Trail Plumbing

Inspiration and source materials drawn in-part from: Trail Wisdom, LLC (Woody Keen); Volunteers for Outdoor Colorado/Crew Leadership Manual; Trail Services LLC (Lester Kenway); NPS: the Ice Age National Scenic Trail, a handbook for trail design, construction and maintenance; Natural Surface Trails by Design (Troy Scott Parker) and (tm) trail layout and design notebook *draft.*

DRAFT

The following pages are an in-progress draft printed July 2019 for use with multiple trainings conducted as part of "Ice Age Trail University, or IAT-U"

"Trail" as used here-in is defined as:
An area of focused impact, managed as an outdoor recreational facility, that reacts to and interprets the landscape

There's a quiet confidence in natural land that no university degree, or any level of razor intellect, can understand. It's…a mystery to me: a wisdom in the trees, a strength in the soil - a dance of seasons that never really moves. Only by being open to the possibility of a natural dialogue can human eyes begin to see that we are only ripples of a tide of a century still to come.

"Trail Eyes" are not our eyes. Not the eyes that we superimpose when we tromp into the stillness. Trail Eyes are preexisting eyes, eyes that have been patiently growing with the world since its advent - eyes that continue to grow in the midst of our confusing times. Learning how to see the natural world in the context of its lifespan is the imperative responsibility of any individual.

To adopt "Trail Eyes" is to see the land with which one interacts as a dynamic, living force, with an indefatigable story.

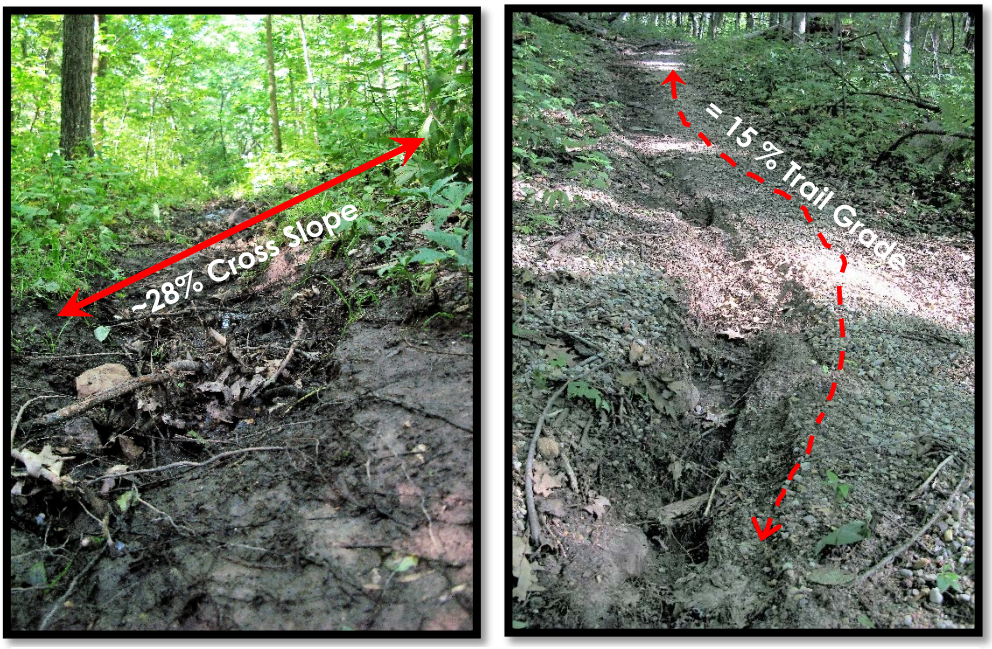
- *Jed Munson, Crew Leadership and Skills Trainee, Class of 2014*

PROPERTIES OF EROSION

Erosion is a natural and ongoing process that moves soil from one place to another. We recognize the effects of erosion by soil loss and soil movement. *Every* trail experiences some degree of erosion. As trail designers, builders and stewards our efforts are aimed toward accommodating, not eliminating, erosion. The two primary means to accommodate erosion are to design resistive trail alignments and to shape and maintain the surface of the trail to limit the effects of and how much erosion occurs.

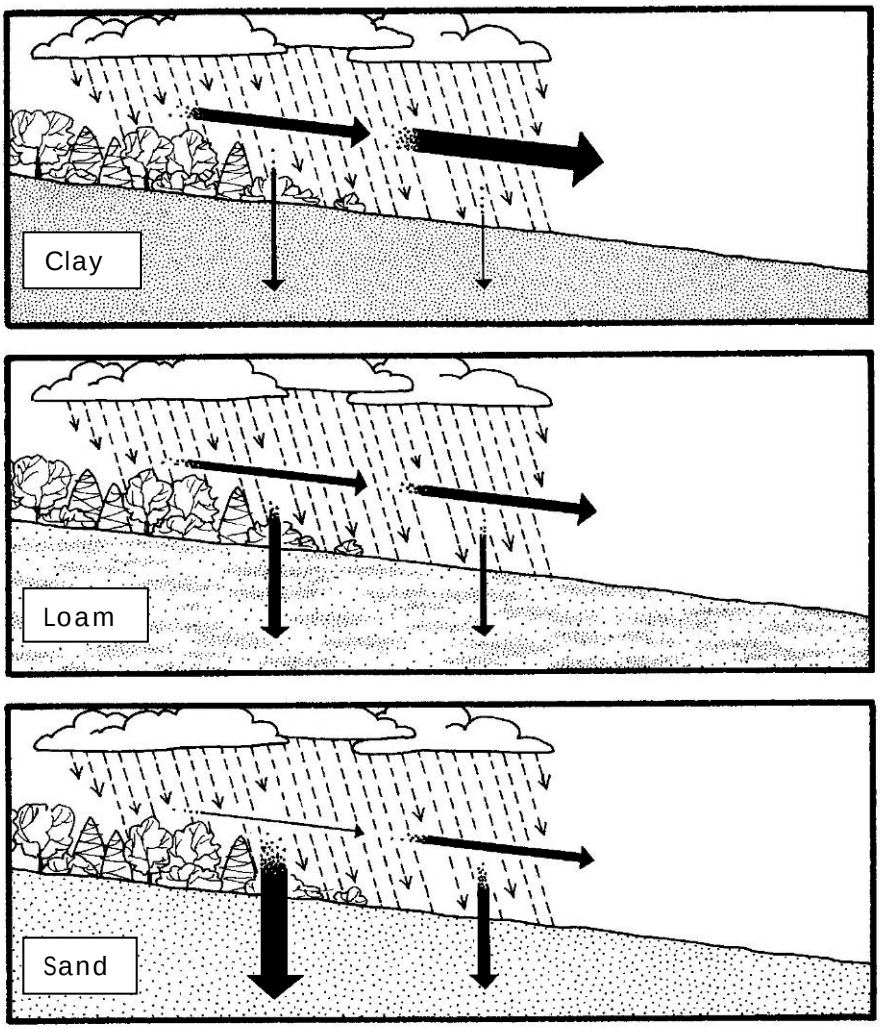
Tips:

- Try to locate the trail so the sun and wind assist us in drying out the surface.
- Design the trail to accommodate, or work with, normal water flows.
- Having awareness of sub-surface level drainage and ground water conditions helps to avoid seeps and seasonal wet areas along the trail.
- The relationship between slope, length of slope, velocity of flow and erosive power of the water flow creates patterns.
- Steeper and longer slopes create conditions that produce high energy water flows that can cause rapid erosion.
- Vegetation influences water surface flow and infiltration rates by actually blocking flows and promoting infiltration.
- When we build trails we are at risk of altering natural flow patterns



The two scenes above represent damage created during a 8" rain event. Cross Slope is ~ 28%. Trail Grade is ~ 15%. Closed canopy forest.

If I am a raindrop…where do I go???



Upon striking the ground I can:
1) Flow across the surface;
2) Enter the ground through infiltration;
3) Collect in holes and depressions.

Slope, soil type, vegetation cover and land use are the principal determining factors.

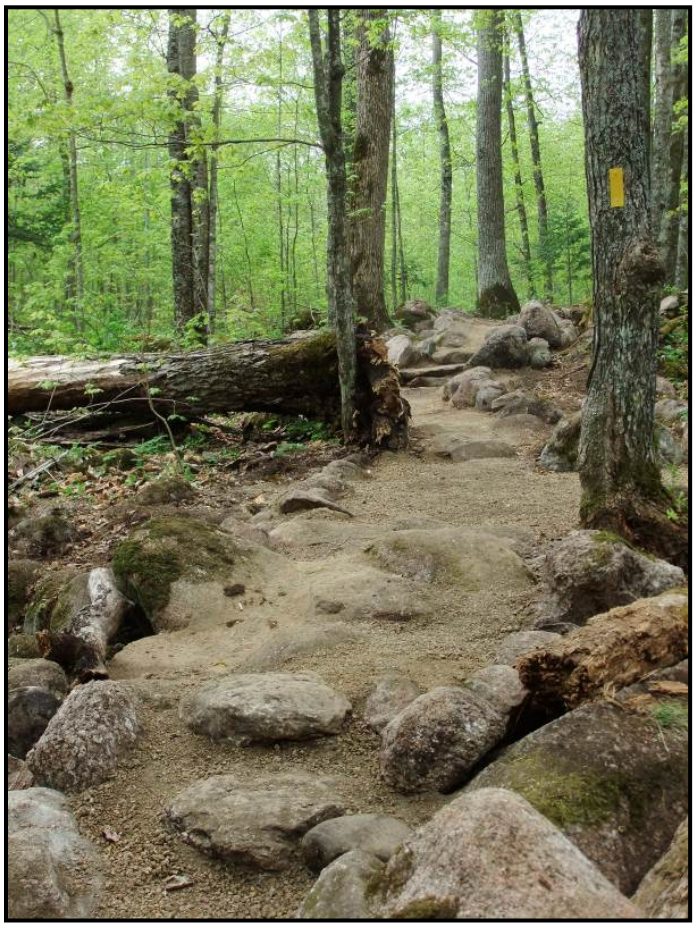
Surface flow > with greater slope
Surface flow < with greater vegetation
Surface flow > in clayey soils
Surface flow < in sandy soils
The coefficient of runoff is the proportion of rainfall available for overland flow after infiltration has taken place. A coefficient of .8 means that 20% of the precipitation will most likely infiltrate the ground and 80% will be available as runoff. Identifying slope/soil/vegetation/land use relationships allows us to plan and design all aspects of the trail for maximum durability.

Soil loss and soil movement is the end result of a combination of physical forces: Water, Wind, Gravity, Compaction and Displacement.

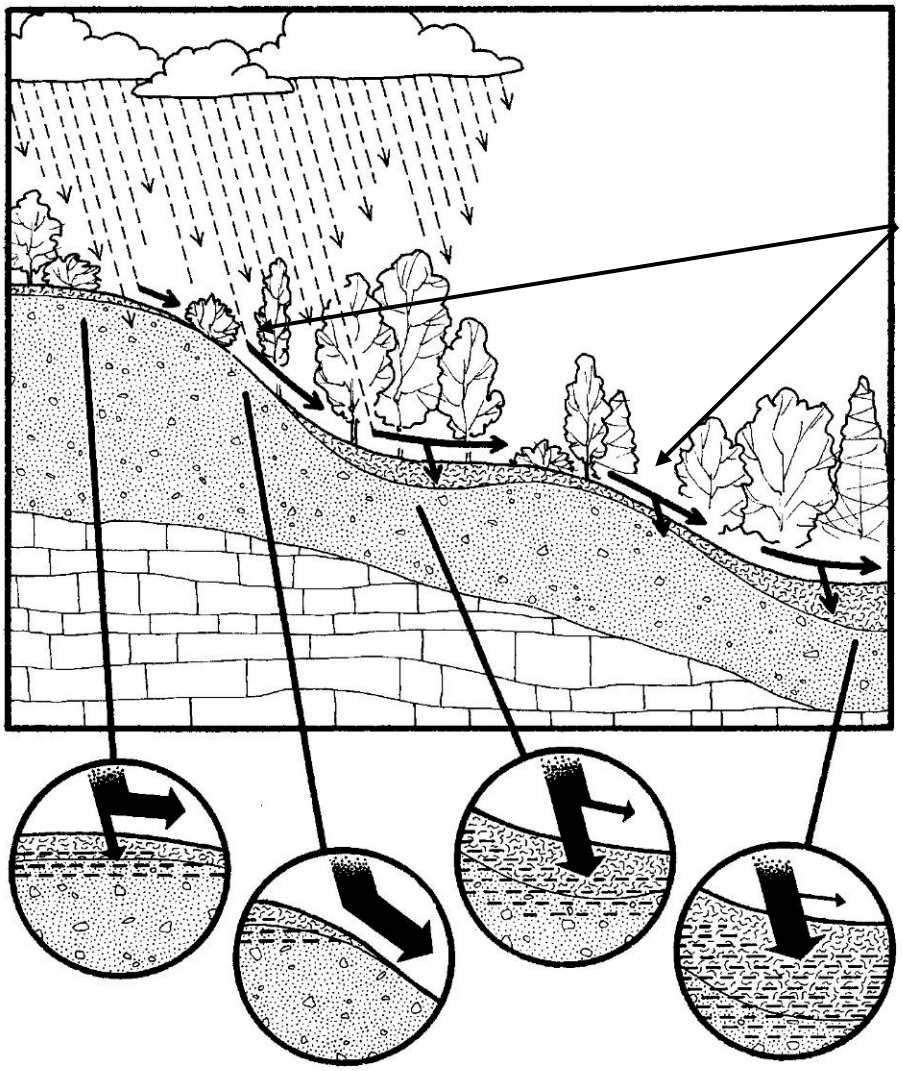
- *Active physical forces* include precipitation, airflow, solar radiation, surface and sub-surface hydrology, infiltration, direction, velocity, mass, and force.

Over time, *compaction and displacement* modifies every tread shape. Tread material characteristics (soils) are a major factor that influences how much compaction and displacement will affect the tread surface. All natural surface trails are modified by nature and use and require tread maintenance to stand the test of time.

Compaction is the downward force of a trail user's weight and modalities on the tread surface. Compaction is caused by vertical force. One positive aspect of compaction is that tread becomes more resistant to displacement as it hardens. The downside is that as trails compact, they cup and there-by take on the shape of a vessel, become U-shaped, and then capture and channel water.



Displacement is the horizontal movement of trail tread material (soil, rock, etc.) caused by friction and subsequent lateral lifting by boots, tires, hoofs, etc. Displacement is caused by horizontal force. Faster speeds and torque increases displacement. Soil that mounds along the outside edge of trails in the form of a low berm is an outcome of displacement.



Soils tend to be thinner and erosion coefficient greater on steeper sections of sloped areas where flow energy is higher.

Soil deposition is greater in flatter areas where water slows and soil is deposited as the flows loose energy. Such areas generally contain large amounts of organic matter.

Soil Characteristics

Soils are of special interest to trail designers because soils are our most basic building material. Soil maps available from on-line resources http://websoilsurvey.nrcs.usda.gov/app/ are a great help in the design process.

The best soils for trail building are well-drained with moderate amounts of sand (drainage and strength), clays (binding agent), and high mineral content. Avoid high clayey, silty, and organic content; avoid pure sand, thin or delicate soils.

In the field, we can **identify soil types** using the hand-cast method by squeezing a partial handful of dampened soil into three basic shapes: Cast, Thread and Ribbon.

Cast: a lump formed by squeezing a sample in a clenched fist.

Thread: a pencil shape formed by rolling soil between the palms.

Ribbon: a flat shape formed by squeezing a small sample between the thumb and index finger.

Field test	Soil type				
	sandy loam	**silty loam**	**loam**	**clay loam**	**clay**
CAST	Must be carefully handled without breaking	can be handled without breaking	can be handled easily without breaking	solid, easily handled	can be molded without breaking
THREAD	thick, crumbly, easily broken	thick, soft, easily broken	can be finely pointed, easily broken	strong thread, can be easily rolled	strong, plastic thread, easily rolled
RIBBON	will not form a ribbon	will not form a ribbon	forms short thick ribbon that breaks under its own weight	forms thin ribbon that breaks under its own weight	long, flexible ribbon that does not break under its own weight

Sandy soils and larger particle size are conducive to drainage, clayey soils are characterized as "poorly drained" and are generally highly erosive; silty soils and soils with a high organic content are also poorly drained and erosive. Obviously-moist areas also may indicate the presence of springs, seeps, intermittent streams, etc. and such areas require special consideration.

PROPERTIES OF WATER

- Volume + Velocity = Damage
- Water 'takes on' the shape of its' container
- Water doesn't like to change directions
- Water clings to itself and other surface areas
- Keep water in sheet (laminar) flow and don't allow it to focus energy
- Water must be micro managed
- Drainage is either Positive or Negative
- Water always flows downhill
- Trail alignments need to be *resistive* (tread watershed) and composed of *resistant* (durable) materials.

HYDROLOGICALLY INVISIBLE: What did water do before the trail was built? What is it doing now? If hydrology patterns are functioning the same after the trail is built and while the trail is in use as before the trail was built, the trail is considered "hydrologically invisible" on the landscape.

TREAD WATERSHED: A watershed is the total land area that drains into a given body of water; a *TREAD WATERSHED* is a linear segment located between a local high point (crest) and the next low point (trough). A trail that undulates and meanders will have a higher number of tread watersheds and thus create more *positive drainage* opportunities. There are innumerable tread watersheds throughout the length of any given segment of trail.

- The *length* of a tread watershed is determined by the local crests and troughs of and in the tread, whether they are naturally occurring or constructed.
- The *height* of a tread watershed is from the critical edge of the tread to the top of the closest topographic basin to the tread.

SPLASH EROSION describes the cumulative effect of individual raindrops as they strike the tread from above and displace soil particles. Splash erosion is more pronounced in open areas compared to similar tread protected overhead by tree canopy. The steeper the tread grade, the more that splash erosion contributes to displacement.

MAINTENACE MUST-HAVE'S

Whether a trail segment was well designed and properly built at the start of its life; or, came into being informally and adopted for recreational purposes, three effective tread maintenance techniques are:

- De-berm the critical edge
- Clean existing trail drainage structures of debris and sediment
- Allow light and air to freely circulate within and through the trail corridor prism by keeping the trail corridor clear of overhanging vegetation.

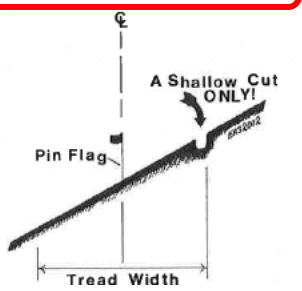
Sheet Flow and Tread Outslope in Action

Well-designed and well-crafted trails <u>are not exempt from erosion</u> - the tread surface is continually being acted upon and modified by the physical forces of water, wind, gravity, compaction and displacement. Most trail erosion problems are the result of water staying on the trail *(Velocity + Volume = Damage)* versus flowing across it.

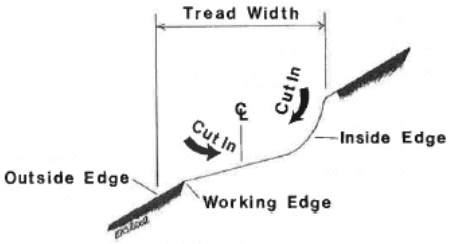
The Critical Edge

The art of crafting sustainable sidehill tread construction is shown in the "4-step" summary below:

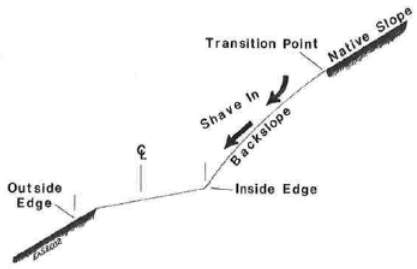
STEP 1: Establish the inside edge of the tread



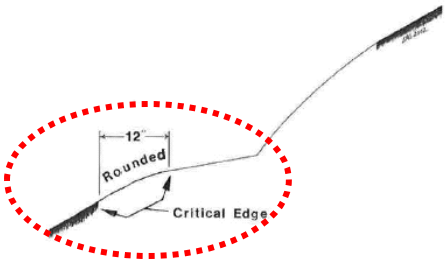
STEP 2: Cut outsloped tread with a vertical backslope



STEP 3: Cut the backslope

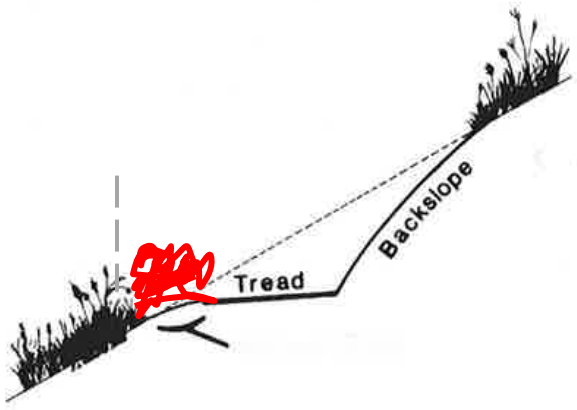


STEP 4: Establish the critical edge

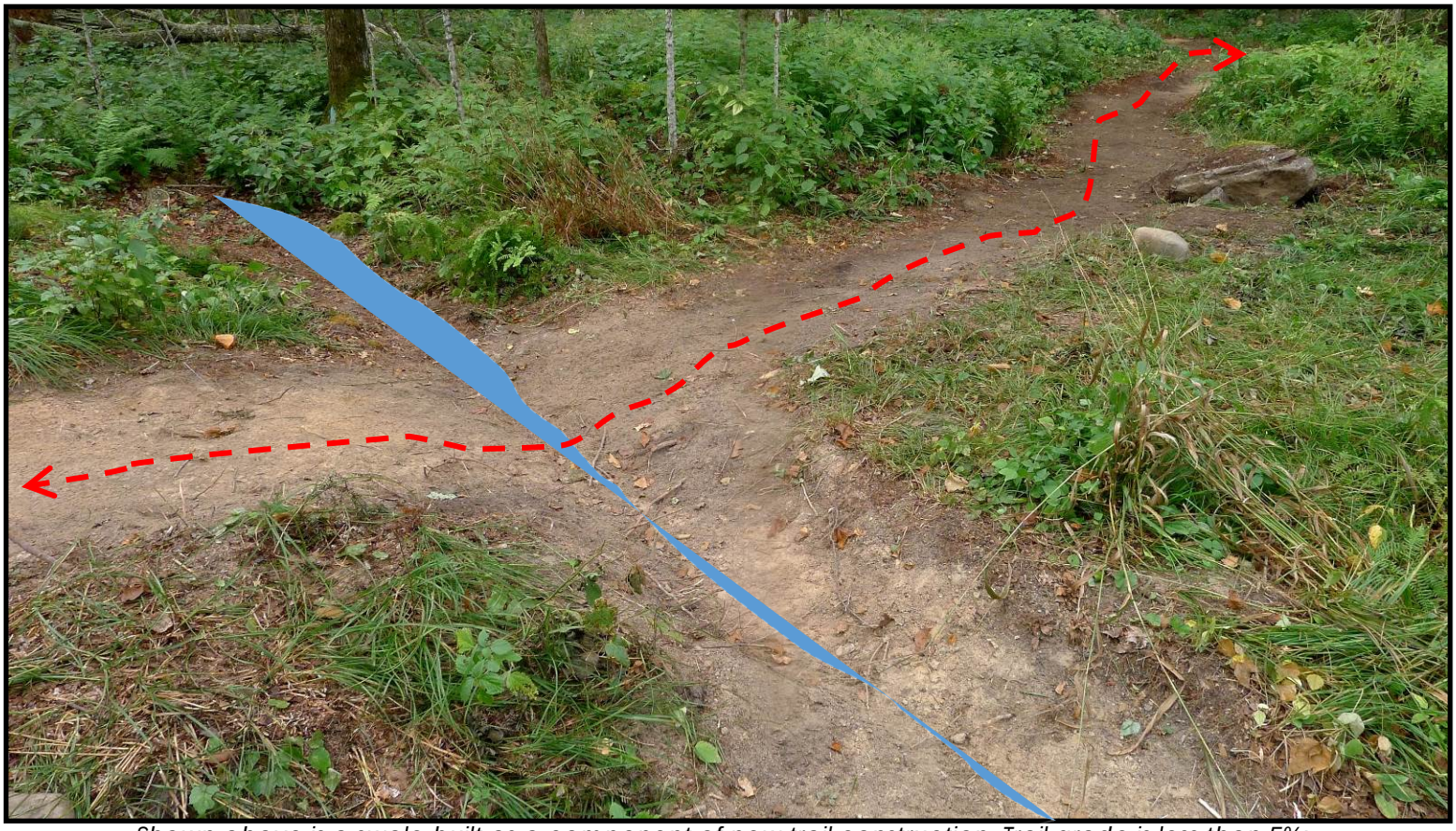


Trail use modifies the shape of the tread by compacting and displacing particles of soil. Cumulative use of a trail, year-in and year-out, is akin to beating the ground with a hammer. This causes the tread surface to harden and to sink relative to adjacent areas. As each boot or sneaker lifts off the tread, a small amount of soil is transported horizontally, toward the edge of the trail. Soil accumulates and becomes a berm. The berm obstructs sheet flow, keeping water on the trail.

"Red" represents a low berm of accumulated soil trapping water at the critical edge. To remove the berm, stand on the tread and cut towards the back line (shown as a vertical gray dash mark) to round-off the outside shoulder of the trail.



Swales



Shown above is a swale built as a component of new trail construction. Trail grade is less than 5%; cross slope is less than10%; soils are of high organic content; setting is a recently logged area w/25% canopy cover; user group is foot travel.

Swales are an excellent trail plumbing choice in relatively 'flat' terrain that challenges us to tune-up our "Trail Eyes" to recognize and enhance subtle, naturally occurring topographic characteristics to get water off the trail.

- Swales are analogous to culverts in that they help to provide equalized cross drainage, which in turn helps dry the surface of the trail. Swales should extend perpendicular across the tread as far as practical. Swales do a good job of mitigating reoccurring hydrological events and seeps where water tends to pool adjacent to the trail, leading to saturated (muddy) soils.
- Swales do not dispense of large volumes of water but to help take "a little from many places" adding to the cumulative net positive effect that focuses use on the trail, protects the surrounding ecology and enhances the user's experience because trail tread will be drier.

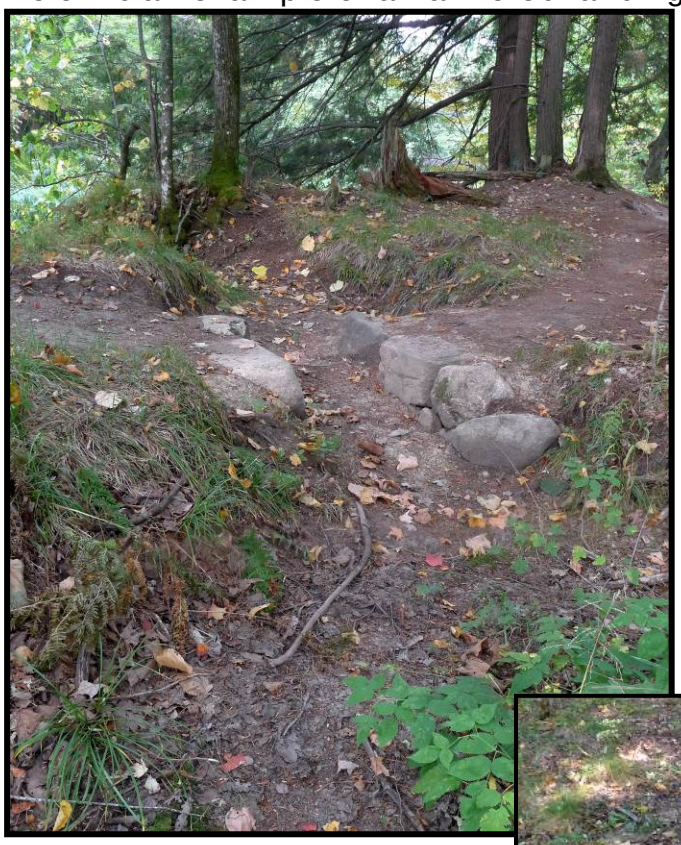
Armoring

Armoring is the use of rocks to harden and solidify areas where the soil is consistently wet or running water is present at various times during the year.

Trail Plumbing applications include:

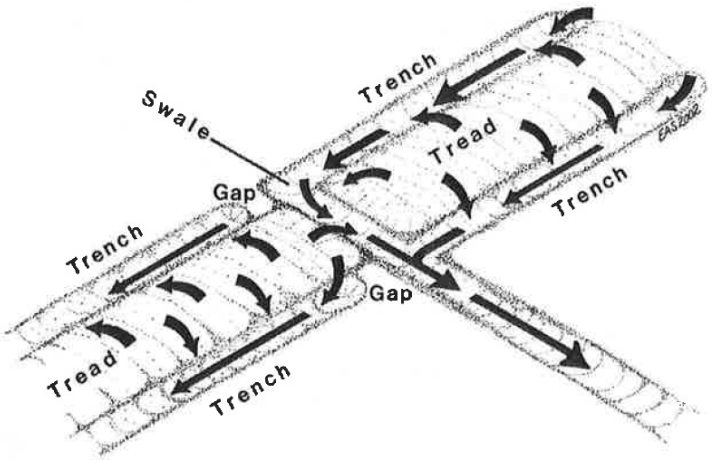
- Create a step-landing on either side of a ditch or wet area
- Line the edge of a drainage ditch to help prevent scouring
- Reinforced water bars and swales
- Place flat stones across a drainage to mitigate erosion and provide stable footing when moving water is present

Below is an example of an armored landing



<u>ASSIGNMENT:</u> Describe what was done, why, what the potential maintenance needs, how often maintenance may be needed and other trail plumbing options that may have been considered by the builders.

Side Ditches and Trenches



Trail in flat terrain is one of the hardest trail plumbing scenarios trail stewards face because there are few options available to get water off the trail. One effective tactic is to build a series of stacked swales and trenches.

Plumbing Tips: study natural patterns, look for lighter colored soils washed atop tread, identify vegetation types, look upslope and down a considerable distance from and of the trail to observe and locate contributing factors; change your viewing perspective and occasionally drop lower to the ground, on your haunches, to gain a different perspective; think like water.

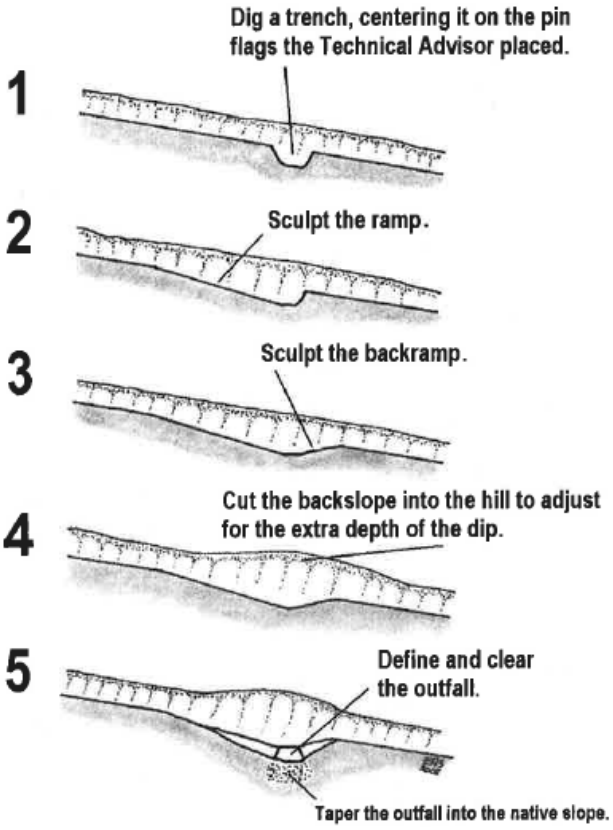
<u>ASSIGNMENT:</u> Name and describe the trail plumbing tactics used in the two photos above and what problem or potential problems you think the builders hoped to mitigate. Next, look at the vertical photo on the left and describe in what sequence you think the various trail plumbing tactics were performed, and why.

Trail Drainage Dips

Trail drainage dips are an essential trail plumbing structure used on modest (15% +) to steep (40% +) trail grades. Done correctly, dips require a substantial time and labor investment that includes moving a fair amount of dirt. Dips carry significant amounts of water off the trail and help prevent gullies and washouts of the tread. Dips need periodic maintenance to remove sediment and debris.

Core decisions include: deciding where to locate dips on the slope and how many dips are needed.

- Take time to study and plan where to located dips; build the trench at a 45 to 60 degree angle to the running direction of the tread
- Locate dips high, in the upper third of a steep run, to capture and remove water before it gains scouring velocity. Add dips as necessary downslope (middle and lower third)



The most common mistakes trail builders and stewards make when constructing a dip is not extending the trench (step one) past the backline; shaping too small of a backslope, and not extending the outfall of the trench far enough past the critical edge of the tread.

Dip anatomy is deceptive in that the downslope apron, not the trench, is where we want water to exit the trail. It is helpful to visualize a triangular pie shape upslope of the trench.

Drainage Dips are known by various names throughout the country. “Bleeders”, or “Knicks” extend from the critical edge and do not include a ramp or backramp. They help, but are not as effective as a full drainage dip.

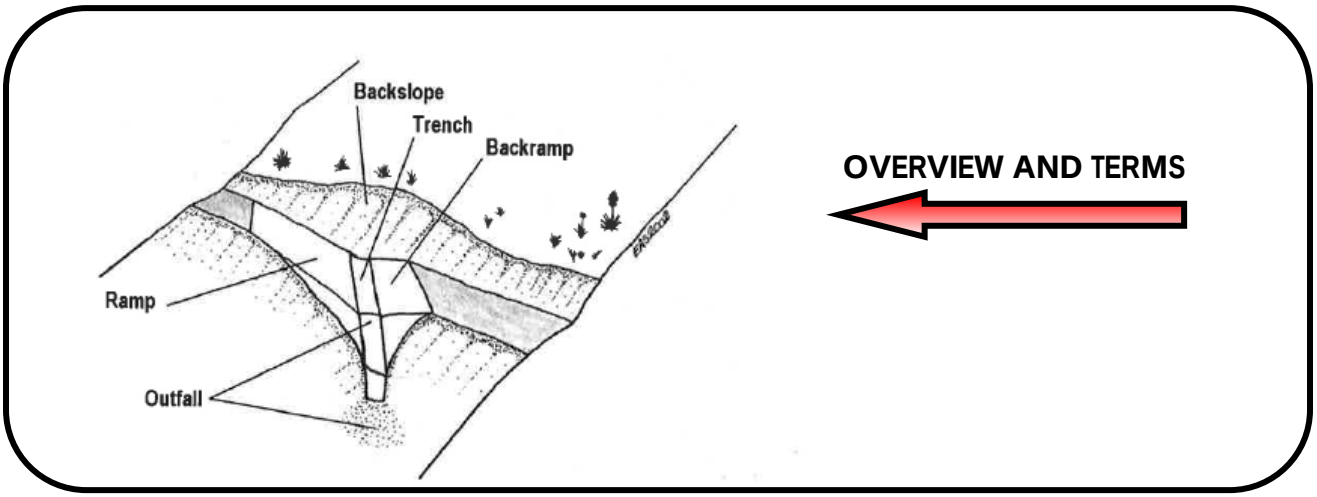
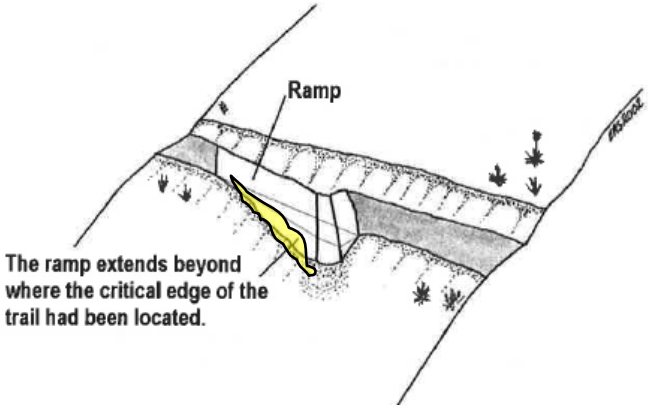
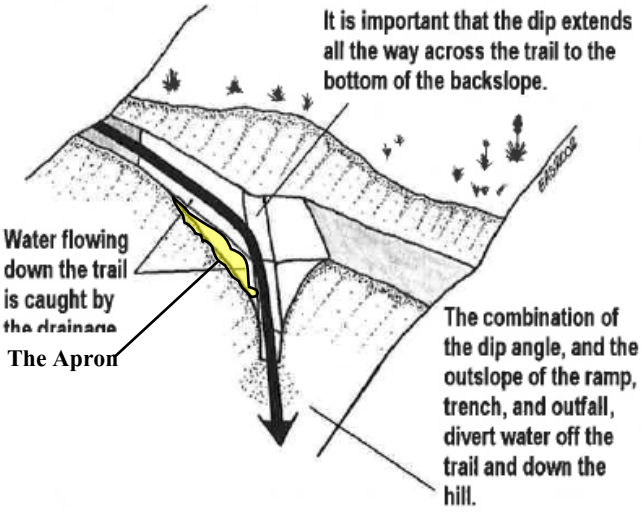
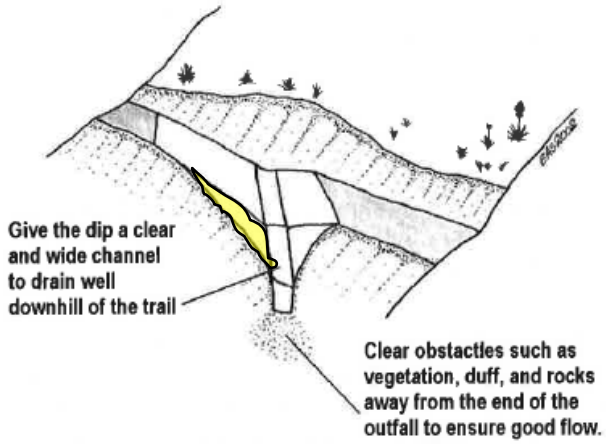
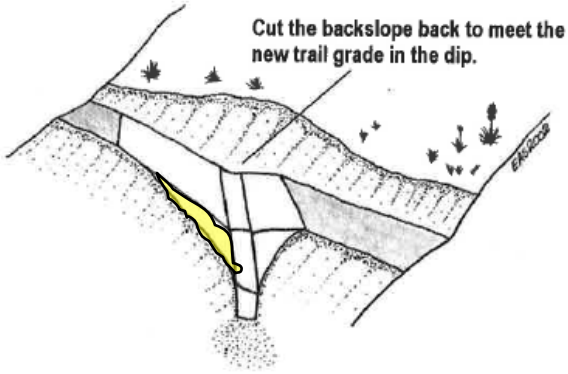


FIGURE 12.1: ANATOMY OF A DRAINAGE DIP.



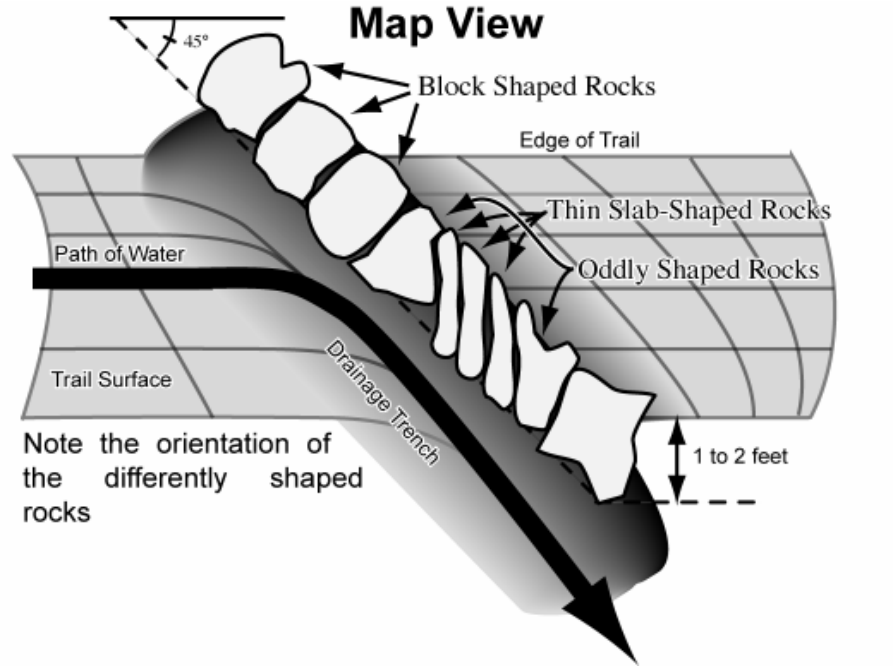






The Traditional and the Reinforced Waterbar

As sustainable trail design and construction methods have become more known and widely understood, drainage dips have supplanted water bars as the go-to trail plumbing structure. Traditional water bars are not without their merits; in particular, rock reinforced water bars are the right choice on steep or deeply gullied grades, including when an existing section of trail is decommissioned but needs remediation. Below is an example from Trail Services LLC, Maine.



Where, How Often, How Frequent???

The actual number of and spacing for drainage dips and water bars depends on the amount of water entering the trail, the steepness of slope, how resistive to water the trail alignment is, the availability of places to divert the water, and how resistant the tread surface is.

- The final placement of trail plumbing features is dictated by terrain.
- The greater the degree of slope and the more water channeled by the trail, the greater the need to force water to change directions.
- Construct drainage dips, reinforced water bars and or swales above rock retaining walls and other constructed trail features, and below points where a significant amount of water enters the trail.
- On uniform, sustained grades, swales and dips should be built to divert water before it does damage.

Guide to Water Bar and Drainage Dip Spacing

Material Type	2% grade	4% grade	6% grade	8% grade	10% grade	12% grade
Loam	350'	150'	100'	75'-50'	50'-40'	40'-25'
Clay-Sand	500'	350'	200'	150'	100'-50'	50'-25'
Clay or Clay-Gravel	-	500'	300'	200'-150'	100'	75'

Trail Layout and Design Tools

Clinometer / Compass / Folding Hand Saw

Topo / Aerial / Site / Plat Maps

Black Sharpie Permanent Markers / Tape Measure(s) (16' & 50-100')

Weatherproof Notebook & Pens / Voice Recorder

First Aid Kit / Camera / Cellular Phone / Personal Items for comfort and safety
Plant and Tree Identification Book(s) / Masons Line & Line Level

Multiple Colors of Flagging Ribbon and Wire Stake (Pin) Flags

Definitions and Terms

"Trail" as used here-in is defined as: **an area of focused impact managed as an outdoor recreational facility that reacts to and interprets the landscape.**

SUSTAINABLE CHARACTERISTICS

- Supports current and planned uses with minimal impact to natural systems
- Protects the environment
- The Trail Alignment results in negligible soil loss or movement
- Requires little rerouting or more then routine maintenance
- Is easier to maintain to a set standard
- Mitigates potential user conflicts
- Provides a positive user experience
- Satisfies users expectations
- Ensures and/or informs user safety needs
- Is durable, i.e., able to withstand the natural process of erosion caused by natural and human forces
- Is hydrologically invisible on the landscape
- Anticipates user motivations (destination/journey/experience)
- Anticipates off-site threats
- Creates a constituency for the outdoors
- A long-term management plan or TMO (Trail Management Objectives) is in place

MEASURING TECHNIQUES & TERMINOLOGY

Trail Grade is the objective measurement of steepness. Grade is expressed as a percentage – the elevation gained divided by the linear distance taken to do so. For example, if the trail rises 10 feet over the course of 100 feet, the percentage of rise, or trail grade, is 10%.

- Use the term "Percentage" to express what the trail grade or cross slope measures. Try not to confuse Degree's – which measures angles – with Percentage.
- A clinometer is used to measure the grade of any given section of trail or cross slope. Clinometers typically have two scales; one is percentage, the other degrees. Confirm which the percentage scale is and always use that.
- Use a clinometer to measure trail grade between low and high points.

FALL LINE: The prevailing slope and the direction water naturally flows. Fall Lines exist on all slopes, whether the slope is gentle or abrupt.

TRAIL ALIGNMENT: The orientation of the trail to the prevailing slope. Sustainable trails follow the lay of the land on physical contours. Fall lines are to be avoided. A route that is perpendicular to the fall line has a trail alignment angle of 90 degrees; a trail parallel to the fall line is a 0 degree alignment.

THE ONE OVER THREE RULE: To ensure a sustainable alignment trail grades (percentage of rise or fall) should not exceed 1/3rd of the grade of the sideslope it is located on. If the trail alignment contours on a 30 percent slope, the trail alignment will be sustainable if it does not exceed a 10 % rise or fall. Soil types and tread materials influence this formula. In degradable soils, such as loose sand, reduce the trail alignment to a ratio of one over four. Other instances may permit a higher ration then one over three. This rule is especially important to remember in gently sloping areas.

GRADE REVERSALS: Undulate and Meander the trail to force water to change directions. Grade reversals effectively divide the trail into small continuous watersheds. Each small watershed can be managed for erosion control independently. Grade reversals provide frequent drainage without structures or maintenance by undulating the trail with a short descent followed by a short rise.

CONTROL POINTS: Positive or negative natural or cultural features that determine where a trail may or may not be desirable to locate.

OUTSLOPE: A method of sustainable 4-step tread construction that leaves the outside edge of a sidehill trail lower than the inside edge to shed water.

ANCHORS: A distinct vertical feature that attracts attention in the landscape. Anchors give a trail visible reason to be “here” instead of “there.” Anchors can take on many shapes, forms and sizes.

GATEWAY: Where the trail is clearly constrained on two or three sides. Gateways create a sense of passage and distance and have both anchor and edge characteristics.

BASIC TRAIL: A path which traverses a hillside or otherwise and is constructed to drain water without producing erosion effects. Trail Layout and Design maximizes basic trail components.

BERM: A raised shoulder on the critical edge of the trail. Berms block the flow (sheet or laminar) of water across the tread and focus this erosive force on and within the trail as negative drainage.

BIOLOGICALLY INVISIBLE: When sunlight patterns are not changed dramatically by the presence of a trail.

TRAIL CONFIGURATIONS: Out and back, destination, loop, spur, lollipop.

FAT ALBERT AND SEXY SADIE: Poorly designed and constructed/maintained trails widen with time; well-designed and constructed/maintained trails narrow with time.

TREAD: The actual surface of the trail that we walk/travel on.

SOILS: the backbone of Tread.

CENTER LINE: The middle of the constructed tread.

PIN FLAG: A wire stake with flag attached used to delineate the center line of a trail for layout, construction, maintenance and stewardship purposes.

SIDESLOPE: The natural slope of a hillside.

GRADE: Slope expressed as a percentage (elevation gain divided by distance).

UNDULATION: a wavy, curving form or outline, especially one of a series.
-Distinguish between PUDS – pointless up and downs

MEANDER: To take a winding course

TROAD: A former extraction route created for non-trail purposes that has been adopted as a recreational trail (*-Extraction activities include logging, agriculture and mining.*

RESOURCES

USFS Trail Construction and Maintenance Notebook 2007 Edition
https://www.fhwa.dot.gov/environment/recreational_trails/publications/fs_publications/07232806/

Wetland Trail Design and Construction
https://www.fs.fed.us/t-d/pubs/htmlpubs/htm07232804/index.htm
https://www.fhwa.dot.gov/environment/recreational_trails/publications/fs_publications/07232806/page10.cfm

Additional US Forest Service on-line publications)
https://www.fhwa.dot.gov/environment/recreational_trails/publications/fs_publications/index.cfm

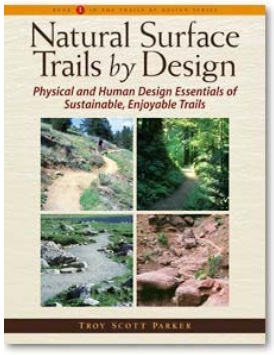
Trail Planning, Design and Development Guidelines (MN DNR)
http://www.americantrails.org/views/MNmgmt.html

SCA - Lightly on the Land
https://www.amazon.com/Lightly-Land-Building-Maintenance-Manual/dp/0898868483

National Trails Training Partnership
http://www.americantrails.org/resources/trailbuilding/index.html

Troy Scott Parker
http://www.natureshape.com/pubs/nstbd.html
(Almost sold out; reach out to Troy directly or miss out!)

Appalachian Mountain Club
https://amcstore.outdoors.org/amc-guide-to-outdoor-leadership-2e



WEBSITES to PERUSE
http://www.appalachiantrail.org/
https://www.pcta.org/
https://trailism.com/
http://www.americantrails.org/ee/
http://www.trailbuilders.org/
https://www.imba.com/
http://www.nps.gov/iatr/parkmgmt/trail_handbook.htm
http://www.wi.nrcs.usda.gov/