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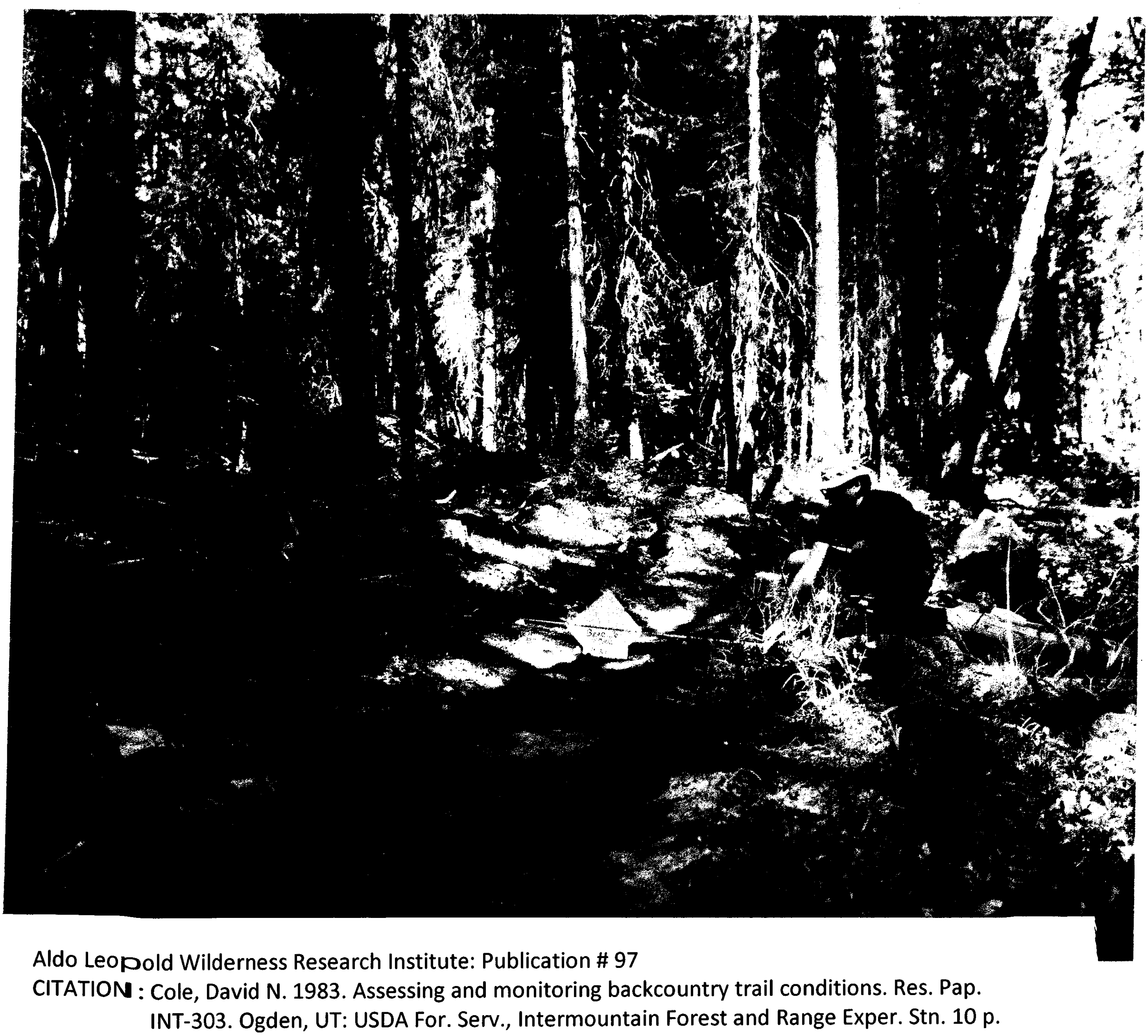
Assessing and Monitoring Backcountry Trail Conditions

David N. Cole



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RESEARCH SUMMARY

The costs of mitigating trail deterioration problems could be reduced through improved trail location and design and through improved monitoring of conditions. This paper describes assessment techniques with the potential for improving management of backcountry trails. Three types of assessment techniques are considered—replicable measurements, rapid surveys, and censuses. Sampling and measurement techniques are described for each, and the utility of the results is assessed.

To illustrate their application, specific techniques are applied to the Big Creek trail system in the Selway-Bitterroot Wilderness. Both repeated measures of the cross-sectional area of the trail and rapid surveys show that most of the trail system is stable and in good condition. Certain segments are in poor condition, however. An examination of the relationship between trail condition and site, design, and use characteristics indicated that poor location was the major cause of problems. A census of trail problems and associated site and design characteristics identified (1) vegetation and soil indicators to guide trail location, and (2) design techniques to avoid damage where poor locations cannot be bypassed.

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INTRODUCTION

Deteriorating trails are a common problem in wilderness and other backcountry areas. They detract from the major goals for such areas—to maintain natural conditions and to provide outstanding opportunities for wilderness recreation experiences. Large sums of money are spent every year to maintain, rebuild, and relocate trails. These costs could be greatly reduced if we could better predict where deterioration is likely to occur and how it can be minimized through trail location and design. Costs could be further reduced by monitoring trail conditions so that protective actions are taken before more costly remedial actions are necessary.

Physical deterioration of trails—for example, widening, deepening, and damage to the tread—is generally of more concern than vegetation change. Vegetation change is less obvious to visitors, is usually confined to about 3 ft (1 m) on either side of the trail (Dale and Weaver 1974; Cole 1979), and, most important, does not impair the trail's planned function as a transportation facility.

Several studies of the physical condition of trails have been undertaken (Cole and Schreiner 1981), from which potentially useful techniques for assessing current conditions and monitoring future changes have emerged. This paper presents various approaches and measures available and the types of information each can provide. To illustrate their application, specific techniques were applied to about 17 miles (27 km) of established trail in the Big Creek drainage of the Selway-Bitterroot Wilderness in Montana. Results of this case study provide an assessment of current conditions and the severity of ongoing deterioration, as well as guidelines for trail location and design. The paper concludes with a discussion of the usefulness of these techniques to managers.

TYPES OF ASSESSMENT TECHNIQUES

Available techniques can be conveniently grouped into three types: replicable measurements of a small sample of trail segments, rapid surveys of a large sample of trail segments, and complete censuses of trail problems or conditions.

Replicable Measurement Techniques

Detailed quantitative studies provide an understanding of subtle changes that cannot be detected using rapid survey techniques. If the sampling points are permanently located, change over time can be monitored on these sites, providing particularly valuable information to the manager. Establishing permanent points is worthwhile whenever time-consuming measurements are taken for management purposes, because the additional time invested is usually minor and the benefits of an opportunity for repeat measurements are great.

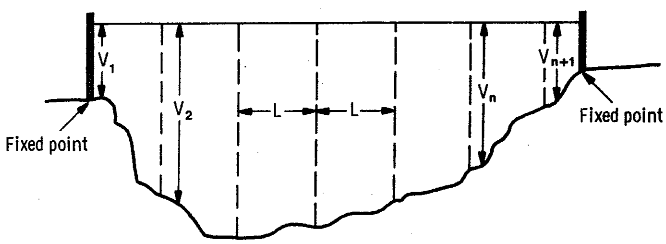
Two sampling schemes can be used in detailed quantitative studies. First, sampling points can be distributed in either a random or systematic manner along the trail. A systematic scheme, such as locating points every mile along the trail, is more practical. This permits an assessment of the condition of the trail system as a whole. Later remeasurements establish how much change has occurred on this trail during the period it was studied and how that change varies from place to place. However, considerable time may be invested in measuring sites that are of no particular concern to the manager. I have found no published results from studies of this type.

Alternatively, sampling points can be purposively located at places where pronounced change has already occurred or is expected. By concentrating samples on sites of particular concern (for example, sites experiencing pronounced trenching), we can learn much more about change on these particular sites. However, the purposive sampling scheme does not permit an evaluation of changes on the system as a whole. Studies using purposively located samples are relatively common (for example, Ketchledge and Leonard 1970; Helgath 1975; Summer 1980).

The most commonly used method for measuring soil erosion on trails involves measuring the cross-sectional area between tread surface and a taut line stretched between two fixed points on each side of the trail. Periodic remeasurements of these trail transects document the amount of soil lost over the elapsed time.

Leonard and Whitney (1977) provide a detailed description of the technique, using nails in trees as fixed points. As described, this technique is suitable only for purposive sampling in forested areas. The method can be adapted to treeless areas or to a random or systematic sampling design by using other fixed points, such as rods set in the ground or, preferably, rods temporarily placed, at the time of measurement, in receptacles permanently buried in the ground (Trottier and Scotter 1975). Regardless of what type of fixed point is used, points should be far enough apart to allow for future increases in trail width or the development of multiple trails.

The next step is to stretch a taut line and/or tape measure between the two points. A series of vertical measurements of distance between line and trail tread are taken at fixed intervals along the tape. Precision will be greatest when (1) the line is elevated high enough above the fixed points to clear vegetation and microtopography along the trail, (2) the line is kept taut, and (3) a plumb bob or level is used to take vertical measurements (Coleman 1977). The cross-sectional area below the taut line can then be computed from the vertical measurements using the formula in figure 1.



$$A = \frac{V_1 + 2V_2 + \ldots + 2V_n + V_{n+1}}{2} \times L$$

Where A = cross- sectional area

$V_1 - V_{n+1}$ = Vertical distance measurements, starting at V_1, the first fixed point, and ending at V_{n+1}, the last vertical measurement taken.

L = Interval on horizontal taut line

Figure 1.—Layout of trail transect and formula for calculating cross-sectional area.

When remeasurements are taken, the fixed points should be relocated and the taut line should be positioned at precisely the same height above the fixed points as for the original measurements. The vertical measurements should be taken at the same interval and starting from the same side of the trail as in the original measurements. When the cross-sectional area is calculated from these measurements, it can be compared with the original area to determine how much change has occurred and whether soil has been eroded or deposited.

Rinehart and others (1978) developed a technique for measuring cross-sectional area with stereo photographs. After trying both photographic and field measurement techniques, we concluded that field measurements were both more rapid and more accurate.

The location of sampling points must be well documented. Distance from the trailhead can be measured with a highway-distance measuring wheel (cyclometer). If readily visible markers are used, this may be all that is necessary. We have used buried metal stakes as markers to minimize the likelihood of vandalism. We reach the general vicinity of the markers using the cyclometer and photographs taken both up and down the trail from the transect location. The precise location of the markers is noted on a sketch map giving distance and direction to at least three permanent reference points (usually trees recorded by species and diameter at breast height). The metal stakes are found with a metal detector.

Numerous additional measures could be taken at these sample locations. Root and Knapik (1972), Bryan (1977), and Epp (1977), for example, dug soil pits and studied changes in soil profiles. Summer (1980) used a penetrometer to measure compaction, fluorescent pebbles to measure pebble movement, and repetitive photography to measure surface pebble and gravel armoring. However, cross-sectional area is probably the most useful measure for managers in that the technique is replicable, requires relatively little training, and provides results that are easy to use and interpret.

Rapid Survey Techniques

Rapid survey techniques permit more trail segments to be examined, but the only types of observations possible are those that do not take very long. Precision in monitoring is also reduced because sample points are not permanently located. With these techniques, monitoring involves comparing two independent samples, each consisting of a large number of observations, instead of reexamining a single, smaller sample of sites. Despite this reduced precision, the accuracy of trail condition assessments may be greater than with detailed measurements because more trail segments can be examined.

Rapid surveys are most valuable when the primary goal is to evaluate the gross condition of the trail and how it is changing over time. Replicable detailed measures are necessary to detect subtle changes in condition over short periods or to examine more thoroughly the nature of change along trails.

Most rapid surveys have utilized a systematic sampling design and collect data on both trail condition and characteristics of environment, trail design, and use. Samples were taken every 500 ft (152 m) by Root and Knapik (1972), every 164 ft (50 m) by Bayfield and Lloyd (1973), and every 1,640 ft (500 m) by Bratton and others (1979). These studies provide an assessment of overall trail condition, and allow variations in trail condition to be related to differences in site, design, and use characteristics. This leads to a good understanding of where and why trail deterioration is occurring, which can be invaluable when either planning new trails or developing strategies for mitigating existing problems.

If an assessment of overall trail condition is unnecessary, it is more efficient to stratify the sample by site, design, or use characteristics. Summer (1980), for example, made a qualitative assessment of degree of erosion on 60 sections of trail located on contrasting geomorphic surfaces. Stratifying her sample by geomorphic surface allowed her to relate erosion damage to trail location (geomorphic surface) with fewer samples than if she had used a strictly random or systematic sample. This sampling design did not allow her to generalize about overall trail conditions, however.

When using a stratified sampling scheme one must avoid bias when locating samples. Bias can be avoided in at least two ways. Epp (1977) located potential sample sites every 100 paces along the trail. A sample site was used if its environmental characteristics fit into one of the categories in the stratification for which further sampling was required. Alternatively, one could walk along the trail locating segments that fit the desired characteristics and then take the sample at some predetermined distance, such as 20 paces, farther along the trail.

Once a sampling scheme is determined, the choice of what data to collect at each site will depend upon the aims of the study. The most common measures of trail condition have been width of the trail (either the tread or the entire disturbed zone), width of bare ground, and maximum depth of the trail. Bayfield and Lloyd (1973) note the number of parallel trails and the presence or absence of the following "detracting features": rutting, stepping, surface deterioration, gullying, lateral erosion, bad drainage, esthetic intrusions, vandalism, or litter. Summer (1980) used erosion ratings, with written descriptions for each erosion class, to evaluate damage at each sample site. Commonly recorded site characteristics include amount and type of use, vegetation type, slope and aspect of both the trail and the surrounding terrain, landform, parent material, drainage, and soil characteristics.

After these data have been collected, means and standard deviations for each trail condition parameter can be calculated and used to assess the overall condition of the trail. Severely damaged segments can be identified and mapped. Finally, differences in trail condition can be related to environmental, design, and use characteristics using standard statistical techniques. This should help identify likely causes of trail deterioration and means of avoiding future problems.

Census Techniques

Several researchers have censused entire trail systems. Trails are subdivided into individual segments that can simply be described as either damaged or undamaged (Root and Knapik 1972). Some studies have gone a step further and rated the degree of impairment of each segment. Trottier and Scotter (1975) express trail condition in a single number determined by rating five parameters (width, depth, moisture regime, stones and roots on the tread, and walkability). This number is the sum of individual ratings for each of the five parameters. Ratings range from zero (low impact) to three (high impact). Bratton and others (1979) use two rating systems. One is based on quantitative measures of total width; total width minus tread; depth; percent water erosion, mud, rut, horse impact, foot impact, or vehicle track; percent exposed roots or bank erosion; and total area of mud erosion. Their other system has five descriptive classes ranging from the very little erosion class to the very extensive erosion class. The latter class is defined as: "trail to bedrock or other substrate, or tree roots badly damaged, or some ruts more than 50-cm deep, or large areas (over 50%) of bank erosion, or mud holes so extensive that the trail is largely outside of its maintained width" (Bratton and others 1979). Similar rating scales could be adapted to other areas. The key to success is describing each category quantitatively or in prose as precise as possible.

These techniques provide particularly useful assessments of overall trail condition. Although they are more time consuming than taking a sample, complete maps of trail condition can be compiled. Such maps could be very useful to managers for planning and budgeting.

Another useful approach to assessing and mapping trail condition is to census all trail "problems." Again it is important to define precisely what is to be considered a problem. The number and length of problems can be recorded while walking along the trail; then the location of each problem can be mapped. Finally, by noting the site, design, and use characteristics of each problem segment, it is possible to develop a better understanding of where and why problems occur. This information can be used to guide trail location, design, and maintenance.

THE CASE OF BIG CREEK TRAIL

To test methods and illustrate how they work, several of these techniques were used along about 17 miles (27 km) of established trail in the Big Creek drainage of the Selway-Bitterroot Wilderness (fig. 2). Most of the trail system is in montane valley-bottom forest between 3,900 and 6,000 ft (1 200 and 1 800 m). Above this elevation the trails more frequently leave the valley bottoms and nonforested vegetation types are more common. The Big Creek trail is one of the more heavily used trails in the Selway-Bitterroot, by both hikers and stock. The South Fork trail, which branches off from the main trail about 8 miles (13 km) above the trailhead, is infrequently used.

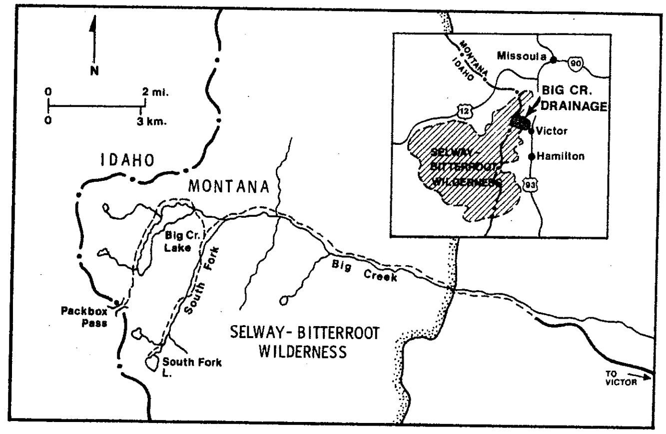


Figure 2.—Location of the Big Creek drainage within the Montana portion of the Selway-Bitterroot Wilderness.

Study Methods

We established 10 permanent trail transects along the main Big Creek trail in 1978. These were systematically located every mile (1.6 km) after establishing a randomly selected starting point. No transects were located on the South Fork trail. In 1979 we established two additional transects across trail segments selected because they were deeply incised.

With all of these transects, a tape was placed flush with the permanent stakes at ground level; it was not elevated above the trail-side microtopography and, therefore, some precision was lost. Vertical measurements were taken every 0.2 ft (6 cm) and determined to the nearest 1/8 inch (0.32 cm). The cross-sectional area below the tape was then calculated using the formula in figure 1. In 1980, the 10 systematically located transects and the two purposively located transects were remeasured.

In 1980 we did a rapid survey along the Big Creek and South Fork trails, taking observations every 0.2 mile (0.32 km) for a total of 83 observations. At each observation point the following data were collected: overall trail width (the zone obviously disturbed by trampling); bare ground width; maximum depth; presence or absence of multiple trails, trail deepening (maximum depth of over 10 inches [25 cm]), erosion of trail sides, roots, rocks, or mud (in quantities greater than in adjacent areas), and "washboard" (alternating rises and depressions in the trail caused by horses stepping repeatedly on the same spots); habitat type;[1] and slope, both along and across the trail.

This survey provided data on the overall condition of the trail and the frequency of occurrence of various trail problems. However, the small number of problem observations suggested it would be valuable to look more closely at the problem segments along the trail. Consequently, we censused all trail segments that were either incised more than 10 inches (25 cm) or muddy for at least part of the use season and that were at least 3 ft (0.9 m) long. For each segment we noted length of the problem segment, maximum depth and width of the segment, habitat type, and slope of the trail. We also made observations about soils and landforms, and potential remedies for the problem.

Overall Trail Condition

Results of the systematic sample of trail transects show that between 1978 and 1980, only 4 of the 10 sample sites experienced a net loss of soil; the cross-sectional area below the transect **decreased** on the other 6 sites, indicating that deposition of material exceeded erosion. On those sites with a net loss, the mean loss was 12 in^2 (77 cm^2); losses ranged between 6 in^2 (39 cm^2) and 17 in^2 (110 cm^2). Generally more material was lost from lateral erosion of the "banks" of the trail than from further incision at the deepest part of the trail (fig. 3).

The mean decrease in cross-sectional area on those sites experiencing a decrease was 13 in^2 (84 cm^2), with a range between 1 in^2 (6 cm^2) and 47 in^2 (303 cm^2). The decreases are a result of both slumping of the trail "banks" and infilling of the trail tread (fig. 4). The site where 47 in^2 of material was deposited had been disturbed by trail work immediately upslope.

To test the accuracy of our measurements, 10 replicate measures of one transect were taken. The mean area for the 10 measures was 83.6 in^2 (540 cm^2); the 95 percent confidence limits around this mean were $\pm$ 4.1 in^2 (26 cm^2), about 5 percent of the mean value. The amount of change that occurred in 2 years exceeded this measurement error value on only 5 of the 10 transects. Of these five sites, two experienced a net loss of soil and three a net gain.

These results suggest that over the trail system as a whole little erosion is occurring. Some loss occurs where soil sloughs off banks, is transported by moving water, and deposited where water drains off the trail. However, sediment is also deposited on the trail by overland flow, and material eroded from one trail segment is often deposited elsewhere along the trail. Although individual cross-sectional profiles are changing, the trail as a whole exhibits a relatively steady state. Trottier and Scotter (1975), working in Canada's Banff National Park, also found little short-term increase in the cross-sectional area of trails that were properly located.

A larger sample size would be necessary to draw more definitive conclusions. The rapid survey we took increased the number of observations to 83, although trends over time were not quantified. The mean trail width of the entire trail system was 3.2 ft (98 cm); the mean width of the nonvegetated part of the trail was 2.3 ft (70 cm). The mean maximum depth of the trail was 0.41 ft (12 cm). These values are similar to those recorded elsewhere in the Northern Rocky Mountains (Dale and Weaver 1974), but these trails are narrower and deeper than trails in Great Smoky Mountains National Park (Bratton and others 1979).

The trail problems we defined (multiple trails, deepening, lateral erosion, roots, rocks, mud, and "washboard") were absent on 65 percent of the trail segments we examined. This supports the conclusion of our trail transect study that most of the trail system is in good shape and appears to be stable.

There are, however, certain trail segments with severe problems (fig. 5). Of the 83 segments, 13 percent were more than 5 ft (152 cm) wide; 1 segment was 7.1 ft (216 cm) wide. The width of exposed soil exceeded 4 ft (122 cm) in 8 percent of the cases, and reached 6 ft (183 cm) in one case. Of the segments, 35 percent had at least one problem and 12 percent had more than one problem. Three problems occurred on more than 10 percent of the segments: mud (17 percent); rocks (13 percent); and root exposure (11 percent). Incision of more than 10 inches (25 cm) occurred on 8 percent of the sites, and multiple trails were present at 5 percent. Lateral erosion and "washboard" were rarely encountered.

[1]Habitat types are a site classification system based on potential climax vegetation. We used the types presented in "Preliminary Forest Habitat Types of the Nezperce National Forest" (Robert Steele and others 1976, preliminary draft, USDA Forest Service, Intermountain Station.)

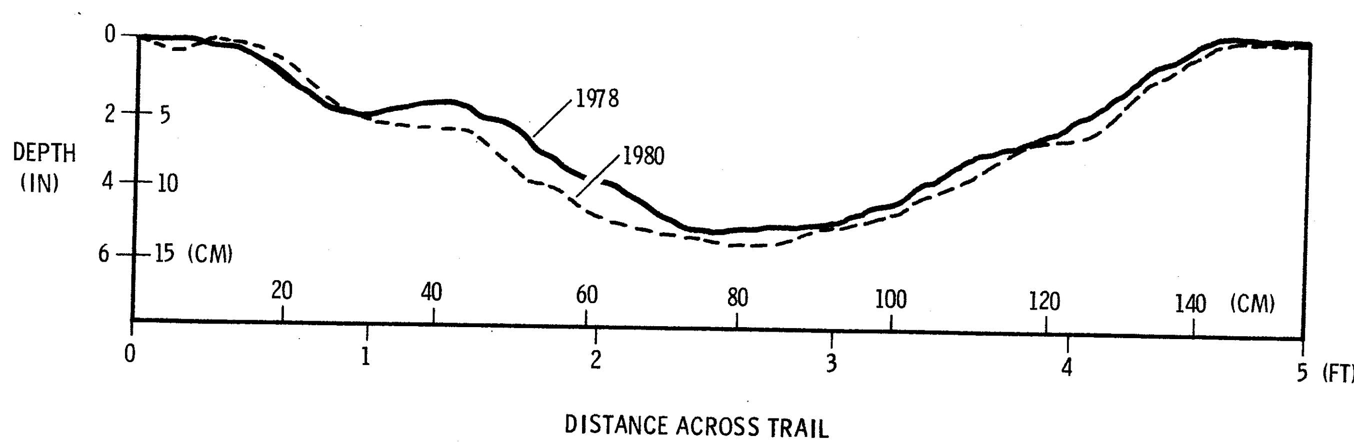


Figure 3.—The cross-sectional profiles for transect 8 indicate a net loss of 17 in^2 (110 cm^2) of material (erosion) between 1978 and 1980.

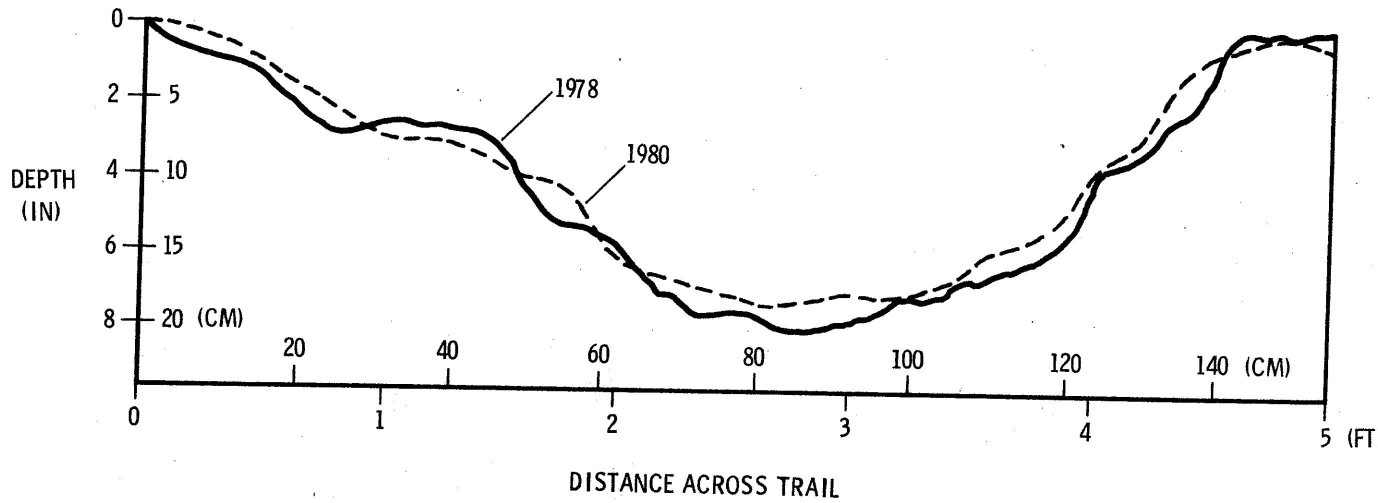


Figure 4.—The cross-sectional profiles for transect 5 indicate a net gain of 15 in^2 (97 cm^2) of material (deposition) between 1978 and 1980.

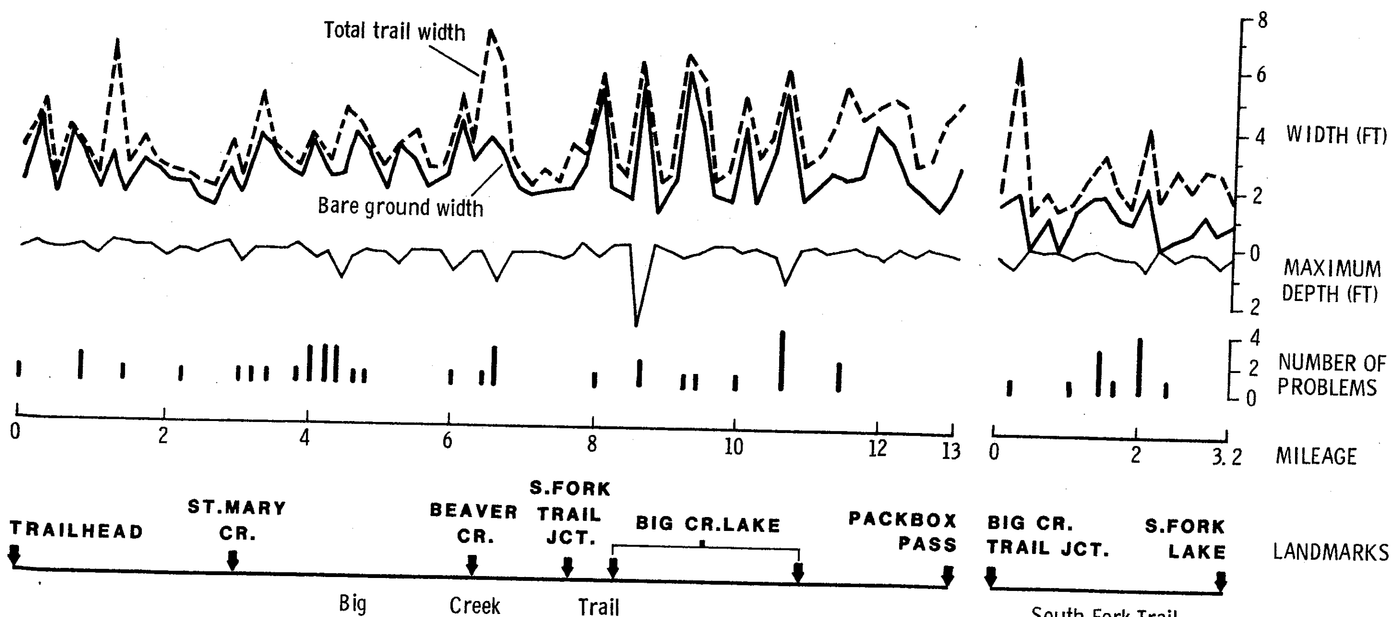


Figure 5.—Measurements and observations taken every 0.2 mile along the Big Creek and South Fork trails.

The severity of trail deterioration in some locations was also illustrated by the results of trail transects at sites purposely selected as examples of deeply incised trails. In 1 year the cross-sectional area at one site (fig. 6) increased 56 in^2 (362 cm^2), from 944 in^2 (6 090 cm^2) to 1,000 in^2 (6 452 cm^2). At the other site, the cross-sectional area increased from 478 in^2 (3 084 cm^2) to 508 in^2 (3 277 cm^2), an erosional loss of 30 in^2 (194 cm^2). These losses occurred primarily as deepening on steep trails and were probably more a result of water erosion than excessive use. The amount of soil loss involved is roughly comparable to that found by Ketchledge and Leonard (1970) in the Adirondacks and by Summer (1980) in Rocky Mountain National Park.

Figure 6.—Deeply incised trail segment on which trail transect measurements showed a 1-year soil loss of 56 in^2 (362 cm^2).

Trail Conditions in Relation to Habitat Type

Using data collected in the rapid survey, we examined the relationship between trail condition and factors related to the trail's location, design, and amount of use. The major locational variable we examined was habitat type. Most of the trail was located in forests with the potential to be dominated by *Abies lasiocarpa*. Three habitat types characterized by *Streptopus amplexifolius, Clintonia uniflora,* or *Menziesia ferruginea* in the undergrowth were common. Two types with a potential overstory of *Abies grandis* and undergrowth characterized by either *Linnaea borealis* or *Clintonia uniflora* were also common. The other types were *Pseudotsuga menziesii/Physocarpus malvaceus* and a nonforested herbaceous vegetation type usually found on avalanche paths.

All measures of trail condition differed significantly between habitat types (table 1). Trail segments located in the *Abies lasiocarpa/Streptopus amplexifolius* type were more consistently in poor condition than segments in other types. Trails in this habitat type, which is indicative of a high water table, are easily trampled into quagmires. Visitors attempting to avoid muddy conditions widen the trail, and water erosion frequently deepens the trail where the water table is intercepted by the trail tread. Working on the west side of the Selway-Bitterroot Wilderness in Idaho, Helgath (1975) found similar problems in *Thuja plicata/Athyrium filix-femina* and *Abies lasiocarpa/Pachistima myrsinites* habitat types. Two of our trail samples were in *Thuja plicata* forest. These samples had three problems each and a mean trail width of 4.0 ft (122 cm), bare width of 3.0 ft (91 cm), and maximum depth of 1.1 ft (34 cm), suggesting that these types are also poor trail locations.

The two *Abies grandis* types had fewer problems. Most problems in the *Abies grandis/Linnaea borealis* type were with exposure of rocks in the trail as finer particles are eroded away. This leads to excessive trail widening as hikers and stock attempt to skirt the rocks exposed in the tread (fig. 7). Excessive muddiness, root, and rock exposure were all occasional problems in the *Abies grandis/Clintonia uniflora* type.

In contrast, trail segments located in nonforested areas were consistently in better shape than segments in other types. The only problem encountered was one case of muddiness where the trail crossed the drainageway of an avalanche slope. These locations are usually better drained than the forests, which have developed on glacial deposits in the valley bottoms. Consequently, trail deepening by water erosion is less pronounced.

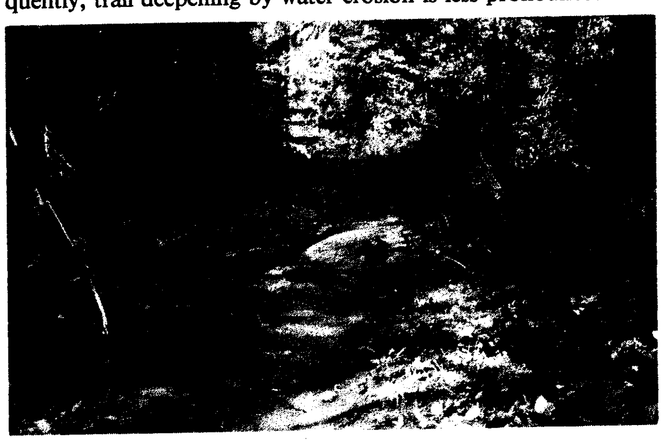


Figure 7.—Pronounced trail widening commonly occurs where hikers and stock skirt rough rock outcrops exposed in the trail tread.

Table 1.— Trail conditions in various habitat types[1]

Habitat type	N	Trail width	Bare width	Maximum depth	Problem frequency
		Feet			Percent
Abies lasiocarpa/Streptopus amplexifolius	11	4.9 a	3.2 a	0.66 a	82 a
Abies grandis/Linnaea borealis	9	3.6 b	2.8 ab	.38 ab	55 ab
Abies grandis/Clintonia uniflora	10	2.8 cd	2.1 ab	.39 ab	50 b
Pseudotsuga menziesii/Physocarpus malvaceus	6	2.4 cd	2.3 ab	.48 ab	0 c
Abies lasiocarpa/Clintonia uniflora	15	3.2 bc	2.1 b	.29 bc	20 c
Abies lasiocarpa/Menziesia ferruginea	11	3.2 bc	1.8 b	.28 bc	9 c
Nonforested avalanche slope types	10	2.0 d	.9 c	.18 c	10 c
Mean		3.2	2.3	.41	35

[1]Any two means in a column followed by one or more of the same letters are not significantly different at the 95 percent confidence level, using the difference-of-means and difference-of-proportions tests (Blalock 1972).

Trail Conditions in Relation to Slope

Regressions showed the following significant positive relationship between slope along the trail and maximum depth of the trail:

$$\text{maximum depth (ft)} = 0.30 + 0.02\,X\ (\text{slope in degrees})$$

There were no significant relationships between slope along the trail and trail width or bare width. The frequency of problems was also unrelated to slope along the trail. Although steep segments often are more highly deteriorated—they are deeper in particular—flat segments are also prone to problems due to poor drainage. Effective use of water bars and other means of controlling erosion can prevent damage on steep trail segments. Even for maximum depth, trail slope does not explain much variability ($r^2 = 0.08$). It might have if extremely steep pitches were more common and maintenance was less frequent.

Trail Conditions in Relation to Amount of Use

To examine the effects of amount of use, we compared the infrequently traveled South Fork trail with the frequently traveled section of the Big Creek trail above the junction with the South Fork (table 2). The widths of both the entire trail and the bare portion of the trail were significantly greater on the more heavily used trail. The mean maximum depth was greater on the heavily used trail, but the difference was not statistically significant. The relative frequency of problems on the two trails was identical.

Table 2.—Trail conditions in relation to amount of use

Amount of use	N	Trail width[1]	Bare width[1]	Maximum depth	Problem frequency
		Feet			*Percent*
Light (South Fork)	17	2.4	1.0	0.28	35
Heavy (Big Creek Lake)	17	3.7	3.0	.42	35

[1]Significant at p = 0.05; one-tailed difference-of-means test.

Other studies support the contention that trail width responds more to amount of use than either trail depth or problem frequency. Bayfield and Lloyd (1973) and Dale and Weaver (1974) both found that trail width increased with increasing use. In a series of experiments, Weaver and Dale (1978) found that a small amount of use caused most of the increase in trail depth they recorded, while trail width continued to increase substantially with further increases in use. A probable explanation is that the major mechanism maintaining a wide trail is trampling. To maintain a bare width of 3 ft (91 cm), a consistently high level of trampling must occur over that area. Where use levels are low, only the central part of the trail—a much narrower path—is trampled frequently enough to remove all vegetation. However, once the vegetation has been removed, even along a narrow path, water erosion can be pronounced. Water erosion is probably the major mechanism of trail deepening in most situations and can be as pronounced on light-use trails as on heavy-use trails. Most problems can also be triggered by low levels of use on a poorly located or poorly maintained trail segment. Beyond this low threshold, further increases in use have little effect on problem frequency. Helgath (1975) found that erosional problems were actually more severe on lightly used trails, probably because they were more poorly designed and maintained.

Problem Segments—Locations and Solutions

In order to develop some guidelines for avoiding future problems resulting from poor trail location and design, we censused all sections of the trail that were either incised more than 10 inches (25 cm) or were excessively muddy. We found 28 trail segments, about 1,200 ft (365 m), to be muddy to the point that it made travel difficult, at least seasonally. This amounts to only 1 percent of the trail system, considerably less than the 17 percent of the systematic samples that exhibited less severe muddiness problems. The average length of these segments was 43 ft (13 m), but some muddy segments exceeded 100 ft (30 m). These occasional long, muddy segments are probably what leaves the impression that much of the trail is in poor condition. The average width was 4.7 ft (143 cm), considerably more than the average of 3.2 ft (98 cm) for the trail system as a whole. Trail widening is a frequent consequence of trail muddiness (fig. 8).

Figure 8.—This muddy trail segment is more than 6 ft (183 cm) wide and provides a good example of multiple trailing and "washboard."

Of the severely muddy segments, 68 percent occurred in the *Abies lasiocarpa/Streptopus amplexifolius* habitat type; our systematic sample indicated that only about 13 percent of the trail was in this habitat type. Vigorous growth of *Athyrium filix-femina, Boykinia major, Senecio triangularis,* or *Veratrum viride* was usually a strong indicator of trail muddiness problems. These same species have also been identified as reliable indicators of unstable slopes (Pole and Satterlund 1978). Most of the sites had surface soil colors of 10 YR 2/0 or 10 YR 2/1, suggesting this might also be a useful indicator of problems. The Appalachian Mountain Club uses soil color and mottling as a guide when locating trails (Proudman 1977).

About one-third of the problems on muddy segments could be corrected by relocating trails on better drained sites, avoiding the indicators mentioned above. However, unless the trail is relocated completely out of the valley bottoms, the remaining problems can only be mitigated by constructing bridges, corduroy, or turnpikes. Most trail assessments elsewhere have also concluded that poor drainage is the major trail problem and that improving drainage and raising walking surfaces are the most effective solutions where rerouting is not feasible (Root and Knapik 1972; Bayfield and Lloyd 1973).

We found that 45 segments, about 2,500 ft (762 m), were deeply incised. The average length of these segments was 57 ft (17 m); the average depth was 1.6 ft (48 cm). The average width was 2.2 ft (67 cm), less than the average for the trail system as a whole.

Incision problems occurred on a wide variety of habitat types, so we could not identify any useful vegetative indicators of potential problems. Almost 90 percent of the problems occurred where the slope along the trail exceeded the overall trail average of 4.7 degrees (fig. 9). The mean slope for problem trail segments was 11.5 degrees (more than a 20 percent slope). About 80 percent of the problems could be solved either through better use of water bars or by ditching trails so that drainages are not diverted down the trail. However, most of these segments are so deeply eroded that they would have to be filled in before water bars could be effective. This emphasizes the importance of recognizing the need for such drainage devices during initial trail construction.

Figure 9.—Trail incision commonly occurs even on moderate slopes if water bars have not been used.

Erosion on gentle slopes usually occurred in soils with uniform textures, particularly in the fine sand to silt size classes. These are most likely small areas of outwash or lacustrine deposits in a matrix of glacial till. Root and Knapik (1972), working in the Canadian Rockies, also found such locations to be particularly erosive. Localized trail rerouting through till deposits would alleviate most of these problems.

MANAGEMENT IMPLICATIONS

Value of the Techniques as Management Tools

These techniques provide two types of information that can be useful to the manager. First, they can provide guidelines for trail location, relocation, design, and maintenance. Both rapid survey and census techniques can be used to gather information. We feel the best method is to take a census of problem trail segments, look for associations between problems and environmental conditions (such as habitat type, slope, or parent material), and suggest solutions to the problems. This amounts to learning from past mistakes. Not all trails need to be examined. Choose trails that are examples of the range of conditions in the area of concern, develop guidelines for these conditions, and extrapolate the results elsewhere. Indicators of potential trail problems should be identified and trail design features should be developed to avoid problems where poor locations cannot be bypassed.

These surveys should be taken by personnel well trained in ecology and soil science, preferably with experience in trail construction and maintenance. While such a survey involves an initial outlay of funds, this investment will be quickly recovered in reduced trail relocation, maintenance, and rehabilitation costs. This is probably the most useful type of trail analysis the manager can undertake.

Managers should also be concerned about monitoring trail conditions to determine the effectiveness of their trail management programs. The first step in developing a monitoring program is to decide which types of trail deterioration are of most concern, and whether to monitor the severity of individual problems (for example, how wide the trail is), the frequency of problems (for example, the number or length of excessively wide trail segments), or both.

These decisions should be in written standards stating conditions that are unacceptable. Standards might state, for example, that no trail segment should be deeper than 1 ft, that muddy segments should be no longer than 10 ft, or that no more than 1 percent of the trail should be more than 3 ft wide. Once standards have been defined, trails can be surveyed to determine whether current conditions are acceptable or not. If they are not, mitigating actions will be necessary. Periodic reassessments will show whether these actions are successfully controlling the problem.

Rapid survey assessments noting presence or absence of problems or simply measuring trail width or depth should usually be sufficient for monitoring overall trail condition. A census of all segments with potential problems will be necessary where a standard has been written to limit the severity of individual problems. For example, if a standard states that no trail segment will be deeper than 1 ft, monitoring should involve periodically measuring the depth of all segments where depth might exceed 1 ft. Systematic sampling, however, can provide a more efficient estimate of problem frequency. If the standard stated no more than 1 percent of the trail will be deeper than 1 ft, depth measurements could be taken every 0.2 mile (or some other distance) to see if depth exceeds 1 ft on more than 1 percent of the sample segments.

More detailed monitoring of permanent sites would be useful to managers wanting to evaluate how well some trail hardening or maintenance technique is working. Changes over time could be followed on otherwise similar hardened and nonhardened trail segments to determine the effectiveness of the hardening technique. Such a study would also be useful in evaluating the consequences of a change in amount or type of use. Detailed monitoring of randomly or systematically located sites will be of limited use to managers.

Trail Management

A major conclusion of these studies is that most of the Big Creek trail system is in good condition. Erosional loss from the trail is generally low, and problems are absent on most of the trail. The severely deteriorated segments we surveyed amounted to only 4 percent of the trail system. Similar conclusions have also been reached for most other trail systems examined (for example, Root and Knapik 1972; Bayfield and Lloyd 1973).

These results suggest that the significance of trail deterioration to maintaining natural conditions in the Big Creek area and elsewhere is negligible. The only important ecological effect likely to occur would be if the trail disturbed an extremely rare plant, animal, or ecosystem. It is unlikely that this has happened in the Big Creek drainage. Where this does occur, the problem is a result of trail placement, not trail deterioration, and the solution is relocation.

Managers, however, should not interpret this to mean they can be lax in minimizing ecological disturbance associated with trails. Rather it suggests that in most cases the significance of trail deterioration problems should be determined primarily by their effect on the visitor's experience. Lee (1975) found that backcountry visitors were bothered most by features that detract from the trail's functional ability to provide a pleasant and easy walking surface, such as loose rock or muddiness. As long as trails are not unnecessarily overengineered, trail characteristics that are primarily esthetic detractions, such as excessive trail width, are probably less important, although they certainly can be bothersome to some people. Therefore, in a monitoring program, managers might want to pay particular attention to changes that make a trail more difficult to walk along.

Although trail condition is generally good, some trail segments have severe problems. The probability that a given segment will deteriorate is a function of the trail's immediate environment, its design and maintenance, and the amount and type of use the trail receives. In the Big Creek drainage, amount of use had a significant effect on trail width and bare width, features probably of secondary importance to visitors and in terms of ecological impact. The slope of the trail affected only the maximum depth of the trail. Deeply incised trail segments are a significant impact. However, until incisions become so deep that footing is difficult, they are probably a less severe problem in the eyes of the visitor than is muddiness. Frequency of muddiness and other trail problems, as well as trail width, bare width, and maximum depth, all differed between habitat types, indicating that the most significant trail problems are primarily related to local environmental conditions. This conclusion is supported by the results of several other studies that found that more variability in trail conditions is explained by local environment (usually vegetation type) than any other factor (Bayfield and Lloyd 1973; Helgath 1975; Weaver and others 1979).

Such a conclusion implies that most problems can be avoided through careful attention to trail location. In the Big Creek drainage, trail problems would have been minimal if the route had avoided areas with a high water table, often indicated by the *Abies lasiocarpa/Streptopus amplexifolius* habitat type, and glacial deposits with a homogeneous silt to fine sand texture. Where these locations cannot be avoided, problems could be reduced through proper design during construction. Areas with a high water table need to be either drained or bridged (Proudman 1977). In the glacial deposits, slopes should be minimal and water bars should be used and frequently maintained. Proper trail location avoids most problems, while engineering avoids most remaining problems. Restrictions on amount of use are less helpful.

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Three types of trail assessment techniques—replicable measurements, rapid surveys, and censuses—can provide useful information for backcountry managers. This paper discusses how to apply these methods in the field and utilize the results to improve backcountry management. To illustrate their application, specific techniques are applied to the Big Creek trail system in the Selway-Bitterroot Wilderness.

KEYWORDS: monitoring, wilderness, backcountry management, trails, ecological impact, trail condition