

BUILDING BETTER TRAILS



I·M·B·A

***Designing, Constructing and
Maintaining Outstanding Trails***

The International Mountain Bicycling Association



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Building Better Trails

By the International Mountain Bicycling Association with contributions from Mike Riter, Jan Riter, Joey Klein, Rich Edwards and Jen Edwards.

This publication is available at www.imba.com in both HTML and PDF formats. Additional copies can be purchased from the website or by contacting the IMBA office. Visit www.imba.com for many other trailbuilding and trail management resources.



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Bicycling Association



Special Thanks

This book's concept and first edition were created by Jan and Mike Riter, the original Subaru/IMBA Trail Care Crew. Between March 1997 and January 2000, the Riters taught trail construction and maintenance techniques to thousands of land managers, mountain bike club leaders and other trail users. Their pioneering work took them to 48 U.S. states, several Canadian provinces and nine European countries. The Riters built such an awesome trail legacy that their number, Trail Care Crew No. 1 (TCC1), has been retired by IMBA. The Riters can be reached at their Georgia-based consulting business, Trail Design Specialists, at traildesign@mindspring.com.

In 2001, this booklet was updated and expanded by IMBA to include new information from additional years on the trails. Major contributions were made by Joey Klein of TCC2 and Rich and Jen Edwards of TCC3. The guidelines that follow come from the observations, techniques and theories of many people working on trails in many places.

Special thanks also to various photographers and to John Halloway at KTU&A Landscape Architecture and Planning in San Diego, California (john@ktua.com) for providing illustrations.

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The Subaru/IMBA Trail Care Crew program is made possible by the generous support of Subaru of America.



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About IMBA

IMBA was founded in 1988 as a coalition of California mountain bike clubs concerned about the closure of trails to cyclists. IMBA's founders believed that mountain biker education programs and innovative trail management solutions should be developed and promoted.

While this first wave of threatened trail access was concentrated in California, IMBA's founders saw that crowded trails and trail-user conflict were fast becoming worldwide recreation issues. This is why they selected International Mountain Bicycling Association as the organization's name. IMBA's mission has always been to encourage responsible mountain biking, support volunteer trailwork, assist land managers with trail management issues, and improve relations among trail user groups.

IMBA has members in all 50 U.S. states and 30 other countries. This includes 32,000 individuals, 400 bicycle clubs, 200 bicycle retailers and 120 corporate supporters. IMBA's Rules of the Trail are recognized worldwide as the standard code of conduct for mountain bikers. IMBA members annually contribute more than 500,000 hours to trailwork projects on public land. As a result, more than a thousand miles of new trails become available for cycling, hiking and (often) horseback riding.

IMBA continues to bring out the best in mountain biking through education, trail construction, volunteer support, management advice, cash and grants for trail improvement, and worldwide leadership. IMBA gives mountain bikers national and international clout – a voice that is heard and respected by Federal land managers, environmental groups, the mainstream media, and other trail users. IMBA works closely with the U.S. Forest Service, Bureau of Land Management, many National Park Service units and state, local and international agencies.

IMBA's key projects include the Subaru/IMBA Trail Care Crew, the National Mountain Bike Patrol, IMBA Trailbuilding Schools, IMBA Epic Rides, IMBA State Representatives Network, mountain biking programs for children and several international initiatives.

For more information, visit www.imba.com or call or write our headquarters: IMBA, P.O. Box 7578, Boulder, CO 80306 USA; phone (303) 545-9011.

Introduction

IMBA supports the development of trails that encourage public access to natural settings without harming the ecosystem. IMBA promotes concepts that reduce trail erosion, increase sustainability and lessen user conflict.

Building a constituency for the outdoors is vital to ensure the future of open space. If people visit and enjoy the outdoors, they'll support preservation of natural and undeveloped land.



Two world-renowned Subaru/IMBA Trail Care Crews spend 10 months each year traveling coast-to-coast in Subaru Outbacks.





I-M-B-A

Chapter 1 Trailbuilding Philosophy

IMBA Rules of the Trail

1. Ride on open trails only

If a trail is posted with a "no bikes" sign, don't ride it.

2. Control your bicycle

This is particularly important when you meet hikers, horseback riders, or other cyclists on the trail. Good balance and proper braking are essential mountain biking skills.

2. Leave no trace

Don't ride in conditions where you will leave evidence of your passing, such as on certain soils after a rain. Stay on existing trails and don't create new ones.

4. Always yield the trail

The steps are simple: slow down, establish communication with the people you meet, and pass safely. Yielding doesn't always mean stopping and dismounting, though sometimes that's the best idea, particularly when passing horses.

5. Never spook animals

It doesn't matter if it's a horse, fox, cow, deer, elk or mountain lion: give all animals plenty of room and try not to startle them.

6. Plan ahead

Carry everything you need for a good ride: a spare tube and a pump, a rain jacket, basic tools. Know where you're riding. Wear a helmet.



What is a sustainable trail?

- It supports current and future use with minimal impact to the area's natural systems.
- It produces negligible soil loss or movement while allowing vegetation to inhabit the area.
- It recognizes that pruning or removal of certain plants may be necessary for proper maintenance.
- It does not adversely affect the area's animal life.
- It accommodates existing use while allowing only appropriate future use.
- It requires little rerouting and minimal long-term maintenance.

– From the National Park Service, Rocky Mountain Region, January 1991

IMBA works to create **sustainable trails**. Two key considerations are proper siting and construction to reduce erosion. Minimal maintenance is important because trails are just one of many facilities that land managers must care for. The less time, labor and money needed for trail maintenance, the more likely trails will remain open for mountain biking and other public use.

Achieving balance between soil protection and recreation is what good trail design and construction are all about. *A good trail is both sustainable and fun.* Trails also must be appealing enough to keep users from wandering off and increasing the risk of erosion.

The Problem: Erosion

Erosion is the natural process of wearing down and moving rock and soil by wind and water. Trail erosion can be accelerated by a combination of trail users, water and gravity.

All trail users loosen soil, especially on steeper grades where they resist gravity. Water compounds the process if it's allowed to channel or "focus" down the trail. Water takes loose soil with it, cutting deeper into the **tread** (clear path for travel) each time it flows.

The goal is to encourage **sheet flow** – a dispersed flow of water down a hillside. When water is allowed to focus, it can do more damage than any trail user. Erosion is minimized when trails are designed to make water sheet rather than focus.

The Solution: Contour Trails

A **contour trail** gently traverses a hill or sideslope. It's characterized by a gentle grade and a tread that **outslopes** slightly toward the low side. These features minimize tread erosion by encouraging sheet flow of water across the trail.

Subtle undulations in a trail create **grade reversals** and **grade dips** that also defend against water damage. These features diminish erosion by redirecting water off the trail.

Contour trails are sustainable, environmentally friendly and appealing to users. They thwart water damage in ways that are nearly invisible.



While not many land parcels have contour lines as visible as those in this photo, contour lines play a key role in trail design. Trails that follow the contour are much more sustainable than trails that go straight up and down the slope.

Blending with Nature

Straight lines are rare in nature, and they're rare in good trails. Trails should blend with the land. When building or maintaining a trail, the goal is to complement natural processes. Determine what that means for the area, then imitate it. A contour trail that snakes and dances across a hillside can be invisible from below. Trails that are pleasing to the eye are usually friendly to the land.



Chapter 2

Trail Design Process



Ten key steps for planning and designing an appealing, sustainable trail:

1. Get permission from the landowner or management agency and form a partnership.
2. Identify ownership boundaries.
3. Determine who the trail users will be and the experiences they desire.
4. Familiarize yourself with the area and identify **control points**.
5. Conceptualize a trail system that incorporate loops.
6. Plan a contouring route with sustainable trail grades, an outsloped trail tread and grade reversals.
7. Determine the type of trail **flow**.
8. Walk and flag the proposed **trail corridor**.
9. Develop a construction plan with the trail users, work crew and land manager.
10. Flag the exact tread location before beginning construction.

1. Get Permission

Establish a professional relationship with the landowner or **land manager**. Get permission before you do anything. Clear and frequent communication is the backbone of all good partnerships.

A professional relationship accomplishes more and creates an "everyone wins" situation. Meeting with different user groups gives everyone a sense of ownership and ensures the trail's future.

Let land managers know you're part of an organized group. Present a written proposal that describes how and where you want to improve the trail system. For their part, land managers should seek input from users on trail projects.

Groundbreaking on Federal land may require a National Environmental Protection Act (NEPA) study. Some trail projects fall under a Category Exclusion that can save land managers time and money. It may take a while to obtain a permit, but it must be done. Protection of the land always comes first.

Be patient and willing to compromise. Great trails often result from a blend of ideas.

2. Identify Ownership Boundaries

Locate the boundaries, then find the people who own or manage the land within them. This is crucial so the trail is not built on land that's off limits. In some cases, trails should divert people away from boundaries. For example, you wouldn't want users to go near a rifle range.

A well-presented trail system can gain access to areas not in the original plan. Landowners adjacent to open space may be willing to allow use of their property, too.



3. Determine Trail Users

Think about the potential trail users. Does the trail system accommodate their needs and desires? Think about the future as well. Will different trails be necessary to serve a growing population and evolving mix of users?

A trail's design shapes the experiences of those who use it. The best trail system offers something for everyone by recognizing that each trail user is unique.

It would be wrong to assume that all mountain bikers want challenging terrain or that all hikers want solitude. Even so, it's possible to make a few generalizations about trail users.

Foot Travelers

Walkers: They usually want a relatively brief jaunt. They do fine on short trails that give them a direct path from one natural feature to another.

Hikers: They're usually familiar with the outdoors and like a more strenuous walk. They can handle difficult terrain and steep grades. They will generally stay on trails that are direct yet interesting.

Rock Climbers: They use trails to reach climbing areas. Contour trails may meander too much for their needs. They prefer **fall-line** trails that provide direct access. To be sustainable, fall-line trails must be armored with rock or have a sturdy staircase with excellent drainage.

Backpackers: This group yearns for a backcountry experience, and will travel many miles to reach it. Even though they have an intended destination they are less apt to shortcut because they carry heavy loads that hinder maneuverability. Gentle trail grades linking natural features help keep long distance foot travel interesting. Water sources should be regularly spaced and near suitable camping sites.

Trail Runners: They enjoy connecting trail loops to add variety in their workouts. Most runners want several miles of rolling contours with occasional challenging sections.

Equestrians: People on horses are the heaviest, widest and tallest non-motorized users. Their trails require a wide corridor and a high ceiling. Contour trails with a durable tread are the most sustainable. When designing a trail for horses, dogs and other pets, include water crossings or drink stops.



Endurance Athletes: Some trail runners, mountain bikers and equestrians like to push their limits. These people seek trail networks that are as much as a hundred miles long. A large network is more appealing than multiple laps of a short loop.

Disabled Trail Users: The Americans with Disabilities Act is a 1990 federal law that helps disabled people have equal access to public facilities. With improved skill, endurance and equipment such as off-road wheelchairs, more trail opportunities are being sought. Suitable trails have a wide, smooth tread with a gentle grade (an average of five percent) and no staircases.

Motorized Users

ATVs: All-terrain vehicles require a 4- to 5-foot-wide tread that's open and flowing. Their wide tires and horsepower allow travel on sandy or rocky trails. Fitted with racks, ATVs are popular with hunters, fishermen and others who take loads into the backcountry. Land managers and trail crews find ATVs useful in many work situations.

Motorcycles: Also known as dirt bikes, they require more operator skill than ATVs and can be used on narrower trails. Riders prefer trails that are open and flowing, and they can cover more than a hundred miles a day. Sensitive trails can be armored to withstand the weight.

Mountain Bikers

Beginner Cross-Country Riders: Casual cyclists like gentle, relatively short trails. As they become more skilled, they often seek longer, more difficult trails. Rough, arduous or twisty sections satisfy the need for technical challenge and help control speed. Mountain bikers tend to stay on trails if they're fun to ride.

Avid Cross-Country Riders: These experienced cyclists are comfortable in the backcountry. They're typically self-sufficient, carrying tools, water, food, clothing and sometimes a first-aid kit. Avid riders seek trails that let them cover from 10 to 100 miles in search of solitude, nature and challenge. Desirable trails feature several miles of connecting loops with natural obstacles.

Downhillers: These are advanced riders with sophisticated equipment that's specifically designed for descending steep and technical trails. They like steep, difficult trails. The most sustainable are rocky contours with many grade reversals. It's helpful to have a vehicle shuttle for reaching the top. Ski areas that provide summer lift service are popular with downhillers.

Technical/Trials Riders: They like challenges such as drop-offs, ledges, logs, elevated bridges, dirt jumps and seesaws. Some riders want these technical features within cross-country rides, while others prefer them as a stand-alone experience. One solution is special-use areas, similar to snowboard parks at ski resorts. On backcountry trails, these technical features should blend with nature, flow with the trail and be built well.

Trail-User Summary

People enjoy trails for solitude, escape, exercise, training, fresh air, social interaction and many other personal reasons. But all trail users have one thing in common: They want to be outside, in a natural setting. The number and variety of trail users has increased dramatically in just a few years. The best trail systems offer variety, challenge, long distances and sustainability. They keep users on-trail by providing the experiences people want.

4. Familiarize Yourself With the Area

Save time in the field by studying maps, aerial photographs, master plans and so on. In some areas, a Geographic Information System (GIS) study may have already been done. A detailed GIS might have many layers of information on one map, including ownership, topography, hydrography, soils, vegetation, habitat and slope grades. Use these resources to become familiar with the area and begin establishing control points.

When it's time to go into the field, take your compass, map and altimeter. A global positioning system (GPS) is also a valuable tool. It can help you pinpoint boundaries, control points and trail mileage.

In forested areas, the ideal time to survey is during autumn or winter when visibility is at its best. Return in spring or summer to check water levels.

Control Points are places that influence where a trail goes. The beginning and end are basic control points. Others include parking areas, trailheads, structures, slopes for turns or switchbacks, road or water crossings and other trails.

In addition, desirable control points can be places you want trail users to visit. These include scenic overlooks, waterfalls, rock outcroppings, historical sites, archeological sites, lakes, rivers and other natural features or points of interest. Consider the mix of users and the control points or terrain that will appeal to them. Design the trail to connect these places, keeping the route interesting along the way.

Inappropriate control points are places you want users to avoid. Examples are low-lying wet areas, flat ground that may hold water or sand, extremely steep sideslopes, fall lines, environmentally sensitive wildlife habitat or plant communities, certain water crossings, riparian areas, unresearched archeological sites and private property. If there's an inappropriate control point, keep trail users well out of range. People are notorious for spotting something interesting and creating their own unsustainable **social trail** to it.

Water crossings present special challenges as control points. Can a stream be forded or should a bridge be built? Geography and regulations usually provide the answer. Consult land managers and check other trails in the area to see what's customary. In general, design trails to avoid frequent water crossings.





Rich Etchberger

A rock outcropping is a great example of a desirable control point.

5. Conceptualize Loops

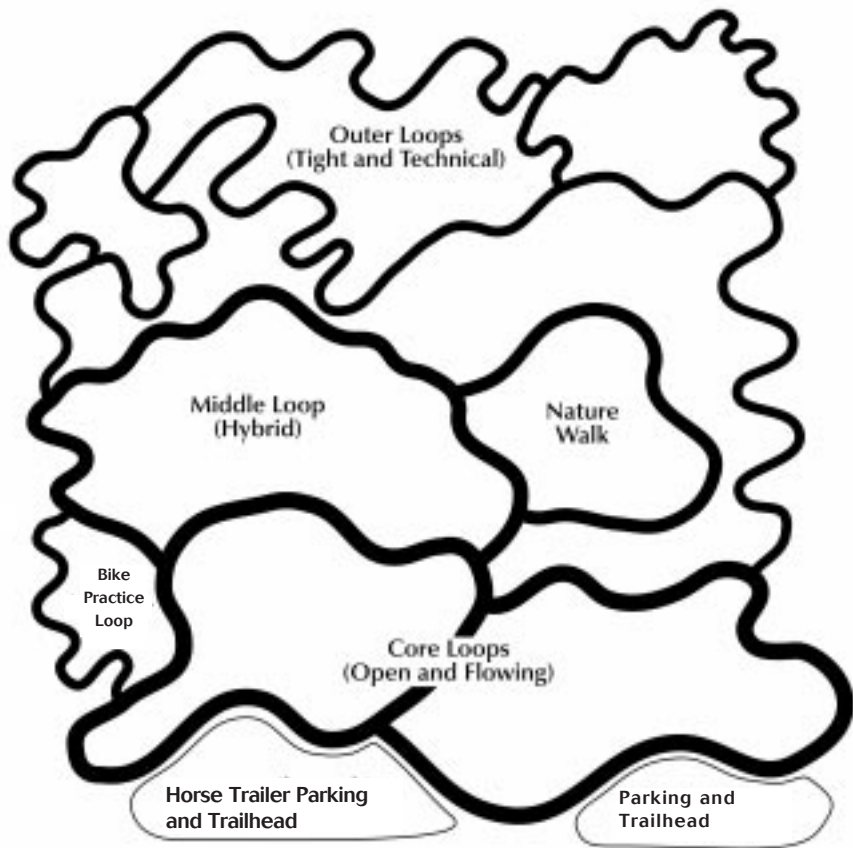
Trail systems with loops are appealing because they offer the most variety. People love the adventure of starting down one path and returning to the same point from another direction. Loops let people enjoy trails of varying distances, difficulty or ecosystems.

Several different types of loops can work for a trail system, depending on geography. A park that parallels a river may use linked loop trails that follow the water. Each loop is like a link in a chain. Users can choose a small loop, a combination of loops or take the whole outer loop. In mountainous terrain, a trail may climb one drainage to a summit, then descend another drainage. Stacked loop-trail systems make optimum use of available land.

In metro areas, the core trail leading from the trailhead or parking lot should be wide and smooth to appeal to a variety of users. People like to travel side by side and socialize at the start. Because a core trail is the entrance to the rest of the system, it gets the most use. Other loops branch from it and become narrower and more challenging as they get farther from the trailhead. Users seeking difficult or remote experiences are willing to travel greater distances.



STACKED LOOP TRAIL SYSTEM



Loops provide options. The majority of the system can be shared use, with a few areas designed for single use. Keep core loops near trailheads open and flowing to accommodate the widest variety of users. Outer loops can become progressively more technical and strenuous for people who want challenge.

6. Plan a Contour Route

Now you can begin to connect the control points. Mark each one on a **topographic (topo) map**. Use green for desirable points, red for inappropriate ones.

Draw a contouring route connecting green points while avoiding red points. Also avoid **fall lines** – the most direct route from the top of a hill to the bottom. That’s the path water takes.

Look for natural contouring corridors, but don’t let ease of construction override proper design. The best trails require few man-made structures such as staircases, water bars, **bridges** and **turnpikes**. Place the trail on the uphill side of large trees so it’s less likely to impact root systems. In the northern hemisphere, south-facing slopes may be desirable because they dry faster. In hot or desert environments, cooler north-facing slopes may be better.

The ideal ground drains well yet has cohesive soil (sticks together). Some soils are much more resistant to impact and loosening than others. Sand drains well but is not cohesive. Clay is highly cohesive but doesn’t drain well. Silt, another main soil type, falls somewhere in between.

Trail Grade

"Water always wins; the trick is not letting it play the game."

– Mike Riter, Subaru/IMBA TCC1

Sustainable trail grades minimize the effects of water and people. Good grades are usually shallow and address factors such as topography, soil type, rainfall and the number of trail users.





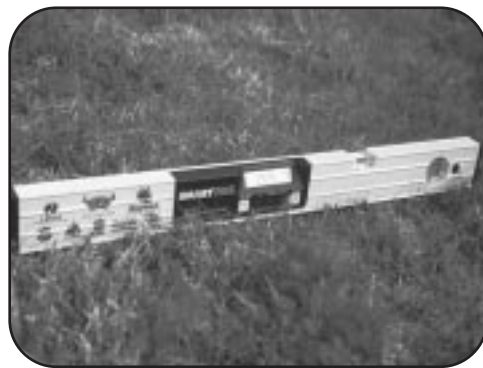
Joey Klein of the TCC works with a clinometer.

Determining the Steepness or Grade of Trails.

A **clinometer** measures a grade in degrees or percent. For highways, roads and trails, percent is used because it's more precise. **Percent of grade** is the relationship between vertical gain and horizontal distance, known as "rise over run." It's found by dividing rise by run. For example, a 100-foot section of trail that gains 10 feet of elevation has a 10 percent rise (10 divided by 100 equals 0.10). Therefore, the trail has a 10 percent grade.



Clinometer.



Digital Level.

The Half Rule

A trail **tread** grade shouldn't exceed half the grade of the hillside or **sideslope** that the trail is traversing. If the grade does exceed half the sideslope, it's considered a fall-line trail. Water will flow down the trail rather than sheet across it. Measure the sideslope, then keep the trail tread grade under half of that figure to ensure good drainage.

For example, if you're building across a hillside with a sideslope of 20 percent, the trail tread grade should not exceed 10 percent.

There is a limit to this **half rule**: A trail cannot be indefinitely steep. There can be short, steep sections, but try to limit the maximum tread grade to 15 percent. Of course, this depends on a number of factors, including soil integrity, rainfall, trail flow and number of users. Consider the surroundings to decide what works best.

Trail grades can be steeper on solid rock. But earthen sections between rock may need to be fortified or armored to prevent soil loosening and erosion.

The 10 Percent Rule

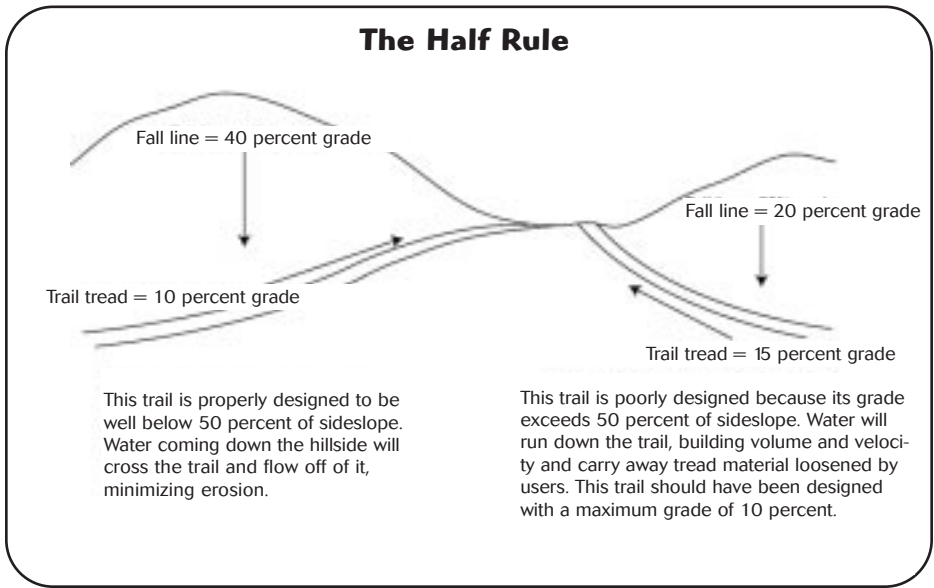
Generally, an overall trail grade of 10 percent or less is sustainable. However, there may be steep places where this grade can't be achieved. Trail tread grades can be as high as 15 percent as long as the trail's overall grade doesn't exceed 10 percent.

Begin flagging the route with conservative grades under 8 percent. This allows flexibility in case there's an inappropriate control point. By staying under the maximum grade, you can adjust the route without starting at the beginning.

Outslope in Contour Trail Design

As the trail contours across a hillside, the tread should tilt slightly away from the high side. This tilt, called **outslope**, ensures that water will sheet across the trail. Outslope is a major reason why contour trails work. For more information, see Chapter 4.



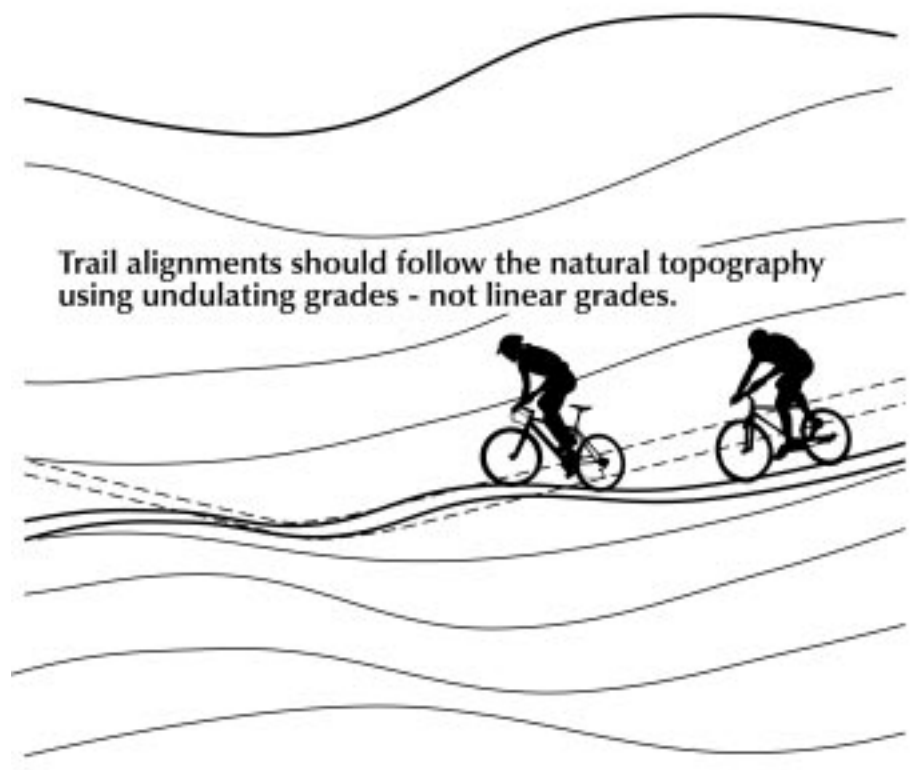


Grade Reversals

A well-built trail has gentle trail grades, an outsloped trail tread and **grade reversals**. As the trail snakes across a hillside, a subtle left or right turn creates rolls or undulations – grade reversals that help divert water off the trail. A contour trail on a steep slope may need grade reversals every 20 to 50 feet, depending on soil type and rainfall. The steeper the grade, the more grade reversals you should have.

To reduce the need to build water-diversion structures later, the original design should encourage smooth water runoff through subtle grade changes. Without proper maintenance, any trail will eventually lose outslope. Grade reversals act as a backup to prevent water from focusing. For more details, see Appendix A.

GRADE REVERSAL



Grade reversals direct water off trail surface and are self cleaning.

Grade reversals are effective before a water crossing, because they divert water and sediment off the trail before they can reach the stream.



7. Determine Type of Trail Flow

Trail users are defined by their means of travel (e.g., foot, horse, bicycle), but this is just one distinguishing characteristic. Speed is important too. For example, a mountain biker and a runner probably have a more similar trail experience than a runner and a walker, because their speeds are nearly the same.

Mountain bikers, runners and some equestrians travel faster than walkers or hikers. A trail designed for them should have a certain tempo or rhythm. We call this flow. Understanding flow can reduce erosion, user conflict and accidents.

Contour trail designs can have three basic types of flow: open and flowing, tight and technical, or a hybrid.

Open and flowing trails are relatively gentle. They have smooth surfaces, a wide tread corridor, long sight lines, sweeping turns and few technical challenges. They appeal to less-skilled cyclists and people who enjoy traveling fast. Open and flowing trails are fine, but they invite higher speeds and are also attractive to motorized users.



Open and flowing trail in the Utah desert.

Tight and technical trails have sharper turns and twists, rougher surfaces, a narrower tread and natural obstacles. They provide challenges and thrills for mountain bikers while keeping speed down, which in turn may reduce user conflict. Smooth trails can be made more technical by adding rocks or logs, a process known as **texturing**.



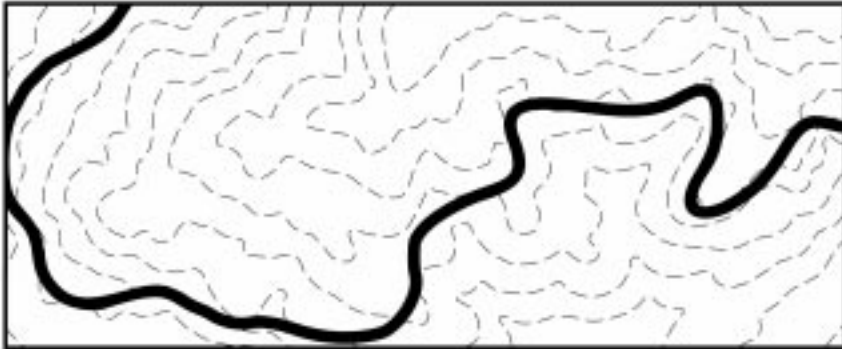
Tight and technical trail near Bellingham, Washington.

Hybrid trails successfully blend features of the above two types. Hybrid trails are often a good choice for urban areas. These trails may be wider, yet twisty with a rocky, technical tread. Trees, brush and obstacles should be below eye level, allowing for long sight lines that help reduce user conflict. Slightly wider trails allow users to pass each other, while technical challenges reduce speed and add variety.

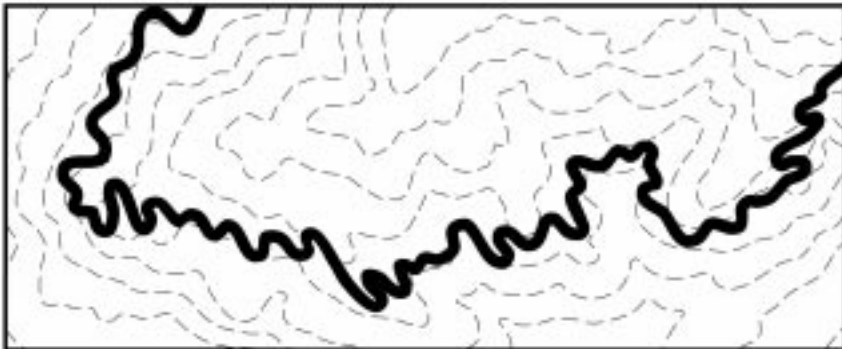
Proper transitions are essential when open and flowing sections are combined with tight and technical sections. Transitions should occur gradually or be atop hills. Abrupt transitions are likely to make cyclists brake hard and skid, resulting in braking bumps, and in some cases forcing users off trail.

Flow is vital on trails for cyclists. Mountain bikers love the rhythm of a trail where one turn blends into the next, and every descent leads into another rise. A trail with good flow helps minimize erosion, user conflict, and safety concerns.

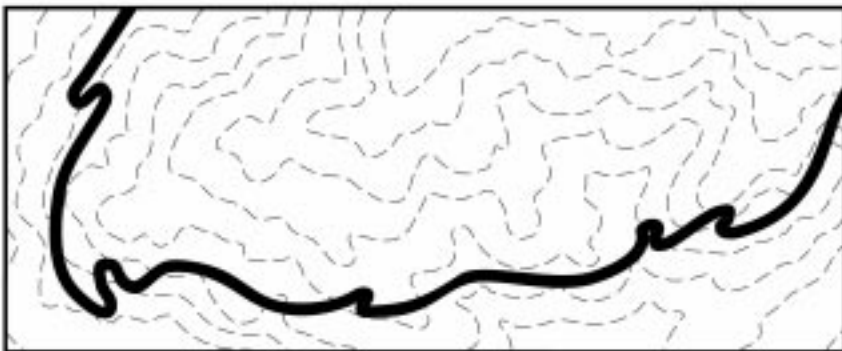
TRAIL FLOW



Open and flowing



Tight and Technical



Poor Design - Abrupt transitions from one type of design to another.

8. Walk and Flag Corridor

After the above preliminary work is done, use flagging tape to mark the trail corridor you're proposing. Once this general layout receives environmental clearance and land manager approval, you can establish the specific route.

Be sure you can see at least two consecutive flags from any point along the proposed trail. There's no such thing as over-flagging. Use plenty of flagging to make your design clear to the construction crew, ensuring that the trail is built the way you envision it.

When choosing your flag color, remember that yellow or orange don't work well during autumn where hardwoods grow. Green won't stand out in summer. Fluorescent pink is good in most areas year-round. Check with the local land manager to make sure other projects aren't being flagged with the color you intend to use. When tying flags around tree trunks, put the knot on the side you want the trail to pass. Also, put flags at eye level so it's easier to establish grades with a **clinometer**.

9. Develop a Construction Plan

This step should involve trail users, land managers and the work crew. Including the key players in decisions gives everyone a sense of ownership and pride in the trail.

Reach agreement on trail dimensions, including corridor width, tread width and ceiling. Consider how the trail will be built, how long it will take, how much it will cost and who will provide the labor. Develop a timeline for construction.

Many land management agencies require studies prior to new trail construction. These may be biological, botanical, cultural, archaeological, or historical. Or, a simple walk-through by the area's naturalist may be sufficient. Studies can be expensive and time consuming, so be patient. Make sure the plan you propose is exactly what you want, because changing it after this step may require going through the entire process again. Assessment studies usually cover a corridor 20 to 50 feet on either side of the flag line.

10. Flag the Final Alignment, Confirm Permission

Now you're ready to stake the exact location of the trail. This includes the design details that give the trail its unique character and ensure its sustainability. Flag the dimensions of the corridor, ceiling and tread. Identify the obstacles that will be left in the tread or included in its design. Let natural terrain features guide you.

Pin flags work best for marking tread location. Pin flags are reusable, lightweight and can be placed almost anywhere. Short flags are fine for desert or arid areas. Use long flags when there is vegetation.

For open and flowing trails, flags can be placed six or more feet apart. A tight and twisty trail might require flags to be three to six feet apart. It's important to keep spacing consistent. Each flag is like a dot – connect the dots to mark the trail. This helps you visualize flow, grades, grade reversals, turns and all the other key features.

Walk (or run if you can) the entire flag line in both directions, making adjustments to improve flow. Avoid long, straight lines. Use natural obstacles to accentuate curves and grade reversals. Be creative to produce an exciting pathway.

A well-flagged tread resembles a serpentine line with rounded arcs. Optimum flow comes from consistency in the radius of turns.

Outline the proposed tread by putting pin flags on the inside (uphill) edge, the center, or the outside (downhill) edge. The downhill edge is preferable because flags can remain during excavation to help the construction crew envision flow and the depth of **bench cut**.

When building a crib wall to raise the trail's downhill edge, place pin flags in the center of the trail to indicate the tread's finished depth. This is important for maintaining the grade.

Design Summary

By following these 10 steps you can create a contour trail design that will withstand the test of time, people and water. There are exceptions to every rule and some of these are covered in later chapters.



Chapter 3 Trail Construction



Safety

Safety is paramount in any kind of trail work. Sharp tools, difficult ground, weather, fatigue and natural hazards can cause injuries. Trail crews should wear sturdy boots and gloves. Long pants and long-sleeve shirts are recommended. Eye protection and hard hats are a good idea too.

Crew leaders should know the location of the closest medical facility and who will go for help. When an accident happens far afield, time is critical. Create an emergency plan before heading out. Make sure everyone knows his or her responsibility during an emergency.



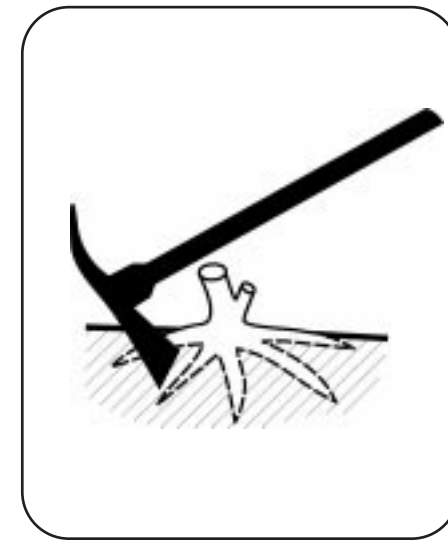
Start each workday with reminders about tool safety and the emergency plan. Cover these points:

1. Carry tools at the side, not on a shoulder.
2. Carry tools with the sharpest side facing down.
3. Carry only one tool in each hand.
4. When carrying just one tool, hold it in the downhill hand.
5. While working, maintain at least a tool-length distance to the next person.
6. If a tool must be raised higher than waist level, advise nearby workers.
7. Before walking past others using tools, announce yourself and make eye contact before passing.
8. Lay tools down on the uphill side with handles pointing towards the trail.
9. Stay alert for environmental hazards such as poison ivy, stinging insects, poisonous creatures, sunstroke, altitude sickness, dehydration, hypothermia, and so on.
10. Crew members with medical conditions must have their medication with them. Know who is susceptible to heart problems, bee-sting allergies, asthma and other common ailments.
11. Drink, eat and rest adequately. Avoid fatigue to reduce accidents.

Clearing the Trail Corridor

The trail corridor should be at least twice as wide as the **tread** width. This can vary with the terrain and type of user the trail is designed for. Leave grasses and trees when they're outside of the tread. Get approval from the land manager if there is any question about tree removal. There may be a size limit for cutting. When small trees and bushes are within the tread, don't cut them flush with the ground. They must be dug out, roots and all, or they'll become "pungee sticks" when the trail compacts around them. Cutting them at waist level leaves a handle for levering them out. Fill the resulting hole to match the tread.

When trimming tree branches, always cut just outside the branch junction. The resulting nub helps prevent disease from infecting the tree, and the cut will heal quicker. When removing larger branches, start by making a partial cut underneath. Then when the branch falls it won't strip protective bark.



(L) Rich Edwards of the Trail Care Crew clears a trail corridor. (R) Woody plants should be dug out, roots and all.

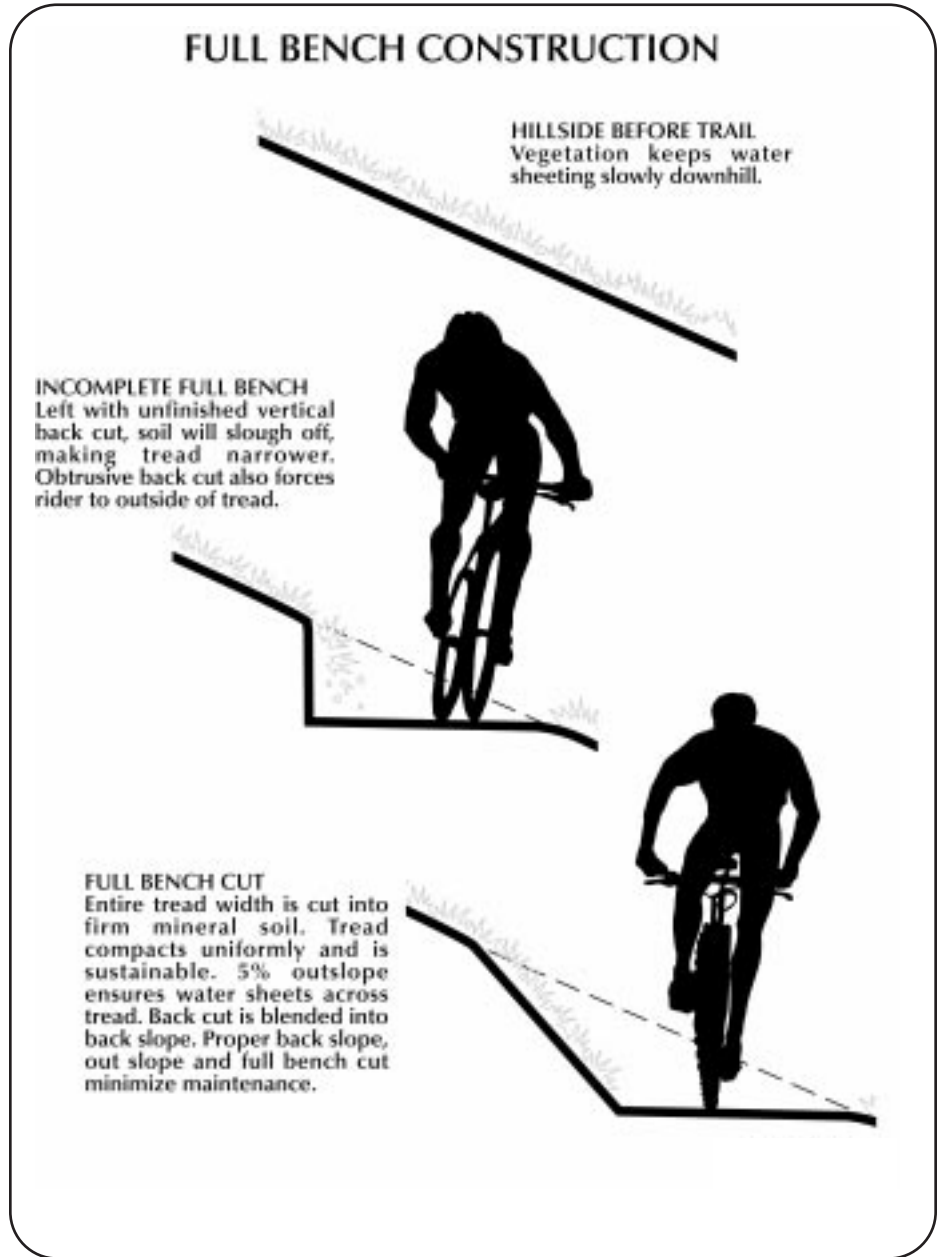
Put cut trees and branches at least 10 feet from the corridor. Lay them with the butt end pointing away.

Clear an area equal to the planned tread width. Also clear four feet downhill from the tread's lower edge. Next, rake the duff and debris from the tread area onto the uphill side. It can be used later to cover dirt removed from the bench cut and give the trail a more finished look. If it's too steep to rake uphill, rake downhill into large piles. Scatter dirt removed from the bench cut over the downhill area. Cover it with the duff and leaf litter.



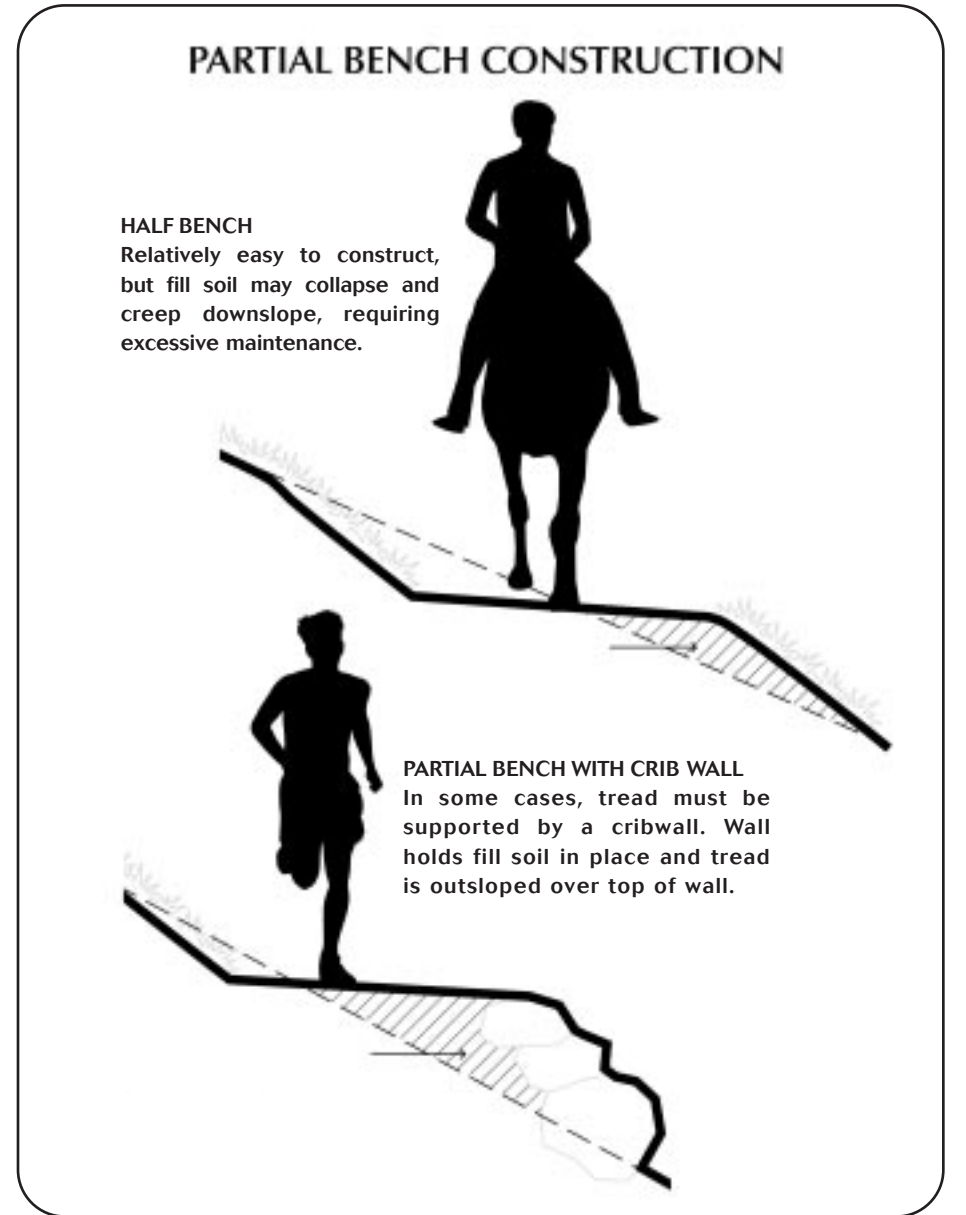
Full Bench Tread

When possible, excavate down and into the hillside to put the entire tread width on **mineral soil**. This is called **full bench** tread construction. It creates a consistent and stable tread. It takes more time to build, but it lasts longer and needs less maintenance.



Partial Bench Tread

Not recommended: A portion of the tread width is excavated and placed on the downhill side of the tread. This forms an incomplete or **partial bench**. The tread rarely compacts consistently, and eventually it begins slipping down the hill (**tread creep**). Partial bench construction usually results in an unsustainable trail if it gets substantial use.



Cribbed Bench

When essential roots or impenetrable rock make it impossible to establish a full bench trail, a retaining wall can be built to support the downslope side of the tread. This **crib wall** holds in soil, stopping the tread from creeping downhill. It's important for the top of the wall to be lower than the tread so water can sheet across. The construction cost of a crib-walled tread is usually at least twice that of a standard full bench tread. On sideslopes of 100 percent or greater, a partial bench supported by a crib wall will reduce the height of the backslope and the trail's impact on the hillside.

Back-cut and Backslope

The uphill side of the tread where it blends into the slope above the trail (the **backslope**) is called the back-cut. Often, the first rough cut of a full bench tread produces a vertical back-cut. If left vertical, water can undercut the backslope, which eventually sloughs off onto the tread. That's why it's very important to blend the back-cut into the grade of the hill. It lengthens the trail's life by preventing water from cascading onto the tread.

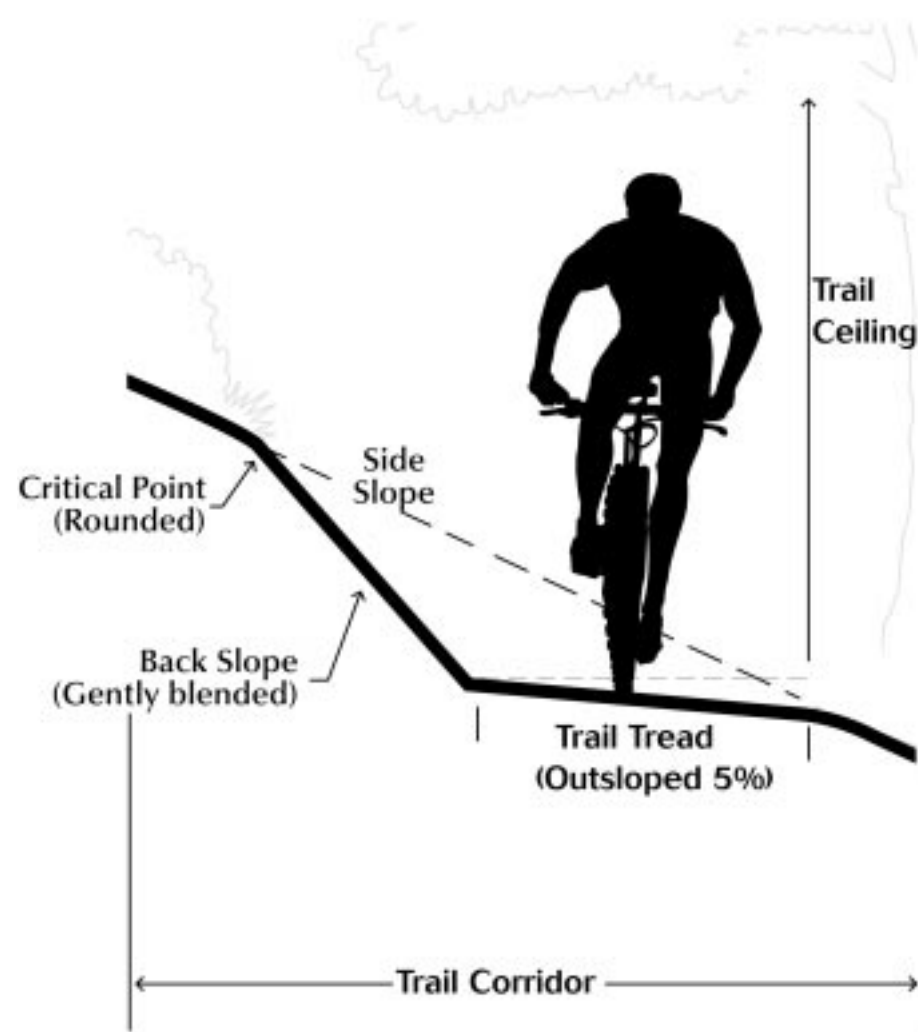
Outslope

Trail tread should have a subtle tilt (3-5 percent) in the direction of the fall line. This is known as **outslope**. It's the most important part of the tread because water won't sheet without it. Depending on soil type, newly constructed tread can have up to an 8-percent outslope to compensate for settling. To estimate, stand a McLeod on the tread to see if the handle leans into or away from the hillside, and at how much of an angle. To measure precisely, use a digital level or clinometer.

The Edge

Throw excavated topsoil several feet downhill, away from the trail. If topsoil is left near the edge, it can settle and become a **berm** that interrupts sheet flow, causing water to puddle or flow down the trail. The ground beyond the edge of the tread should slope away, if possible. This might require digging and removing vegetation.

TRAIL CROSS SECTION



Tread Surface

This depends on who the primary trail users will be. For more technical trails, leave natural obstacles such as rocks and roots that aren't a safety hazard and won't contribute to erosion.

On a bench-cut trail, remove rocks on the inside edge. If you don't, they'll force users to the outside of the tread and cause the edge to break down. On the other hand, obstacles on the outside edge will keep users in the center of the trail. Remove logs that are parallel to the tread on the downhill side so they won't act as gutters.

Rocks

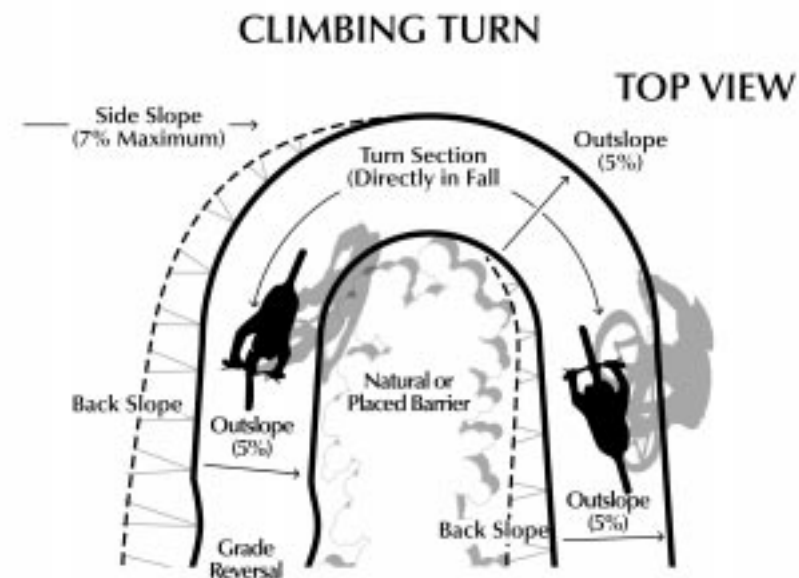
Large, stable, round rocks are good for the tread surface. So are reasonably square or rectangular rocks with ledges. But sharp, pointy rocks tend to force users off trail. Remove them as well as loose rocks that are likely to work free and create holes.

Roots

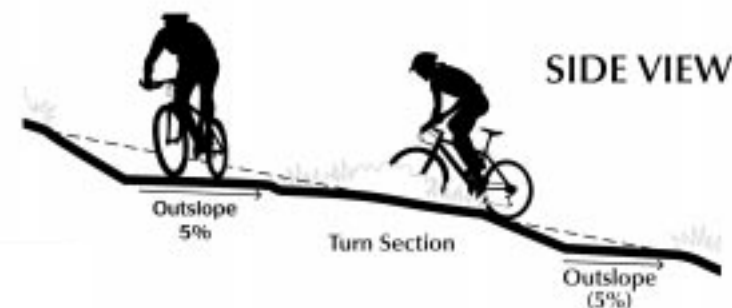
During construction, take out most roots with a diameter larger than a pencil. This is especially necessary for roots running parallel to the tread. They will channel water and may force cyclists off-trail. Sometimes large roots that are perpendicular to the tread offer an appealing challenge. But they might force cyclists to the low side of the trail, causing widening (tread creep). It depends on the nature of the trail and whether leaving roots exposed will cause significant damage to the tread or tree. Cutting large feeder roots near the downhill side of a tree may kill it and cause it to fall across the trail. Sometimes it's better to build a small crib wall and fill over large roots.

Turns

Two types of turns are used to reverse direction on hillsides in order to gain elevation in a short distance. A **climbing turn** on the existing grade doesn't have a constructed turning platform or landing. A **switchback turn** reverses direction with the help of a relatively level constructed landing. Both turns take skill to locate and are difficult and expensive to build and maintain. Think of them as a last resort. Whenever possible, it's better to gain elevation by maximizing long contour trail sections.



Maintain constant grade and radius through the turn section. Climbing turns may not be sustainable on sideslopes exceeding 7 percent grade.



A climbing turn is any turn that ascends (or descends) on the fall line of a sideslope. Improve sustainability by placing climbing turns on gentle slopes and using grade reversals to drain water above them. Climbing turns should have a large turning radius and barriers between legs to prevent shortcutting.

1. Climbing Turns

Climbing turns are used on shallow slopes that don't exceed a grade of about 7 percent. To control cyclists' speed and prevent skidding, climbing turns should be free flowing and gentle. Keep the turn radius as wide as possible, ideally 30 feet.

Minimize erosion by having a short uphill section or **grade reversal** just above the turn. A grade reversal diverts water off the trail before it reaches the fall-line section. Climbing turns are best used on elevated ridges or slopes where water accumulation is minimal.

Because climbing turns include a section of trail on the fall line, they aren't as durable as well-constructed switchbacks.

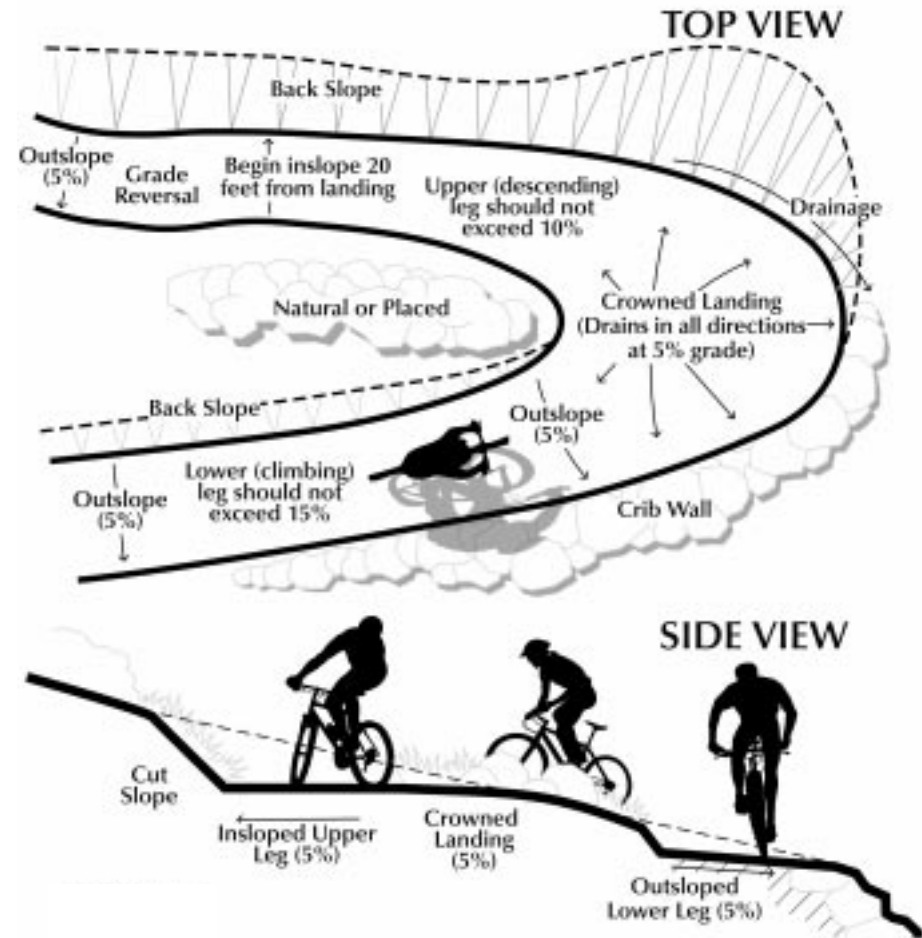
2. Switchbacks

Switchbacks are difficult to build but are more durable on steep slopes. They will last longer than climbing turns if properly designed. We recommend a version called the "rolling crown" switchback. It's carefully engineered for good drainage.

Key Features of a Rolling Crown Switchback.

- It's located on a gentle slope (consider it a control point).
- Water drains off the back of the turn.
- Turns occur on a near-level platform that's slightly crowned (domed).
- The trail stays on the contour on both approaches.
- Bench cuts and crib walls are combined as needed.
- Material excavated from the top leg is used to build up the bottom leg behind a crib wall.
- Crib walls are carefully built to ensure stability.
- The upper leg is insloped.
- The lower leg is outsloped.
- Approaches are designed to control user speed.
- Grade reversals in the approaches divert water.
- Switchbacks aren't built directly above one another. They're staggered on a hillside to prevent shortcutting and water accumulation.

ROLLING CROWN SWITCHBACK



This shows the most sustainable type of turn on steep sideslopes. Inslope the trailbed only on the upper leg as it transitions to the crowned landing. The landing should have a 12- to 18-foot diameter, depending on trail width. The landing is outsloped in all directions. Build a grade reversal just before the upper leg to move water off the trail before it reaches the landing.





Rolling Crown Switchback

Crib Walls

Build a crib wall (retaining wall) when you need to shore up the turning platform. It's better to use rocks instead of logs, and better to use large rocks (at least 50 pounds) than small ones. If you can lift the rock by yourself, it's probably not big enough. Ideally, many of them will weigh at least 150 pounds and be rectangular, not round. Excavate the footing, then place large, well-anchored foundation rocks. The wall should tilt into the slope – described as the wall's "batter." Batter should never be shallower than 4:1, defined as an inward tilt of one foot for every four feet of height. A 2:1 batter is better. Building large crib walls is difficult, so enlist the help of someone who has experience.



Crib wall

Water Crossings

A water crossing doesn't always have water. It's also the site of a potential conduit for water. Every crossing is important for two reasons:

1. It's where a trail has the most impact on water quality.
2. It's where water has the most potential to damage a trail.

When water from two sources join, it's called hydrologic connectivity. An example is a trail that collects water and channels it into a stream. Runoff from trails may carry soil that causes sedimentation, which can harm aquatic plants and animals. A well-designed water crossing minimizes the trail's negative impact on water quality and the riparian corridor (the habitat along the edge of a river or stream). Good design minimizes hydrologic connectivity by building gentle grades near water crossings to direct flow off the trail. Never design a trail with fall-line sections oriented toward water crossings. This encourages land erosion and sedimentation.

When crossing a waterway, also consider how it may affect the trail. Will water be diverted by the tread? What will happen when the waterway floods? Even desert trails require careful consideration when intersecting with possible drainages. What seems like a perennially dry gulch could channel a roaring torrent following a cloudburst.

Bridges

These are the most common solution for water crossings. By putting the trail above the water, you minimize the impact each has on the other. Make the bridge high enough so the approach is on a gentle grade (if not level). Proper height also helps avoid flood damage. Make the bridge and adjoining trail have good flow (no awkward transitions).



Tips for Successful Bridge Building:

1. Make bridges strong enough to support the heaviest potential user (bicycle, horse, ATV, etc.).
2. Build with materials that meet your needs and budget as well as what's available. This could be wood, rock, metal or plastic.
3. For wooden bridges, screws hold much better than nails.
4. Extend approach ramps into the trail.
5. Avoid letting bridge stringers touch the ground, which can lead to rotting. Sit stringers on sills of stone or replaceable wood.
6. When building with unfinished wood from the bridge site, use only naturally rot-resistant species such as cedar, hemlock, locust, redwood or cypress. In eastern North America, for example, locust is by far the most rot-resistant wood.
7. Bark must be stripped or wood will rot and suffer insect damage.
8. Bridges and their approaches should not have sharp turns. A tight turn onto a bridge deck is very dangerous when it's wet or icy.
9. If railings are required and the bridge is located just before or after a turn, make the railing low on the inside edge to accommodate cyclists leaning in.
10. Design the bridge so that users on either end can see each other and slow or yield before meeting abruptly in the middle.

Before beginning work, consult an experienced bridge builder or at least check with the U.S. Forest Service for its construction guides.

Fords

Bridges can be expensive and may require a lengthy permitting process. So consider an alternative – the armored ford. This lets users pass through water but minimizes sedimentation. The approach to a ford is similar to one for a bridge. Use care to prevent sediment runoff from the trail to the water. Place stone to make a hard surface for the entrances and crossing. This prevents trail users from degrading the banks or stirring up silt. Consult the land manager before disturbing any creek or streambed.



Ford in Keystone, Colorado.

Culverts

A culvert is a large pipe that allows water to flow beneath the trail bed. This is an appealing solution thanks to low cost and easy installation.

Tips for successful culvert installation:

1. Use a culvert large enough to handle the maximum expected flow. Estimate this by checking the stream corridor. Culvert diameter should be at least 24 inches, and sometimes two or more culverts may be needed.
2. Think about culvert maintenance before installation. The longer the culvert, the more likely it is to clog – and the harder it is to clear.
3. Slope a culvert downstream on a grade of at least 10 percent.
4. Armor the face of the tread surrounding a culvert. This helps it survive a flood. Remember, the soil used to fill around a culvert will be less compacted than the surrounding soil. It's susceptible to being washed away.



Chapter 4 Maintenance



The same care, thought and hard work that go into new trail construction must be applied to trail maintenance. Thankfully, it shouldn't take much to keep a well-designed trail in good shape for many seasons.

Maintenance shouldn't substantially change the character of a trail or diminish user experiences. Just as a good trail appears to have always been there, good maintenance should be almost invisible.

"It's simple: keep the users on the trail and the water off of it."

– Joey Klein, Subaru/IMBA Trail Care Crew

Corridor

Trim back vegetation each season – or more frequently, if necessary. Maintain a high ceiling on trails used by equestrians. Keeping the corridor open helps keep people on the trail. For example, cutting vegetation on a trail's uphill side allows users to stay on the center of the tread. Otherwise, they may be forced off the downhill side. Creative pruning along alternate sides of a trail accentuates curves to keep a twisty trail twisty. Don't trim more than necessary. Over-trimming tends to make a trail too straight, inviting speed. (Of course, many desert trails and paths through open terrain don't need trimming.)

Tread

Tips for maintaining the trail tread:

1. Look for places where water is being trapped on the tread. Try to do this when it's actually raining. Remove obstacles or features that cause puddles and force users off the trail to get around.
2. Restore the outslope and/or remove berms. This is often the primary maintenance job. If a trail has become insloped or developed a berm, it will collect and channel water.
3. Fill and pack any holes or ruts after removing a problem.
4. Because certain soil types won't bond to each other, you may need to fix a hole or a rut by skimming the surrounding tread down to its level. Don't forget to re-establish the outslope.
5. On trails with very steep grades, or in rainy areas, armoring may be necessary to sustain the tread. Armoring means placing stones or other highly durable material into the tread surface. When using stones, be sure they're large enough not to be displaced by use. Proper armoring helps a trail bed last indefinitely.



Natural Obstacles

Rocks may roll onto a trail and trees may fall across it. In most cases, these things should be removed. But sometimes natural obstacles are a blessing, giving a trail an interesting, technical character. If the majority of people can pass over or through an obstacle while staying on trail, and it isn't trapping water, consider leaving it. Obstacles help keep speed down while giving experienced trail users the challenge they like. For details, see Appendix A.

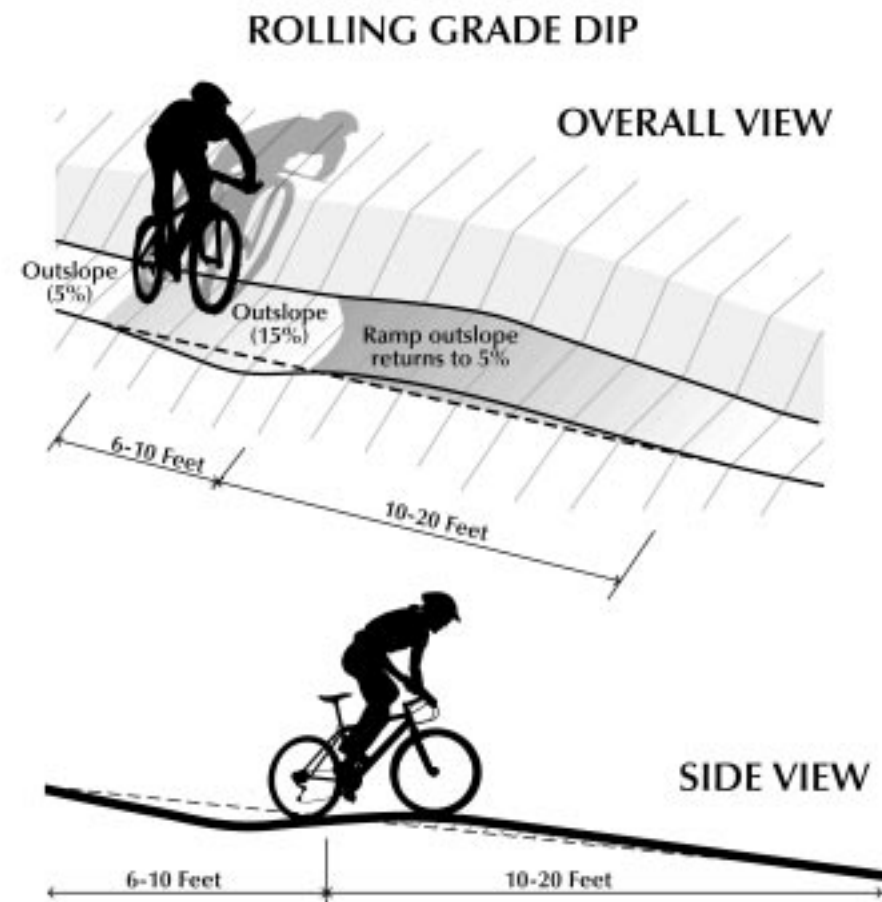
Drainage

As just mentioned, outslope restoration and **de-berming** are essential to maintaining sheet flow across a trail. However, many contour trails (even those with proper outslope) can benefit from improved drainage. If a trail doesn't have natural grade breaks or reversals to direct water, artificial ones can be added. We recommend two types: rolling grade dips and knicks.

Rolling Grade Dips

A **rolling grade dip (RGD)** is an unobtrusive way to divert water off the side of a trail by altering the grade. Water is pulled from the trail, not forced off abruptly. RGDs are longer and subtler than traditional water bars. They also are more effective than water bars because they're large and durable, yet smooth enough to be negotiated by all users. They're a particularly good drainage device for trails used by mountain bikers. Unlike water bars, they don't entice cyclists to ride off-trail to get around them. And cyclists won't impact the tread by braking hard as they approach.

Please visit the trailbuilding section at www.imba.com for more details and photos explaining RGD construction.

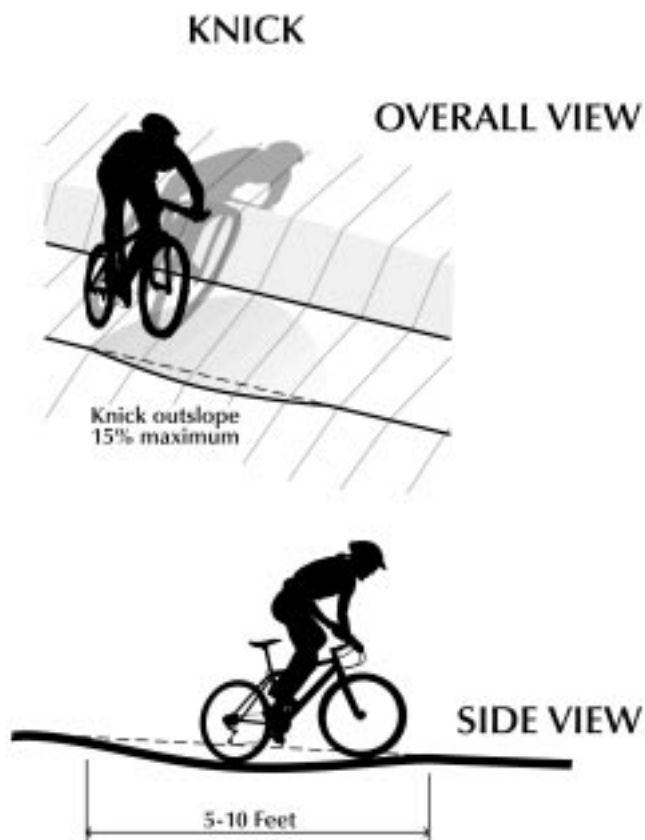


Rolling grade dips are a sustainable alternative to water bars. Dips are large enough to be self-cleaning and subtle enough that cyclists won't steer around them. A dip is longer than a bike and shaped like a knick. Use bondable soil from a dip to make a long, gentle ramp just past it. The ramp should be nearly twice as long as the dip.



Knicks

Like a RGD, a **knick** is smooth and subtle. This is a shaved-down section of trail, about 10 feet in diameter, canted with the hill's natural slope. Knicks are typically built on flatter sections of trail where water tends to puddle. They work well on non-cohesive soils.



Knicks are used on gentle terrain to direct sheet flow off the trail. In contrast to rolling grade dips, soil from the knick is spread downslope off trail. The goal is sheet flow, not concentrated runoff.

Knicks can be used on contour trails to accentuate natural grade breaks and direct water off trails. Knicks should be long and subtle to be self cleaning, yet unobtrusive to trail users.

Re-Routes

Too many trails have been hastily designed. Perhaps they were easy to build, but now they're impossible to maintain. Has a certain trail become a maintenance nightmare? Stand back and look at the big picture. We often find that various problems along a section can be solved with one contouring re-route.

Perhaps a trail is almost always muddy because it goes through the lowest point in an area. It might have fall-line sections, steep grades, poor flow or vulnerability to floods. Look for a new route that solves as many problems as possible. Get permission and do the proper studies. Plant removal or passage through a particular habitat may be issues when proposing a re-route, but in the long run closing a bad piece of trail is better for the environment.

Of course, a trail that's viewed by one person as a steep, eroded, maintenance nightmare might be someone else's favorite challenge. When re-routing around steep sections, look for special features that make the new route challenging while keeping grades sustainable. See Appendix A.

Think about trail flow. Does the new passage fit the flow of sections it connects? Make the re-route more appealing than the old trail with a mix of suitable grades, interesting features and sustainability. The new trail must make users forget the old one. Make it more fun!

Trail Retirement

After constructing an appealing re-route, you need to close the old trail. This means restoring its natural state.

Six Key Points for Retiring a Trail:

1. If the old trail was steep, check dams may be needed to hold sediment.
2. The old tread should be scarified, tilled or in some way loosened so that seeds can grow.
3. Cover the old trail with duff, topsoil, plants, grasses and small trees from the new construction.
4. Hide the visual corridor. Low-lying obstacles are not enough. Only when the old trail is out of sight will users abandon it.
5. Education is important. Signs explaining the re-routing benefit help keep people off the old trail.



Chapter 5 Trailbuilding Resources



More Information

- IMBA Website: www.imba.com
- U.S. Forest Service: [Trail Construction and Maintenance Notebook](#) – Call (406) 329-3900 to order.
- Student Conservation Association: [Lightly on the Land, The SCA Trailbuilding and Maintenance Manual](#) – Call (800) 553-4453 to order.
- South Carolina Trails: www.sctrails.net
- Western Trailbuilders Association: www.trailbuilders.org
- American Trails: www.AmericanTrails.org

Professional Trail Design and Construction Services

- IMBA: www.imba.com or (888) 442-4622
- Arrowhead Trails: www.arrowheadtrails.com or (720) 244-7804
- Trail Design Specialists: traildesign@mindspring.com or (678) 342-9549

Trailwork Tools

Trailwork tools aren't discussed in this publication. We recommend the U.S. Forest Service's comprehensive guide, *Hand Tools for Trail Work*. Call (406) 329-3900 to order.

Zac Tools manufactures trailwork tools. Contact: zactools@aol.com, www.zactools.com, (805) 527-5207. IMBA members may receive a price discount.

Recommended Zac Tool Products:

- 10-inch Mcleod, \$41 (approximate retail price)
- Fiberglass Handle Pulaski, \$65

We highly recommend Zac's 10-inch Mcleod fire rake. This is the classic RockShox/IMBA Mcleod that's a combination heavy-duty rake and hoe for clearing a fire line in matted leaves and loose debris. Supplement this tool with a pulaski in rocky or bushy terrain.

Ben Meadows Company

This outfit provides excellent customer service and pricing on a number of products – from Suunto clinometers to your everyday pin flags. Contact: mail@benmeadows.com, www.benmeadows.com, (800) 241-6401..

Recommended Ben Meadows products:

Suunto Self-Damping Clinometer. This instrument provides fast and accurate height, slope and vertical angle measurements. Graduated 0 to $\pm 90^\circ$, 0 to ± 150 percent. Accuracy to 1° or 1 percent.





Appendix A

Designing Trails with Technical Challenge



In This Section:

1. Where to Locate Technical Challenges in a Trail System
2. How to Make Tough Trails Rock-Solid
3. How to Use Exposure to Add Challenge
4. How to Use Logs to Add Challenge
5. How to Build Short Ups and Downs (An Easy Way to Toughen Trails)
6. How to Use a Clinometer

1. Where to Locate Technical Challenges in a Trail System

The Subaru/IMBA Trail Care Crews are sometimes accused of sanitizing trails. This is heard most often when an eroded gully is replaced with a sustainable contour trail. But if the plan calls for a challenging trail, the crew will build it burly and difficult to navigate. If the new path must be rideable and walkable by everybody (including horses), then that's the specification followed.

IMBA crews have built several re-routes that are more sustainable and more difficult to navigate than the problem sections. In each instance, the locations were appropriate for technical features. Ideal spots for tough sections are rural regions or remote parts of large, diverse trail systems. Urban areas with a large trail-user population generally aren't the best place for aggressive trails. But there may be room for a challenging trail or two when urban green space is large enough to support a more extensive trail system.

In planning, think about all the people who will support and use the trail system. Don't build a public system that will appeal to only a small percentage of potential users. Instead, build a diverse system that spans a variety of desires and abilities.

A stacked loop system facilitates diverse trail styles. It typically includes:

A core or trunk trail. This begins at the trailhead, usually right off the parking area. It can be a loop. It's heavily used because it connects to the rest of the trail system. A core trail tends to be wider, smoother and have longer sight lines than other trails. It may need to be designed to ADA (Americans with Disabilities Act) specifications. It's often short (half mile or less) and non-challenging, allowing leisurely strolling side by side or family cycling. It doesn't provide as much solitude or exertion as other sections.

Primary trails. These comprise much of the loop system, forming circuits that don't require use of challenging trails. Primary trails add some excitement, though. Compared to a core trail, they typically have a narrower, rougher tread with more elevation changes and tighter turns. A few challenging features may be appropriate.



Challenging trails. The best location is at the back of a stacked loop system, or in a trail system that's more than an hour's drive from a metro area. The remoteness and rugged tread deters some users while providing a high-quality experience for others. Challenging trails give runners, avid cyclists and other enthusiasts a greater chance to find solitude as well as a way to test their skill and stamina.

One attraction of outdoor recreation is using physical talent to overcome adversity while enjoying natural surroundings. People don't walk the Appalachian Trail because it's easy. Pushing limits and reaching goals has been part of American outdoor recreation since the days of Roosevelt and Leopold. We can grow our constituency by building diverse trail systems that satisfy newcomers as well as backcountry veterans.

2. How to Make Tough Trails Rock-Solid

As mountain bikers become more skilled and equipment improves, they seek difficult trails to test their skill. For many riders, difficult means steep. But as we've seen, steep trails can create big erosion problems. We don't want people locking their brakes and taking the trail with them. To preserve the land and ensure future trail access for cyclists, new trails must be routed gradually across the slope and generally avoid the fall line. Some mountain bikers may consider these contour trails too tame, so the design can add elements that enhance technical challenge while not reducing sustainability. Rock is effective because it "hardens" a trail as it increases difficulty.

Here are five ways to use rock in trail design:

Steeps. Locate solid rock slabs or faces where a trail can run straight down the fall line without causing erosion. San Antonio riders are challenged by The Wall – a 15-foot-high rock face that falls away at a 90-percent grade. It's a favorite challenge for local riders yet remains erosion free. When designing a feature like this into a trail, open the outrun to prevent heavy braking, or floor it with rock. Use a natural grade reversal or dip above the steep to keep water off the trail.



A steep rock section in Whistler Bike Park, British Columbia.

Rock gardens. Route your trail over and through rocky areas. West Virginia's Tea Creek Mountain Trail has a rock garden that everyone tries to clean but rarely does. This rubbly section batters bikes and appeals to hikers and equestrians, too. People expect rocks in nature and won't avoid them if they seem natural. The key is that no matter how difficult a rock section might be, it still must be the easiest route. This gives people no choice but to stay on the trail, preventing trail widening or shortcuts.



A nice East Coast rock garden.



A narrow rock chute and drop.

Rock chokes. A series of boulders staggered on either side of the trail makes a narrow choke or slot that enhances the challenge. It also reduces cycling speed. Be sure this narrowing blends naturally with the trail. Otherwise, people will find it annoying instead of interesting, and may create a new route around it.



Very old armored trail.

Armoring. Use large rocks to "pave" a trail and prevent erosion. Trailbuilders in soggy Wales are forced to armor entire pathways to escape year-round mud. Large, ominous rocks are buried in the tread, making the trail interesting and dry. When armoring, use boulders that take two or three people to move. This ensures that the rock will stay in place. Bury at least a third of each rock, taking care to make the section look natural. Experiment with different placements to mimic natural outcroppings.

Drop-offs. Incorporate natural ledges or use rock to build short drop-offs. This addition on a contour trail challenges cyclists ascending or descending. Six to 12 inches is the right height for most riders. Be sure drop-offs fit the overall flow of the trail. Put them in a bike-length series where riders won't be taken by surprise. This spacing makes it possible to climb as well as descend. Transitions are important. A tight turn following a drop-off will cause cyclists to skid or ride off the trail. Tall drops can offer two lines – one difficult and one easier using a ramp or chock stone.

3. How to Use Exposure to Add Challenge

Build narrow trails with exposure and you're guaranteed to raise the technical ante. Exposure is empty space beside the trail tread. It adds challenge while retaining sustainability. Riding singletrack across a steep hillside with nothing but air on one side always produces grins – and a shot of adrenaline in even the most experienced rider. We've ridden bench-cut trails on slopes that exceed 45 percent. The exposure on such trails provides a psychological challenge, too. A three-inch rock seems like a boulder when a 50-foot drop looms on your side!

Adding exposure is even more effective in areas where it's uncommon or unexpected. You don't need mountains. Seek features such as rock outcroppings, small embankments or any elevation change. A trail across a slope will seem more challenging with a rock or thorny bush on the uphill side, forcing cyclists to tightrope along the downhill edge.

Examples of great trails with significant exposure include Bootleg Canyon, NV; Portal Trail, Moab, UT; Shenandoah Mountain Trail, VA; Tea Creek Mountain, WV; and many trails in Fruita, CO.

4. Using Logs to Add Challenge

Fallen trees. Leave them on the trail, but not all the way across. Some trail users like logs for the test they present. Others will avoid them by going around, even if it means leaving the trail. A well-designed trail accommodates everyone, which means no major obstructions. Leave a log covering only part of the trail, allowing an unblocked route to one side. This gives users the option of scaling the log or skirting it. (This won't work on tight singletrack, however). Make sure there are good sight lines in both directions and that the direct line is over the log. Try to keep the trail narrow. Don't use logs as a way to make cyclists slow down. In fact, they may ride faster in order to jump them.

Log ramps. A popular maintenance technique is using small logs to create ramps before and after big logs. This is generally a bad idea. Most trails are shared use, and these log piles are a big obstacle to horses and hikers. One solution is to cut a gap and make the ramp optional. However, we've seen hundreds of ramps and only three or four were well constructed. Throwing a bunch of rotting logs and branches at an obstructing log and calling it trail maintenance is just being lazy. A well-built ramp uses logs at least 8-10 inches in diameter. If they need to be fastened, use rope or wire, not dangerous spikes. Should you decide to make a ramp, build it well and take pride in your work. Always create an easier option, too.

Log chokes. Conflicts between mountain bikers and other trail users often result from the faster speed bikes travel. Just like traffic calming devices on roads, the best way to slow cyclists is by narrowing the tread, creating tight spots and adding curves. Make a log choke by staggering logs on either side of the trail. Be sure this narrowing flows naturally with the trail. Otherwise, cyclists and other users may avoid it by creating a route around it.

Balance beams. A log placed lengthwise next to the trail will be used as a fun and challenging balance beam by people on foot and bikes. It's also a handy place to rest. Place these logs upslope of the trail where they won't impede drainage. Set them into the ground so they don't roll.

Log steps. Use large logs to make short steps or drop-offs. This is a good way to challenge cyclists in an area without natural difficulties. A drop of 6-12 inches is right for most users. Make sure steps fit with the trail's flow. Use them in a bike-length series where riders won't be taken by surprise. Transitions are important – a tight turn following a step is awkward. Also, be sure to account for water flow.

5. How to Build Short Ups and Downs (An Easy Way to Toughen Trails)

First, a reminder: Put trails on side slopes whenever possible. Avoid flat areas because water or sand may accumulate. Flood plains, river bottoms, plateaus, meadows, old roads – trails in these places can turn into mud bogs or sand traps that require continual maintenance. On the other hand, contour trails along side slopes provide good drainage. They are far more appealing and will pass the test of time. Here's how to add spice to contour trails by using ups and downs.

Grade reversals. On sideslope traverses, make the route more interesting by "surfing" the contour lines. Create a rolling trail that dips and rises frequently. Reverse the grade subtly every 20-40 feet. Visualize rhythmically spaced "waves." Remember that the trail grade must always remain less than half the sideslope at 40 percent, no part of the trail should exceed 20 percent, and we recommend 10 percent as a maximum overall grade. Route the trail on the uphill side of trees to use bench and avoid roots. Surf around natural obstacles. Grade reversals make a trail fun and improve drainage.



Example of a grade reversal.

Grade breaks. Lack of grade changes is a common trail design error. Long runs of constant grade encourage excessive speed (if downhill) and they're boring (if uphill). Erosion will be a problem if water focuses down the path. For these reasons, interrupt grades with breaks where possible. Short descents mixed into long climbs help users regain momentum and catch their breath. On downhills, short climbing interludes provide variety, challenge and let cyclists get off their brakes. Grade breaks also ensure that water doesn't gain speed and erode the trail.

Constant ups and downs. If your local terrain is generally flat, it's even more important to use short ups and downs to challenge cyclists. Make use of every available change in terrain. The 1996 Olympic mountain bike course in Conyers, Georgia, is a good example. It's always undulating. Despite the lack of big hills, the course is very challenging because racers never get a chance to rest.

Gravity drops. The goal is to create a large dip in the trail with an equal fall and rise. Cyclists drop in and their momentum shoots them up the opposite side. G drops are one place where the trail grade can be a bit steeper than we recommend. The key is a smooth transition and clear sight line. If the drop is designed correctly, the average rider won't need to brake. That's important so dirt won't be pulled down. G drops shouldn't be used on trails that have lots of hiker or horse traffic. These users tend to scrape a downhill grade, increasing erosion. Good sight lines are key. Cyclists must be able to see the entire drop from either side. Remember to keep the trail grade under half the sideslope grade, and limit steep sections to 15-30 feet. **Back-cut** - The vertical part of the bench cut that is blended into the backslope.

6. How to Use a Clinometer

A clinometer is also known as an inclinometer or "clino." It's a hand-held instrument that tells the slope of a hillside or grade of a trail, making it an essential tool for building sustainable trails.

Step 1: Zeroing the Clinometer

On level ground, stand about 20 feet from your partner and hold the clino to one eye while closing the other.

You'll see a line and a rotating scale of numbers. Tilt the clino up or down until the zeros align with the line. Now open your other eye and extend the (imaginary) line onto your partner. The point where the line falls on your partner is the "zero point."

Step 2: Measuring Grades

To measure or "shoot" the average grade of a hill, fall line, sideslope or tread grade, have your partner stand directly uphill from you. Hold the clino to your eye, keep the other eye open, and set the line onto your partner's zero point. This time, instead of zeros, there will be a number behind the line. This is the grade of the slope you're standing on. Most clinometers have two scales: degrees and percent. Always use percent.

It doesn't matter exactly how far away your partner is. What is important is that both of you are standing on the same slope. If the slope changes in between, you'll get an average of the two slopes. For example, if you stand across a gully from each other, it would be possible to shoot a 0 percent grade. You need to measure the two grades independently.

One Final Thought

The best trail systems strike a balance between protecting resources and providing recreation. A well-designed contour trail system takes people into nature while safeguarding the environment. Techniques for design, construction and maintenance constantly evolve, but the goal is always the same: Build trails that are sustainable and appealing.





Glossary of Terms



Rich Etchberger

Back-cut - The vertical part of the bench cut that's blended into the backslope.

Backslope - Slope on the uphill side of the trail. This should be a gradual change from the tread, slowing runoff by preventing a waterfall effect.

Bench cut - A semi-flat trail tread created by digging down to mineral soil in the hillside. Care must be taken to preserve some outslope while making a rideable and walkable path.

Berm - The ridge that develops along the downhill edge of a trail. It's caused by tread compaction and soil displacement during trail use. A berm traps water on the trail.

Bridges - Allows trail users to pass over ravines, bogs, creeks, rivers and similar obstacles.

Climbing turn - A turn that transitions from one leg to the next as the trail ascends (or descends) a hill.

Clinometer - Instrument used to measure the slope of ground. Also known as an inclinometer or clino.

Contour trail - Pathway that gently traverses a hill or sideslope, following natural contour lines as illustrated by a topo map. Allows water to sheet across the trail, thus minimizing impact to the tread.

Control points - Places of interest that trail users will be attracted to (desirable) or should avoid (inappropriate). Mark control points and use them to determine the placement of a new trail.

Crib wall - A retaining wall that raises the trail significantly. Often used to stabilize the trail tread and prevent it from collapsing down the fall line. Can be built with rock or wood.

De-berming - Removing the berm, or ridge of dirt that forms along a trail's downhill edge. Restores the tread's outslope, allowing water to sheet off. (See "outslope" and "berm.")

Directional use trail - A trail intended for travel in one direction only. May be reversed periodically.

Drainage - Removal of water from the trail.

Erosion - The natural process of wearing down and moving rock and soil by wind and water. Trail erosion can be accelerated by a combination of users, water and gravity.

Fall line - Direction that water flows down a hill. The path of least resistance.

Fillslope - The portion of a trail that's constructed from excavated material. Fillslope can be unstable so should not be used to build trail tread. Full bench construction is preferred.

Flow – The rhythm or "feel" of a trail. Two basic types include "open and flowing" and "tight and technical."

Full bench tread construction – Tread construction method of excavating down and into the hillside. Puts the entire tread width on mineral soil, maximizing sustainability. (See "bench cut.")

Grade – Trail steepness. (See "percent of grade.")

Grade reversal – Brief change in trail grade direction, such as routing a downhill section back up the hillside for a short distance. Used to divert water off the trail.

Grade dip – Undulation in the tread that traps water and diverts it off the trail. Makes trails more interesting and fun to use.

Half rule or 50 percent rule - If the trail grade exceeds 50 percent of the hillside slope, gravity will pull water down the trail instead of across it. This is known as "exceeding the fall of the hill."

Hybrid – A trail design that blends "open and flowing" and "tight and technical" features.

IMBA - International Mountain Bicycling Association, P.O. Box 7578, Boulder, CO, USA 80306; (303) 545-9011; www.imba.com. Leading resource for mountain bike-oriented trail design, construction, maintenance and management information, and mountain biking in general.

Knick – Shaved-down section of trail, about 10 feet in diameter, with an exaggerated outslope. Like a rolling grade dip, a knick is used to shed water off a trail.

Land manager - Any person responsible for decisions regarding the use of public or private lands.

Mineral soil - Dirt that's below the top layer of leaves, roots and other organic material. When making a bench cut, always dig down to mineral soil if possible.

Multiple-use trails - Those used for more than one type of activity, such as for cycling, hiking and horseback riding.

Open and flowing - A trail design marked by sweeping turns, higher speeds and longer sight lines.

Outslope – Trail tread that's canted very slightly in the same direction as the hill's slope. Allows water to sheet across rather than be trapped.

Percent of grade – Preferred method of measuring slope or a hill's steepness. For example, a grade of 10 percent means there is a rise or fall of 10 vertical feet per 100 linear feet.

Re-route – A new section of trail that replaces an existing section. Re-routing is often the best remedy for a poorly designed trail that requires frequent maintenance.

Rolling grade dip - A non-obtrusive feature that diverts water off the trail by altering the grade. It's essentially a man-made grade reversal.

Sheet flow - A dispersed flow of water. It minimizes erosion by preventing water from achieving high velocity and carrying away topsoil.

Sill - Stone or timber supports that keep bridge stringers from contacting the ground.

Singletrack - A trail so narrow that users must generally travel in single file.

Single-use trails - Designed for only one type of user. This can be a problem if other users begin traveling the trail.

Slope - The natural (or man-made) pitch of the land, as shown on contour maps. Generally refers to the hill, not the trail. The trail "slope" is called "grade."

Social trails - Paths created by people who wander away from set trails.

Stringer - A structural component of a bridge. It spans from bank to bank and supports the decking.

Subaru - Great cars! Sponsor of the Subaru/IMBA Trail Care Crews. Ask for the heated seats.

Subaru/IMBA Trail Care Crews - IMBA's "Johnny Appleseed" program for spreading expert information about trail design, construction, maintenance and management.

Sustainable trails – What every designer and construction crew should strive for: low-maintenance trails that have minimal impact on natural systems.

Switchback – A sustainable turn on a hillside. The trail is routed onto a level deck where it makes a transition to the opposite direction.

Texturing - Placing natural features (rocks, logs, etc.) back into the tread to increase its technical nature. Helps limit speed, and thereby reduces user conflict.

Tight and technical - A trail design that includes tight turns, natural technical features and mandates slower speed.

Topographic map or "topo" map - Charts elevation changes and shows features such as knolls, ravines, rivers and contours.

Trail corridor - The area around and above the tread. Remove fast-growing impediments, but leave grasses and trees.

Tread - Ground on which trail users travel. It may include grass, bare dirt, roots or rocks. Tread width varies depending on the type of trail and its users.

Tread creep - Describes a contour trail sagging or sliding down the hill. Causes include bushes or trees protruding into the trail from above, exposure of roots from an uphill tree, an improper bench cut or poor trail flow.

Turnpike – Trailbuilding technique that uses a combination of gravel, soil or other filler material to make the tread higher than the surrounding water table. Useful in low-lying areas with poor drainage.