PCTA Trail Skills College Curriculum

Instructor Planning Guide

Course 201. Drainage Design & Drain Dips

Intended for someone who has taken 102 Tread & Drainage and/or has experience doing drainage work. Learn how to design and locate effective drainage structures. After a comprehensive explanation of hillside hydrology and how trails work when they shed water properly, this class shows students how to design and construct long, rolling drain dips as a way of reducing erosion on existing trails.

STUDENT SKILL OUTCOMES:

- A basic understanding of hillside hydrology, drainage principles, and how trails should work.
- How to identify the best location and construct new drain dips on existing eroded trails.
- Developing “trail eyes” and an eagerness to hike on a rainy day to learn to “think like water.”

KEY TERMS:

hillside hydrology, out-slope, sheet flow, berm, slough, grade reversal, drain dip, rolling grade dip, backramp, apron, outfall ditch

TRAIL MAXIMS:

“Think like water”; “See water flowing on the trail, even on a sunny day.” “If it’s worth doing, it’s worth doing well.” “A job well done will be little noticed, and stand the test of time.”

TOOLS NEEDED PER 8 STUDENTS:

1 fire shovel, 2 McLeods, 2 adze hoes, 2 Pulaskis, 2 rheinhards, 40 pin flags, 4 rolls flagging tape; 2-4 clinometers, 2-4 measuring tapes, 4 marking pens, and a tennis ball or orange

WORK SITE REQUIREMENTS:

One half mile section of trail, ideally near a trailhead, in need of repair and/ or new construction of earthen drain dips. Ideally a trail that has grades of less than 10% with durable moist soil suitable for earthen structures.

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:
    - Fire shovel, McLeod, adze hoe, Pulaski, Rheinhard
4) Hillside Hydrology/ How Trails Work:
    - Effects of water in diverse soil types
    - Out-slope and sheet flow
    - Trail grade and cupped tread
    - Grade reversals and drainage structures
5) Develop “Trail Eyes”:
    - Suggest hiking in rain to better understand water on trails
    - Notice every drainage, even disappearing ones
6) Locating New Drain Dip Sites:
    - Locate areas of erosion, fix any existing dips, reevaluate
    - Berm and slough removal vs. new drainage structure
    - Trail conditions for a new drain dip
        – Grade less than 10%, moist durable soil, avoid top or bottom of hill
        – Spacing between drainages determined by grade, soil, volume of water
    - Trail conditions that call for reinforcement of the dip with rock or log (Waterbars are covered in Course 203)
7) Constructing New Drain Dips:
    - Build a broad gradual apron
        – 20 – 30’ in length
        – 15% or greater out-slope to help self clean
    - Excavate a 24” wide outfall ditch
        - Extend below tread as far as you need to keep water off trail
    - Pack soil VERY well
    - Test drainage with tennis ball
8) Report Work Promptly

BACKGROUND

Trails must shed water or they will erode over time until they are difficult to use. Such erosion can also damage plants and streams, as well as become unsightly. Providing effective drainage for trails is a complex challenge that has led to development of a wide variety of techniques, some of which, though still used some places, do not work very effectively.

As a result, in the array of trail work manuals, there is a very confusing range of conflicting advice and terminology. Some of this arises from the dramatically different terrain, soils, vegetation, and types of trails found across the country. But mostly it is because there is not clear consensus among trail workers on just what should be done. We'll do our best to make sense of all this here, but in truth, it is a work in progress that needs refinement.

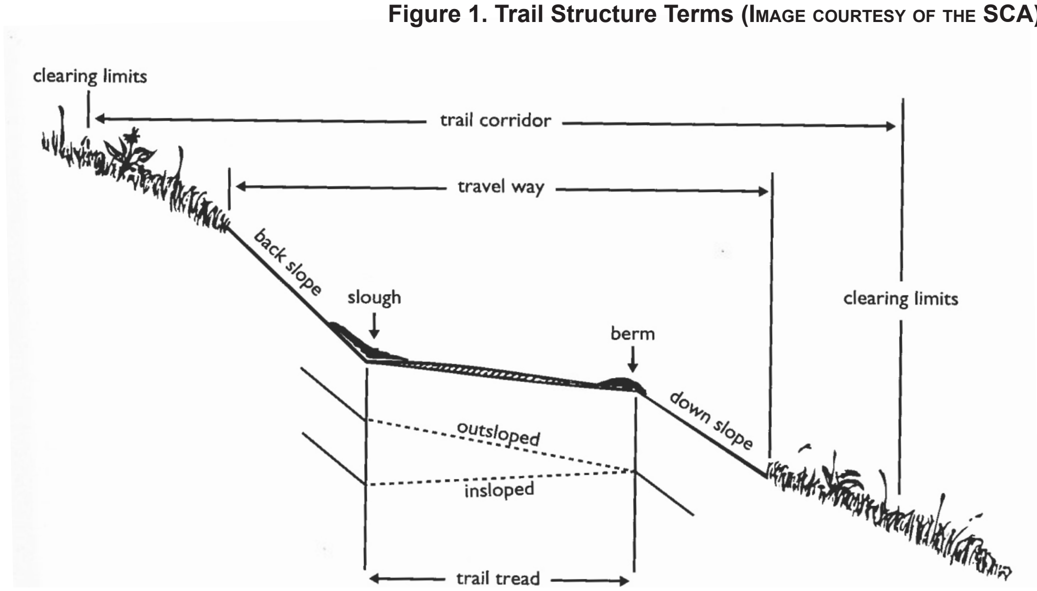
Hillside Hydrology **and How Trails (are supposed to) Work:**
Water from rain, melting snow and seeps is a major threat to trails. In a perfect trail world, water traveling down a hillside encounters a trail with good ***outslope*** and immediately crosses the trail and continues down the hillside without causing any ***erosion*** of the trail ***tread***. In the worst case, hillside water 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 prevent it; and that is the objective of this class.

In a more typical world of trails, 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 and horses on the PCT) loosen tread soil as they walk. 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 moved 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.

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



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 faster on steeper trail grades, giving it more force and thus eroding more soil. Greater water volume also increases the amount of soil that can be moved. To protect a trail from erosion one or more of 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 (http://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 (http://www.imba.com/resources/trail_building/contour.html).

Alas, because many trails had unskilled designers and poor construction and/or maintenance, today trail volunteers often must 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) (http://www.imba.com/resources/trail_building/gradedips_2.html) or modern style ***waterbars*** made of rocks or with 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 decommissioning the trail. 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 volunteers need to identify the portions of their trail section that need the most drainage work and regularly give them special attention.

Quality Work: Drain dips have been built for decades and until recently were constructed as sudden sharp ditches across the trail, or if more gradual, still much too short. It is still common to see such outdated drainage structures, which PCTA calls ***"old school" drain dips***. Their design flaws include: 1) they fill with sediment rapidly; 2) they are easily damaged or eroded out completely by horses; and 4) they are abrupt, detracting from users trail experience and sometimes causing them to leave the trail to avoid them.

Locating New Drainage Structures on Existing Trails: There are probably as many ways to select sites for new drainages as there are experienced trail workers. The bottom line is that new ***drainage structures*** on existing trails should be laid out very carefully, because constructing them properly is a huge amount of work, as is maintaining them over the years. It is essential not to have trail crews do work that is unnecessary or ineffective. Ideally, a trail worker will have installed many drainage structures, closely supervised by an experienced trail worker, before they take on drainage lay out, again closely supervised. Every time you mark a location for a new drainage structure, stop to think, "Is this the right place that warrants the labor to construct and maintain if for the next 20 years?" In other words, new drainage structures require very keen trail eyes. Keep this in mind for the entirety of this course. It is also important to recognize that adding new drainage structures is a kind of trail patching. The goal is to use keen trail eyes to find the most important locations for drainage structures for a trail and then to construct them appropriately.

The simplest method to locate new drainages, used only by experienced trail workers, is to walk a trail using keen trail eyes to identify places where noticeable erosion has begun. Always carefully evaluate whether improving outslope (by berm removal) in critical areas might be an efficient solution. Soft or sandy soil types will not sustain outslope, nor will steep trails with heavy use, especially by horses. Trails through recently burned forest may be especially fragile and not suitable for outsloping. If berm removal is not appropriate, then carefully consider where to mark locations for installation of new drainage structures. The key is to divert water off the trail before it does significant damage to the trail. Especially look for long descending sections of insloped and/or cupped tread where water clearly runs regularly and is carrying away soil. Heavy soil deposition in drainage structures, or at the bottom of a slope, is an indication of erosion up the trail.

There are three factors that may call for installation of more frequent drainage structures: steeper trail grades, the frequency and quantity of water that runs down the trail, and softer soils. Use pin flags or stakes to mark the precise locations and write on them the type of structure to be installed. This sounds simple enough, but actually it is a fine art if all the factors are considered and only the right amount of drainage is added.

Here is another more elaborate multi-step approach, better suited to beginners.

First, walk the trail, flagging the beginning and end points of sections that show evidence of erosion. Cupped tread or gullying are the most obvious symptoms. Walking a trail during or just after heavy rain or snow runoff is the best way to see clear evidence of active water erosion.

For each eroded section marked, walk up hill to see if an existing drainage has failed and is sending water down the trail. If that is the case, fix the uphill drainage first and then reevaluate if the erosion seen down hill might still need additional drainage structures. That might not be possible until you repair the tread damage and then observe the trail again during or after the next rain event.

If the soil type is durable (see chart below) and the grade is less than 15%, consider if removing slough, berm, and cupped tread in key locations is sufficient to solve the drainage problems. Another alternative to consider is complete ***tread reconstruction*** whereby a new trail bench is cut, though this also is a major undertaking.

After fixing failed drainages and ruling out alternatives, evaluate a section of eroded trail to locate new drainage structures, ideally, by doing the following:

Use a clinometer to measure the trail ***grade*** in percent (not degrees). Most water erosion occurs on grades more than 5% and is especially severe above 15%. If the trail is less than 5% and there is still erosion, it may be caused by something other than water, such as wind combined with physical abrasion of trail users. If the erosion is not caused by water, building drainage structures will not stop such erosion. Only ***trail hardening*** or relocation of the trail can make a difference for such trails. However, not every gullied trail can or should be fixed, when compared to all the other trail maintenance that is needed. Remember the idea of ***trail triage***- when there is more work to do than available labor (almost always), we must make choices about which work to do now and what to postpone. Usually problems that threaten the safety of users or are causing serious erosion are top priority. A supervisor may provide guidance with trail triage decisions, but ultimately all trail workers need to develop their own critical thinking skills.

A certain amount of tread damage is normal and acceptable, depending on the ***intended users*** and intended ***difficulty level*** of the trail. For example, a trail intended for wheelchairs must be kept nearly perfectly flat.

Measure how much tread soil has been lost by estimating the depth of cupping or gullying compared to the original tread surface. To do this, lay a tool handle across the trail from ***inside edge*** to ***outside edge***, and then measure from the handle to the bottom of the cupped or gullied tread. Some cupping and gullying may have occurred from simple compaction of soft soil or wind blowing away fine dirt kicked up by users feet. The goal is to guestimate how much tread has been lost to flowing water over the years since the trail was newly constructed or reconstructed. If less than 3 inches has been lost in 10 or more years, adding drainage structures may not be essential compared to other priorities. Trails that erode very slowly may have very durable soils, little use, and/or forest canopy that deflects water from reaching the trail tread.

If the tread is obviously eroding actively from water flow, mark the spot with a pin flag where you estimate the erosion first becomes obvious. Again, this is best done just after a heavy rain or snow melt. You will likely build a drainage structure near this spot, unless you are less than 30’ from the next drainage structure or a grade reversal. Before deciding the exact location for a new drainage structure, look up and down the trail to see if there is an easier place nearby to build it. Such places include slight bends in the trail, just above a large tree or rock, or a place where the berm or gullying is thinnest If there is no practical way to excavate an ***outfall ditch*** any where near by because the trail descends the ***fall line*** and/or is too deeply gullied, consider installing log or rock ***check dams*** to slow further erosion.

In time, a skilled trail worker develops good instincts about where to place new drainages, but until then they must exercise extreme care, and preferably work under an expert's supervision. It is very valuable for even the most seasoned trail worker to have an extra set of eyes on a trail. Multiple people looking at the same piece of trail will have different perspectives. Work on communicating what you see and keep your mind open to nuances that others pick up on. Using multiple perspectives is in the best interest of ensuring quality trail work. There is nothing more frustrating than to build an unneeded drainage structure and maintain it year in and out.

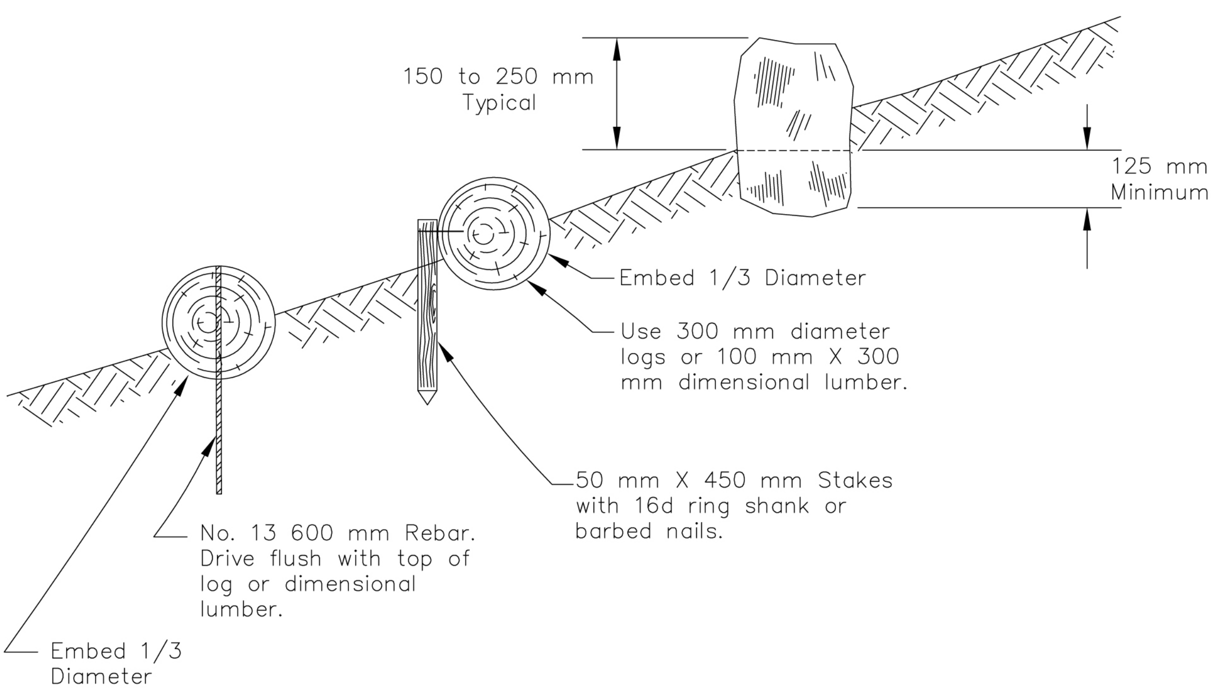
A third way to help determine drainage structure locations is guided "by the book". Below, is a Forest Service Trail Handbook chart suggesting spacing of drainages for specific soil types (because of their varying durability) for different trail grades. Of course you'll need to know how to identify various soil types. The spacings shown are, of course, for sections of trail between natural grade reversals or existing drainages.

An even more elaborate system to determine spacing of drainage structures is described in Troy Scott Parker's Natural Surface Trails by Design. Parker also presents a method to test if a given soil will be sufficiently durable for sustainable trail construction.

Where Not to Locate Drainages: Almost never install a drainage structure too close to a previous one, nor near to or at the top or the bottom of a hill. Trail users with trail eyes will chuckle and wonder why someone wasted so much effort.

What Kind of Drainage Structure to Build: The type of drainage structure chosen for a location also requires very keen trail eyes. When is a drain dip appropriate and when is a water bar? This is a question that is highly dependent on the local conditions and varies from place to place. In general there are two instances when un-reinforced drain dips should be ruled out: when a prevailing grade is greater than 12 percent and when soil conditions are unstable enough that the impact of traveler's feet and hooves will cause the dip to severely erode and lose its purpose. In these instances a log or rock waterbar is more appropriate, because the log or rock armors the drain dip and helps retain the

Figure 2. Check Dam (Image courtesy of USFS)



soil. Choosing the type of drainage structure is an essential critical thinking choice for the trail worker. Experience in choosing types of drainage structures takes time to gain. Talk out options with others and capitalize on common experiences.

Constructing Drainage Structures Overview

Drain Dips: While drain dips can be built in many different shapes and are called by many different names around the country, PCTA encourages only two styles: 1) the rolling grade dip style described by the International Mountain Biking Association (IMBA), http://www.imba.com/resources/trail_building/gradedips_2.html or 2) the design prescribed by Volunteers for Outdoor Colorado (VOC). Both should be very long and gradual, in the 20-30' range, with very steeply outsloped (> 15%) ***aprons***.

For drain dips, use any good moist dirt (not organic debris, rocks or sticks) from excavating the apron to accentuate the height and length of the back ramp, being sure to compact it well. Make sure to not use the top duff layer to fill in the back ramp.

All excavation and ramping should be very gradual so users hardly notice the drainage structure as they walk through it. Sculpt the structures so water exits with increasing speed. This is done by accentuating the outslope of the whole apron so that it is greater than the trail's grade leading into it. By increasing the speed of flowing water this helps to insure that the structure is somewhat self-cleaning, thus requiring less maintenance. Some trailworkers advocate using the IMBA "knick" shape (seen in rolling grade dips) for all drain dips rather than the VOC funnel shape.

Figure 3. Frequency of Grade Reversals or Cross Drains
Source: Forest Service Trails Handbook 2309.18, Chapter 3, Trail Preconstruction & Construction

	Grade (percent)						
Material Type	**2**	**4**	**6**	**8**	**10**	**12**	**15**
Loam	350'	150'	100'	75'	50'	*	*
Clay-Sand	500'	350'	200'	150'	100'	50'	*
Clay or Clay-Gravel	-	500'	300'	200'	150'	100'	75'
Gravel (rounded rock)	-	-	750'	500'	350'	250'	150'
Shale or Angular Rock	-	-	800'	600'	400'	300'	250'
Sand	Varies with local amounts of fine clay and silt. Drainage diversions generally are not required in "pure" sand because of the fast rate of water absorption. For sand with appreciable amounts of fine binder material, use "clay-sand" distances as shown above.						

* Grades not recommended in this material.
- Generally no diversion required for soil stability.

If you use the funnel shape, clear the ***outfall ditch*** to carry water away easily. It should be 24" or wider and end 12" below the level of the tread. On flat ground or on nearly ***fall line*** trails, extend the ditch as far as it needs to go to keep water from returning to the trail (this may be a couple yards long on flat ground). 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.

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.

As mentioned earlier with drainage principles, the volume and speed of water expected to run down the trail determines the size and frequency of drainages needed.

Finally, to test drainages, roll a tennis ball or orange to test efficacy of the final work--it should easily leave the trail. Also evaluate your drainage from a distance to assess if trail users are likely walk or ride around it. If so, install large rocks or logs in such a way to block cutting around, without blocking water

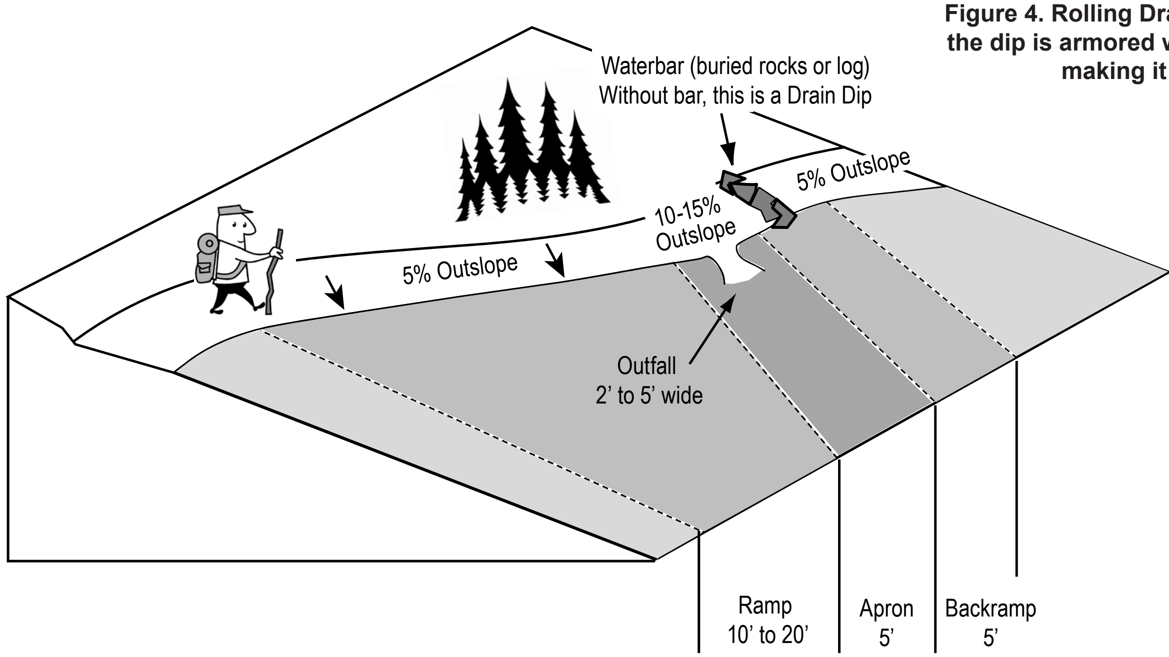


Figure 4. Rolling Drain Dip. In this case the dip is armored with rock (optional), making it a Modern Waterbar

flow.

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, hide brush whenever possible, store tools and take breaks off the trail, and never leave stubs (a.k.a. staubs, pungy sticks) when brushing.
- 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 & pet waste properly.

TEACHING TIPS & TECHNIQUES

While some of the theory portion of this course could be taught in a classroom using a projector or drawing surface, taking students in the field as soon as possible is the best approach. Never stay in a classroom for a drainage class because it is raining. There is no better time to be in the field to see water at work!

Locating and Constructing New Earthen Drainage Structures

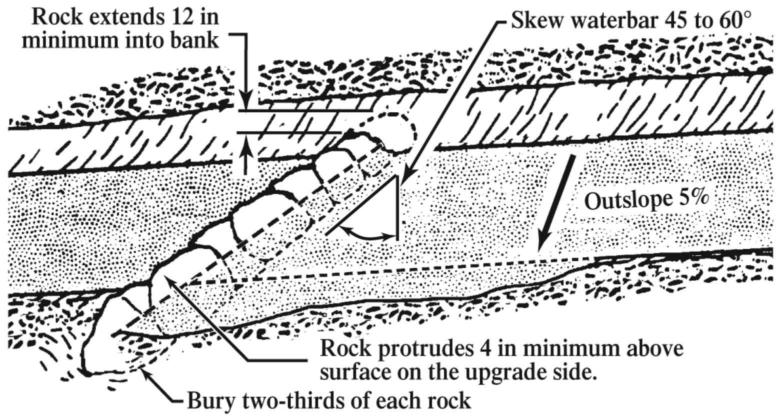
Exercise 1: After reviewing the background concepts with the group on a trail, assign each team of two students a minimum of 200 yards of trail, preferably with as many earthen drainage structures as possible, and ask them to pin flag all drainages.

Next ask them to evaluate in detail two of the existing drainage structures. Ask them to answer the following questions: Is the structure needed? Could there have been an equal or more effective alternative solution? Was it built properly? What kind and how often will maintenance be necessary? Have them offer their critique to the group and then ask for the group's input. Finally offer your own perspective. If there is time and it would be helpful, repeat the exercise on new sections of trail.

Exercise 2: Assign each team of two students 200 yards of trail in need of new drainage structures--it could be the same section of trail as above, though likely not. Provide them a roll of flagging tape and

10 pin flags. Ask them first to flag sections of the trail they believe to be eroding. Then ask them to pin flag the best location(s) of their proposed drainage structure(s). Ask other students to critique the pairs’ conclusions. Offer your own suggestions. Write on the flag the consensus conclusion for construction later. If there is time and it would be helpful, repeat the exercise.

Figure 5. “Old School” rock water bar. (Image courtesy of the USFS)



“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, and can be covered with debris to make them nearly invisible. 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.

Constructing Drainage Structures: It is essential that new trail workers develop high standards for quality work. Simply put, shoddy work isn’t worth the time and effort put into it. See Trail Maxims above.

Have the students work in pairs on the structures for which they selected a location and design. Encourage them to be perfectionists on their first one, emphasizing if it is done correctly and well it will have a long life. The difference between a structure that lasts one year or lasts 10-20 years if often just one extra hour. Clearly it is worth the extra investment. Warn them that you will require them to tear it out and start over.

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 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 build at least one (and preferably several) well formed drainage structures. It is essential that they not carry forward bad habits that may not be broken for years.

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 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 Construction and Maintenance Notebook. 2007. Woody Hesselbarth. USDA Forest Service. Pages 29-37 covers drainage well, though water bar section is not recommended.
http://www.fhwa.dot.gov/environment/fspubs/07232806/page06.htm
http://www.fhwa.dot.gov/environment/fspubs/07232806/page06a.htm

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

APPENDIX

The following material is from course 102 Tread & Drainage. It might be useful if students of 201 have forgotten it or have not had much hands on experience with tread and drainage work since. If that is the case, it will be good to include this material in 201.

Slough and Berm Removal: Under normal circumstances this would be done only in specific areas identified as critical for drainage. It is impossible to keep an old trail completely free of slough and especially berm. Thus remove them in areas where tread cupping has started, though if water is running on the trail be sure to first 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: There are many variations on drain 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.

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. 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. There are some soil types, such as coarse sand or pumice that will never compact well, even in ideal moisture conditions.

Field Reference

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STUDENT SKILL OUTCOMES:

- A basic understanding of hillside hydrology, drainage principles, and how trails should work.
- How to identify the best location and construct new drain dips on existing eroded trails.
- Developing "trail eyes" and an eagerness to hike on a rainy day to learn to "think like water."

KEY TERMS:

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 alignment 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***).

Hillside hydrology: generally describes how water from rain, melting snow, and seeps travels down natural slopes. Here we are especially concerned with how such water interacts with trails. Troy Parker uses the additional term, "tread watersheds", to describe the subsections of a hillside that shed water to a particular piece of trail between two drainage structures.

(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."

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.
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    - Test drainage with tennis ball
8) Report Work Promptly

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

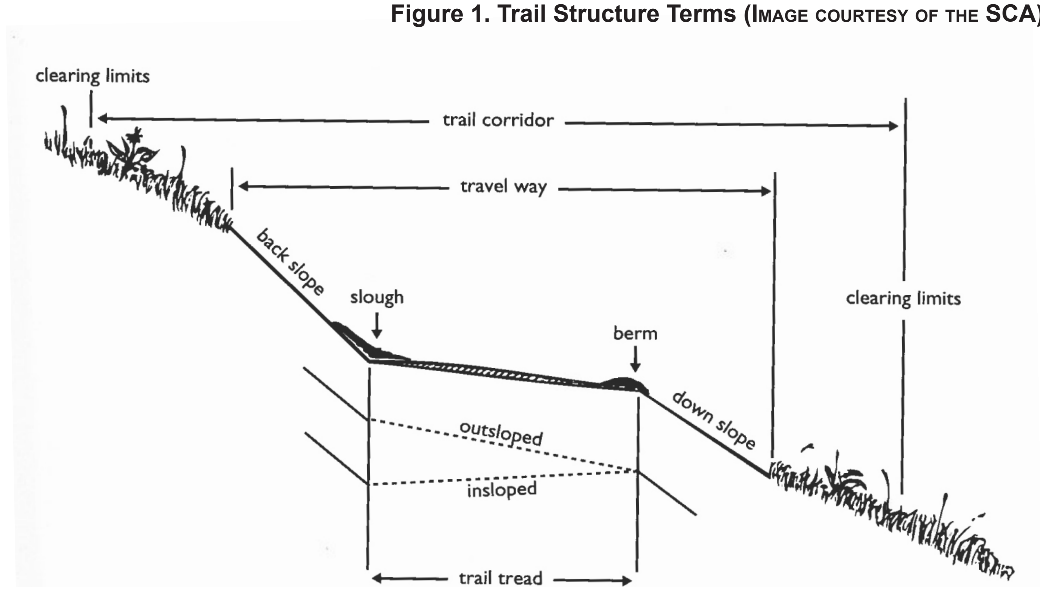


Figure 2. Check Dam (Image courtesy of USFS)

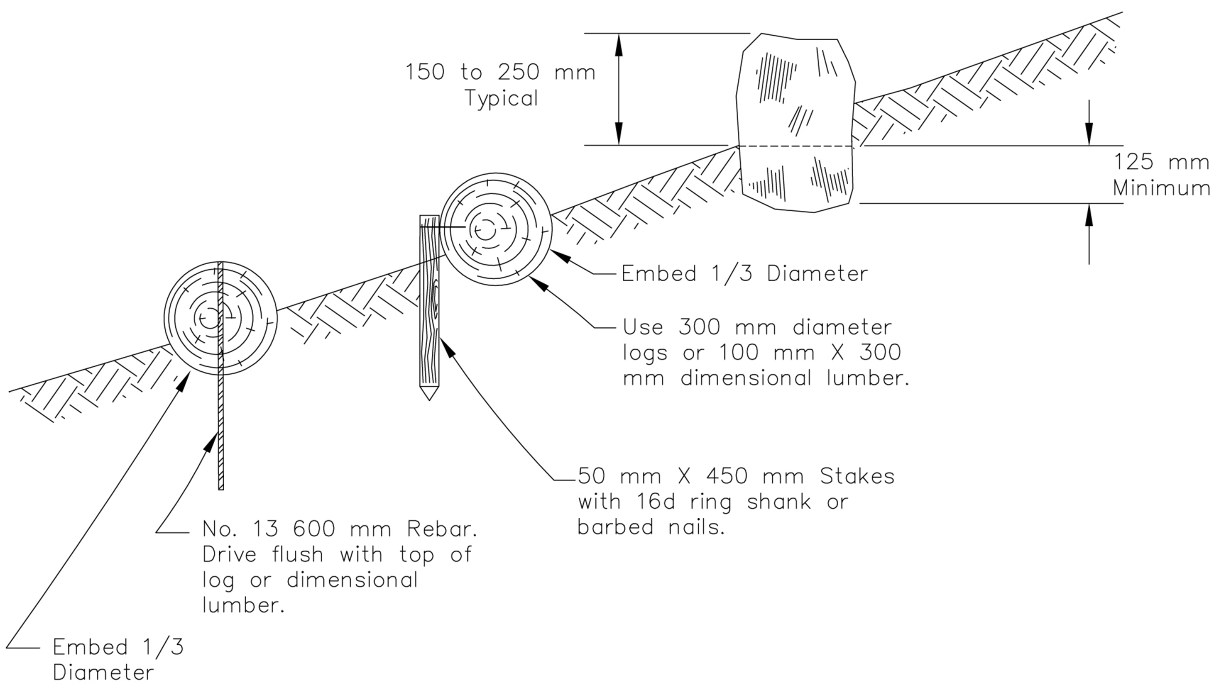
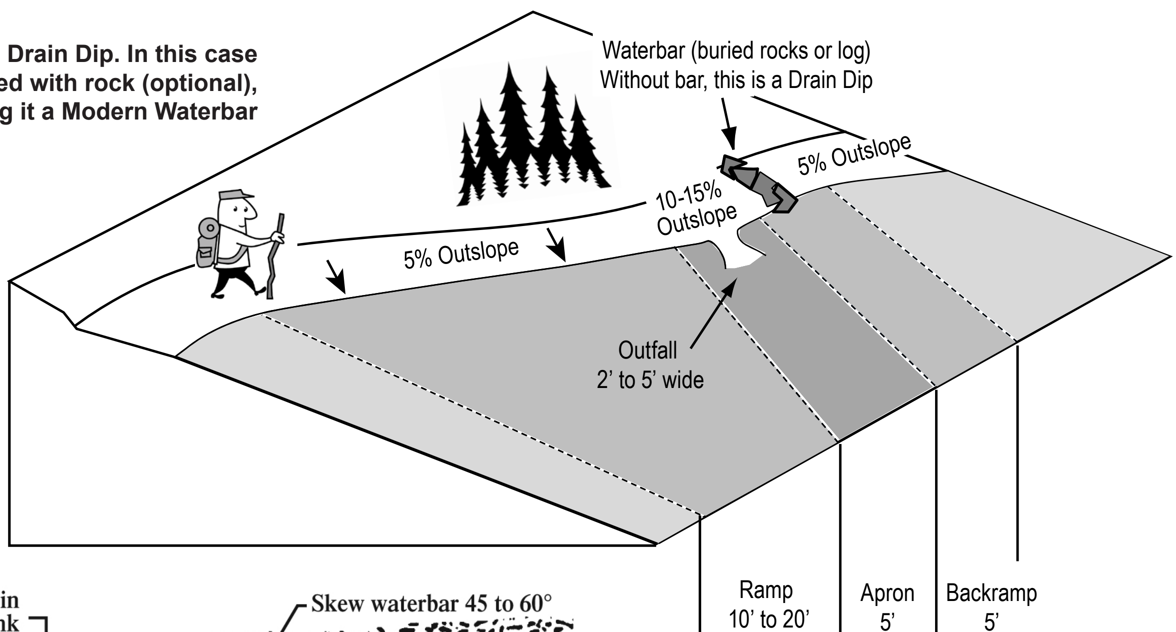


Figure 3. Frequency of Grade Reversals or Cross Drains
Source: Forest Service Trails Handbook 2309.18, Chapter 3, Trail Preconstruction & Construction

	Grade (percent)						
Material Type	**2**	**4**	**6**	**8**	**10**	**12**	**15**
Loam	350'	150'	100'	75'	50'	*	*
Clay-Sand	500'	350'	200'	150'	100'	50'	*
Clay or Clay-Gravel	-	500'	300'	200'	150'	100'	75'
Gravel (rounded rock)	-	-	750'	500'	350'	250'	150'
Shale or Angular Rock	-	-	800'	600'	400'	300'	250'
Sand	Varies with local amounts of fine clay and silt. Drainage diversions generally are not required in "pure" sand because of the fast rate of water absorption. For sand with appreciable amounts of fine binder material, use "clay-sand" distances as shown above.						
* Grades not recommended in this material. - Generally no diversion required for soil stability.							

Figure 4. Rolling Drain Dip. In this case the dip is armored with rock (optional), making it a Modern Waterbar



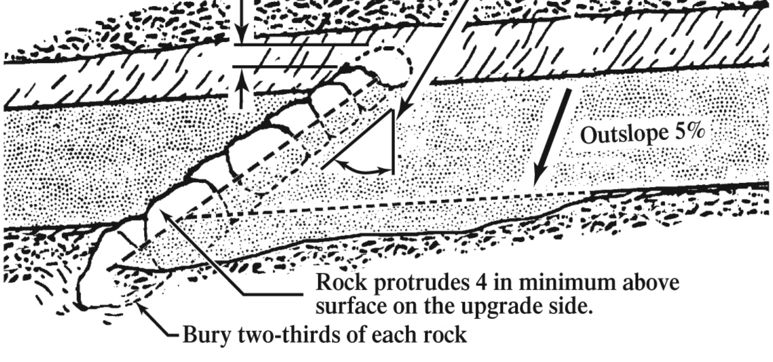


Figure 5. "Old School" rock water bar. (Image courtesy of the USFS)