TRAIL DESIGN & MAINTENANCE

By Jeff Marion, Recreation Ecologist

INTRODUCTION

Trails act as the primary transportation network for roadless portions of protected natural areas. They encourage the public to get out and enjoy natural settings without harming them. For trails to be considered "sustainable" they must meet these recreational needs while providing adequate protection to the environment while minimizing trail maintenance. Poorly designed trails require frequent maintenance and are often susceptible to excessive erosion, muddiness, and tread widening. Poorly designed trails are also less enjoyable and less safe to hike due to these impacts and to steep grades.

DESIGNING SUSTAINABLE TRAILS

The most influential element of trail management is the original trail design and alignment. A well-designed sustainable trail requires little maintenance, has stable resource conditions, and is more pleasant to use. A poorly-designed trail is difficult to maintain, deteriorates quickly and, once soil has been lost, it's exceedingly difficult to restore it. Even a trail that loses ½ in. of soil per year will become a foot-deep gully in 24 years.

Elements of a Well-Designed Trail

Grade

All trail designers should use clinometers when laying out trail alignments. Generally, the grade along a trail (Figure 1) should be less than 10%. In highly erosive, sandy soils, a 5% slope may be excessive. Granitic soils or soils with a substantial rock component are more forgiving and can allow long sections of trail to be constructed at 13 to 15%. Short, well-drained segments can range up to 20%, but steps and tread armoring are generally essential. However, trail grades < 10% are far more comfortable to hike and ride. Substrates may allow for a trail that exceeds 10%, but the users might not!

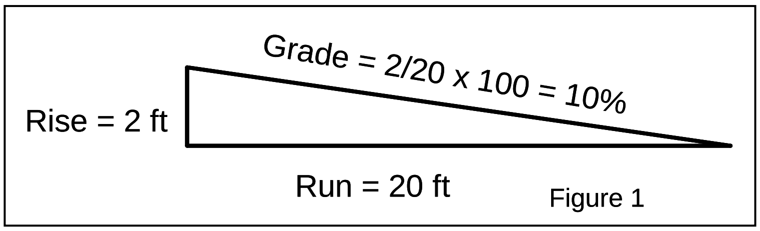


Figure 1

Trail Alignment Angle: Relationship to the Contour and Fall-Line

A "contour" is a line of points that are at the same elevation. If you walk precisely parallel to a contour, you are walking at a level (0%) grade. If you walk downhill perpendicular to a contour you are walking along the "fall-line," the same path that water would flow down during a rainstorm. A well-designed sustainable trail is always laid out to traverse a hillside, <u>angled closer to the contour line than the fall-line</u>. Trails aligned with the fall-line or near it collect and pass water directly down the trail, eroding soil from the tread, exposing roots, and creating gullies. It's nearly impossible to remove water from an entrenched fall-line trail. Trail professionals always avoid these alignments and relocate trail segments with fall-line alignments to side-hill positions.

The "Half Rule" provides guidance for avoiding fall-line alignments: a trail's grade shouldn't exceed half the grade of the hillside or sideslope that the trail traverses. If it does, the trail is considered a fall-line trail. The figure below (Figure 2) shows two proposed trail routes to the top of the hill. Although Trail A stays within a gradient of 10%, it is the poorer route because it travels perpendicular to the contours. Water can't be removed from its tread and it will quickly erode, even at a 10% gradient. The only way to get water off the trail is for the route to **traverse** the natural slope (Trail B). At 5% grade, Trail B is the maximum grade possible on a sideslope of 10%. This trail uses side-hill or bench cut construction (Figure 3), where one side is always lower than the other. For this type of trail design it becomes a simple matter to redirect water across and off the trail, rather than allowing it to cut a channel in the tread. The most sustainable trails also cross landform grades of between about 10% and 30%, where the natural topography (steeper sideslopes adjacent to the trail) limit trail width and allow easy drainage of water from the tread.

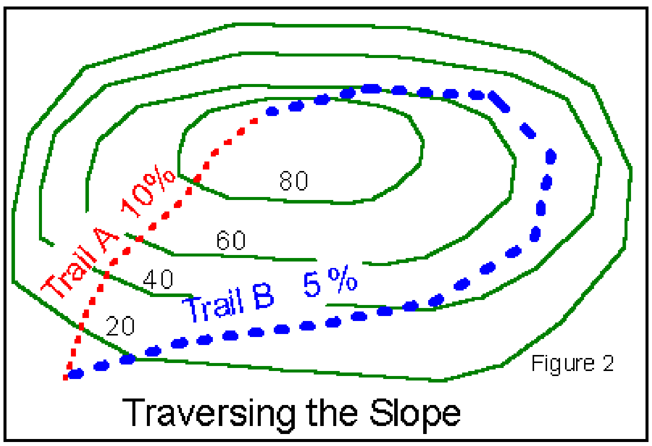


Figure 2

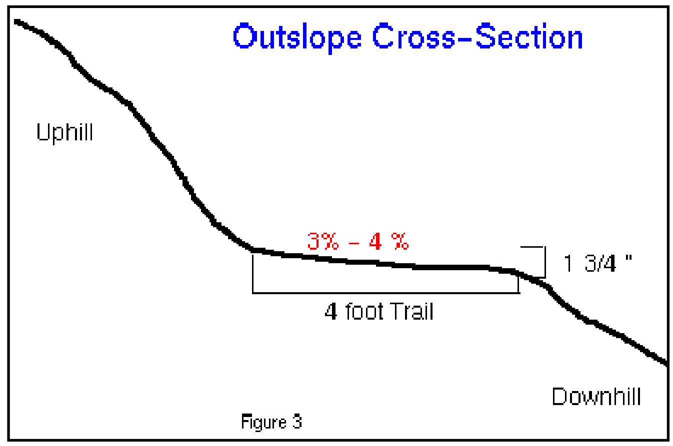


Figure 3

Outslope

A well-designed trail should have a 3% to 5% outsloped cross-section so water runoff crosses the trail in a non-erosive "sheet flow" rather than being intercepted by the trail and channeled down it (Figure 3). Unfortunately, an outsloped tread rarely lasts very long, as trail users compact the center of the tread or displace soils to trailside positions. A berm or mound of soil often develops on the lower side of a trail, trapping water on the tread. Constructing the initial tread with a steeper 5% outslope can help, along with several trail maintenance actions described later. These issues also explain why it is difficult to construct a sustainable trail in flat terrain. Either trail construction or subsequent use will create a cupped tread that will hold water and become muddy. Avoid flat terrain, or consider bringing in soil or gravel to slightly mound the tread. <u>Where possible, always place your trail in sloping terrain</u>.

Grade Dips

All new trails should be designed to incorporate periodic **grade dips** or **grade reversals**, locations where a descending trail turns upwards briefly before returning to a descending alignment. Grade dips force all water running down the tread to leave the trail before it can gain in volume, momentum, and erosive power. The spacing of these features depends on the trail's grade; recommended spacing is included in the table below.

Trail Grade	Spacing
3-5%	500 ft
7-10%	300 ft
11-15%	100 ft
>15%	<50 ft

A significant benefit of grade dips is that they **never require maintenance** to ensure their effectiveness, provided there is a reasonable gain in trail elevation following the feature (e.g., 1 ft). Treads should be outsloped for several feet either side of grade dips so that water runs off the trail in sheet flow.

KEY ELEMENTS OF TRAIL MAINTENANCE

Trail treads are damaged by traffic, which compact or displace tread soil, or by water, which erodes soil and creates muddiness. While traffic-related damage is largely inevitable, trail managers have an array of practices available to address water-related degradation. The first step of trail maintenance is to inspect the trail. When erosion and muddiness problems are evident, the principle questions to ask include, *"Are some trail segments so poorly designed that they should be rerouted?" and "Where is the water going and how can I get it off?"* Trail maintainers can learn a great deal by taking a hike in a rainstorm to see the how, why, and where a trail intercepts and transports water. Try it sometime!

Identify Segments in Need of Rerouting

It is generally best to reroute trail segments with substantial design deficiencies or resource impacts. Even though traffic will likely be shifted to a longer new route, the old alignment is simply not sustainable, representing a substantial drain on limited trail maintenance capabilities and unacceptable environmental impacts. A careful cost-benefit analysis taking a "50+ year view" will almost always favor rerouting poorly designed trail segments. Refer to the Trail Design section and trail maintenance books in the References section for guidance on judging when trail segments should be rerouted. Examples include trails with grades over 20%, fall-line alignments, flat terrain with wet soils, and trails so badly eroded that water cannot be removed from their treads.

Maintaining the Outslope

This is the first order of business in trail maintenance. It is the simplest, but most labor intensive trail maintenance tool. Trails are usually constructed with a 3-5% outsloping tread to pass water across and off the trail (Figure 4, Stage 1). Normal trail use will compact and displace soil from the tread and create a berm along the trail's downhill edge (Stage 2). If allowed to continue, the berm will grow and cause increasing volumes of water to flow down the trail, eroding soil (Stage 3). If this erosion is allowed to continue unchecked, the trail will trench deeper until it is both unusable and unredeemable (Stage 4).

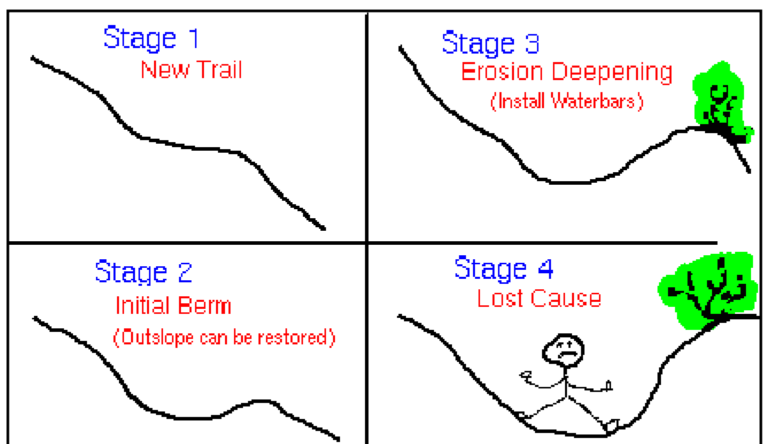
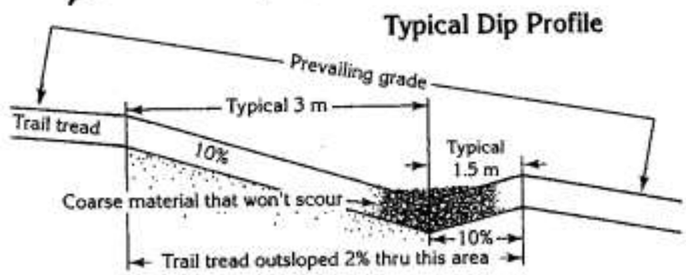


Figure 4

The trail outslope can be maintained at Stage 2 by pulling the berm soils (minus organic litter) back into the tread to restore a 3-5% outslope. This work must be performed frequently. However, some use patterns (heavy traffic), soil conditions (sandy) and climates (high rainfall) combine to minimize the effectiveness of this practice. A less labor intensive alternative is to create 5-10 ft sections of outsloped tread at places where it's most needed and/or easiest to complete. Once a trail has reached Stage 3, the berm is too large and overgrown with vegetation to be removed; the tread outslope cannot be restored and other maintenance approaches (e.g., grade dips, water bars or drainage dips) must be employed. These should be angled >45^{o} so that water carries its sediment load off the trail before dropping it. When a trail deteriorates to Stage 4, the trail is a lost cause, and the best solution is trail relocation. Exceptions would include: a) the tread is stable due to exposed rock, 2) extensive rock steps and trailside armoring can be installed, or c) heavy machinery can be used to cut periodic drainage outlets along the embedded trail section.

Grade Dips, Waterbars, and Drainage Dips

The most sustainable and preferred solution for removing water from trail treads is to design and construct the trail with **grade dips**, locations where a descending trail turns upwards briefly before returning to a descending alignment. All water will have to leave to the trail at these locations and recurring maintenance to ensure this will be unnecessary. This technique is mentioned under trail maintenance because it is possible to construct grade dips on existing trails, though this may be impossible on trails with a steep grade due to the added increase in grade required to rejoin the original alignment. The key to installing these on existing trails is in finding locations that require a minimal amount of tread reconstruction.

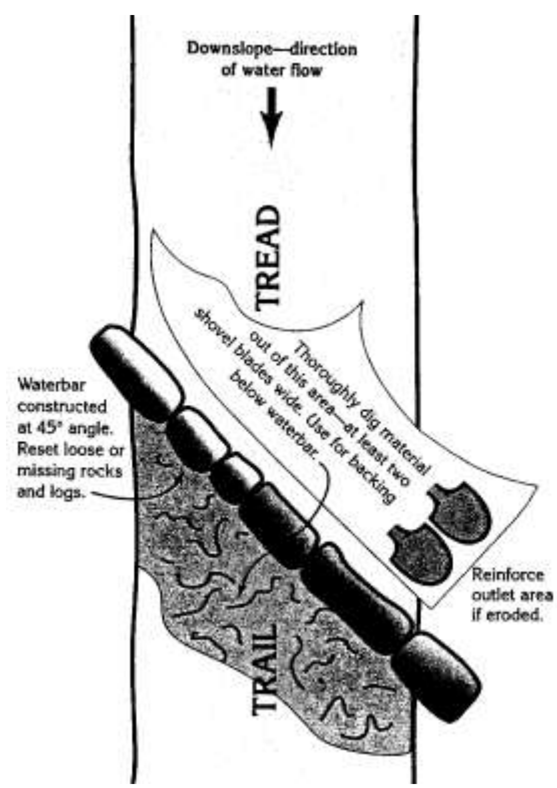


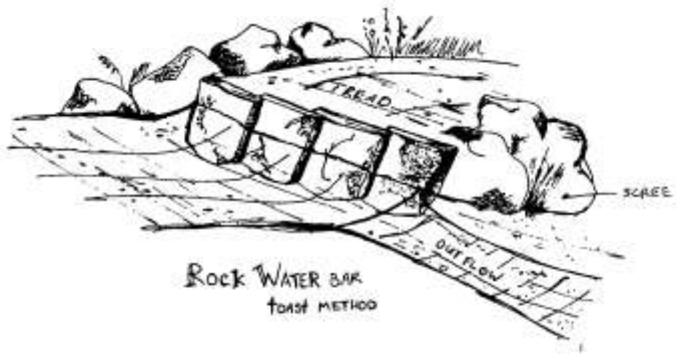
Other methods employed to divert erosive water off treads that are not outsloped is to construct rock or wood **waterbars** or **drainage dips**. These features should be constructed at the approximate intervals shown in the adjacent table. Tread relocation or construction of rock steps should be considered for trail segments with grades in excess of 20%.

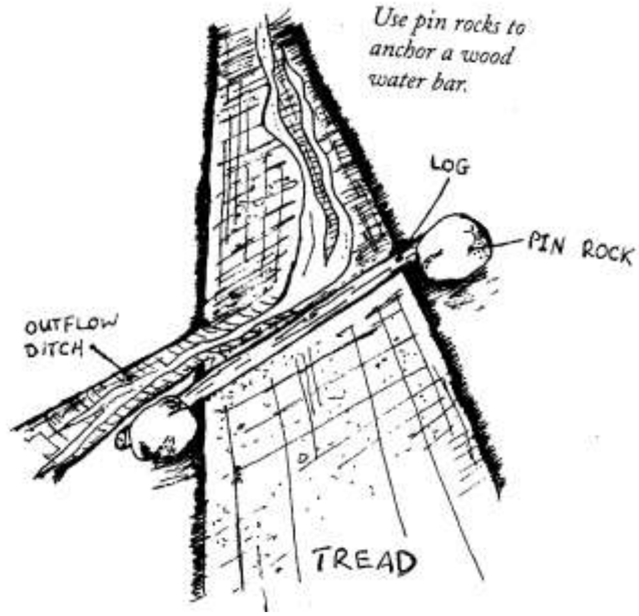
Trail Grade	Spacing
3-5%	500 ft
7-10%	300 ft
11-15%	100 ft
>15%	<50 ft

Waterbar Installation Steps:

1) Mark waterbar location on the ground, extending 1 foot beyond trail borders. Angle the waterbar at about 45^{o}.
2) Collect *large* flat or rectangular rocks (12-16 in. long) or cut rot-resistant logs (e.g., cedar, locust, oak) 6-8 in. in diameter (best to remove bark).
3) Dig a trench almost as deep as the rocks or log and install the rocks or log so that the top is several inches above the uphill side of the trail. Flat rocks can be overlapped like roof shingles; blocky (not rounded) rocks should be fit tightly. Arrange the straightest edge of the rocks across the top. Rocks or log must be securely anchored to withstand trail traffic. Logs can be anchored by embedding large rocks on either side at the ends or by driving wooden stakes (2-3 in. by 2 ft.) at an angle from both sides to pin the log to the ground.
4) Rework the soil up to 2 ft. on the uphill side of the waterbar so that there is a deep wide drainage swale extending down off the trail with a 4-5 in. step on the uphill side of the waterbar. Place the excavated soil on the downhill side and build it up level with the top of the waterbar. Compact all loose soil by stomping.







Waterbars must be extended about a foot beyond trail borders to prevent water or hikers from going around them. A pile of rocks at each end can help anchor them and discourage hikers from widening the trail. A six foot length is generally about right for most hiking trails. Waterbars are oriented at a >45^o angle so that water flow is shunted off the trail with sufficient force to carry its sediment load off and below the trail before being deposited. Otherwise water traveling down the trail will be slowed too much when it contacts the water bar and the sediment will be deposited on the trail, quickly filling in the drainage channel so that water overtops the waterbar and continues down the trail. The drainage swale must be wide and deep as it will quickly accumulate leaves that will slow and capture sediment from runoff, filling in the exit channel.

Drainage Dips: These are an unarmored form of drainage. Look for places where tree roots, rocks or a slight grade reversal occurs where a minimal amount of digging on the lower side of the trail will effectively drain water. As for water bars, dig a wide swale across the trail at a >45^o angle and mound the soil on the downhill side. While these require less time to install they also wear down faster and require more frequent maintenance to remain effective. Drainage dips are also used to drain mudholes or rutted areas that hold water. Make the drainage swales deep, wide, and pronounced as water runoff will soon redeposit soils and organic litter at these locations and render your work ineffective.

Maintaining Water Bars & Drainage Dips

These features require regular maintenance. Twice each year the excess soil and organic litter that builds up at the downslope end of the drainage feature needs to be cleaned out and graded to assure that water flows off the trail. **Without regular maintenance these features lose their effectiveness**. Also check and reset loose rocks or logs.

Vegetation Maintenance

Falling trees and limbs require routine removal and growing trees, shrubs, and herbs or grasses must be trimmed back from obstructing the trail corridor. Hiking trails should generally have 6' horizontal by 8' vertical clearance (with exceptions to protect larger trailside trees).

Blowdowns: For fallen trees carry a saw to cut out <4 ft. sections centered on the trail. These actually are beneficial as they help center and narrow traffic, which effectively narrows the trail in their vicinity. Also remove fallen branches and sticks from the trail corridor.

Tree Branches: Your goal in pruning trees is to minimize future maintenance work. Cutting the end of a protruding tree branch will cause it to send out several new shoots that will require additional pruning work by the next trail maintainer! Instead, cut tree branches < 1 in. from the main trunk – always make a small undercut first followed by a top-cut to prevent stripping bark from the tree.

Tree saplings (<2 in. dia.), shrubs and raspberry canes: If growing within the 6 ft trail corridor these should be cut close to the ground to prevent a tripping hazard. It is better to remove shrubs and canes from the trail corridor as trimming them higher can stimulate growth that quickly obstructs hikers. All cuttings should be thrown butt end first as far from the trail as possible, not left along trailsides.

Ground Vegetation: Gasoline powered string trimmers or weed cutters with a grass-brush blade are an efficient means for quickly removing taller herbs and grasses that obstruct the trail. Whenever possible, be selective in cutting herbs and ferns, leave plants that grow close to the ground and target only those that have or will grow tall enough to overhang the trail. Learn how to identify the non-native (exotic) species of plants that grow in your area and take the time to remove these plants whenever possible. It's best to cut all of these plants, even those ranging up to 20 ft from the trail as the mature plants often produce considerable seed that will fall and colonize the trail corridor due to the greater daylight it provides.

Safety

Trail work involves working with tools that may be unfamiliar in terrain with unstable rocks and footing. Carry a good first aid kit and a communication device and know how an injury will be evacuated before you set out. Break workers into smaller groups guided by a knowledgeable leader. Start trail work with talks about tool safety. Workers should wear long-sleeved pants, sturdy boots, gloves, and hard hats when possible. Participants should always remain outside the reach of anyone swinging a tool and overhead swings should be avoided. Maintain a firm grip on all tools, including when carrying them. Watch out for branches that can interfere with a swing and unstable footing. Point out poison ivy to others and stay hydrated and cool.

Recommended Trail Construction/Maintenance References

Birchard, W. and Proudman, R.D. (2000) *Appalachian Trail Design, Construction, and Maintenance*. 2nd ed. Appalachian Trail Conference, Harpers Ferry, WV.

Birkby, R.C. (1996) *Lightly on the Land: The SCA Trail-Building and Maintenance Manual.* Student Conservation Association, Inc. The Mountaineers, Seattle, WA.

Demrow, C. and Salisbury, D. (1998) *The Complete Guide to Trail Building and Maintenance*. 3rd ed. Appalachian Mountain Club Books, Boston, MA.

Hesselbarth, W. and Vachowski, B. (2007) *Trail Construction and Maintenance Notebook.* USDA Forest Service, Technology and Development Program, Missoula, MT. Order free copy at: http://www.fhwa.dot.gov/environment/rectrails/trailpub.htm

IMBA. (2004) *Trail Solutions*. International Mountain Bicycling Association, Boulder, CO.

Note: The IMBA book is perhaps the most comprehensive and best single source of information on trail design, construction and maintenance. In particular, look here for detailed design and construction practices for building tread, switch-backs, and stream crossings.

Developed by Jeff Marion, jmarion@vt.edu. Some figures and text were borrowed or adapted from the listed references and online resources.