation

Increases in **foliar cover** are correlated with increased resistance to degradation. **Basal cover** is a more reliable long-term indicator. Basal cover is less sensitive to seasonal and annual differences in precipitation and use. Increases in **bare ground** nearly always indicate a higher risk of runoff and erosion.

Where species composition changes may be occurring, calculate basal and foliar cover for each major species. Foliar cover usually is used for shrubs, trees and sometimes grasses. Basal cover is used for perennial grasses. When calculating single species foliar cover, be sure to include each time the species is intercepted, regardless of whether it is in the top or lower layer.

Use these indicators together with the indicators from the **Gap intercept** and the **Soil stability test** to help determine whether observed erosion changes are due to loss of cover, changes in the vegetation's spatial distribution, or reduced soil stability. Use these indicators together with the **Belt transect** to track changes in species composition. For more information about how to interpret these indicators, please see Chapter 17 in Volume II.

.

Typical effect on each attribute of an increase in the indicator value			
Indicator	**Soil and site stability**	**Hydrologic function**	**Biotic integrity**
Foliar cover (%)	+	+	+
Bare ground (%)	–	–	–
Basal cover (%)	+	+	+

Gap intercept

Gap intercept measurements provide information about the proportion of the line covered by large gaps between plants. Large gaps between plant canopies are important indicators of potential wind erosion and weed invasion. Large gaps between plant bases are important indicators of runoff and water erosion.

Materials.

- **Measuring tape (at least as long as transect)—if tape is in feet, use one marked in tenths of feet.**
- **Two steel pins for anchoring tape**
- **Meter stick or other stiff stick**
- **Clipboard, Gap Intercept Data Form (page 20) and pencil(s)**

Standard methods (rule set)

Steps 1-4 for both canopy and basal gap intercept.

1. Pull out the tape and anchor each end with steel pin.

Rules

1.1 Line should be taut.

1.2 Line should be as close to the ground as possible (thread under shrubs using a steel pin as a needle).

2. Begin at the "0" end of the line.

3. Work from left to right, move to the first point on the line. Always stand on the same side of the line.

Rules

3.1 Look straight down on the tape. Use a meter stick or other stiff stick to project a line vertically to the ground.

3.2 Assume that there is a wall at each end of the tape. Do not consider gaps or vegetation that occur off the end of the tape.

4. Record whether or not annuals are included.

Rules

4.1 The standard method is to include annual grasses and ignore annual forbs due to the highly variable and ephemeral nature of forb production in most arid and semiarid ecosystems.

4.2 Annuals may be ignored in ecosystems where they have little effect on reducing wind and water erosion and/or where their occurrence is extremely variable among years.

4.3 Apply the same method each year.

Figure 9. A canopy gap.

Final step for canopy gap intercept

5. Record the beginning and end of each gap between plant canopies longer than 20 cm (0.7 ft).

Rules

5.1 Canopy occurs any time 50% of any 3 cm (0.1 ft) segment of tape edge intercepts live or dead plant canopy based on a vertical projection from canopy to ground. Always read on the graduated side of the tape.

5.2 The minimum gap size can be increased or decreased as appropriate for the site. For example, where wind erosion is important, the minimum gap size can be increased for plant communities with tall vegetation. Once monitoring has begun, the minimum gap size can only be increased. Be sure to record the minimum gap size on the data form.

5.3 A plant canopy can stop a gap whether live or dead.
5.4 Record the start and end of a gap to the nearest centimeter (or 0.1 ft).
5.5 Dead plant bases count as canopy.
5.6 Litter is not canopy, regardless of size.
5.7 Canopy overhead (~>2.5 m) can be measured in different ways: a) If canopy is relatively short (2-3 m above ground) a straight wire can be raised by hand to determine the canopy edges; b) A right-angled mirror with crosshairs can be placed over the transect tape, then observer looks through mirror to determine canopy edges; or c) A laser pointer can be placed over the transect tape and aimed upwards to the canopy.

Final step for basal gap intercept

6. Record the beginning and end of each gap between plant bases longer than 20 cm (0.7 ft).

Rules

6.1 A plant base is any plant stem emerging from the soil surface along the graduated 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 or 1/25 of an in).
6.2 A basal gap occurs any time there is at least 20 cm (0.7 ft) of intercept without a plant base. Therefore, there should always be at least 20 cm (0.7 ft) between basal gap starts and basal gap ends.
6.3 A plant base can stop a gap whether live or dead.
6.4 Plant bases may be live or dead, but they must be anchored in the ground. Litter is not a plant base.
6.5 Record the start and end of a gap to the nearest centimeter (or 0.1 ft).

Step gap (Semiquantitative alternative)

Walk 50 paces in each direction (e.g., 0°, 120°, 240°) and record the number of times your boot lands completely within a vegetation gap. In other words, the gap is the size of your boot or larger. Another variation is to record the number of gaps larger than a particular size that your toe lands in.

$$\text{Indicator} = 100 \times \frac{\text{No. of gaps}}{\text{Total No. acres}}$$

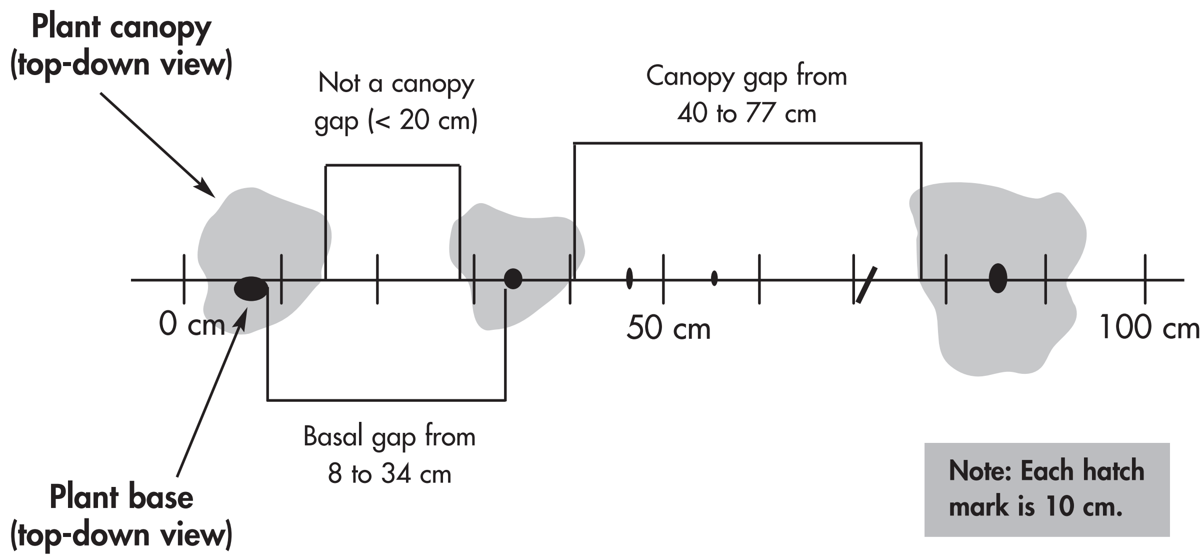


Figure 10. Example of canopy gap intercepts (above the line) and basal gap intercepts (below the line) for 1 m (100 cm) of a 50 m line. Canopy gaps: There is a gap between 40 and 77 cm because the plant canopies present do not cover more than 50% of any 3 cm segment. Basal gaps: There is a basal gap 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.

Table 4. Gap intercept data form example associated with Figure 10.

Canopy gaps: Minimum size = 20 cm							Basal gaps: Minimum size = 20 cm						
Starts	Ends	Gap size	25-50	51-100	101-200	>200	Starts	Ends	Gap size	25-50	51-100	101-200	>200
40	77	37	37				8	34	26	26			

When using feet instead of meters, use the decimal (1/10) side of the tape. Most long tape measures include inches on one side and 1/10s of feet on the other. This makes calculations much easier.

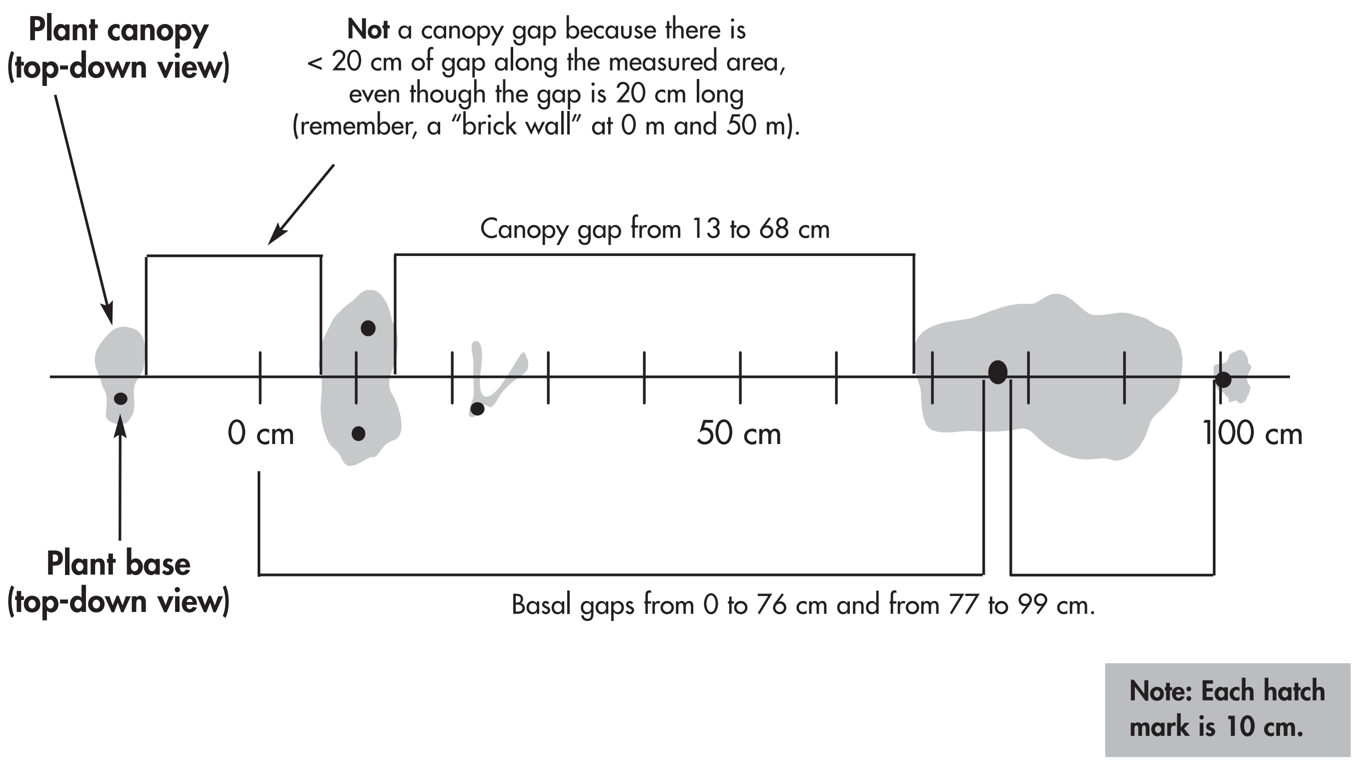


Figure 11. Example of canopy gap intercepts (above the line) and basal gap intercepts (below the line) for 1 m (100 cm) of a 50 m line. Canopy gaps: Look at the plant canopy intercept between the 20 and 30 cm marks on the transect. Because each canopy intercept covers less than 50 percent of a 3 cm segment of the line, it does not count as canopy.

Table 5. Gap intercept data form example associated with Figure 11.

Canopy gaps: Minimum size = 20 cm							Basal gaps: Minimum size = 20 cm						
Starts	Ends	Gap size	25-50	51-100	101-200	>200	Starts	Ends	Gap size	25-50	51-100	101-200	>200
13	68	55		55			0	76	76		76		
							77	99	22				

Riparian note: No changes are needed for this method in riparian areas.

Gap Intercept Data Form

Monitoring plot: __________ **Line:** ___________ **Date:** _________ **Shaded cells for calculations**

Reader: _______________ **Recorder:** ________ **Line Length** ____ **m or ft** **Page**____ **of** _____

Circle one: includes only perennial vegetation **OR** includes annual and perennial vegetation

Canopy gaps: Minimum size = ___cm (___ft)							Basal gaps: Minimum size = ___cm (___ft)						
Starts	Ends	Gap (cm) size (ft)	25-50 1-2	51-100 2.1-3	101-200 3.1-6	>200 >6	Starts	Ends	Gap (cm) size (ft)	25-50 1-2	51-100 2.1-3	101-200 3.1-6	>200 >6
SUM (cm/ft)							SUM (cm/ft)						
LINE LENGTH (cm/ft)							LINE LENGTH (cm/ft)						
SUM ÷ LINE LENGTH							SUM ÷ LINE LENGTH						

	x 100	x 100	x 100	x 100		x 100	x 100	x 100	x 100
% of line in gaps					% of line in gaps				

Example: If SUM 25-50 = 1,573, Line Length = 5,000 cm, then % of line in gaps 25-50 cm = 100 x (SUM 25-50/line length) = 100 x (1,573/5,000) = 31.5%.

Gap intercept indicator calculations

1. **Canopy gaps: Calculate the percentage of the line covered in gaps 25-50 cm, 51-100 cm, 101-200 cm and greater than 200 cm long.**

Rules

1.1 Calculate each **Gap size** in centimeters (**Gap ends – Gap starts**) for each canopy gap entered on the data sheet.

1.2 If a gap is 25-50 cm long, record its "Gap size" (cm) under the "25-50" column. Repeat this for the remaining columns (51-100, 101-200 and >200) and for all gaps.

1.3 Add the gaps up for each shaded column and record this value next to "SUM" on the data form. This is the total amount of the line (in centimeters) covered by gaps 25-50, 51-100, 101-200, >200 cm.

1.4 Record the "LINE LENGTH" in centimeters on the data form. Line length is equal to the length of the line (in meters) multiplied by 100.

1.5 Starting with the gaps 25-50 cm, divide the "SUM" by the "LINE LENGTH" and multiply this value by 100 to obtain the percent of the line covered in gaps 25-50 cm. Record this value under the appropriate column next to "% of line in gaps". Repeat this for gaps 51-100, 101-200, and >200 cm.

2. **Basal gaps: Calculate the percentage of the line covered in gaps 25-50 cm, 51-100 cm, 101-200 cm and greater than 200 cm long.**

Rules

2.1 Follow steps 1.1 through 1.5 above for basal gaps.

3. **Optional for canopy and basal gaps: Use a different color or pattern to mark a slice of the pie chart for each gap's size class. The dark green section represents the area covered by plants and gaps less than 25 cm (Fig. 12).**

Table 6. Gap intercept data form example showing part of a 50-m line and associated indicator calculations.

Canopy gaps: Minimum size = 20 cm (___ft)							Basal gaps: Minimum size = 20 cm (___ft)						
Starts	Ends	Gap size	25-50	51-100	101-200	>200	Starts	Ends	Gap size	25-50	51-100	101-200	>200
40	60	20					27	64	37	37			
101	202	101			101		70	264	194			194	
237	963	726				726	269	459	190			190	
:	:	:	:	:	:	:	:	:	:	:	:	:	:
4704	4754	50	50				3560	4684	1124				1124
4761	4925	164			164		4720	4813	93		93		
4931	5000	69		69			4817	5000	183			183	
SUM (cm)			50	69	265	726	SUM (cm)			37	93	567	1124
LINE LENGTH (cm)			5000	5000	5000	5000	LINE LENGTH (cm)			5000	5000	5000	5000
% of line in gaps			1%	1.4%	5.3%	14.5%	% of line in gaps			0.7%	1.9%	11.3%	22.5%

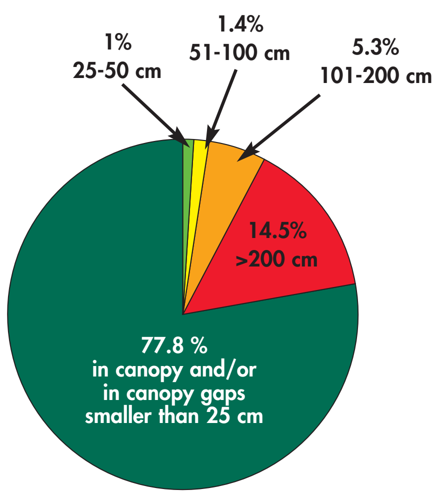
100 x (50/5000)
100 x (69/5000)
100 x (265/5000)
100 x (726/5000)
100 x (37/5000)
100 x (93/5000)
100 x (567/5000)
100 x (1124/5000)

Gap intercept basic interpretation

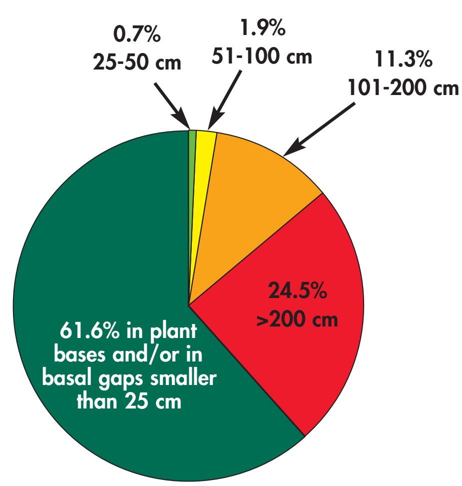
Increases in the proportion of the line covered by **canopy gaps** are related to increased risk of wind erosion and invasive "weed" species establishment. For example, wind velocities in most areas of the western United States are capable of moving disturbed soil in 50-cm (20-in) gaps in grasslands. Disturbed soil in gaps 1-2 m (3-6 ft) in diameter is nearly as susceptible to erosion as that with no vegetation. Minimum gap size required to cause wind erosion increases with vegetation height. Increases in the proportion of the line covered by large **basal gaps** reflect increased susceptibility to water erosion and runoff. Plant bases slow water movement down slopes. As basal gaps increase, there are fewer obstacles to water flow, so runoff and erosion increase. Increases in large basal gaps have a greater effect where rock and litter cover are low, because they are the only obstacles to water flow and erosion.

Use these indicators together with the cover indicators from the **Line-point intercept** and the **Soil stability test** to help determine whether observed erosion changes are due to loss of cover, changes in spatial distribution of vegetation or reduced soil stability. Where the gaps are approximately circular, the typical gap diameter is approximately 1.3 times the gap intercept. For more information about how to interpret these indicators, please see Volume II, Chapter 17.

Typical effect on each attribute of an increase in the indicator value			
Indicator	**Soil and site stability**	**Hydrologic function**	**Biotic integrity**
Canopy gaps (%)	–	–	–
Basal gaps (%)	–	–	–



Canopy Gap Pie Chart



Basal Gap Pie Chart

Figure 12. Examples of how to present gap intercept data in pie charts. Size of each pie slice is proportional to the area covered by each type of gap.

Soil stability test

The Soil stability test provides information about the degree of soil structural development and erosion resistance. It also reflects soil biotic integrity, because the "glue" (organic matter) that binds soil particles together must constantly be renewed by plant roots and soil organisms. This test measures the soil's stability when exposed to rapid wetting. It is affected by soil texture, so it is important to limit comparisons to similar soils that have similar amounts of sand, silt and clay (see Volume II, Appendix E for a simple field procedure to determine soil texture).

Materials:

- **Complete soil stability kits (see Appendix A in Vol. II for construction and suppliers)**
- **Deionized water (or any noncarbonated bottled water, except mineral water) 1 L (32 oz)**
- **Clipboard, Soil Stability Test Data Form (page 27) and pencil(s)**
- **Stopwatch**

Standard methods (rule set)

This is easier than it sounds! With a little practice, it takes about 10-15 minutes to sample and 10 minutes to test 18 samples.

1. Randomly select 18 sampling points and decide whether you will collect surface samples only (1 box), or surface and subsurface samples (2 boxes).

Rules

1.1 Use 18 randomly selected points along the transects used for line-point and gap intercept measurements.

1.2 Record sampling locations (points) under "Pos" on the data form.

1.3 Always sample at least 5 cm (2 in) from any vegetation measurement line.

1.4 Include subsurface samples if you are interested in soil erodibility after disturbance.

2. Determine the dominant cover class over the random point and enter this into the "Veg" column on the data form.

Rules

2.1 The area to be classified is effectively as large as the sample area (6-8 mm (1/4 in) in diameter).

2.2 Record the dominant cover class in the "Veg" column (optional):

NC = no perennial grass, shrub or tree canopy cover
G = perennial grass canopy and grass/shrub canopy mixture
F = perennial forb
Sh = shrub canopy
T = tree canopy

3. Collect a surface sample.

Rules

3.1 Excavate a small trench (10-15 mm (1/2 in) deep) in front of the area to be sampled (Fig. 13).

3.2 Lift out a soil fragment and trim it (if necessary) to the correct size.

3.3 The soil fragment should be 2-3 mm (<1/8 in) thick and 6-8 mm (1/4 in) in diameter (Figs. 14 and 15). This is the diameter of a wood pencil eraser. Try to fit sample in this dot (6-8 mm dia.).

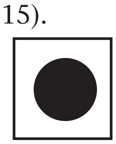


Figure 13. Excavate small trench.

Figure 14. Collect surface sample.

Figure 15. Ensure correct sample size.

3.4 Collect samples at the exact point. Move the sample point only if it has been disturbed during previous measurements or the soil surface is protected by a rock or embedded litter. Move the point a standard distance (1 m) and note this change on the data form.

3.5 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 (see 3.6).

3.6 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 form.

3.7 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, collect the sample from under the moss.

3.8 Gently place the sample in a dry sieve (Fig. 16); place sieve in the appropriate cell of a dry box.

4. Collect a subsurface sample (optional, see Step 1).

Rules

4.1 Sample directly below the surface sample.

4.2 Use the flat, square (handle) end of the scoop to gently excavate the previous trench (in front of the surface sample) to a depth of 3-4 cm (1 1/2 in).

4.3 Directly below the surface sample, remove soil so that a "shelf" is created with the top step 2-2.5 cm (3/4-1 in) below the soil surface (Fig. 17).

4.4 Use the scoop to lift out a subsurface sample from below (Fig. 18).

4.5 The soil fragment should be 2-3 mm (<1/8 in) thick and 6-8 mm (1/4 in) in diameter.

4.6 See steps 3.5-3.6. If you encounter a rock, record "R" and move to the next sample.

4.7 Place the sample in a dry sieve; place sieve in the dry box. Leave box lid open (Fig. 19).

Riparian note: No changes are needed for this method in riparian systems.

Figure 16. Place sample in sieve.

Figure 17. Excavate trench for subsurface sample.

Figure 18. Collect subsurface sample.

Figure 19. Complete soil stability kit with water and samples.

5. Make sure the surface and subsurface samples are dry.

Rules

5.1 Samples must be dry before testing. If samples are not dry after collecting, allow to air dry with the lid off.

5.2 Do not leave lid closed on samples for more than 1 minute on hot/sunny days. Excessive heat can artificially increase or decrease stability.

6. Fill the empty (no sieves) box with deionized or distilled water (Fig. 19).

Rules

6.1 Fill each compartment to the top.

6.2 The water should be approximately the same temperature as the soil.

7. Test the samples.

Rules

7.1 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. 20).

7.2 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.

7.3 Start the stopwatch when the first sample touches the water. Use Table 7 to assign samples to stability classes.

7.4 Follow the sequence of immersions on the data form, adding one sample every 15 seconds. 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.

Figure 20. Place first sample in water.

7.5 Observe the fragments from the time the sample hits the water to 5 min (300 sec) and record a stability class based on Table 7.

7.6 Raise the sieve completely out of the water and then lower it to the bottom without touching the bottom of the tray. 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).

7.7 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.

7.8 Hydrophobic samples (float in water after pushed under) are rated 6.

Bottlecap test (Semiquantitative alternative)

Place a soil fragment in a bottle cap filled with water. Watch it for 30 seconds. Gently swirl the water for 5 seconds. Assign one of three ratings:

M= Melts in first 30 seconds (without swirling)
D= Disintegrates when swirls (but does not melt)
S= Stable (even after swirling)

Table 7. 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, **OR** soil too unstable to sample (falls through sieve).
2	50% of structural integrity lost (melts) 5-30 seconds after immersion.
3	50% of structural integrity lost (melts) 30-300 seconds after immersion, **OR** < 10% of soil remains on the sieve after five dipping cycles.
4	10–25% of soil remains on the sieve after five dipping cycles.
5	25–75% of soil remains on the sieve after five dipping cycles.
6	75–100 % of soil remains on the sieve after five dipping cycles.

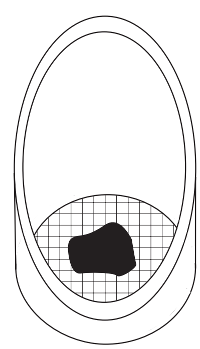
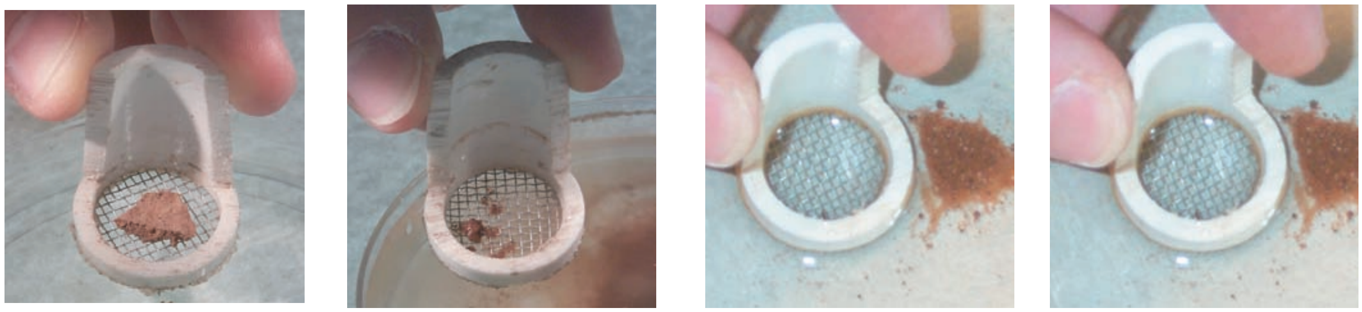


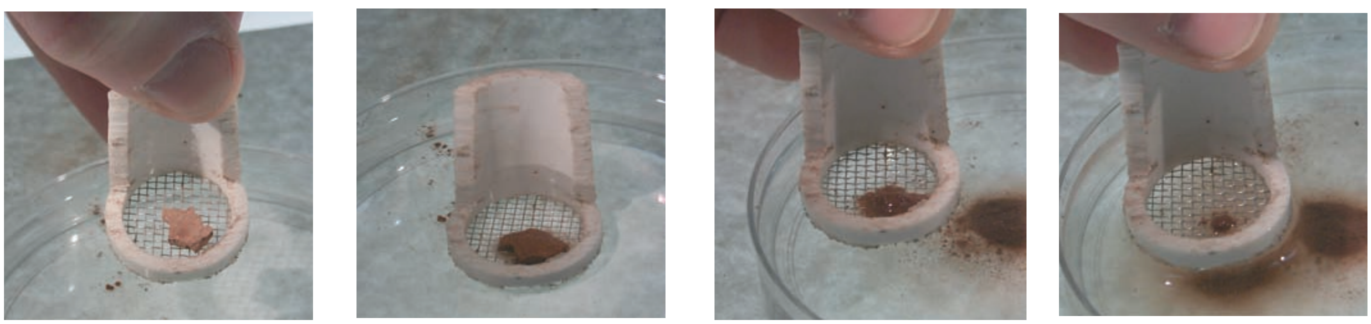
Figure 21. Sample in sieve, drawn to scale.

Sequence for stability class = 1.



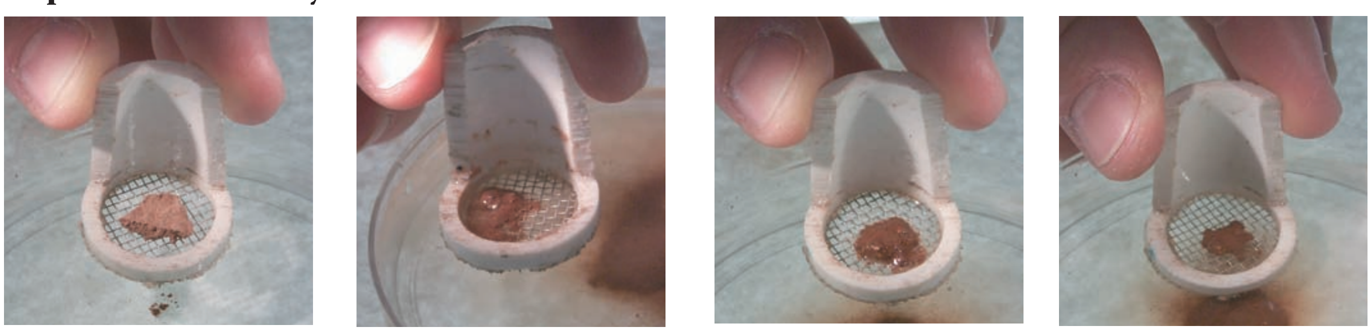
Original sample | After 5 seconds | After 5 minutes | After 5 dips

Sequence for stability class = 4.



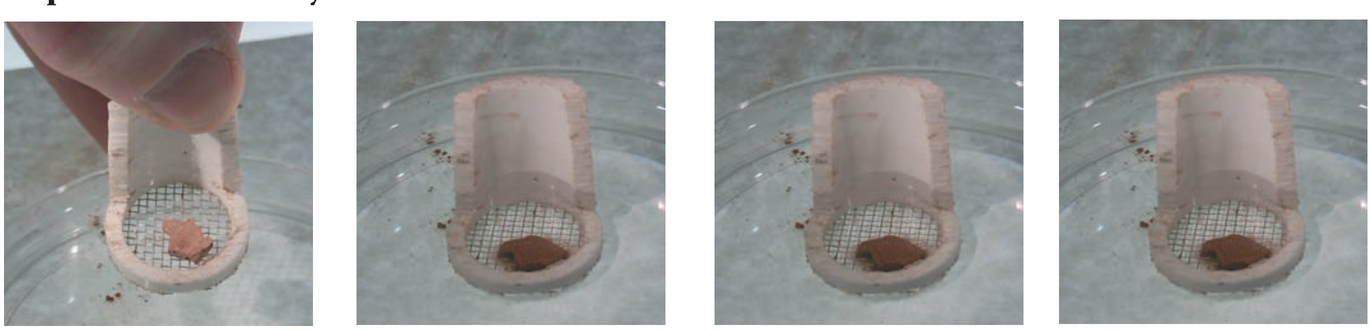
Original sample | After 5 seconds | After 5 minutes | After 5 dips

Sequence for stability class = 5.



Original sample | After 5 seconds | After 5 minutes | After 5 dips

Sequence for stability class = 6.



Original sample | After 5 seconds | After 5 minutes | After 5 dips

Figure 22. The photos above illustrate the key steps of testing a soil sample for four different stability rankings. **Important note:** 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 or 1/4 in) in Rule 3.3 and Fig. 21.

Soil Stability Test Data Form

Monitoring plot: ____________________ **Observer:** ____________________ **Date:** ____________________

Recorder: ____________________ **Page** _____ **of** _____

Veg = NC (no perennial canopy), **G** (grass or grass/shrub mix), **F** (forb), **Sh** (shrub), **T** (tree). **# = Stability value** (1-6)**.** Circle value if samples are hydrophobic.

Surface

Line ___		In	Dip		Line ___		In	Dip		Line ___		In	Dip		Line ___		In	Dip		Line ___		In	Dip		Line ___		In	Dip	
Pos	Veg	time	time	#	Pos	Veg	time	time	#	Pos	Veg	time	time	#	Pos	Veg	time	time	#	Pos	Veg	time	time	#	Pos	Veg	time	time	#
		0:00	5:00				0:45	5:45				1:30	6:30				2:15	7:15				3:00	8:00				3:45	8:45	
		0:15	5:15				1:00	6:00				1:45	6:45				2:30	7:30				3:15	8:15				4:00	9:00	
		0:30	5:30				1:15	6:15				2:00	7:00				2:45	7:45				3:30	8:30				4:15	9:15	

Notes: ____________________

Subsurface

Line ___		In	Dip		Line ___		In	Dip		Line ___		In	Dip		Line ___		In	Dip		Line ___		In	Dip		Line ___		In	Dip	
Pos	Veg	time	time	#	Pos	Veg	time	time	#	Pos	Veg	time	time	#	Pos	Veg	time	time	#	Pos	Veg	time	time	#	Pos	Veg	time	time	#
		0:00	5:00				0:45	5:45				1:30	6:30				2:15	7:15				3:00	8:00				3:45	8:45	
		0:15	5:15				1:00	6:00				1:45	6:45				2:30	7:30				3:15	8:15				4:00	9:00	
		0:30	5:30				1:15	6:15				2:00	7:00				2:45	7:45				3:30	8:30				4:15	9:15	

Notes: ____________________

Avg. Stability = Sum of Stability Rankings (i.e., #) / Total No. Samples Taken

Line	All samples		Protected samples (Samples w/Veg = G, Sh, or T)		Unprotected samples (Samples w/ Veg = NC)	
	Surface	Subsurface	Surface	Subsurface	Surface	Subsurface
Plot Avg.						

Soil stability indicator calculations

1. Calculate the average stability for all samples.

Rules

1.1 Add together all stability values. Divide this sum by the total number of samples taken. Record this value as the average stability for "All samples" on your data form.

2. Calculate the stability for protected soil (Veg = G, F, Sh, or T).

Rules

2.1 Add together all values that were protected by canopy (Veg = G, F, Sh, or T). Divide this sum by the number of samples in this group. Record this value as the average stability for "Protected samples" on your data form.

3. Calculate the average stability for unprotected samples.

Rules

3.1 Add together all stability values that were classified as no canopy (Veg = NC). Divide this sum by the number of samples in this group. Record this value as the average stability for "Unprotected samples."

4. Averages should be calculated separately for surface and subsurface samples.

Table 8. Data form and calculations example for soil surface samples.

Surface

Line 1		In	Dip				In	Dip		Line 2		In	Dip				In	Dip	
Pos	Veg	time	time	#	Pos	Veg	time	time	#	Pos	Veg	time	time	#	Pos	Veg	time	time	#
7	NC	0:00	5:00	3	28	NC	0:45	5:45	3	6	G	1:30	6:30	5	24	G	2:15	7:15	6
14	S	0:15	5:15	5	35	S	1:00	6:00	4	12	NC	1:45	6:45	1	30	S	2:30	7:30	3
21	G	0:30	5:30	6	42	G	1:15	6:15	5	18	S	2:00	7:00	4	36	NC	2:45	7:45	1

Avg. Stability = Sum of Stability Rankings (i.e., #) / Total No. Samples Taken

	All samples		Protected samples (Samples w/Veg = G, F, Sh, or T)		Unprotected samples (Samples w/o Veg = NC)	
Line	Surface	Subsurface	Surface	Subsurface	Surface	Subsurface
1	4.3		5.0		3.0	
2	3.3		4.5		1.0	
Plot Avg.	3.8		4.75		2.0	

Soil stability test basic interpretation

Increases in stability of both **surface** and **subsurface** samples reflect increased soil erosion resistance and resilience. Surface stability is correlated with current erosion resistance, while subsurface stability is correlated with resistance following soil disturbance. Sites with average values of 5.5 or above generally are very resistant to erosion, particularly if there is little bare ground and there are few large gaps. Maximum possible soil stability values may be less than 6 for very coarse sandy soils. High values usually reflect good hydrologic function. This is because stable soils are less likely to disperse and clog soil pores during rainstorms. High stability values also are strongly correlated with soil biotic integrity. Soil organisms make the "glue" that holds soil particles together. In most ecosystems, soil stability values decline first in areas without cover (Veg = NC). In more highly degraded systems, Veg = Canopy values also decline.

Use these indicators together with the indicators from the **Line-point intercept** and the **Gap intercept** to help determine whether observed erosion changes are due to loss of cover, changes in vegetation spatial distribution or reduced soil stability. For more information about how to interpret these indicators, please see Chapter 17 in Volume II.

	Typical effect on each attribute of an increase in the indicator value		
Indicator	**Soil and site stability**	**Hydrologic function**	**Biotic integrity**
All samples	+	*	+
Veg = Canopy	+	*	+
Veg = NC	+	*	+

* Usually positive, but can be negative for hydrophobic (water-repellent) soils. Large increases in water repellency (after a very hot fire) can negatively affect soil and site stability by increasing the amount of runoff water available to erode soils downslope.

Belt transect for measuring perennial invasive plants and woody species

The Belt transect provides a way to measure the presence of invasive plants or woody seedlings. Belt transects provide a good means of monitoring brush or shrub encroachment. For seedlings, small annuals and other species that are hard to see, substitute the belt with a quadrat placed at regular intervals along the line. See *Measuring and Monitoring Plant Populations* (Elzinga et al. 2001)[3].

Materials:

- **PVC pipe with the center marked with a piece of tape (Table 9)**
- **The same transect line that was used for Line-point and Gap intercept methods**
- **Clipboard, Belt Transect Data Form (page 32) and pencil(s)**

Standard methods (rule set)

1. Determine size classes of plants.

Rules

1.1 Before walking the transect, determine if you want to divide the plants into size classes (Fig. 23).

1.2 Record the size classes on the data form under "Size class A =," "Size class B =" and "Size class C = ." For example, Size class A = plants under 10 cm tall, Size class B = plants between 10 cm and 1 m tall, and Size class C = plants greater than 1 m tall.

1.3 You can combine size classes, but you cannot create more size classes at a later date.

2. Determine the belt width.

Rules

2.1 Belt width can vary between 1 and 6 m (3 and 20 ft) in width, depending upon density and size of plants (Table 9).

2.2 Belt width always can be decreased, but once a transect is measured it should not be increased.

2.3 Use the same belt width for all transects within a plot and for all plots within a site.

3. Begin at the "0" end of the line.

Figure 23. Determine size class.

Figure 24. Begin at transect's end.

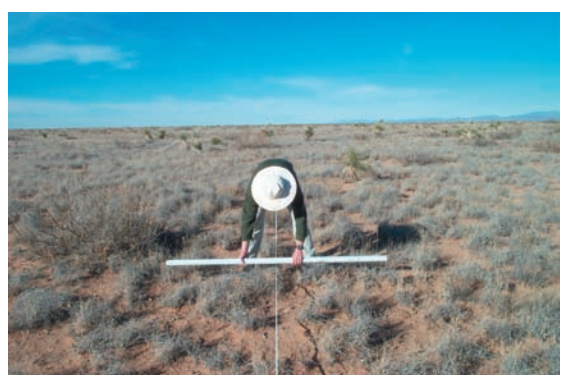


Figure 25. Be sure to center PVC.

[3]Elzinga, C.L., D.W. Salzer, J.W. Willoughby and J.P. Gibbs. 2001. *Monitoring Plant and Animal Populations*, Blackwell Publishing. 368 pp.

4. Begin walking the transect.

Rules

4.1 Stand at the "0" end of the line and face the other end (away from the plot's center) (Fig. 24).

4.2 Hold the PVC pipe, so that its center is directly over the tape (Fig. 25).

5. Count the plants.

Rules

5.1 Walk slowly along the transect and count plants that are rooted under the PVC pipe (Fig. 26).

5.2 Only record species that constitute less than 5% cover on the Line-point intercept or species of management concern.

5.3 Record each individual plant with at least half of the base under the PVC pipe.

5.4 Record the species code in the "Species" column on the data form.

5.5 Make a tally mark in the column of the appropriate size class as individuals are encountered (Fig. 27).

5.6 If desired, each transect can be divided into 10-m (30-ft) segments, and plants can be counted within each segment. You can use a separate table on the data form for each 10 m (30 ft) segment. This is similar to Plant density (see Volume II, Chapter 15).

6. Repeat for all transects.

Table 9. Suggested belt width based on plant density (Tazik et al. 1992)[4].

Estimated individuals of a given species per 6x100 m plot	Suggested belt width
<100	6 m (20 ft)
100-200	4 m (12 ft)
200-400	2 m (6 ft)
>400	1 m (3 ft)

Figure 26. Record all shrubs with at least half of base under PVC.

Figure 27. Record all shrubs encountered by size class.

Riparian note: Run Belt transects on the standard transects (crosses channel) and on the riparian channel vegetation survey lines (Volume II, Chapter 13). For the channel vegetation survey, use the edge of the green line as the belt's outer edge.

[4]Tazik, D. J., S.D. Warren, V.E. Diersing, R. B. Shaw, R. J. Brozka, C. F. Bagley, and W. R. Whitworth. 1992. U.S. Army Land Condition-Trend Analysis (LCTA) Plot Inventory Field Methods. USACERL Technical Report N-92/03. 62 pp.

Belt Transect Data Form

Monitoring plot: ______________________ **Date:** ______________________

Reader: ______________________ **Recorder:** ______________________

Transect area* = ________ **ha =** ________ **meters X** ________ **meters/10,000**
(line length) (belt width)

Transect area =** ________ **ha =** ________ **ft x** ________ **ft x (0.0000093)**

Size class A = ________ **Size class B =** ________ **Size class C =** ________

Density* = number of individuals per hectare (this indicator doesn't need to be calculated in the field).

Line:					Direction:				
	Size class								
Species	A (tally marks)	Total	Density	B (tally marks)	Total	Density	C (tally marks)	Total	Density

Line:					Direction:				
	Size class								
Species	A (tally marks)	Total	Density	B (tally marks)	Total	Density	C (tally marks)	Total	Density

Example: *50 m x 2 m = 100 square meters (m^2). There are 10,000 m^2 in 1 hectare, so 100 m^2/(10,000 m^2 per 1 ha) = 0.01 ha. Density for 15 plants in a 100 m^2 belt = 15/0.01 ha = 1500 plants/ha.
**150 ft x 6 ft = 900 ft^2. 1 ft^2 = 0.0000093 ha, so 900 ft^2 x 0.0000093ha/ft^2 = 0.008ha. Density for 15 plants in a 900 ft^2 belt = 15/0.008 = 1875 plants/ha.

Belt transect indicator calculations

1. Calculate the density of invasive plants and woody seedlings.

Rules

1.1 Count the tally marks for each species and size class.

1.2 Calculate the transect area: multiply the length of the transect by the belt width.

Convert this to hectares:
Square meters to hectares-
Divide this total by 10,000 to get the transect area in hectares.

Square feet to hectares-
Divide this total by 107,639 to get the transect area in hectares.

1.3 Divide each species total by the transect area to get the species density. Repeat this for each species and size class. To convert plants/hectares to plants/acre, divide plants/hectare by 2.5.

Belt transect basic interpretation

Interpreting Belt transect data is site-specific. In a riparian area, woody species may be a positive indicator of biotic integrity. In native grassland, the presence of woody species could be an early warning indicator of degradation. In some cases, it is important to have **size** as well as **density** information. For example, the probability of shrub mortality during fire declines with increases in shrub size.

Use these indicators, together with indicators from the **Line-point intercept** and **Gap intercept** methods to monitor a site's biotic integrity (resistance to invasive species or to changes in community structure) and hydrologic function. For more information about how to interpret these indicators, please see Volume II, Chapter 17.

Table 10. Sample data form and calculations.

Transect area* = 0.03 **ha =** 50 (line length) **meters X** 6 (belt width) **meters/10,000**

Size class A = <10 cm **Size class B =** 10 cm to 1 m **Size class C =** >1m

Line: 1				**Direction:** 120°					
	Size class								
Species	**A (tally marks)**	**Total**	**Density (plants/ha)**	**B (tally marks)**	**Total**	**Density (plants/ha)**	**C (tally marks)**	**Total**	**Density**
PRGL	| | | |	4	133**	~~||||~~ |	6	200***	|	1	33.3

*50 m x 6 m = 300 m². There are 10,000 m² in 1 hectare, so 300 m² ÷ (10,000 m² per 1 hectare) = 0.03 hectare.
**4 plants ÷ 0.03 hectare = 133 plants/hectare; 133 plants/hectare ÷ 2.5 = 53 plants/acre.
***6 plants ÷ 0.03 hectare = 200 plants/hectare; 200 plants/hectare ÷ 2.5 = 80 plants/acre.

Short-Term Monitoring[5]

Why bother? The long-term monitoring methods described previously document progress toward long-term goals. Short-term monitoring is essential to adjust management to ensure that the long-term goals will be met. Short-term monitoring should be designed to show how your management plan is affecting residual plant cover. Plant cover is a good short-term indicator of the plant's ability to recover following grazing and how well the site is protected from erosion. The sizes of the gaps between plant canopies are a good indicator of susceptibility to erosion and weed invasion.

Where should I monitor?

At your long-term monitoring locations. Additional short-term monitoring sites should be located in areas that are sensitive to management.

What should I monitor?

See the data forms on pages 35 and 36 and Table 11 below. It is not necessary to monitor everything or to complete short-term monitoring quantitatively. Because short-term monitoring is used to adjust management rather than document trends, the data are less likely to be used by others. Use this form to organize and help you remember what you see on a daily, weekly or monthly basis.

How often should I monitor?

Use Table 11 as a guide. Sensitive areas should be checked more often, especially during drought years. Frequent checks may not be possible in more remote areas.

Instructions:

- Use one data form for each location. This will allow you to see changes over time. Photos can be taped to the back of each sheet.
- See instructions at the bottom of data forms on the following pages.
- It is not necessary to fill in all columns. Determine the most important attributes and monitor these consistently.

Table 11. Short-term monitoring guidelines.

Management	How Often?	What?
High-intensity grazing Season-long grazing Year-long grazing	Daily Weekly Monthly	Stocking rates by animal and class Dates of use Foliar cover and canopy gap sizes Height of key species
Fire	After fire, after greenup and before grazing	Foliar cover Canopy gap sizes
Off-road vehicle use	After significant events (e.g., holiday weekends); more often when wet	Types and approximate vehicle numbers Dates of use Number of tracks Evidence of compaction

[5]Short-term grazing monitoring adapted from Level II monitoring in C.D. Allison, T.T. Baker, J.C. Boren, B.D. Wright and A. Fernald. 2001. *Monitoring Rangelands in New Mexico: Range, Riparian, Erosion, Water Quality and Wildlife*. Range Improvement Task Force, Agricultural Experiment Station, Cooperative Extension Service, New Mexico State University, College of Agriculture and Home Economics, Report 53. 60 pp.

Short-Term Monitoring Data Form (Annual Use Record) for Grazing Management

(Use one form for each monitoring location—you will not necessarily use all columns.)

Pasture: ______________________ **Location:** ______________________

Precipitation (cm or in): ______________________ **Length of pace (if pace transect used:)** ____cm (____in)

Date	Number and class of livestock	Livestock Date in	Date out	Photo (Y or N), (date & time)	Average grazed plant height[1] (cm/in)	Average ungrazed plant height[1] (cm/in)	Grazed % height[2] or relative use score[3] (circle one)	Production score[4]	% cover Check one ❒ visual estimate ❒ pace transect[5,6]	% steps in "boot" gaps[6,7]	Remarks (Include any other management information and observations on weeds, wildlife use, fires, etc.)

[1] **Average plant height.** Measure at least 10 randomly selected plants. Measure the tallest height of the plant (or longest leaf/seedhead). Be sure to measure same species for grazed and ungrazed pastures.

[2] **Grazed % height.** Divide "Average grazed plant height" by "Average ungrazed plant height"(two previous columns) and multiply by 100.

[3] **Relative use score.** 1. None-Slight (no visible use of key forage species). 2. Light (only preferred areas and key forage species grazed). 3. Moderate (key areas grazed uniformly, especially key species). 4. Heavy (key species closely grazed and low forage value plants moderately grazed). 5. Severe (pasture appears mowed, including low-value species). If temporary exclosures are used to estimate utilization, be sure to mark control plots when the exclosures are installed.

[4] **Production score.** 1. Extreme Drought (no growth this year). 2. Below Average. 3. Average. 4. Above Average. 5. Extremely High (maximum potential).

[5] **% cover.** Number of paces out of 100 for which pin dropped 15-30 cm (6-12in) in front of boot contacts plant foliage, plant base or plant litter (higher cover is better).

[6] **Hint.** To make the pace transect and boot gap method easy, carry two clicker counters. Count your paces (100) out loud. In one hand, click the number of paces with % cover (#4). In the other hand, click the number of paces in boot gaps (#5).

[7] **% steps in "boot" gaps.** Number of paces out of 100 for which boot lands completely within a bare space (does not touch a plant when boot is on the ground). Record boot length here ____cm (in).

Short-Term Monitoring Data Form (Annual Use Record) for Recreation and Off-Road Vehicle Management

(Use one form for each monitoring location—you will not necessarily use all columns.)

Management unit (ranch or allotment): ____________________ **Location:** ____________________

Precipitation (cm or in): ____________________ **Length of pace (if pace transect used:)** _____cm (_____in)

Date	Vehicle type and number	Use dates	Soil condition during use (wet/dry)	Photo (Y or N) (date & time)	No. of vehicle tracks/100 paces	% cover Check one ❒ visual estimate ❒ pace transect[1,3]	% steps in "boot" gaps[2,3]	Evidence of compaction?	Remarks (Include any other management information and observations on weeds, wildlife use, fires, etc.)

[1]**% cover**. Number of paces out of 100 for which tip of boot contacts plant foliage, plant base or plant litter (higher cover is better).

[2]**% steps in "boot" gaps.** Number of paces out of 100 for which boot lands completely within a bare space (does not touch a plant when boot is on the ground). Record boot length here _____cm (in).

[3]**Hint.** To make the pace transect and boot gap method easy, carry two clicker counters. Count your paces (100) out loud. In one hand, click the number of paces with ground cover (#1). In the other hand, click the number of paces in boot gaps (#2).