PCTA Trail Skills College Curriculum

Instructor Planning Guide

Course 102. Tread and Drainage

Water and gravity constantly threaten our trails and thus we must learn how best to deflect them. This course begins with basics of hillside hydrology and how trails work when they shed water properly. Includes introduction of “trail eyes” and basic trail design concepts, as well as how to recognize tread erosion patterns. Hands-on practice removing slough and berm, and effective cleaning and maintenance of existing water bars and grade dips. Tread and drainage work doesn’t require big muscles, though it is fairly strenuous.

STUDENT SKILL OUTCOMES:

- A basic understanding of hillside hydrology and how trails should work.
- How to identify cupped tread and restore it to appropriate outslope by removing slough and berm.
- Ability to identify and clean drain dips and water bars effectively and how to upgrade old school water bars.
- Developing “trail eyes” and an eagerness to hike on a rainy day to learn to “think like water”.

KEY TERMS:

Tread, drain dip, grade reversal, water bar, slough & berm, outslope, cupped tread

TRAIL MAXIM:

“Think like water” or “See water flowing on the trail, even on a sunny day.”

TOOLS NEEDED PER 8 STUDENTS:

2 fire shovels, 2 McLeods, 2 adze hoes, 2 Pulaskis, 1 pick mattock, 1 small rock bar, 2 rheinhards, and/or any other tools used commonly for drainage work in your area. Tennis ball or orange.

WORK SITE REQUIREMENTS:

One half mile section of trail, ideally close to the trailhead, that includes a mix of drain dips and water bars that need cleaning. Ideally, a few of these structures would need reconstruction from “old school” to “modern”. In addition, the trail should have some cupped tread and slough & berm to remove.

KEY CONCEPTS:

1) Safety Documents and Concerns:
   - Personal Protective Equipment (PPE), Job Hazard Analysis (JHA)/ Tailgate Safety Session (TSS), Emergency Action Plan (EAP)
2) Trail Crew Leave No Trace: Have a positive impact on the land through trail work and be sensitive to off trail and camping impacts.
3) Proper/ Improper Tool Care and Use:
   - Shovel, McLeod, Pulaski, adze hoe, Rheinhard, pick mattock, rock bar
4) Develop “Trail Eyes”:
   - Suggest hiking in rain to better understand water on trails
   - Have people critique drainage structures and tread features
5) Hillside Hydrology/How Trails Work:
   - Effects of water in diverse soil types
   - Ideal tread conditions:
     – Sustainable grade
     – Proper out-slope and sheet flow > no trail cupping, berms, or slough
     – Frequent drainage structures > grade reversal, drain dip, or waterbar (rock or log)
6) Tread Work and Cleaning Drainages:
   - Reestablish proper outslope by removing berm and slough
   - Cleaning of Drainage structures:
     – Drain dip and waterbar (rock or log):
       ▪ Clear dip and outfall ditch of any plants, roots, debris
       ▪ Reestablish the apron and backramp, pack soil well
     – If possible, replace any “old school” waterbars with newer design
     – Inside ditch: if present, keep clear and reestablish in-sloped tread
7) Report Work Promptly

BACKGROUND

Hillside Hydrology **and How Trails Work:** Water from rain, melting snow and seeps is a major threat to trails. In a perfect trail world, when water ***sheet flows*** down a hillside and encounters a trail with good ***outslope***, it immediately crosses the trail and continues down the hillside without causing any ***erosion*** of the trail ***tread***. In the worst case, hillside sheet flow is interrupted and follows the trail instead. As the water gains volume and speed on steep ***grades***, it erodes a trail into a deep gully filled with rocks and roots left behind after the soil has been carried away.

This can happen all at once in a major storm event, or slowly over years due to a lack of trail maintenance. Regardless, the outcome is the same: a trail difficult to use and sediment carried downhill, often into streams causing habitat damage. Such a trail needs major reconstruction or to be abandoned. But it doesn't need to happen, if trail workers work to prevent it; and that is the objective of this class.

In a more typical trail world, diverse circumstances cause tread erosion in varying amounts. Trails in soft soils, and especially on steep grades, are at most risk of erosion. In such conditions, trail users (hikers & horses on the PCT) loosen tread soil as they walk along. When water comes along (and to a lesser extent wind), the loosened soil is carried away leaving a concave or ***cupped tread***. Simple compaction of soft soils exacerbates cupping.

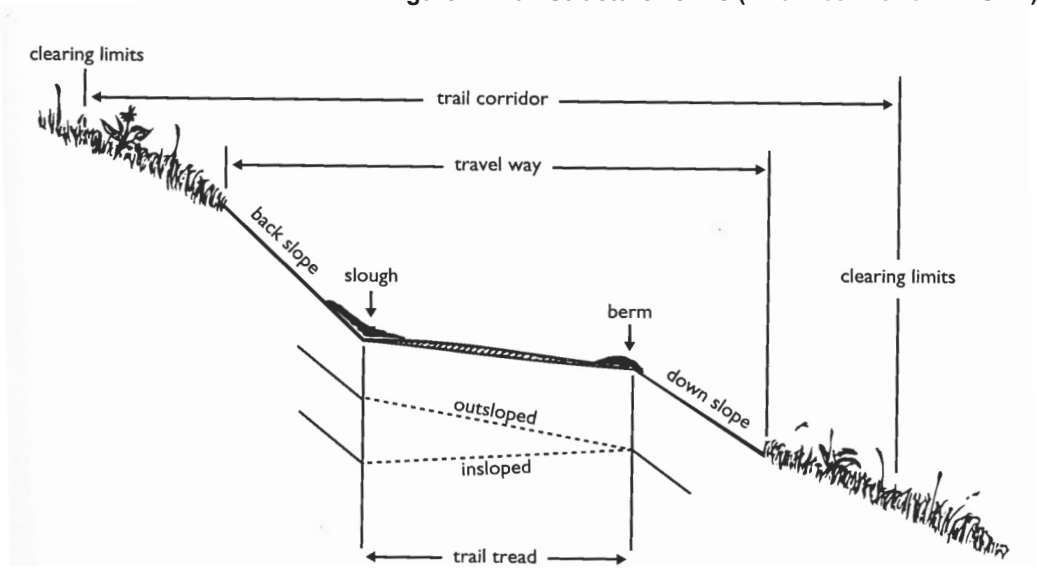
Some of the loosened soil is displaced to the downhill side of the tread, where combined with leaves and needles, it forms a ***berm***. Berm by itself, or combined with cupped tread, disrupts the outslope of ideal tread and prevents water from leaving the trail.

The same process that forms berm happens on the uphill side of the tread, often exacerbated by additional material falling onto the trail from the ***backslope***, creating what is called ***slough***.

Water moves on steeper trail grades, giving it more force it has and thus eroding more soil. Greater water volume also increases the amount of soil that can be moved. Thus to protect a trail from erosion three things need to happen: 1) reduce the amount of water running down a trail; 2) reduce the speed of the water moving down a trail; and 3) reduce the erosive force of users' feet loosening the soil.

The best way to achieve these objectives is by good ***trail design*** and construction, whereby a new trail is built with modest grades (less than 15%), passing only through durable soils, and includes ***grade reversals*** at regular intervals that naturally shed water (www.imba.com/resources/trail_building/up_down.html). In addition, such an ideal trail is well constructed to precise standards with generous outslope on a well-compacted full ***bench*** (www.imba.com/resources/trail_building/contour.html) .

Figure 1. Trail Structure Terms (Image courtesy of the SCA)



Alas, because many trails had unskilled designers, poor construction, today trail volunteers often work on trails with erosion problems. To remedy such problems the two

most common solutions are to construct either earthen ***drain dips*** (aka rolling grade dips) or ***water bars*** made of rocks or a log.

It is important for students to understand that the natural aging process of trails requires vigilant maintenance. If neglected, the problems will only grow worse and require major reconstruction or abandonment. In some cases poor design, construction and maintenance have exacerbated such problems. This all adds up to trail workers facing much work to do to improve tread and prevent further erosion. But that gives us lots to do!

PCT ***trail stewards*** need to identify the portions of their trail section that need the most drainage work and give them special attention.

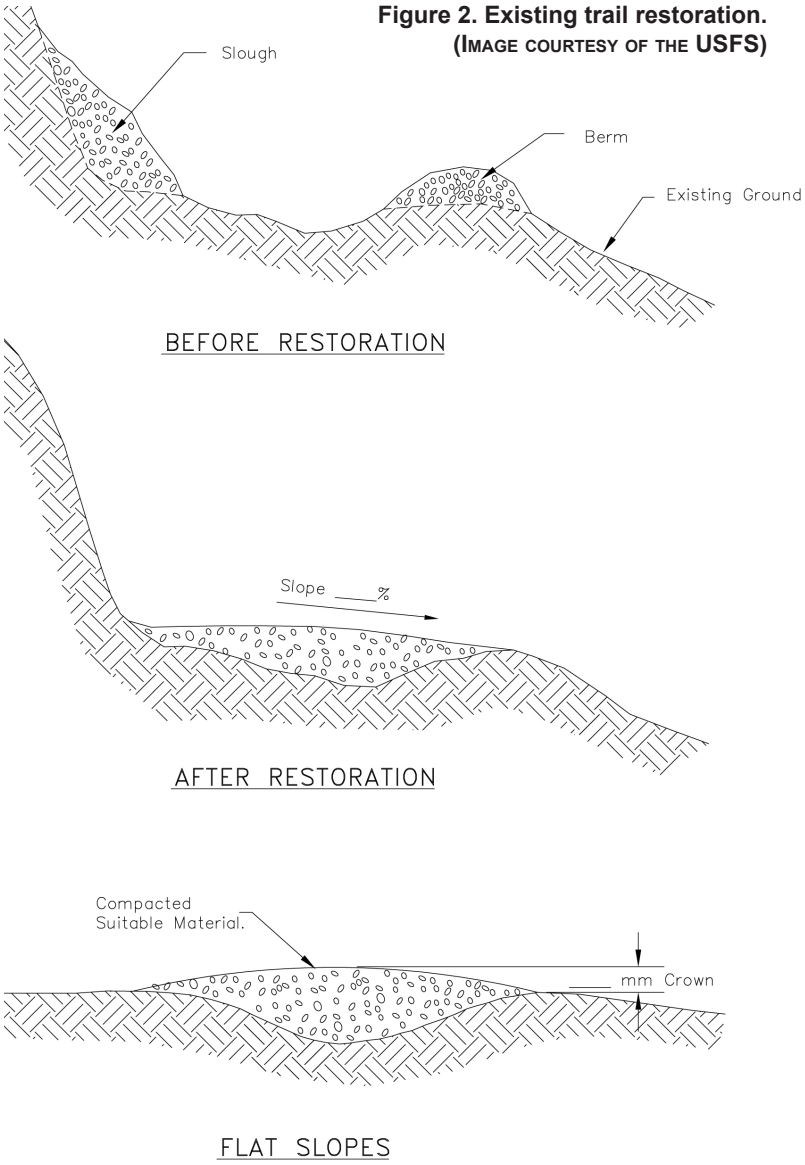


Figure 2. Existing trail restoration.
(Image courtesy of the USFS)

Tread Work & Cleaning Drainages:

While there are dozens of ways to improve the tread and drainage of any given trail, new trail workers should focus on just two: 1) removal of slough and berm to fill cupped tread and re-establish outslope, and 2) cleaning existing drain dips and water bars.

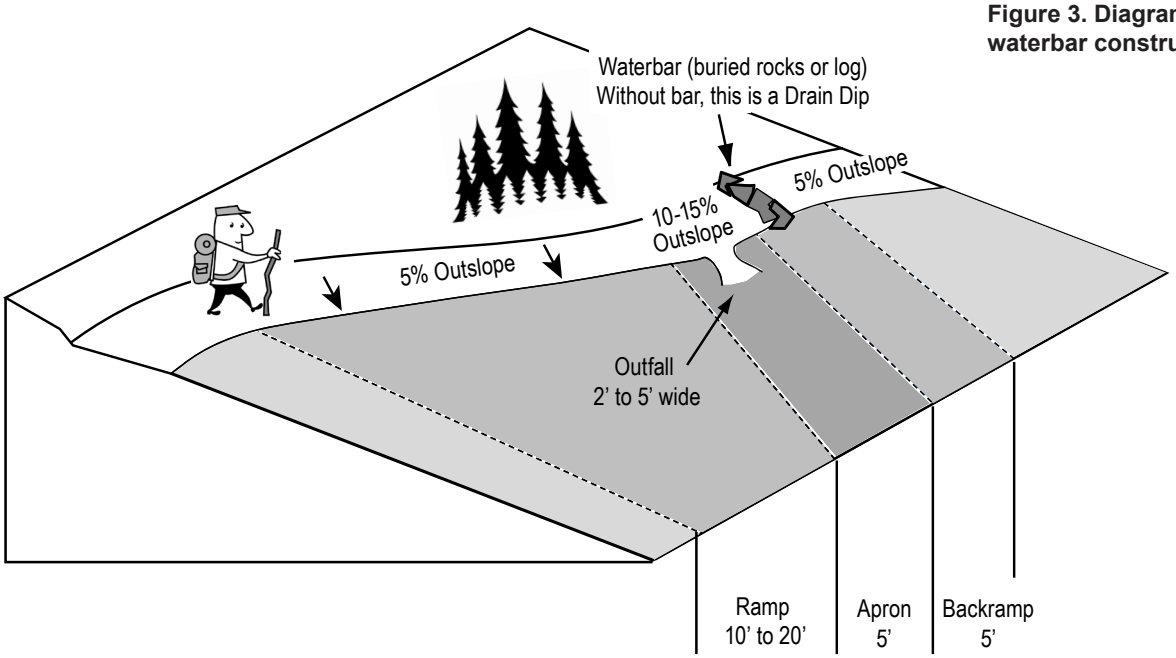
Slough and Berm Removal:

Under normal circumstances this would be done only in specific areas identified as critical for drainage. This is because it is impossible to keep an old trail completely free of slough and especially berm. It is important to remove them in areas where tread cupping has started, though if water is running on the trail, be sure to clean any drainages up hill of the problem. If that is not the problem a new drainage structure is likely needed uphill to prevent further cupping.

Cleaning Drain Dips and Waterbars: There are many variations on drain dips and water bars that can be seen from trail to trail. To keep things simple for beginners, instruct them simply to clean what they find and, as time allows, to make modest improvements to move the drainages toward the PCTA standards described below.

Waterbars have been built for decades and until recently were constructed so that running water was deflected off the trail by directly hitting the rock or log bar. It is still common to see such outdated drainage structures, which PCTA calls ***"old school" water bars***. (Soil conditions in some areas of the PCT do require "old school" water bars; consult your local agency partners if there is a question as what the preferred drainage feature is for your area.) Their design flaws include: 1) they fill with sediment rapidly; 2) the exposed bars are damaged by horses; 3) the bars are often eventually eroded out completely, and 4) they are abrupt, detracting from users trail experience.

Figure 3. Diagram of modern waterbar construction



Contemporary water bar design favored by PCTA is a broad earthen drain dip, reinforced at the the high point of the ***backramp*** with a completely buried log or line of tightly fitted large rocks. See diagrams and "Key Concepts" above for drain dip and water bar specifications. It is possible to convert "old school" water bars into the contemporary style.

All excavation should be gradual so users hardly notice the drainage structure as they walk through it. Sculpt the structures so water exits with increasing speed by accentuating the outslope of the whole apron so that it is greater than the trail's outslope. This helps to insure that the structure is somewhat self-cleaning, thus requiring less maintenance.

Clear the ***outfall ditch*** to carry water away easily. It should be 18-24" wide and end 12" below where it leaves the tread. On flat ground or fall line trails, extend the ditch as far as it needs to go to keep water from returning to the trail. It is essential to remove any rocks, fallen logs, branches, or saplings that obstruct the outfall ditch. All loose dirt and debris excavated from the outfall ditch should be moved to the down hill side of the ditch to help divert water away from the trail–NOT into the path of the flowing water.

For drain dips, use any good moist dirt (not organic debris) from excavating the apron to accentuate the height and length of the back ramp, being sure to compact it well.

For water bars, spread and compact excavated soil on both sides of the bar to protect it from erosion. Bury log and rock bars completely so they are just barely showing, insuring that water exits well before bar. For both drain dips and water bars, if there is excess moist dirt, look for cupped tread to fill down the trail from the drainage–never let good dirt go to waste.

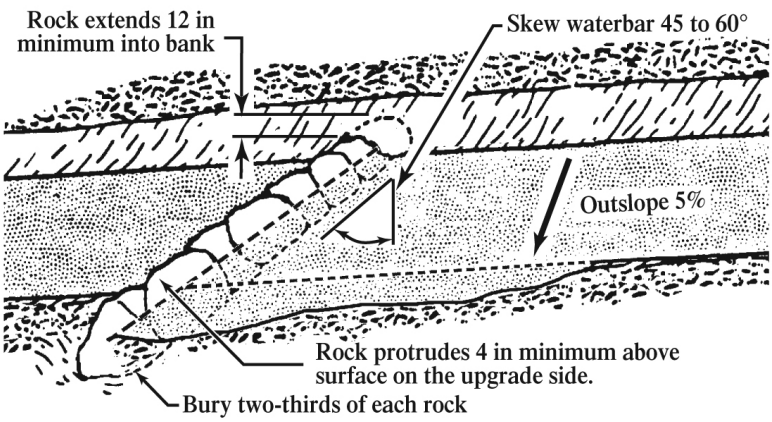
Show (or if none available, describe) "old school" water bars and how they can be converted by re-sculpting the dip further away from the bar and ramping well-compacted dirt on both sides of the bar.

Finally, to test drainages, roll a tennis ball or orange to test efficacy of the final work–it should easily leave the trail.

Note: While it is possible to clean clogged drainages at any time of year, in loose dry soils that do not cohere well, it is impossible to durably restore degraded tread and drainages, or convert "old school" water bars. Such work must be done when there is adequate moisture in the soil so that it can be well

compacted with McLeods and boots. The ideal time is just prior to winter when fall rains have moistened the ground and winter snow will further compact the work. Ideally, material is compacted so that a thumb pressed into the dirt will not penetrate more than a quarter inch–this takes persistence.

Figure 4. "Old School" rock water bar. (Image courtesy of the USFS)



Inside ditch: These may be common in wet terrain with seeps; they must be kept clean and open, adequate to handle the flows they receive.

Explain that the greater the volume and force of expected water running down the trail, determines the size and frequency of drainages needed, whether drain dips, water bars or inside ditches.

Trail Crew Leave No Trace: Students may protest, 'Our job is to leave a trace.' It's true that trail work has an impact on the land… but the work that is completed is meant to reduce overall impacts on the land. There are ways to bring Leave No Trace ethics into all the work completed on the trail, including how we go about completing projects, where we choose to camp and take breaks, and how the crew behaves in relation to other visitors and wildlife. It is important that we foster a Leave No Trace ethic since we are a model for other public land users and are in the position to influence other's behavior.

- Be respectful of other visitors: minimize visual impacts, rehab cut banks and other landscape scars made during work, store tools and take breaks off the trail, and hide brush whenever possible.
- Travel and take breaks on durable surfaces: keep off trail disturbance to a minimum.
- Dispose of waste properly: pack out garbage you find or create, and dispose human and pet waste properly.

TEACHING TIPS & TECHNIQUES

Trail Maintenance to Reduce Erosion: Demonstrate the proper stance and technique for each of the tools to minimize body strain. To reduce back strain bend the knees, have a powerful core, keep legs well apart, and use a rocking motion that uses the whole body.

Encourage each student to try all the tools and then decide which two they would choose, if they were to carry only two tools for a day of tread and drainage work. They should see that everyone has their own preferred tools depending on body type and other factors.

Work with them closely to be sure they maintain at least one (and preferably several) well formed drain dips &/or water bars. It is essential that they not carry forward bad habits that may not be broken for years.

Inform students that after they gain proficiency in these skills, they will later learn how to construct new drainage structures. And, with even more experience, they will learn how to select the best locations for such structures. But first practice, practice, practice the basics of tread and drainage maintenance.

Trail Eyes: The best way for new trail workers to understand drainage issues is to walk trails on a rainy day, the rainier the better. Encourage students to get a pair of rubber boots and an umbrella, in addition to rain gear, so they can be comfortable examining closely how water interfaces with trails. Ask

them to notice how water sometimes sheets off hillsides, accumulates in small rivulets and then crosses an outsloped tread. Where berm or cupping exist see how water follows a trail, carrying loose sediment to drainage structures. Notice how sediment is either carried away or is deposited in various parts of structures. The ultimate goal of seeing water in action is to develop the ability to "think like water" and "see how water might run down a trail, even on sunny days" so that they can maintain effective drainage structures.

See discussion in the curriculum overview for other ideas to help students develop their Trail Eyes. Make sure they notice all drainage structures needing to be cleaned. Nearly full drain dips are the most easily missed. A drainage treasure hunt at the end of the day would be a good final exam, in addition to demonstrating the other "Student Skill Outcomes" listed above.

TRAIL FUN

For a fun wrap-up do a fast-paced "Jeopardy"-style quiz based on the KEY CONCEPTS.

REFERENCES

Drainage Structures. OSI Trail Skill Series. Outdoor Stewardship Institute, a program of Volunteers for Outdoor Colorado. 2009. www.voc.org

Natural Surface Trails by Design: Physical and Human Design Essentials of Sustainable, Enjoyable Trails by Troy Scott Parker. 2004. www.Natureshape.com $30. This is the most comprehensive reference on the theory of trail drainage. It digs into the many factors that affect the durability of trails, such as hillside hydrology, soil types, surrounding vegetation, user types, etc. Excellent discussion of trail design, switchbacks, drain dips, and other features, and especially what makes them sustainable. For trail wonks, this book is a must, but only for trail wonks:-)

Trail Solutions: IMBA's Guide to Building Sweet Singletrack. 2004. International Mountain Biking Association also has some excellent online resources. www.imba.com/resources/trail_building/index.html

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Field Reference

Course 102. Tread and Drainage: Protecting Trails from Erosion

STUDENT SKILL OUTCOMES:

- A basic understanding of hillside hydrology and how trails should work.
- How to identify cupped tread and restore it to appropriate outslope by removing slough and berm.
- Ability to identify and clean drain dips and water bars effectively and how to upgrade old school water bars.
- Developing “trail eyes” and an eagerness to hike on a rainy day to learn to “think like water”.

KEY TERMS:

Berm: the mound of soil that develops at the outside of tread. Berm disrupts tread out-slope and prevents water from leaving the tread to the down-slope.

Cupped Tread: trail tread that is dished out by users feet loosening the soil and then water (&/ or wind) carrying the soil away. Such tread holds water on the trail leading to cupping erosion on grades above a few percent.

Drain Dip: (aka ***dip, drainage dip, earthen water bar, and rolling grade dip***; a close cousin but different from a ***grade dip, Coweeta dip, knick, swale and bleeder***.) A broad, gradual excavated trail feature to shed water off the trail at regular intervals to prevent tread erosion by interrupting the normal grade of a section of trail. Soil excavated is mounded and compacted down the trail from the dip. Ideally 15-30’ long and 8-12” deep. To withstand horse use, drain dips should only be built in very durable soil with trail grades below 10-12%, ideally in the late fall when the soil is moist and just before winter, allowing snow to compact the dip before use in the spring.

Grade Reversal: regular ups and downs designed into a trail allignment is the best way to shed water from a new trail. Such ups and downs can be added to an existing trail with great labor by constructing water bars and drain dips (aka ***rolling grade dip***) imba link

Out-Sloped Tread: a trail surface that tilts to the downhill side of the trail to shed any water that arrives from above. Trails should be constructed and restored with 8-16% outslope (1-2” of drop per 12” of tread width) so that they will age to hold 5-10%. Less durable soils require greater outslope. On rare occasions tread is in-sloped, shedding water to an inside ditch just uphill of the trail, later crossing the trail through a culvert or other drainage structure.

Tread: the surface of a trail, on which users walk or ride.

(Rock or Log) Waterbar: (aka ***(rock or log) reinforced drain dip***). As constructed by the PCTA, this trail drainage structure includes a drain dip reinforced by a peeled log or row of large rocks. The reinforcing log or rocks are buried securely at about a 45 degree angle across the tread and 36” down the trail from the bottom of the dip–thus water leaves the trail well before it reaches the log or rocks. Waterbars are generally required on trail grades in excess of 15%, rather than drain dips. See also, “Old School Waterbar.”

Slough: the debris deposited on the inside of tread at the base of the back-slope, primarily delivered by gravity from the back-slope above. Its accumulation causes the tread to narrow, forcing users to the out side of the tread, which can lead to collapse or tread slip.

KEY CONCEPTS:

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   - Personal Protective Equipment (PPE), Job Hazard Analysis (JHA)/ Tailgate Safety Session (TSS), Emergency Action Plan (EAP)
2) Trail Crew Leave No Trace: Have a positive impact on the land through trail work and be sensitive to off trail and camping impacts.
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4) Develop “Trail Eyes”:
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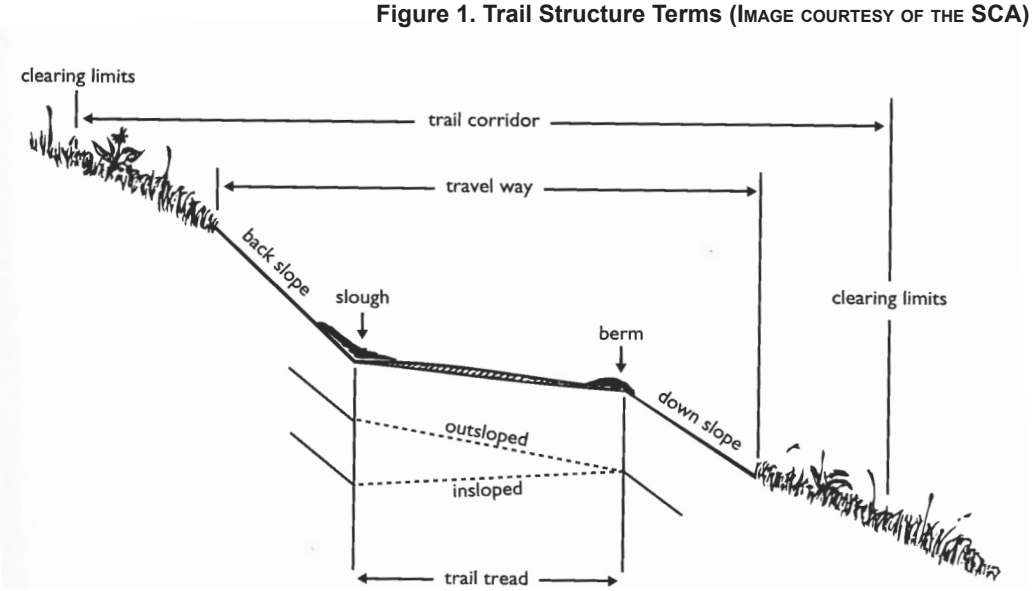

water on trails
  - Have people critique drainage structures and tread features

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   - Effects of water in diverse soil types
   - Ideal tread conditions:
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     – Frequent drainage structures > grade reversal, drain dip, or waterbar (rock or log)
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7) Report Work Promptly

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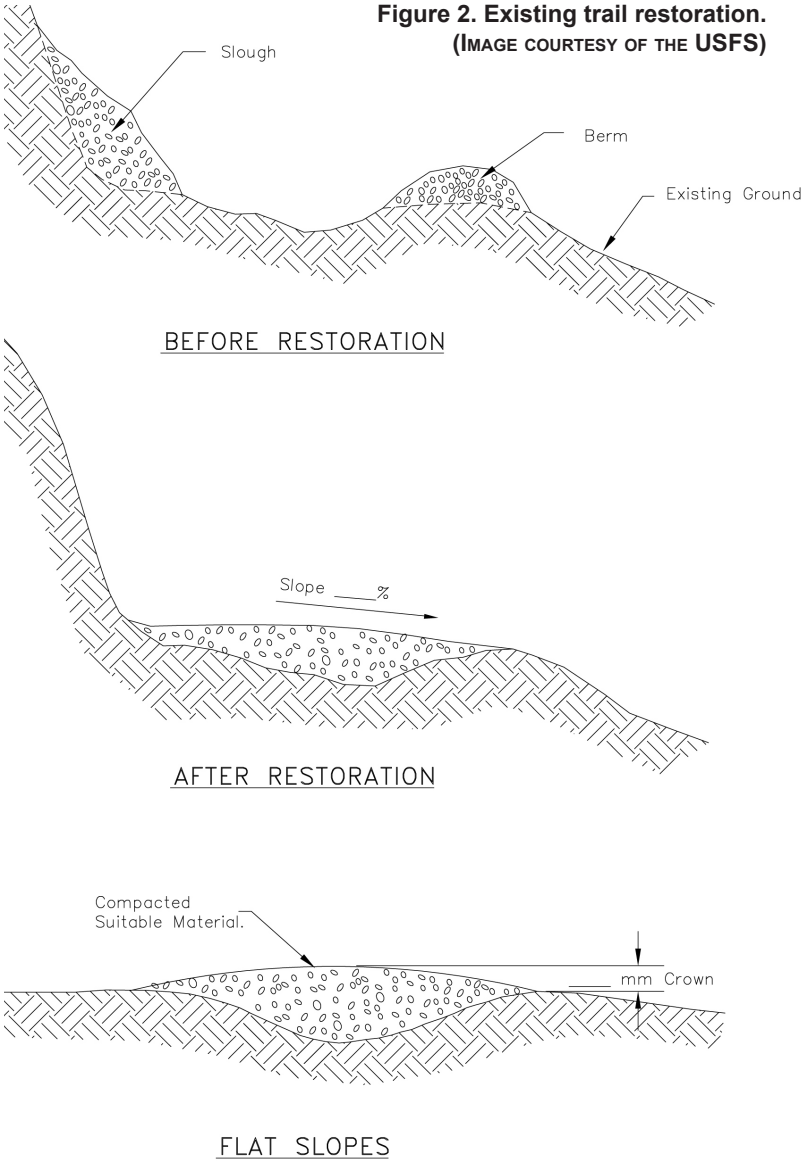

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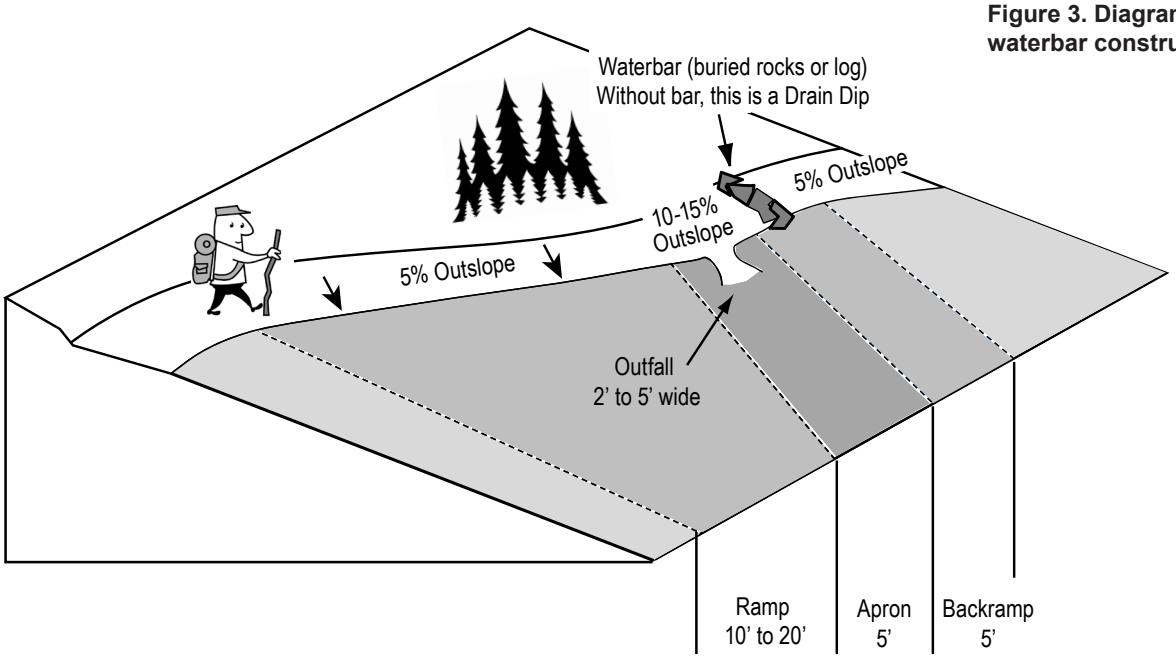

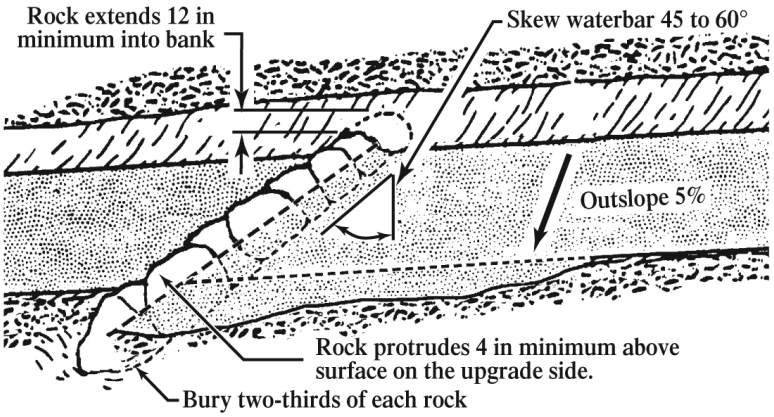

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