Trail Monitoring Manual

Daniel Boone National Forest[1]

Introduction

This manual describes standardized procedures for conducting an assessment of resource conditions on recreation trails. The principal objective of these procedures is to document and monitor changes in trail conditions following construction or creation. Their design relies on a sampling approach to characterize trail conditions from measurements taken at transects located every 300 ft (91 m) along selected trail segments. For trails less than 2400 ft (.45 miles) consult Table 1 for reduced sample point interval distances necessary to accurately characterize conditions on shorter trails. Values are calculated to include about 8 sample points for each trail segment. Distances are assessed with a measuring wheel. Trail condition measurements are applied at sample points to document the trail's width, depth, substrate, grade, and other characteristics. These procedures take between 3 to 6 minutes to apply at each sample point. Data is summarized through statistical analyses to characterize resource conditions for each trail segment. During future assessments it is not necessary to relocate the same sample points for repeat measures. Survey work should be conducted during the middle or end of the primary use season and during the growing season. This is necessary because determinations of trail boundaries are based on trampling-related disturbance to ground vegetation and leaf litter. Subsequent surveys should be conducted at approximately the same time of year.

Table 1. Sample point intervals for trails <2400 ft (.45 mi).

Interval (ft)	Trail Length (ft)
300	>2400
250	1801-2400
175	1201-1800
100	601-1200
75	301-600
50	51-300
25	<51

Materials

This manual and supply of data forms (some on waterproof paper), pencils, clipboard with compartment for forms, measuring wheel (one that removes distance when backed up), topographic and driving maps, clinometer, 12 ft tape measure (25 ft for wide trails), metal stakes (3), compass, 25 ft of thick non-stretchable line marked off every 0.3 feet on a spool, hanging line level marked to show a 3% slope.

Point Sampling Procedures

Trail Segments: During the description of amount and type of use (indicators 5 & 6 below) be sure that the use characteristics are relatively uniform over the entire trail segment. Some of the study trails have multiple uses. For example, a sign in the middle of a study segment restricting horse use beyond it can substantially affect visitation and impact. Even when use types are not regulated the study trail may intersect with another route that diverts one of the user groups. In such instances where substantial changes in the type and/or amount of use occur, the trail should be split in two segments and assigned separate names and forms, upon which the differences in use can be described. This practice will facilitate subsequent statistical summaries and analyses. Also collect and record any other information that is known about the trail's history, such as original construction, past uses, type and amount of maintenance, history of use, etc.

1 - Developed by Dr. Jeff Marion, USDI, U.S. Geological Survey, Patuxent Wildlife Research Center, Virginia Tech/Dept. of Forestry (0324), Blacksburg, VA 24061 (540/231-6603; jmarion@vt.edu)

1) **Trail Segment Code:** Record a unique trail segment code (can be added later).

2) **Trail Name:** Record the trail segment name(s) and describe the segment begin and end points.

3) **Surveyors:** Record initials for the names of the trail survey crew.

4) **Date:** Record the date (mm/dd/yr) the trail was surveyed.

5) **Use Level (UL):** Record an estimate of the amount of use the trail receives (high, med., low), relative to other forest trails, from the most knowledgeable staff member. Work with them to quantify use levels on an annual basis (e.g., low use: about 100 users/wk for the 12 wk use season, about 30 users/wk for the 20 wk shoulder season, about 10 users/wk for the 20 wk off-season = about 2000 users/yr).

6) **Use Type (UT):** Record estimates for the types of use the trail receives (including any illegal uses) using percentages that sum to 100%. These should be provided by the most knowledgeable forest staff member. Categories include: Hiking, Horseback, Other (specify).

Starting/Ending Point: Record a brief but accurate description of the starting and ending points of the survey. Choose identifiable and permanent locations that others can identify in the future, like intersections with other trails, roads, or permanent trailhead signs. If you have a GPS device collect an accurate fix on these locations and record the UTM coordinates on the field form.

Measuring Wheel Procedures: At the trail segment starting point, select a random number from 0 to your sample interval (normally 300 ft). Record this number on the first row of the form. This will be the first sample point, from which all subsequent sample points will be located at whatever your interval is. This procedure ensures that all points along the trail segment have an equal opportunity of being selected. *** Once you get to the first sample point, reset the wheel counter and use it to stop at points separated by your sample interval distance thereafter.**

Push the measuring wheel along the middle of the tread so that it does not bounce or skip in rough terrain. Lift the wheel over logs and larger rocks, adding distance manually where necessary to account for horizontal distances. Your objective is to accurately measure the distance of the primary (most heavily used) trail tread. Monitor the wheel counter and stop at your sample intervals to conduct the sampling point measures. If you go over this distance, you can back the wheel up to the correct distance. If the wheel doesn't allow you to take distance off the counter then stop immediately and conduct your sampling at that point, recording the actual distance from the wheel, not the "missed" distance. Continue to the next "correct" sample point (as though you had not missed the last one).

Rejection of a sample point: Given the survey's objective there will be rare occasions when you may need to reject a sampling point due to the presence of boulders, tree falls, trail intersections, road-crossings, stream-crossings, bridges or other odd "uncharacteristic" situations. The data collected at sample points is intended to be roughly "representative" of the 150 ft sections of trail on either side of the sample point. Use your judgment but be conservative when deciding if a sample point should be relocated. Do not relocate a point to avoid longer or common sections of bog bridging, turnpiking, or other trail tread improvements. The point should be relocated by moving forward along the trail an additional 30 ft, this removes the bias of subjectively selecting a point. If the new point is still problematic then add another 30 ft, and so on. Record the distance of the actual point and continue on to the next "correct" point (as though you did not need to move the last one).

For the following data, in the field or office: If an indicator cannot be assessed, e.g., is "Not Applicable" code the data as -9, code missing data as -1.

7) **Distance:** Measuring wheel distance (ft) from the beginning of the trail segment to the sample point.

8) **Trail Position (TP):** Use the descriptions below to determine the trail position of the sampling point. Record the corresponding letter code in the TP column.
   R - Ridge: Ridge-top or high plateau position
   CB - Cliff base
   M - Midslope/Sideslope: Mid-slope positions
   V - Valley Bottom: Flatter valley bottom terrain

9) **Trail Grade (TG):** The two field staff should position themselves on the trail 5 ft either side of the transect. A clinometer is used to determine the grade (% slope) by sighting and aligning the horizontal line inside the clinometer with a spot on the opposite person at the same height as the first person's eyes. Note the percent grade (right-side scale in clinometer viewfinder) and record.

10) **Trail Alignment (TA):** Assess the trail's alignment angle to the prevailing land-form in the vicinity of the sample point. Sight a compass along the trail from a point about 5ft before the transect to about 5ft past the transect, record the compass azimuth (0-360, not corrected for declination) on the left side of the column (it doesn't matter which direction along the trail you sight). Next face directly downslope, take and record another compass azimuth - this is the aspect of the local landform. The trail's alignment angle ($<90^0$) can be computed by these two azimuths.

11) **Landform Grade (LG):** Assess an approximate measure of the landform slope in the vicinity of the sample point. Turn the clinometer perpendicular to the ground with the window facing your eye. Next orient the bottom of the clinometer in alignment with the prevailing landform slope (placing the clinometer on your clipboard and orienting the bottom of the clipboard may improve your accuracy). Record the degrees (not percent) off the scale in the window to the nearest 5^o (after data entry convert to percent slope = [tan (degrees)] x 100.

12) **Secondary Treads (ST):** Count the number of trails that parallel the main tread at the sample point. Count all treads regardless of their length, ***excluding*** *the main tread*.

13) **Tread Width (TW):** From the sample point, extend a line transect in both directions perpendicular to the trail tread. Identify the endpoints of this trail tread transect as the most pronounced outer boundary of visually obvious human disturbance created by trail use (not trail maintenance like vegetation clearing). These boundaries are defined as pronounced changes in ground vegetation height (trampled vs. untrampled), cover, composition, or, when vegetation cover is reduced or absent, as pronounced changes in organic litter (intact vs. pulverized) (see photo illustrations in Figure 1, placed at the end of the manual). The objective is to define the trail tread that receives the majority (>95%) of traffic, selecting the most visually obvious outer boundary that can be most consistently identified by you and future trail surveyors. In places where the trail boundary is indistinct at the sample point project the boundary to the sample point from immediately adjacent areas. Include the widths of any secondary treads (see #8) crossed by the transect, excluding widths of any undisturbed areas between treads (as defined by the tread boundary definition). Measure and record the length of the transect (the tread width) to the nearest inch (don't record feet and inches).

14-23) **Tread Condition Characteristics:** Along the trail tread width transect, estimate to the nearest 10% (5% where necessary) the aggregate lineal length occupied by any of the mutually exclusive tread surface categories listed below. **Be sure that your estimates sum to 100%**. Record these on

the form by labeling sections of the appropriate row with the relevant code separated by marked vertical lines indicating the appropriate percentage cover for each code.

S-Soil	All soil types including sand and organic soils, excluding organic litter unless highly pulverized and in a thin layer or smaller patches over bare soil.
L-Litter	Surface organic matter including intact or partially pulverized leaves, needles, or twigs that mostly or entirely cover the tread substrate.
V-Vegetation	Live vegetative cover including herbs, grasses, and mosses rooted within the tread boundaries. Ignore vegetation hanging in from the sides.
R-Rock	Naturally-occurring rock (bedrock, boulders, rocks, cobble, or natural gravel). If rock or native gravel is embedded in the tread soil estimate the percentage of each and record separately.
M-Mud	Seasonal or permanently wet and muddy soils that show imbedded foot or hoof prints from previous or current use (omit temporary mud created by a very recent rain). The objective is to include only transect segments that are frequently muddy enough to divert trail users around problem.
G-Gravel	Human-placed (imported) gravel.
RT-Roots	Exposed tree or shrub roots.
W-Water	Portions of mud-holes with water or water from intercepted seeps or springs.
WO-Wood	Human-placed wood (water bars, bog bridging, cribbing).
O-Other	Specify.

24) **Cross-Sectional Area (CSA):** The objective of the CSA measure is to estimate soil loss from the tread at the sample point following trail creation. Accurate and precise CSA measures require different procedures based on the type of trail and erosion, some definitions:

Direct-ascent vs. side-hill trails: Trails, regardless of their grade, that more or less directly ascend the slope of the landform are direct-ascent or "fall-line" trails. Direct-ascent trails involve little or no tread construction work at their creation – generally consisting of removal of organic litter and/or soils. Trails that angle up a slope *and* require a noticeable amount of cut-and-fill digging in mineral soil (generally on landform slopes of greater than about 10%) are termed side-hill trails. The movement of soil is required to create a gently out-sloped bench to serve as a tread. Separate procedures are needed for side-hill trails to avoid including construction-related soil movement in measures of soil loss following construction.

Recent vs. historic erosion: Recreation-related soil loss that is relatively recent is of greater importance to protected land managers and monitoring objectives. Severe erosion from historic, often pre-recreational use activities, is both less important and more difficult to reliably measure. Historic erosion is defined as erosion that occurred more than 10-15 years ago and is most readily judged by the presence of trees and shrubs growing from severely eroded side-slopes.

a) Direct-ascent trails, recent erosion: Refer to Figure 2a and follow these procedures. Place two stakes and the transect line to characterize what you judge to be the pre-trail or original land surface. Place the left-hand stake beyond the trail boundary so that the 1st mark on the transect line will fall on what you believe was the "original" ground surface but at the edge of any tread incision, if present (see Figure 2a). Thus, the transect incision value you record for the 1st mark (T_1) must be 0. Stretch the transect line (marked in 0.3 ft (3 5/8 in) intervals) tightly between the two stakes - any bowing in

the middle will bias your measurements. Insert the other stake just beyond the first transect line mark on the other side of the trail that is on the original ground surface and will be measured as a 0. The transect line should reflect your estimate of the pre-trail land surface, serving as a datum to measure tread incision caused by soil erosion and/or compaction.

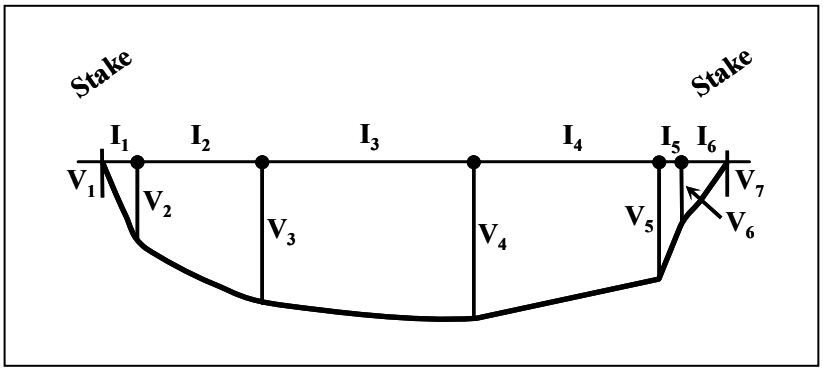
Note: For this and all other options (b-d), if the line cannot be configured properly at the sample point due to rocks or obstructing materials that cannot be moved, then move the line forward along the trail in one-foot increments until you reach a location where the line can be properly configured.

b) Direct-ascent trails w/historic erosion: Refer to Figure 2b – if you judge that some of the erosion is historic then follow these procedures. Generally you will find an eroded tread within a larger erosional feature. Place two stakes and stretch the transect line to reflect and allow measurements of the more recent recreation-related erosion (if present). If there is no obvious recent-erosion tread incision then position the stakes the same as for your tread width measurement and assess incision between tread boundaries (option not depicted in Figure 2b). The left-hand stake can serve as transect 1, record a 0 for this. At the right boundary you must also record a transect with a measure of 0.

c) Side-hill trail: Refer to Figure 2c. The objective of this option is to place the transect stakes and line to simulate the post-construction tread surface, thereby focusing monitoring measuresments on post-construction soil loss and/or compaction. When side-hill trails are constructed, soil on the upslope side of the trail is removed and deposited downslope to create a gently out-sloped bench (most agency guidance specify a 5% outslope) for the tread surface (see Figure 3). Outsloped treads drain water across their surface, preventing the buildup of larger quantities of water that become erosive. However, constructed treads often become incised over time due to soil erosion and/or compaction. The extent of this incision are what these procedures are designed to estimate.

Carefully study the area in the vicinity of the sample point to judge what you believe to be the post-construction tread surface. Pay close attention to the tree roots, rocks or more stable portions of the tread to help you judge the post-construction tread surface. Look in adjacent undisturbed areas to see if roots are exposed naturally or the approximate depth of their burial. Configure the stakes and transect line to approximate what you judge to be the post-construction tread surface. Note that sometimes a berm of soil, organic material and vegetation will form on the downslope side of the trail that is raised slightly above the post-construction tread surface (generally less than 6 inches in height). If present, place the stake and line below the height of the berm as shown in Figure 2c so that it does not influence your measurements. If erosion is severe and/or if the line placement is subjective, use a line level with marks on the bubble glass that allow you to configure the line as a 3% outslope (a 1 in. drop over 33 in.) to standardize the line placement and reduce measurement error. An outslope of 3% is used because actual tread construction is often somewhat less than 5%, and 3% provides a more conservative estimate of soil loss. It is generally easier and more accurate to place the downslope stake first and configure the line to a 3% outslope to reveal where the uphill stake should be placed. Measure the left-hand stake as transect 1 with a 0 measure and also record an additional transect beyond the right-hand stake with a measure of 0.

d) Side-hill trail with historic erosion: Refer to Figure 2d - if you judge that the erosion is historic then follow these procedures. Generally you will find an eroded tread within a larger erosional feature. Place two stakes and stretch the transect line to reflect and allow measurements of the more recent recreation-related erosion (if present). If there is no obvious recent-erosion tread incision then position the stakes the same as for your tread width measurement and assess incision between tread boundaries (option not depicted in Figure 2d). The left-hand stake can serve as vertical transect 1, record a 0 for this. At the right boundary you must also record a vertical transect with a measure of 0.



Vertical (cm)	Interval (cm)	Area (cm^2)
V_1: 0	I_1: 5.0	21.3
V_2: 8.5	I_2: 12.5	146.9
V_3: 15.0	I_3: 20.0	360.0
V_4: 21.0	I_4: 16.5	272.3
V_5: 12.0	I_5: 2.5	21.9
V_6: 5.5	I_6: 5.0	13.8
V_7: 0	CSA:	836.0

Figure 1. Illustration of the variable interval CSA method for assessing soil loss at each transect. Table shows data for use in the computational formula: Area = $(V_i + V_{i+1})$ x I_i x .5 for each row and summed to compute CSA.

Measurement Procedure: On the CSA data form, label a new row with the measuring wheel distance for the transect (e.g., D=600 ft). Starting on one side with a "zero" measurement, measure from each vertical transect line marking, a perpendicular transect down to the ground surface (nearest 1/4 in, e.g., .25, .5, .75). Record the values on the data sheet next to their labeled transect numbers (e.g., V_1, V_2, $V_3 \ldots V_n$) (see Figure 1). Continue measuring each transect height until you reach the far side of the trail and obtain a measure of 0. ***Note:*** The transect line is not likely to be "level" so be cautious in measuring vertical transects that are *perpendicular* to the horizontal transect line.

In the office, use a calculator or spreadsheet to compute and sum cross-sectional area values with the following formula for each consecutive pair of vertical transect measures as shown in the Figure 1 table and using the equation: Area = $(V_i + V_{i+1})$ x I_i x .5 for each row and summed to compute CSA.

25) **Trail Type (TT):** Record whether the tread at the sample point was assessed as a direct ascent or side-hill constructed trail (see definitions in #10). Record the letter code in the TT column.
DA – Direct ascent (fall-line)
SH – Side-hill trail

26) **Erosion Type (ET):** Record whether soil erosion at the sample point, if present, appears to be recent or historic (see definitions in #23). Record the letter code in the ET column.
RE – Recent erosion
HE – Historic erosion

Collect all equipment and move onto the next sample point. **Be sure to record information on indicators 27 - 30 as you proceed to the next sample point.** These indicators are assessed continuously as pre-defined trail tread problems and when found, surveyors either tally or record begin and end distances (from the start of the survey) on the Problem Assessment Form. **Note: after data entry and before analysis the data for these indicators need to be corrected to add in the 1st randomly selected interval distance so that location data is accurate. In particular, examine any indicators that may begin before and end after the first sample point.**

Problem Assessment Procedures

27) **Informal Trails (IT):** Count and keep a running tally of the number of informal or "visitor-created" trails that intersected the survey trail segment as you proceed to the next sample point. Sum and record the total at each sample point. This indicator is intended to provide an approximation of the extensiveness of unofficial, visitor-created trails associated with survey trail. Do not count formal trails, roads of any type, extremely faint trails, trails <10 ft long, or trails that have been effectively blocked off by managers. Informal trails are trails that visitors have created to access streams, scenic attraction features, camping areas, or other features, to cut switchbacks, to avoid mud-holes, rutted treads, steep obstacles, or downed trees, or that simply parallel the main trail. Count both ends of any informal trails ≥10 feet long that loop out and return to or parallel the survey trail. Include any distinct animal or game trails as these are generally indistinguishable from human trails and their true origin is likely unknown.

28) **Soil Erosion (SE):** Sections of tread (≥10 ft) with soil erosion exceeding 5 in. depth within current tread boundaries. Record beginning and ending distances on the Problem Assessment form.

29) **Muddy Soil (MS):** Sections of tread (≥10 ft) with seasonal or permanently wet and muddy soils that show imbedded foot or hoof prints (≥1in). Omit temporary muddiness created from a recent rain. This should generally include any longer mud-holes or treads with running water. The objective is to include only tread segments that are frequently wet or muddy enough to divert trail users around the problem, often leading to an expansion of trail width.

30) **Excessive Grade (EG):** Sections of tread (≥10 ft) with a grade of ≥20%. Record beginning and ending distances on the Problem Assessment form.

Point Sampling Form

Trail Segment Code ________ **Trail Name** ______________________________ **Surveyors** ______________

Date ________ **Use Level** _______ **Use Type(s):** Horse ____ %, Hiker ____ %, Other ____ % ________

Starting Point: **UTM:**______________________________

Ending Point: **UTM:**______________________________

Dist	TP	TG	TA	LG	ST	TW	Tread Substrate Characteristics	CSA	TT	ET
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							0 10 20 30 40 50 60 70 80 90 100			

Dist = Wheel Distance
TP = Trail Position (R, CB, M, V)
TG = Trail Grade (%)
TA = Alignment (Trail° / Landform°)

LG = Landform Grade (deg)
ST = Secondary Treads
TW = Tread Width

S = Soil
L = Litter
V = Vegetation
R = Rock
M = Mud

G = Gravel
RT = Roots
W = Water
WO = Wood, human-placed
O = Other (Specify)

CSA (calculated from data form)
TT = Trail Type (DA, SH)
ET = Erosion Type (RE, HE)

Trail Segment Code ___________ **Trail Name** ____

Problem Assessment Form

Informal Trails (#)	Soil Erosion >5”		Muddy Soil		Excessive Grade ≥20%	
	Begin Dist.	End Dist.	Begin Dist.	End Dist.	Begin Dist.	End Dist.

Cross Sectional Area Form

Transect (in)	Area	Transect (in)	Area	Transect (in)	Area
Dist.=					
V_1=					

Figure 1. Photographs illustrating different types of boundary determinations. Trail tread boundaries are defined as the most pronounced outer boundary of visually obvious human disturbance created by trail use (not trail maintenance like vegetation clearing). These boundaries are defined as pronounced changes in ground vegetation height (trampled vs. untrampled), cover, composition, or, when vegetation cover is reduced or absent, as pronounced changes in organic litter (intact vs. pulverized). The objective is to define the trail tread that receives the majority (>80%) of traffic, selecting the most visually obvious boundary that can be most consistently identified by you and future trail surveyors.

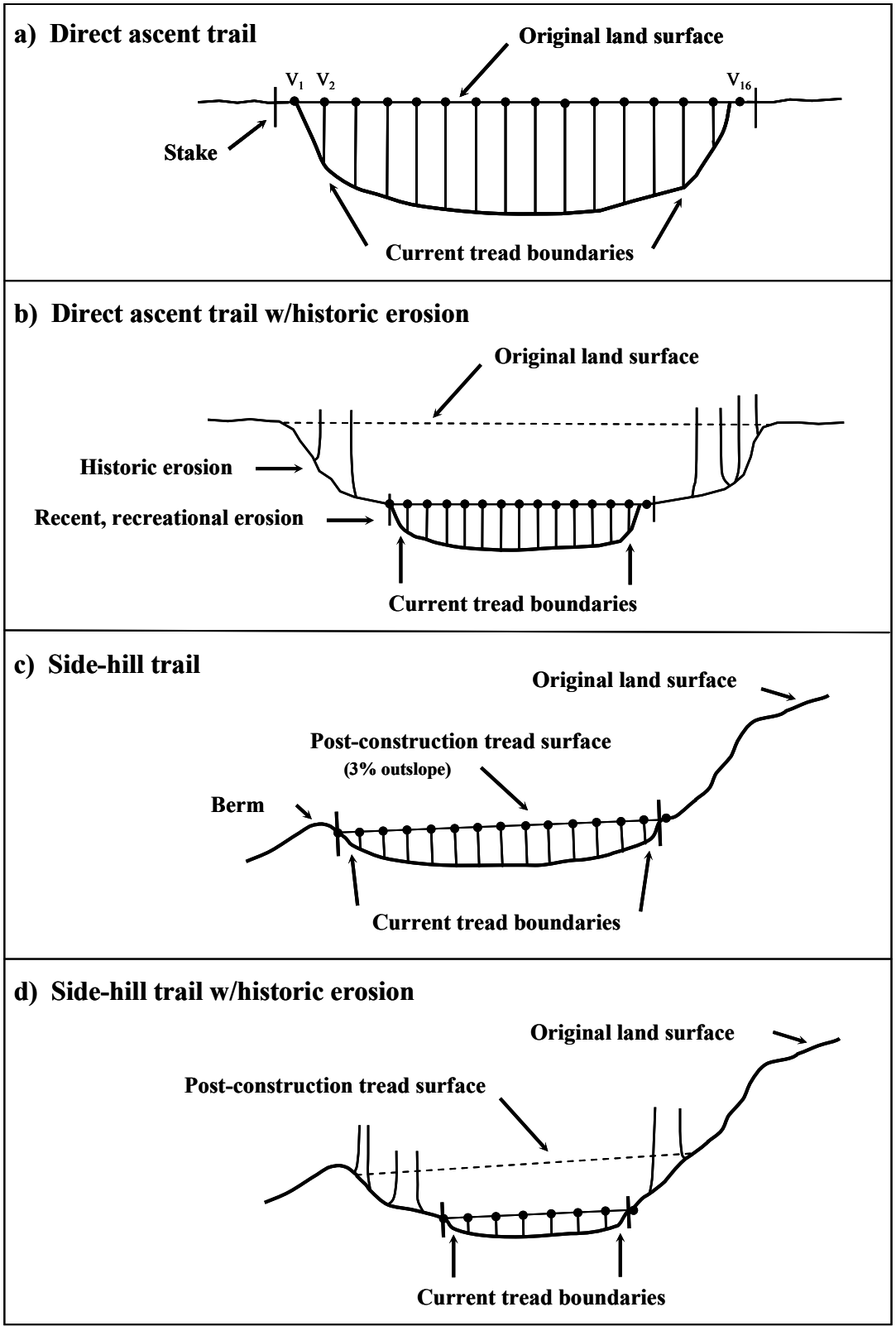

Figure 2. Cross sectional area (CSA) diagrams illustrating alternative measurement procedures for direct ascent trail alignments (a & b) vs. side-hill trail alignments (c & d) and for relatively recent erosion (a & c) vs. historic erosion (b & d).