Outdoor Sports Institute – Online Trail Build School

Building Great Trail Experiences

IMBA
INTERNATIONAL MOUNTAIN BICYCLING ASSOCIATION

IN PARTNERSHIP WITH

IMBA TRAIL UNIVERSITY
PART 2 - CONSTRUCTION

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IMBA's mission is to create, enhance and protect
great places to ride mountain bikes.

TOC

- Recap – Trails Planning
- Design to Construction
- Parts of a trail
- Tools of the trade
- Basic trail construction
- Basic trail maintenance
- Advanced topics

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REVIEW OF PLANNING

Background/prep

- Create the vision
- Engage the stakeholders (community and land manager)
- What types of visitors? What trails objectives do they have?
- Find data

Fieldwork

- What is the setting?
- Collect field data (major control points)
- Zone analysis

The Plan

- Is it feasible?
- Trail visitors and trail types
- Opportunities and constraints (terrain, social, financial)
- Zone or corridor analysis
- Stacked loops/hubs & clusters to connect major control points
- High level cost estimate

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BUILD IT RIGHT, BUILD IT ONCE

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FROM DESIGN TO CONSTRUCTION

FROM DESIGN TO CONSTRUCTION

You'll learn about design more in the next take home. Design is one of the most complex pieces of the trail development life cycle. Understanding high level planning and visioning, and the basics of a sustainable quality trail; can provide much of the important skills to help you as a volunteer, land manager, or community member.

The design highlights provided on the next page are important to know, even as a volunteer trail builder.

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FROM DESIGN TO CONSTRUCTION

- How wide is the acceptable/reviewed corridor?
- What is your role? Builder? Volunteer management? Professional?
- Is there a plan to review? Get familiar with the intent of the trail. What are the experience goals?
- What are the trail specifications? Do they match the planned experience objectives and designed trail type?
- Walk the flagline, bring a clino, ensure the corridor meets all the plan and design goals. Ask questions.
- How will you get into and out of the site? Have a mobilization plan. Then have a backup plan for if something goes wrong.
- What will be your impacts? How will you mitigate?
- Are there regulatory compliance practices? Wattles? Silt fence? Posting permits? Inspections? Reports?
- Do you have all permits and licenses to complete the work?
- Personal protective equipment. Know what it is and always have it.
- Trail building is essentially backcountry work; do you have good backcountry skills? First aid? Leave no trace?

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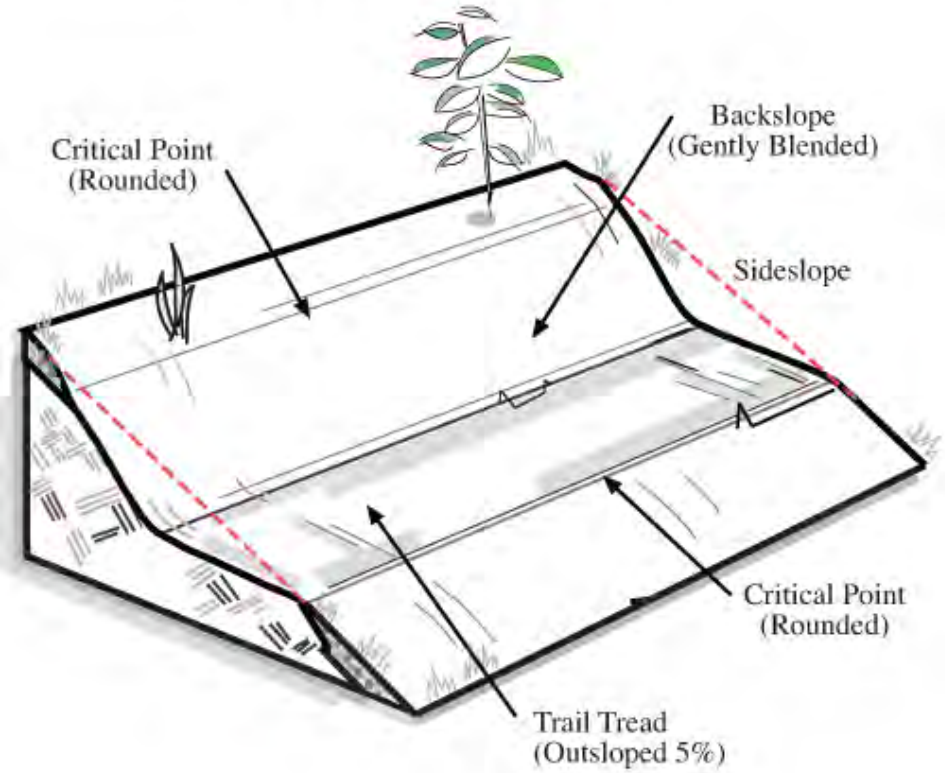
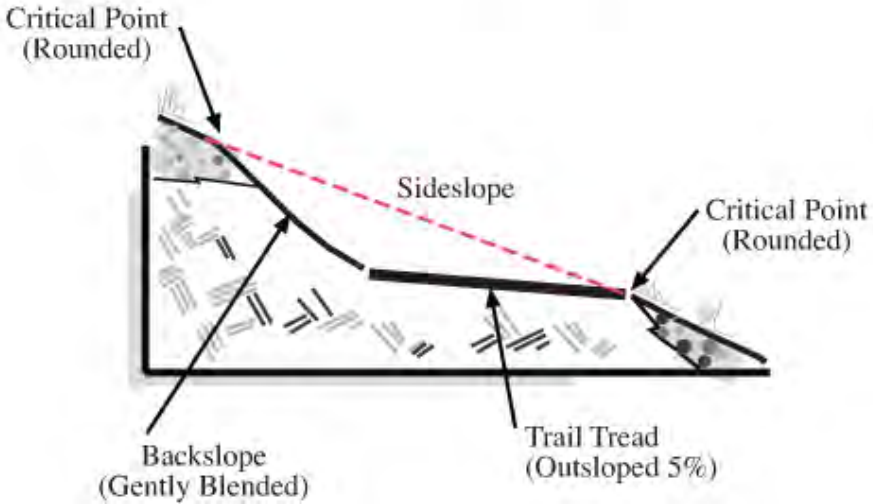
Full Bench Trail





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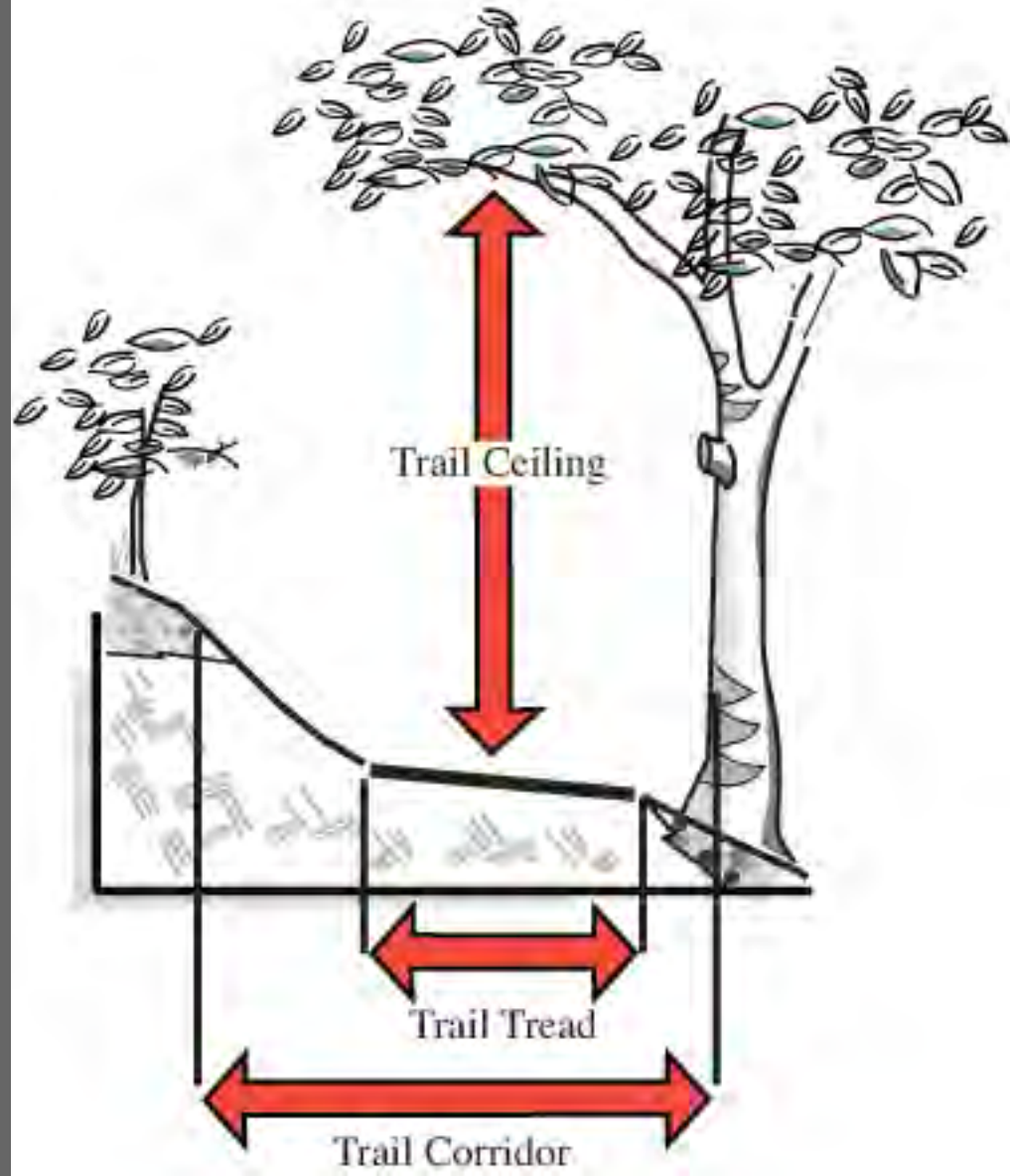
Trail Corridor



PARTS OF A TRAIL

- Trail ceiling – the height above the trail tread to impeding vegetation or natural objects
- Trail corridor – the width outside the trail tread to impeding vegetation or natural objects
- Trail tread – the surface upon which visitors travel during trail use
- Backslope – the disturbed surface which ties the trail tread back to native/natural earth
- Toe/downside edge (lower critical point) – the downside or outside point or edge where trail tread meets native/natural earth
- Top of the backslope (upper critical point) – the higher side or inside point or edge where backslope meets native/natural earth

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TOOLS

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TOOLS

Grading bucket

Mini-excavator

Moto

Trail dozer

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TOOLS OF THE TRADE

Personal Protective Equipment
- Helmet
- Eye protections
- Ear protection
- Gloves
- First aid kit
- Emergency communication

Corridor Clearing Tools
- Handsaws
- Pruners
- Loppers
- Polesaws
- Lead blowers
- Chainsaws (*require PPE and training*)
- Mechanical mowers/mulchers

Trail Building Hand Tools
- Clinometer
- Hoes
- McCleods
- Pulaskis
- Rakes
- Buckets

Trail Building Mechanized Tools
- Dump/Loaders
- Excavators
- Dozers

Rock Work Tools
- Hammers
- Chisels
- Rock nets
- Buckets
- Griphoist
- Rock bars
- Brush

Trail Finishing Tools
- Rakes
- Pruners
- Loppers
- McCleods
- Compactors
- Broom

Naturalization Tools
- Leaf bowers
- Rakes
- Loppers
- Pruners

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HOW CAN MACHINES HELP?

- Human power is slow and expensive
- Move more/larger…dirt, rock, etc.
- Tools to be used, need training and expertise on when to use what and where
- Machines are only as useful as the operator using them
- More efficiency but more responsibility

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PPE AND SAFETY

- Width and height requirements will be in the trail guidelines, they will be dependent upon trail visitors and trail type.
- Some vegetation is more visually appealing and can add to the trail experience. However, plants that grow very fast should be removed or heavily trimmed.
- Consider the mix of visitors. Equestrians need a wider corridor and higher trail ceiling. Jump trails will also require a higher than average trail ceiling.
- A tighter corridor will slow trail users. An open corridor may invite more speed. But a tight corridor on a shared-use trail may not create adequate sightlines for good experiences.
- Trails with high anticipated traffic may need a larger corridor to allow for passing and visibility.
- Corridor size can greatly affect a trail's technical challenge. Narrow openings between trees (gateways), low branches, thorny bushes, or cactus close to the trail tread will make for a tight and tricky pathway, adding to the challenge of the trail.
- What is your maintenance schedule? If you know that you can only clear the corridor once a year, trim a little higher and wider.
- Determine the desired experience before you begin "beating back the jungle." A trail with a tight corridor can help visitors feel a closer connection with nature. Your goal should always be to minimize your impact on the environment and leave the area looking as natural as possible while meeting the land manager and trail experience goals.

CORRIDOR CLEARING

- Tools
- Loppers
- Pruners
- Hand saws
- Straps (for pulling)

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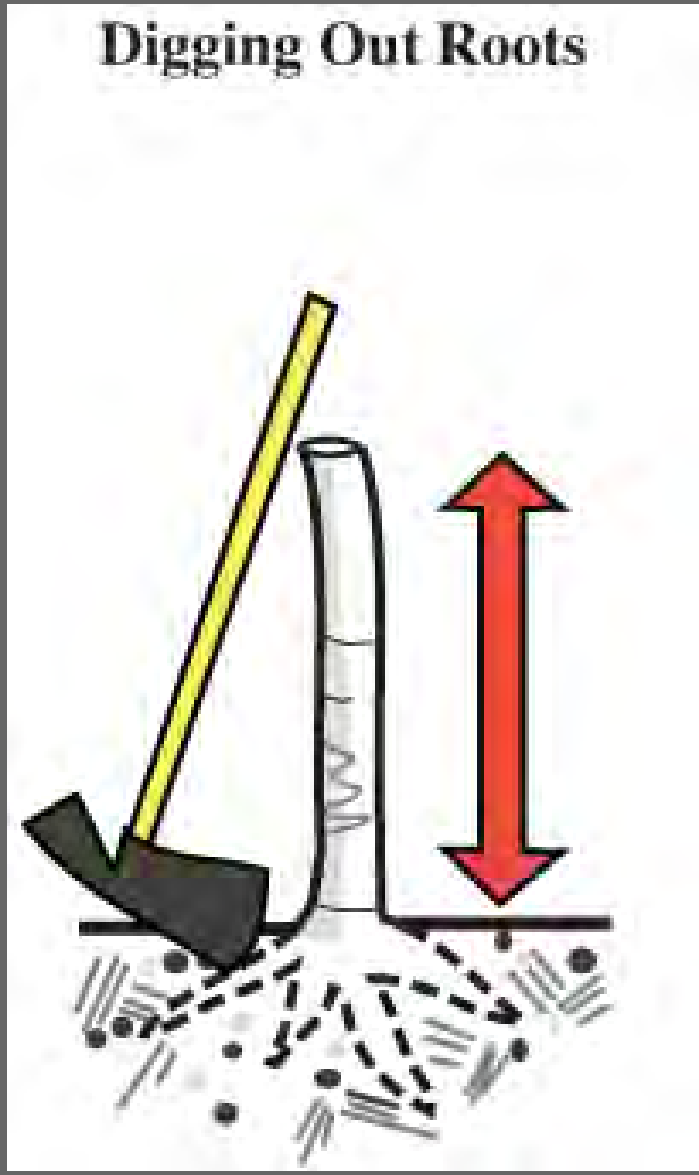

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CORRIDOR CLEARING

- Don’t leave sharp points that can become hazards.
- Staubs and stumps create easily mitigated risks.
- Trim branches back to the tree collar for healthier recovery.
- Remove stumps, even if flush cut compaction will make them “pop” over time.
- When in doubt, you can always cut after the build.

CORRIDOR CLEARING

- Flush cut, no coat hooks.
- Don't leave sharp points that create hazards.
- Only cut at branch junctions.
- Leave canopy intact when possible.
- Don't leave sharp points or buts in corridor
- Cut limbs and branches further away from trail
- Drag slash out of sight with cut ends away from trail
- Straps are handy
- Consider if you're increasing the fall risk.

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CORRIDOR CLEARING

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SIGHTLINES

- Sightlines are extremely important for shared-use trails. Trails with visitors who have large speed differences will require longer sightlines.
- Where sightlines are impossible to lengthen (such as rounding a steep slope, meeting on a ridge, etc.) the trail design should mitigate visitor speeds through uphills.
- Sightlines can be outside the trail corridor. There may be a large chicane or meander in a relatively fast flat trail, trimming the straight line through the S-curve will open up the view for riders and walkers to see each other.
- A crowded trail with a mix of runners, dog walkers, and children calls for greater visibility. However, if the tread surface is smooth and the corridor is wide, mountain bikers may be tempted to ride too fast. Creative corridor cutting can help. Keep some vegetation below waist level to control trail width and anchor turns but still allow for clear sightlines. Don't remove trees near the trail tread, just trim their branches for visibility.
- A one-way trail can be trimmed differently than a two-way trail, as sightlines only need to be clear in one direction of travel. Though it is always good to keep good sightlines all around, in case of emergencies or human error.

SIGHTLINES

Know the preferred sightline distance for the trail.
100’ to 150’ is a good dual direction sightline.

MPH	FPS	3 seconds
5	7.3	22
10	14.7	44
15	22.0	66
20	29.3	88
25	36.7	110
30	44.0	132
35	51.3	154
40	58.7	176
45	66.0	198

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BASIC TRAIL CONSTRUCTION

- Depending on the builders, management, and design you may want to detail pin flag a build line. There are many options and choosing the best on will depend upon your requirements and knowledge.
- Remove the organics – during corridor clearing it may be easiest to use a leaf blower to blow loose debris upslope. This will be used later during the naturalization process.
- Grubbing – continue removing the organic layer, in general you want to move it up slope to use later. Tools such as hoes, McCleods, Pulaskis, and mechanized equipment are used for this stage.
- Digging the tread – once the organic is removed you have mineral soil, which is what is used to create stable and long lasting tread surfaces. A benchcut on sideslopes (contour alignment) will start with excavating soil from the upper critical point (where the backslope will meet native earth). As one excavates soil, move the soil towards the downside edge.
- It may be easiest to dig a minimum length of trail. For instance, a complete grade reversal or 25 to 50-feet of trail may allow you or volunteers to better see the entire trail, versus getting mired in the detail on 1 or 2 feet.
- Work in layers, excavate soil from the uphill critical edge and then move down the line, don't excavate the entire tread for just a few feet.
- As you excavate the trail tread, pay attention to drainage. Where will the trail drain? Is the entire trail tread outsloped? Is it insloped to a rolling grade dip or reversal? This will likely go back to the trail plan and design.
- Once you've established a rough trail tread that meets the basic tread width and grade requirements of the plan and design, its time to sharpen the shaping and dial it in before naturalizing it.

BASIC TRAIL CONSTRUCTION

- Create the backslope – blend the uphill side of the trail down to the trail tread. Ideally the backslope should be gentle, 3:1 slopes are common, steep backslopes will facilitate more potential for soils to slump and slide, creating more maintenance needs.
- Steep backslopes also narrow the tread up considerably, especially for mountain bikers who are mindful of their pedals/feet.
- Some cases require steep backslopes, for instance if you're excavating in very rocky soil (or even bedrock).
- Once the backslope is set and the upper critical edge is rounded to promote sheet flow over the backslope to the trail tread, you can focus on dialing in the trail tread.
- If the trail tread is insloped, runoff will flow down the "gutter line" of the tread and backslope, ensuring this drains properly is key. Debris can build up in this "gutter line", clogging it and creating dams that alter drainage patterns and therefore erosion patterns.
- Where ever runoff should exit the trail, outsloped length of trail or grade reversal, ensure there is nothing to dam or impede flow.
- The lower critical edge should be rounded and compacted. On a full bench excavation this should be native unexcavated soil, partial bench construction means this edge is a fill slope and will settle and compact over time. The more compaction you do at the beginning, the less the trail will drastically change.
- Once your backslope, tread, grades, drainage, and critical edges are set the trail is ready to be naturalized.

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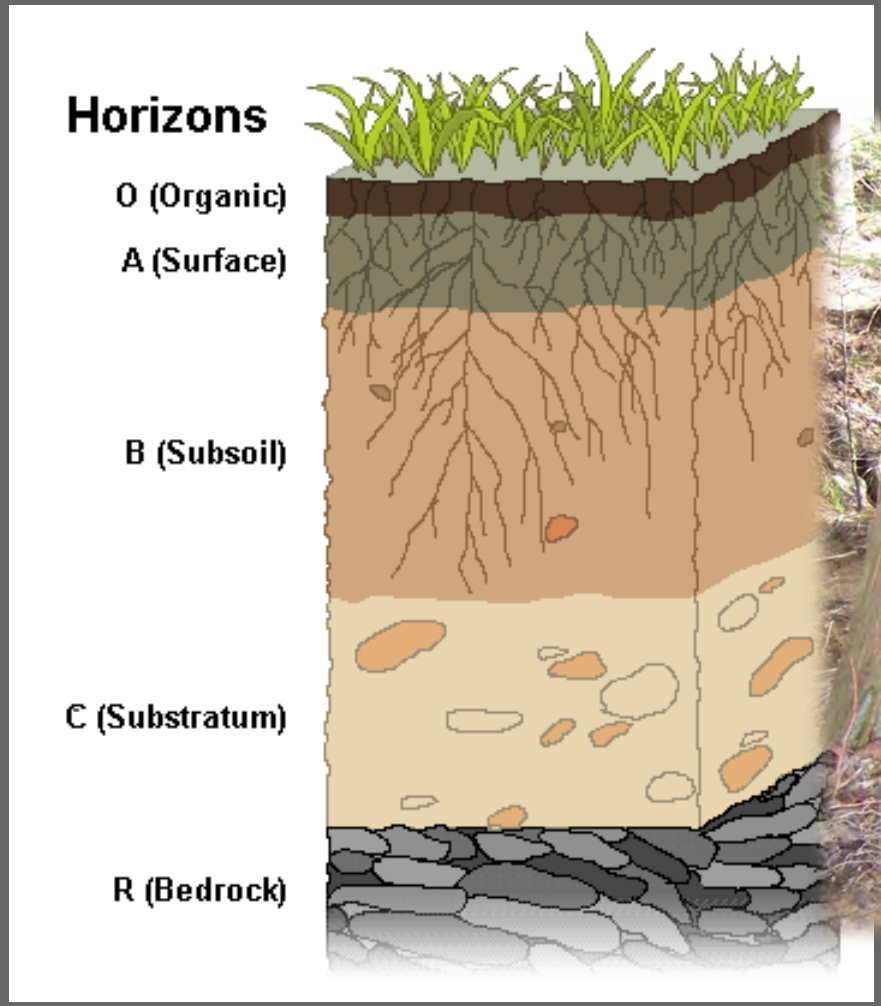
REMOVE ORGANIC LAYER



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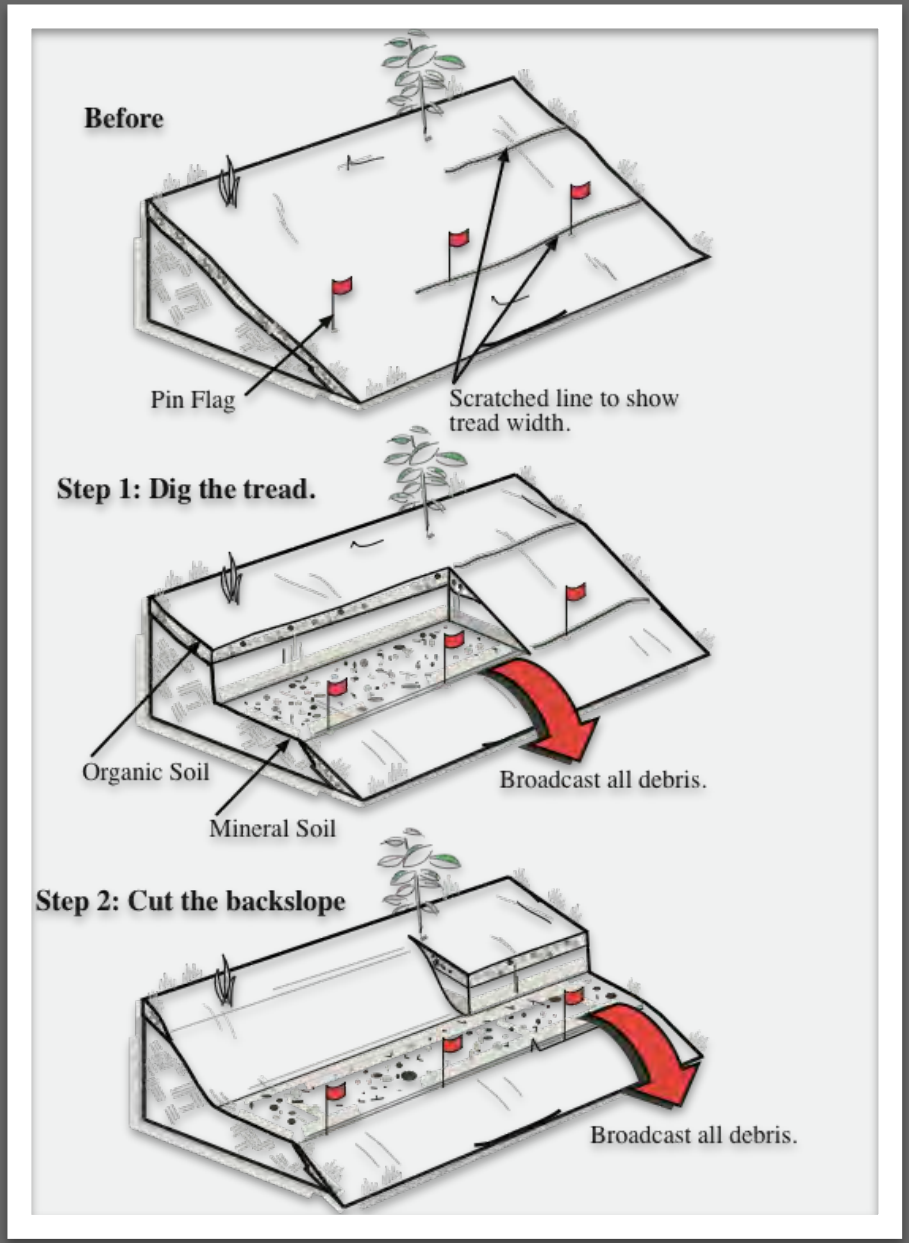

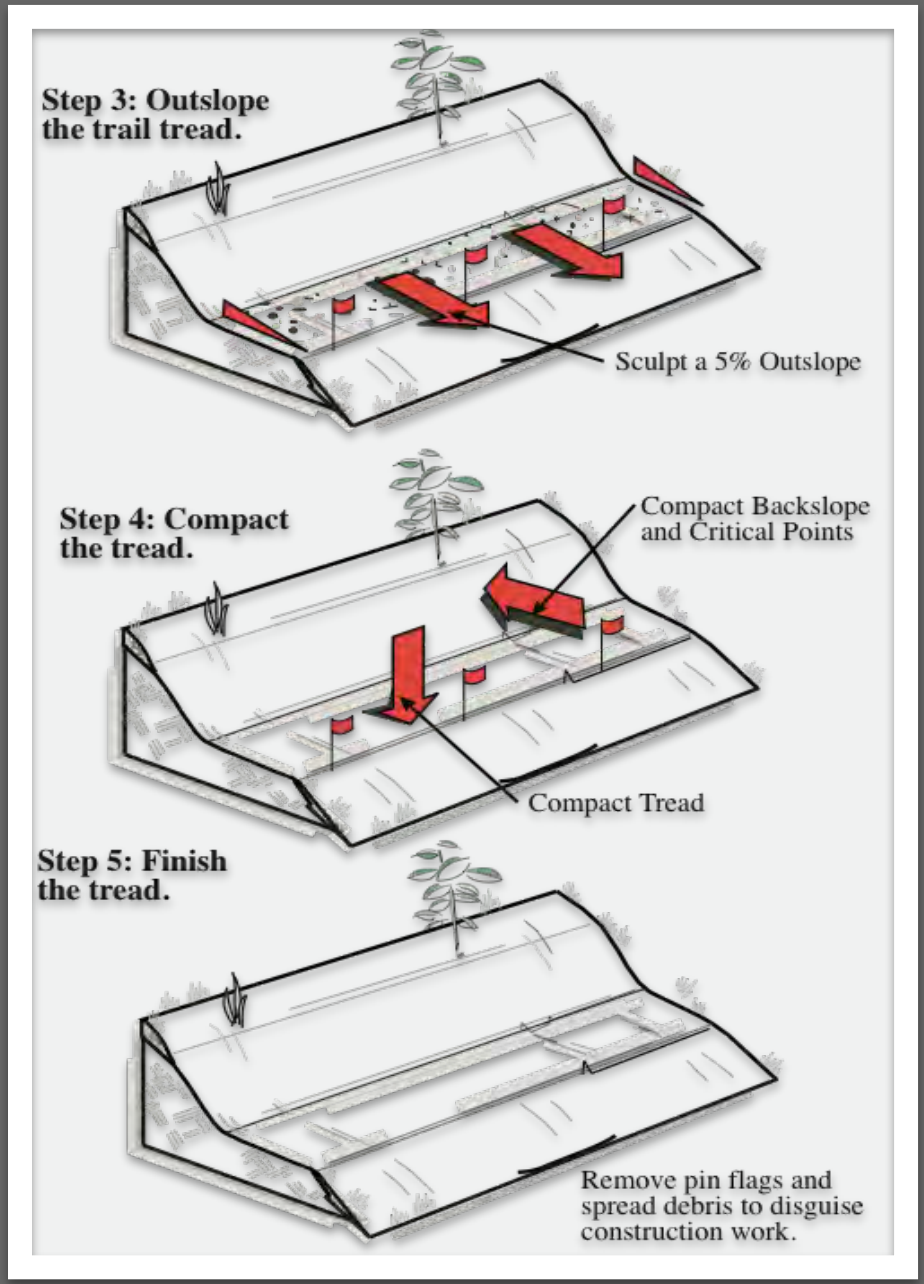

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BASIC TRAIL CONSTRUCTION

Grubbing/rough grading

- McCleod
- Pulaski
- Hoes
- Shovels

Fine/finish grading

- McCleod
- Rakes
- Shovels

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BASIC TRAIL CONSTRUCTION

- Use McCleods, hoes, and other grubbing tools to remove the organic layer and begin the bench cut.
- Work safely a part from other if on a team (with all required PPE).
- Once the organic layer is removed, scatter and spread it well below the bench. Organic material should NOT be used to build a bench on or support trail it will rot and settle, leading to long-term durability issues.
- Continue to bench in a trail, pulling mineral soil down and compacting it as you go to create a stable tread.

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BASIC TRAIL CONSTRUCTION

- Fine tune the tread with rakes and other fine grading tools. Depending on particle size, McCleods may be useful (small rocks, etc.)
- Remember to grade for the intended trail experience, is the trail a smooth flowing beginner trail? A rugged, natural, hiking trail?
- In general, always pull soil uphill!
- Fine grade from the drainages up to rollers, it may be harder to pull soil uphill. but soil will always go downhill with gravity and erosion.

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TYPES OF TREAD CONSTRUCTION

Full Bench

- On rolling contour alignment
- Most stable over time
- Most stable during construction
- Will remain closer to original tread width over time
- Insloped tread possible, recommend for some trail visitor/type combinations

Partial Bench

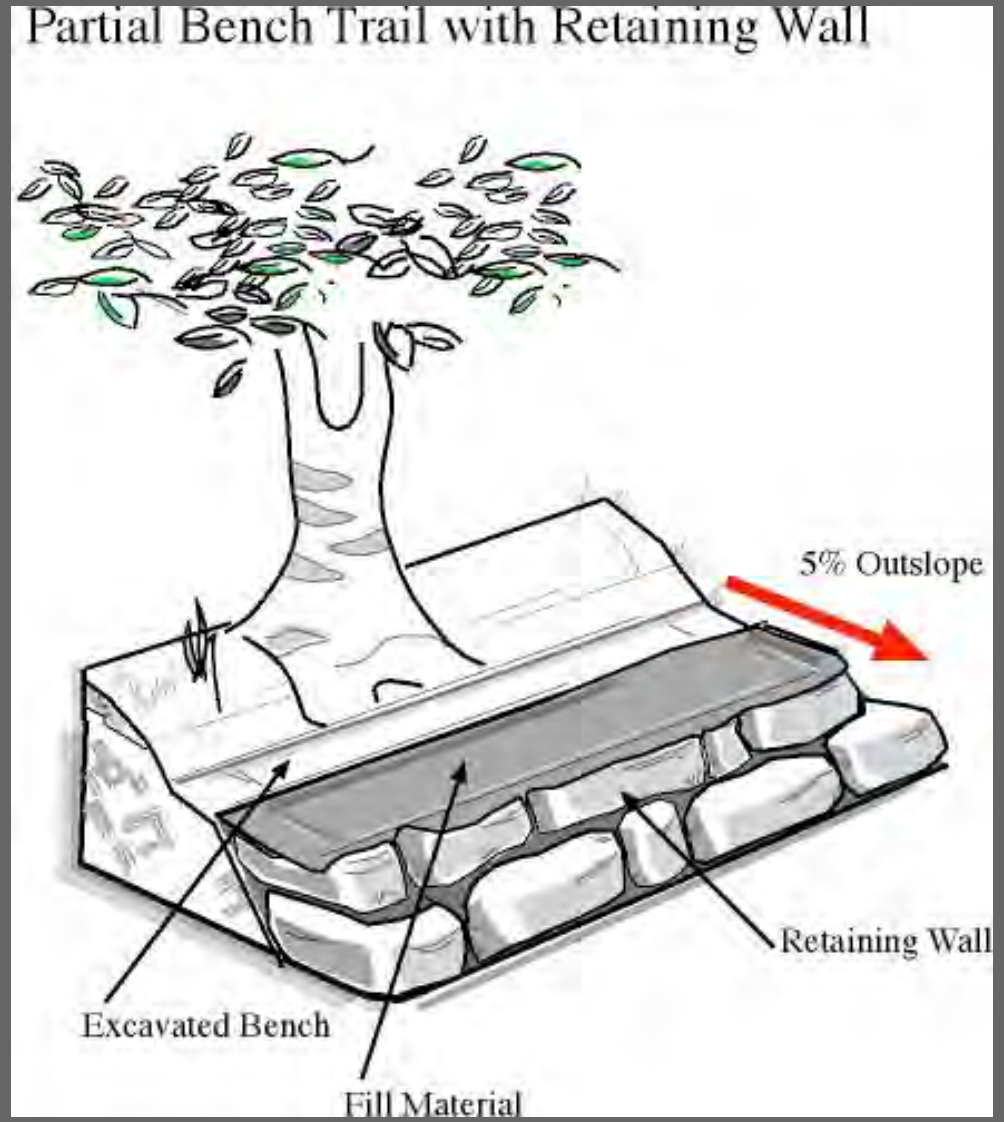
- On rolling contour alignment
- Less stable over time than full bench
- Semi stable during construction, watch the outside/fill edge
- Will narrow over time as the fill edge compacts and settles
- Useful when you want to avoid impacting something (roots, rocks, etc.)

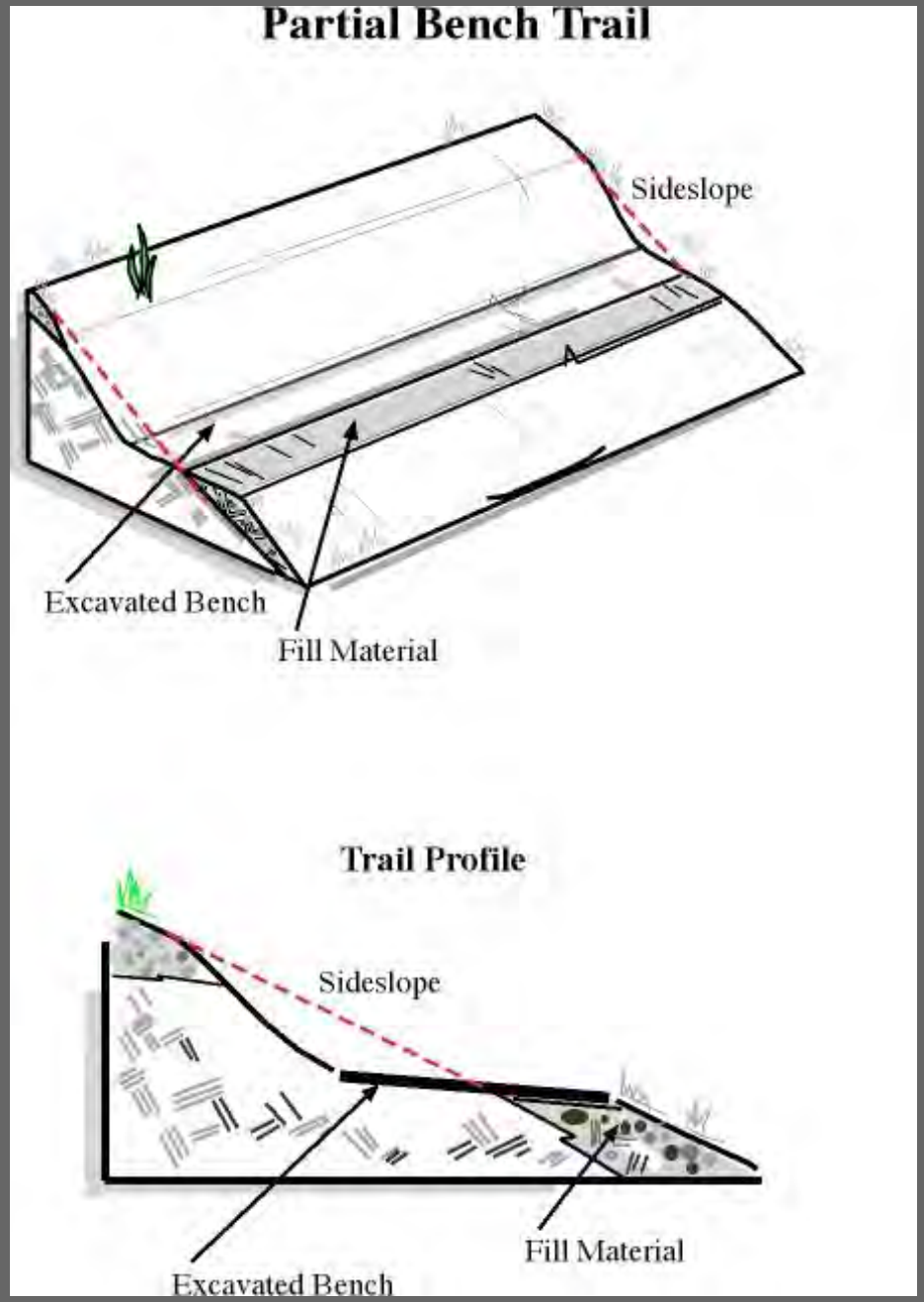
Minimal/No Bench/Rake-n-Ride

- Generally on flatter soils or the fall line
- Will create very outsloped tread on the contour
- On steeper slopes can create issues with trail creep, as roots wear through and organic is pushed downhill

Lift-n-Tilt

- Generally on flattest slopes
- Easiest with mechanized equipment
- Involves borrow pits to harvest useable soil and placement, shaping, and compacting to create micro-drainage
- Results in trail on flat ground that will drain water off tread, may create puddling or pooling beside trai





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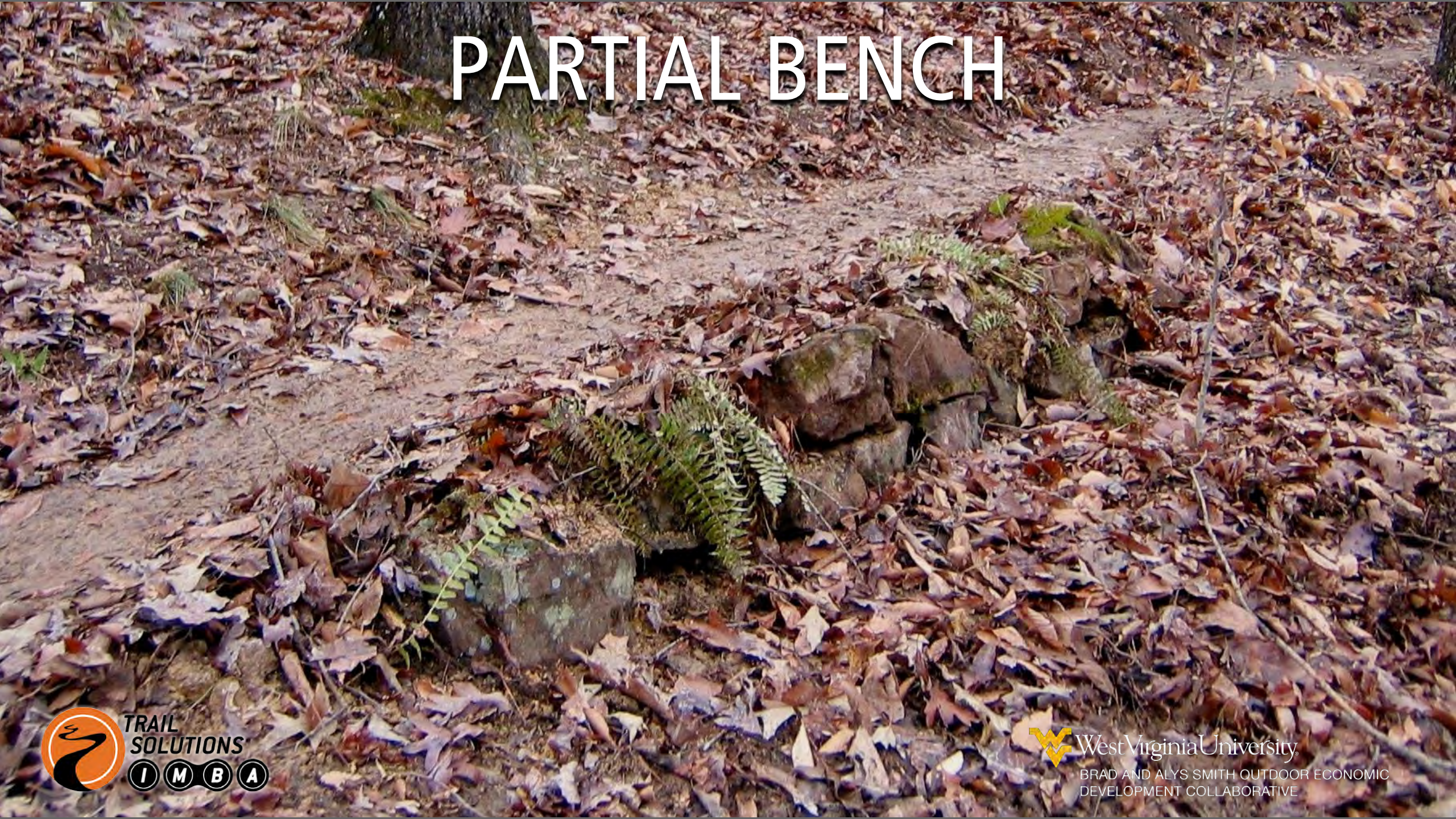
PARTIAL BENCH



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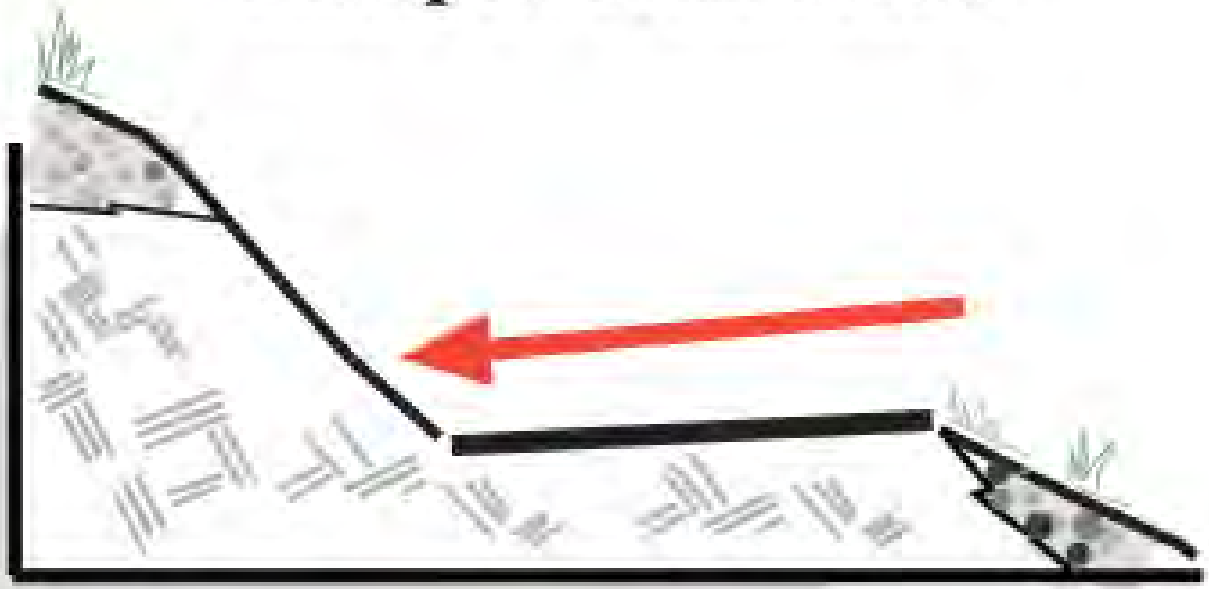
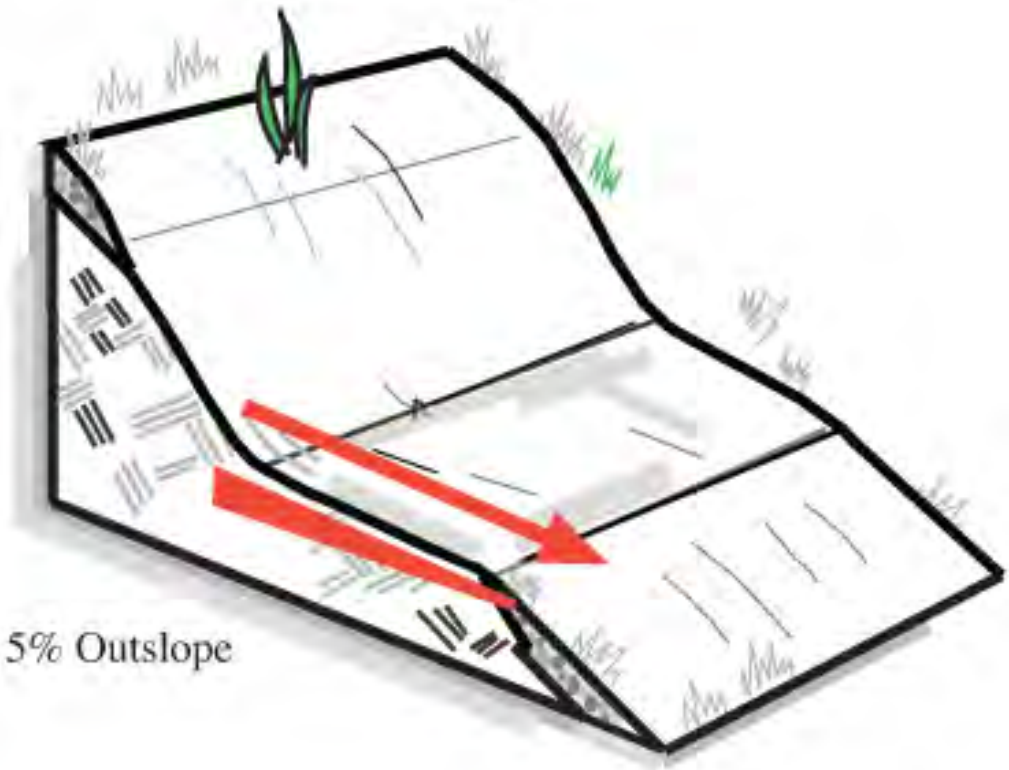
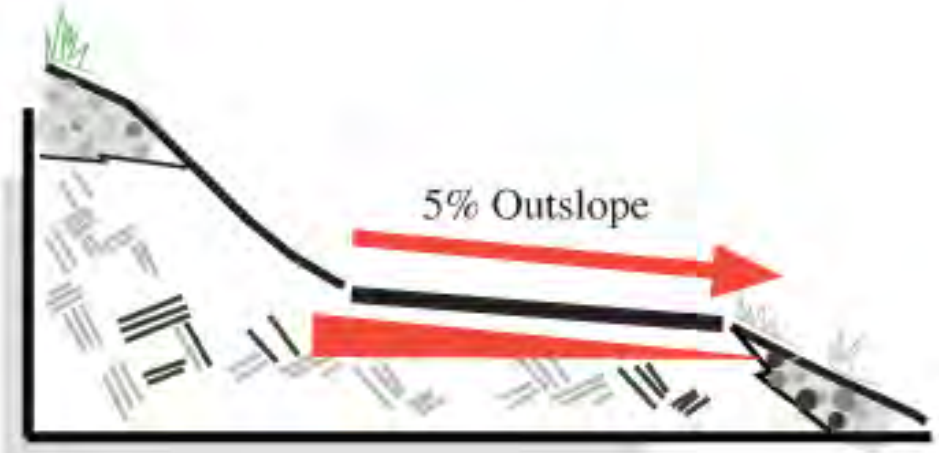
Insloped Trail Tread



Outslope





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WHY INSLOPE TREAD?

- Insloped tread focuses drainage, you can more precisely predict where runoff will flow, how it will effect your trail, and how to mitigate for those effects
- Insloping feels more secure on steeper sideslopes for many users
- Insloping is ideal for mountain bikers, wheeled vehicles roll along the trail, insloping can help riders maintain their momentum, thereby creating more flow in many instances
- All users displace trail tread soil, insloping helps reduce the soil displacement by transferring shear forces from users to force pushing directly into the tread
- Any displaced soil is more easily replaced, you can rake and move soil from the inside edge back up the insloped tread easier than soil which has washed downhill from outsloped trail tread
- On trails intended for beginners, especially mountain bikers, the above described characteristics of insloping helping create a friendly and inviting trail experience
- Insloping can be vital on bike-only descents such as gravity or jump trails, ensuring visitors maintain the intended speed for features and trail experience

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TURNS

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TURN BASICS

- Turns should be sited during design based upon the trail type, planned visitor experience, intended construction style, and terrain features.
- Turns are constructed features, generally defined as a change in direction of more than 90 degrees, although most turns are traditionally 180 degrees.
- Turn radius and elevation lose through the turn create stringent sideslope requirements
- By definition any turn on any slope will eventually go fall line, building the right turn for the trail will mitigate this issue in a variety of ways.
- Turns are generally described with a few key guidelines or specifications, including: radius, maximum grade cross the turn platform, and maximum camber (inslope) of the turning tread.
- Hikers can successfully navigate very tight (small radius) turns, mountain bikers generally need much larger radii turns (the tighter the turn the more advanced the feature is to a rider).
- Because turns can include steep (fall line) grades, drainage is important. The "omega" turn style is very common, ensuring good drainage with grade reversals directly before and after the turn.
- The grade of the turning platform should be the same or lower grade as the trail

TYPES OF TURNS

Climbing/At Grade Turn

- Require mellowest slopes of all turns (under 10%)
- Visitor goes along the fall line at some point
- Widest radii turns (for mountain bikes 10-15 feet minimum)
- Easiest for hand construction
- Require very careful design placement

Elevated Turns - General

- Can be on virtually any slope, at some point larger and larger retaining walls are required
- Generally easiest with mechanized equipment, especially if larger radii is required
- The turn platform will always be largely fill
- Grade reversals before and after will help protect the turn platform
- Generally redirecting the steepest part of the terrain to part of the turn through construction

Elevated Turns – Rolling Crown Switchback

- Generally not recommended, almost always require rock surface to last
- The best and worst feature is they have poor flow, especially for bikes
- Useful for situations on especially steep slopes or where you need to reduce riders speeds
- Mountain bikers generally do not enjoy these types of turns

Elevated Turns – Insloped Platform

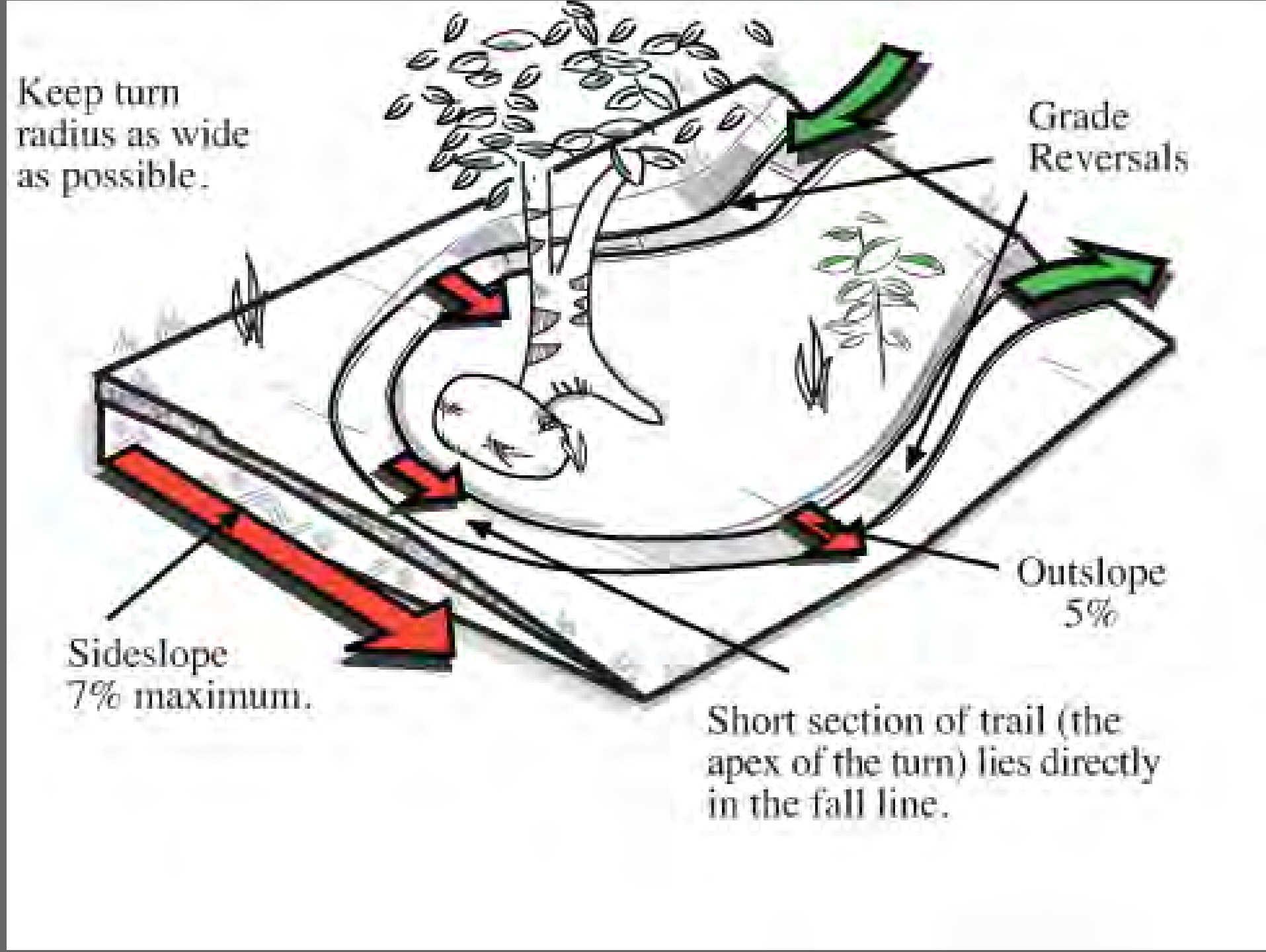
- Best for shared-use and bike climbing trails
- Radii can vary depending on visitor and intended trail difficulty
- More often than not some insloping is used, even mellow 5% inslope on a switchback for hikers is helpful in managing visitors and runoff
- Steepest part of trail generally created as a "ramp" on the lower leg of trail

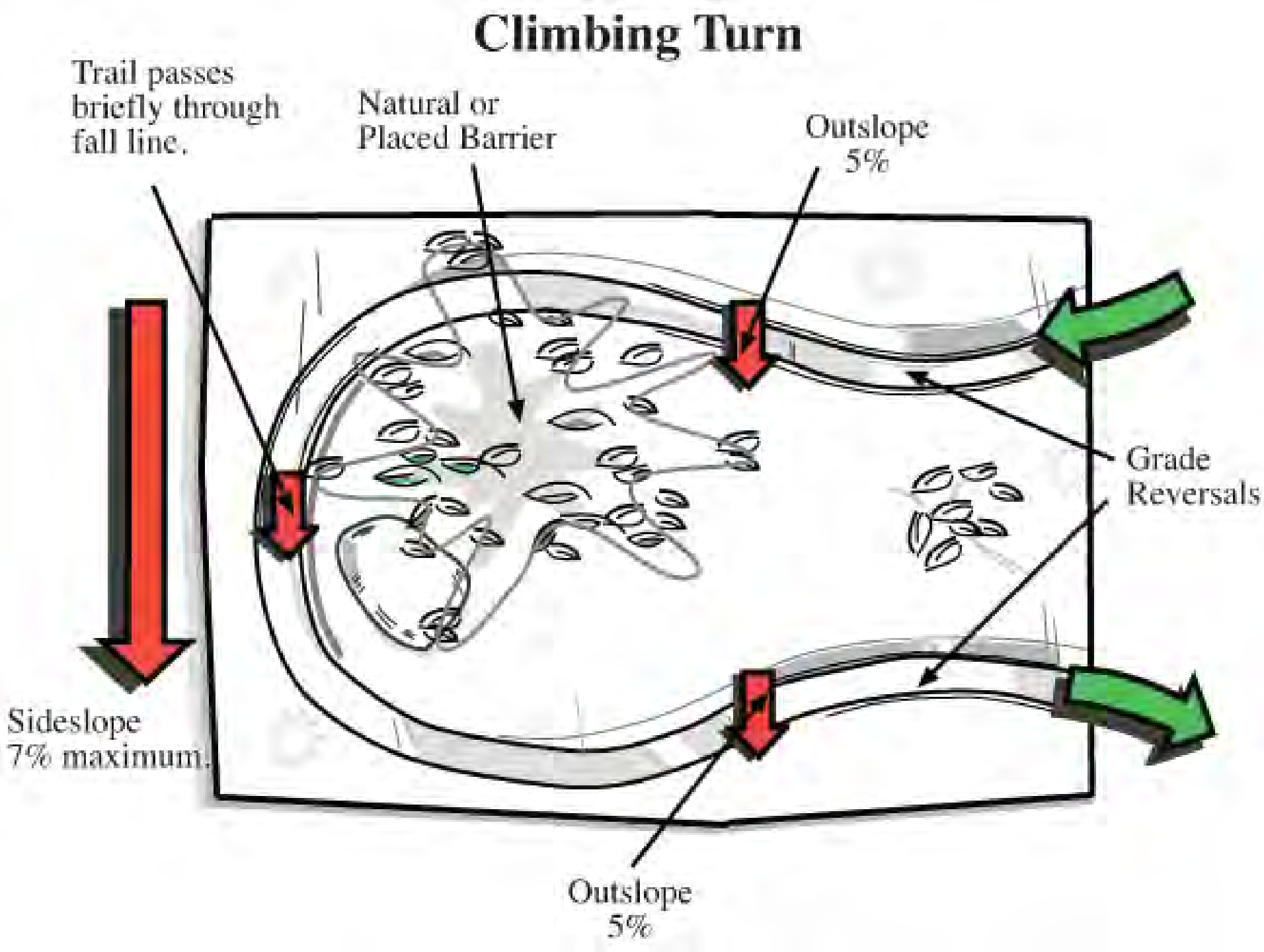
Elevated Turns - Berm

- Generally only on bike-only descents
- Berms are exaggerated insloping, they should have a radius themselves, going steeper as they near the top edge
- The top will be fragile, compacting the edge and outside will help ensure longevity
- Can be "falling away" style where turn goes fall line with some form of catching inslope on the lower leg

TURN TIPS

- Look for good natural turning platforms during design!
- Keep water out of the turn with grade reversals before and after
- Prevent shortcutting with anchoring inside
- Type of turn is dictated by the steepness of the sideslope, trail type, and difficulty level.


Keep turn radius as wide as possible.
Grade Reversals
Outslope 5%
Sideslope 7% maximum.
Short section of trail (the apex of the turn) lies directly in the fall line.


Climbing Turn
Trail passes briefly through fall line.
Natural or Placed Barrier
Outslope 5%
Grade Reversals
Sideslope 7% maximum.
Outslope 5%

AT GRADE TURNS

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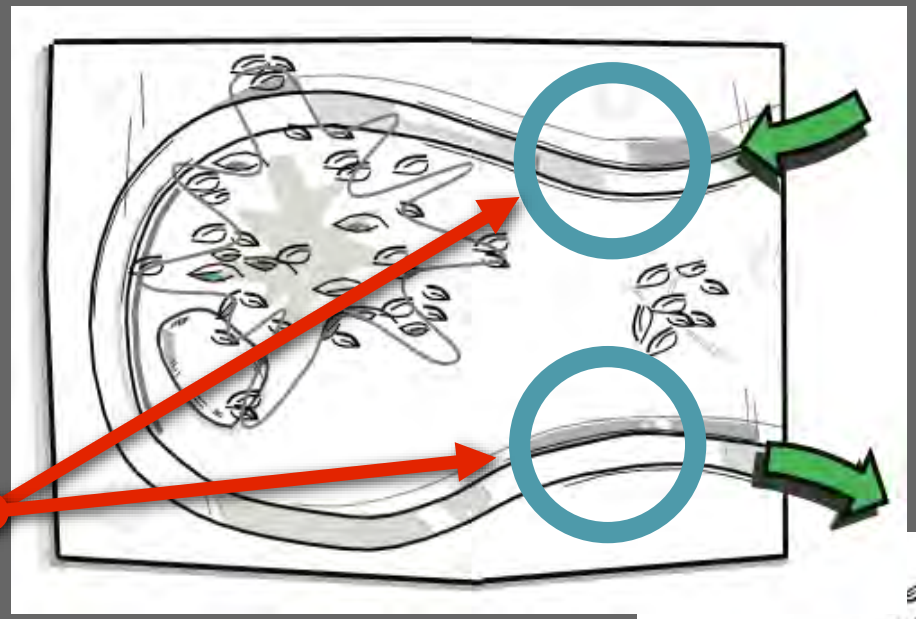
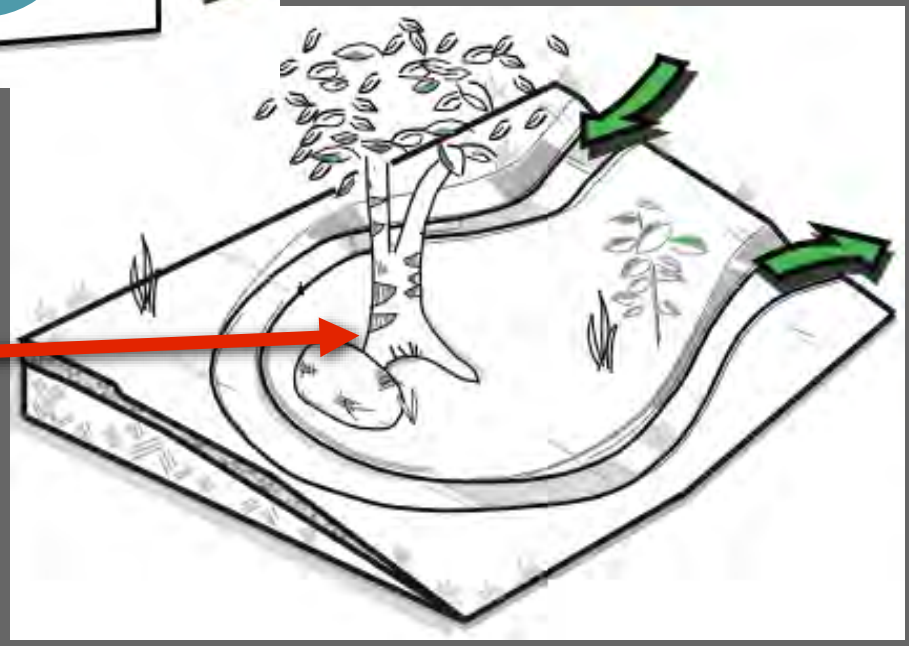
AT GRADE TURNS

- Built on the existing slope NOT on a constructed turning platform
- Sideslope <10% grade
- Grade reversal before and after
- Approximately 15 foot radius
- Well anchored inside





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ELEVATED TURNS

- Involves excavation and construction to create a turning platform
- Sideslope >10%, sideslopes >60% may require retaining ways
- Grade reversal before and after
- Hikers can navigate 2-3 foot radii turns, mountain bikers need between 4 and 12 feet generally
- Constructed turns can be platforms, have insloping, or be fully bermed (where insloping goes near vertical at the top)
- Soil should be excavated from the upper leg of trail or the backslope of the turn pad, do not excavate soil from borrow pits behind or below the turn
- If enough soil can be excavated and placed to create a 3:1 or shallower outer slope a retaining wall is not necessary
- The outer slope will buttress and protect the turn platform, if it is too steep it will erode faster and the turn platform will collapse and crumble
- To further protect the outer fill slope, natural and native organic material should be placed here (described more in the general naturalization notes)
- Advanced bike-only descending trails can have "fall away" turns, which resemble climbing turns on steeper slopes, these types of turns need a "catchers mitt" of insloping on the lower leg to help redirect riders

WHY INSLOPE TURNS?

- Involves excavation and construction to create a turning platform
- Sideslope >10%, sideslopes >60% may require retaining ways
- Grade reversal before and after
- Hikers can navigate 2-3 foot radii turns, mountain bikers need between 4 and 12 feet generally
- Elevated turns can be platforms, have insloping, or be fully bermed (where insloping goes near vertical at the top)
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ELEVATED TURNS

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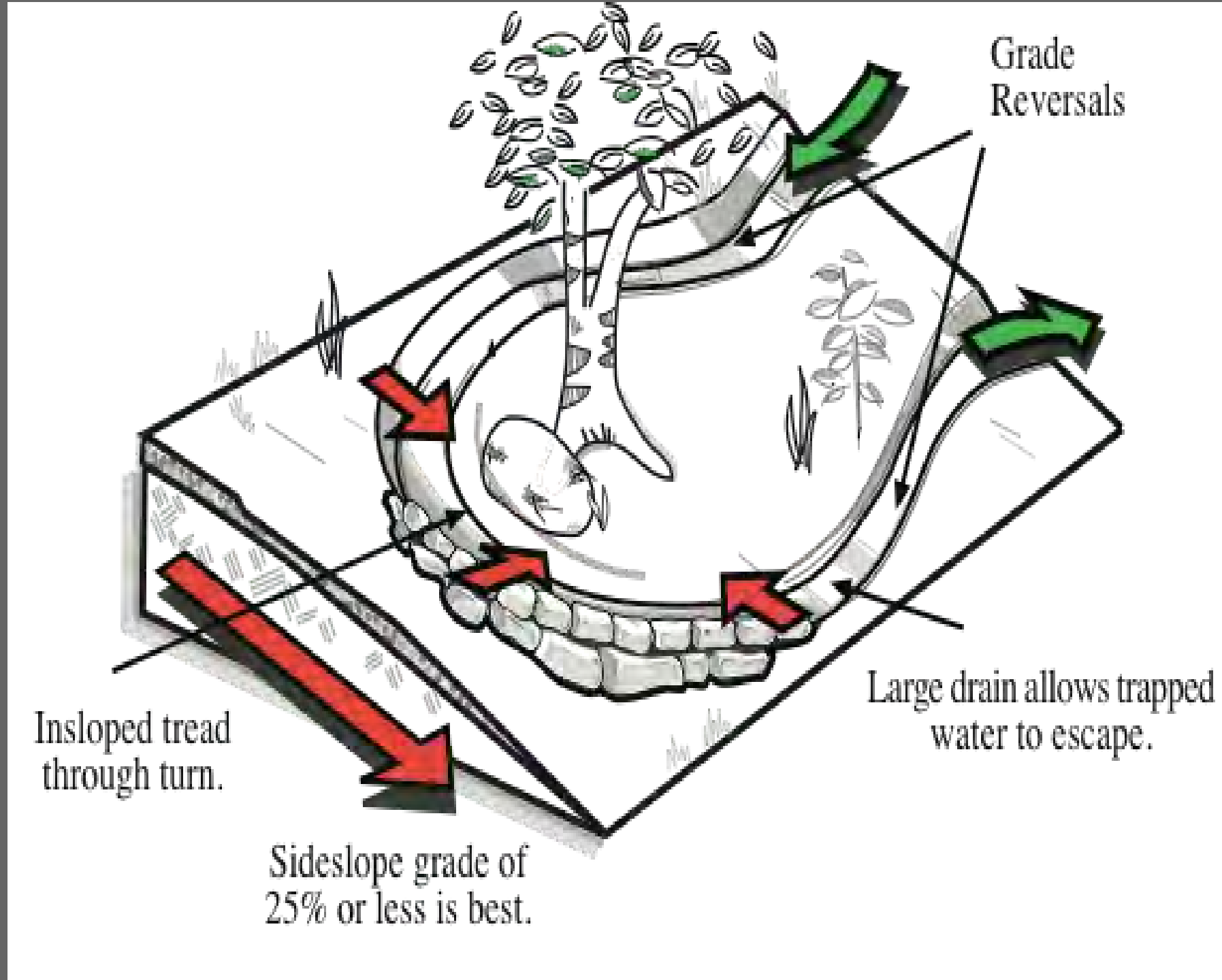
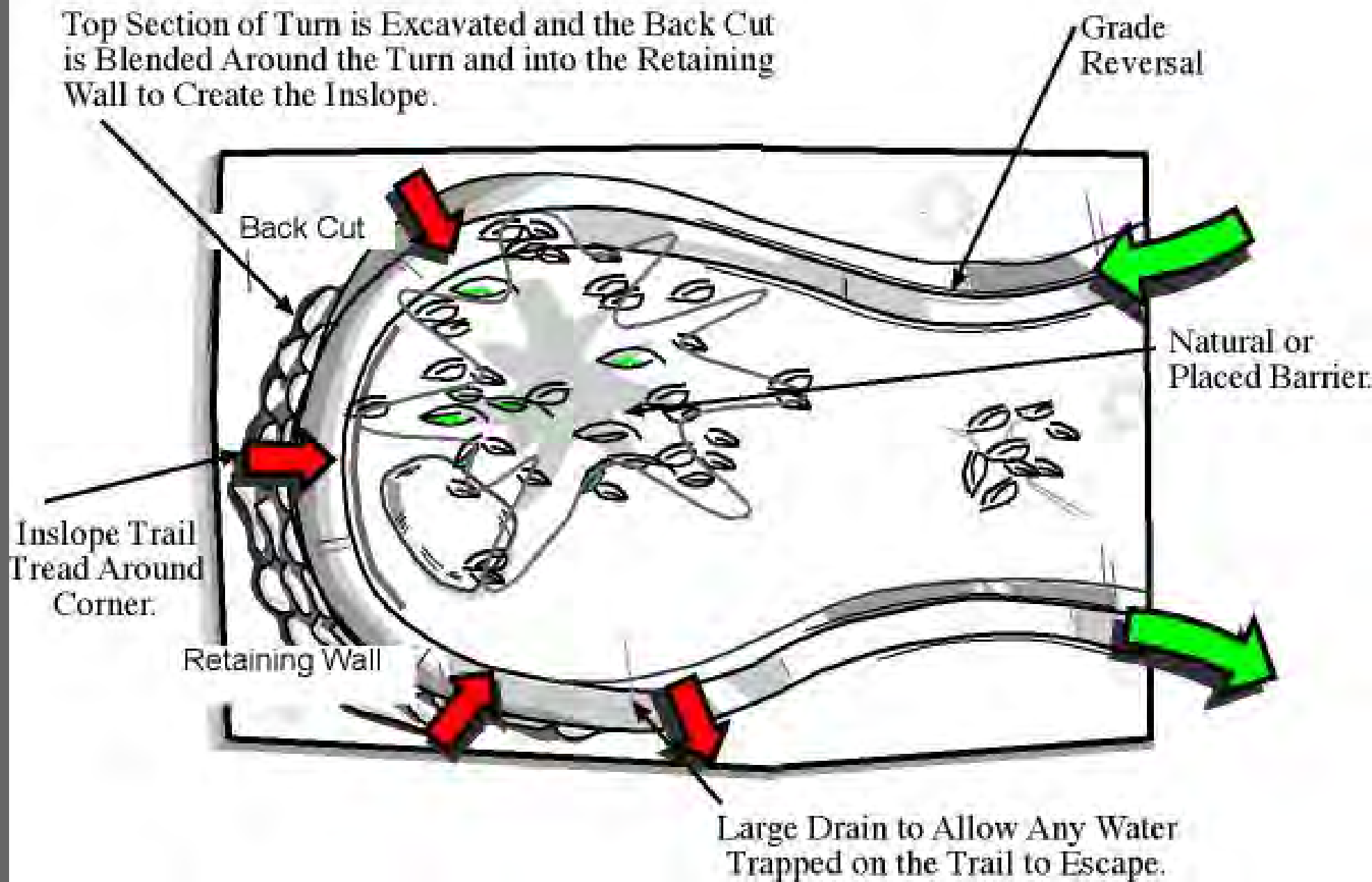

Grade
Reversals
Large drain allows trapped
water to escape.
Insloped tread
through turn.
Sideslope grade of
25% or less is best.

Insloped Turn



PLATFORM TURN

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PLATFORM TURN

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PLATFORM TURN

- Built up lower leg "ramp", in general the best place to put the steepest grades in a platform turn is the lower leg of trail
- The turn and lower leg are insloped, the grade of the lower leg "ramp" is steep so the "gutter line" is armored with riprap
- Grade reversal at the bottom is also armored with riprap

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PLATFORM TURN

- Grade reversals at the top and bottom creates the classic "omega" shape, this chicane is also an ideal weight transfer for mountain bikers to optimize the turn

- The pad and lower leg have been built up with retaining walls. The slope did not necessitate a retaining wall, it was more likely a unique and aesthetically pleasing way to use rock found during construction

- Wide, flat turning pad. The turn is executed on the flattest grades, decoupling the typical steep grade and turn found in at grade or climbing turns

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INSLOPED PLATFORM TURN
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BERM TURNS

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BERM TURNS

- Berms are better for mountain bike trails, best for downhill trails
- Berm holds riders in the turn
- Berms let the rider maintain momentum
- Berms need large grade reversals at the entrance and exit

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SWITCHBACK

- Better for foot users (hikers)
- Should only be built on steep sideslopes
- More challenging to ride because the radius is tight
- May increase erosion because bikes must brake more
- Large grade reversals at the entrance and exit

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TURNS

Platform/Inslope Turn

Platform Turn

Berm turn

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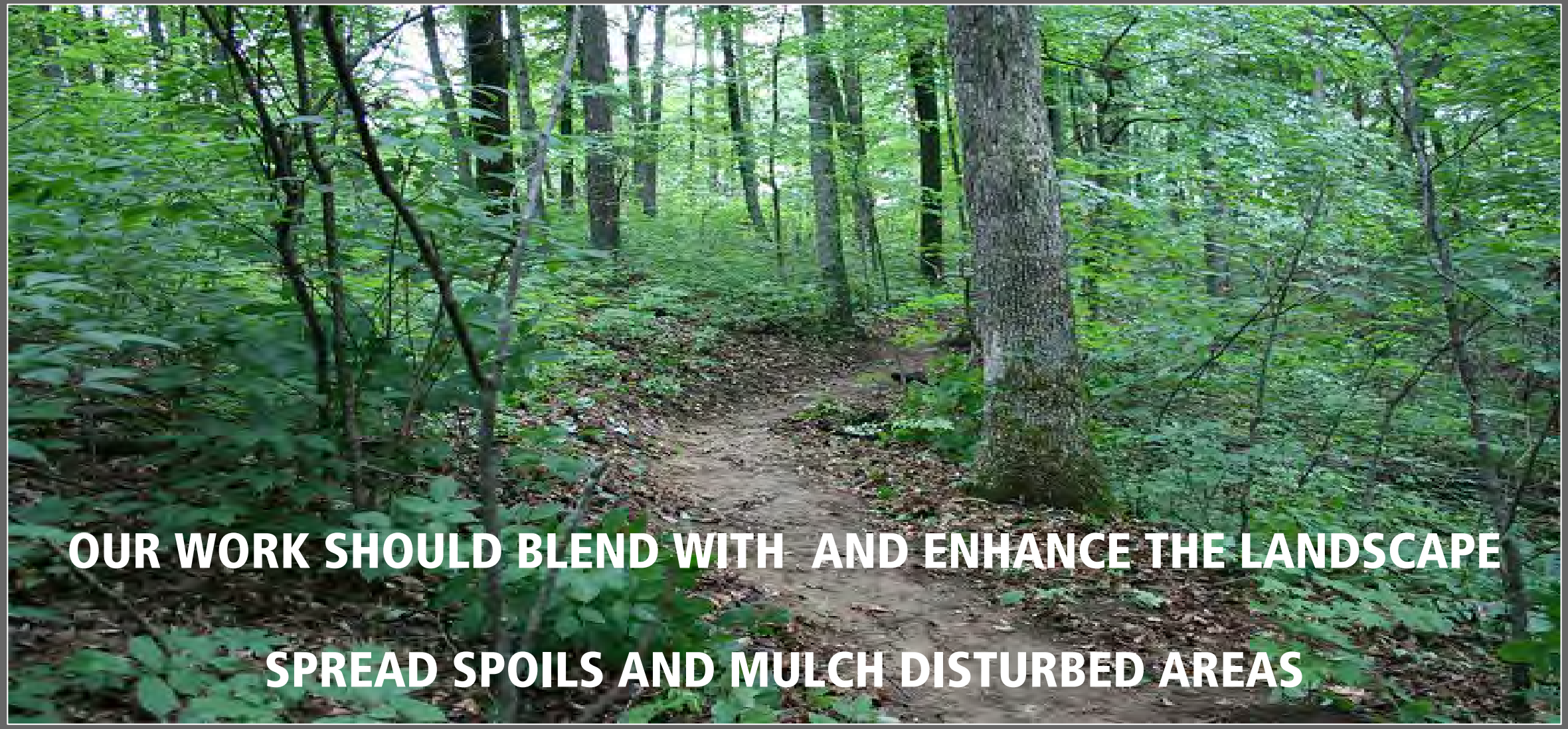
NATURALIZATION

- We recreate to be in nature (most of the time), so it is very important to leave it as we found it
- Naturalization is the process by which we re-wild the trail after construction, this is the very last step prior to opening a trail for use
- In forested areas, leaves, pine needles, and debris are your friend
- What was removed during corridor clearing should be spread over trail edges and critical points to blend the tread back to the un-impacted areas outside the corridor
- If you have enough debris, a leaf blower can work wonders, blowing all organic material back onto the recently built trail and idling down the tread after leaves a nice ribbon of tread exposed
- Cover the backslope if its not a riding surface, make sure gutter lines are clean
- Do not fill your grade reversals or drains!
- The downside edge should always drain, it should not dam water on the trail, ensure the tread always drains
- Roots, trees, and other cut woody debris should be scattered away from the corridor, not piled or placed so its obvious

STABILIZATION

- Essentially the same step as naturalization, this is the process by which we as trailbuilders ensure our site is stable and can be opened for public use
- Generally, stabilization is ensuring loss soil material is minimal, the only expose soils should be the trail tread and it should be compacted (the best compaction is use)
- Insloped sections of trail, turns, and other built up dirt features should be heavily mulched on the outside to "buttress" the pile and help stabilize it
- Steep sideslopes below bench (especially partial benches) may benefit from parallel log or branch placement, these can help act as sediment barriers (especially useful above waterways)
- When naturalized properly, many trails will stabilize quickly
- The seed matter in the organic material will help vegetation take root, which will be the best stabilization possible for the trail



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WATER CROSSINGS TIPS

- Identify water crossings as key control points
- Carefully design crossing approaches (both grade and alignment)
- Include grade reversals before and after (much like turns)
- Find stable location (especially important for larger streams/rivers)
- Don't constrict flow
- Crossing should be at the bottom of a grade reversal, the lowest point, if not water will flow down your trail

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WATER CROSSINGS TIPS

- No corduroy! (Picture to the left) . If there is a wet spot properly mitigate it through armoring, relocation, or structure
- Much like turns, forcing water crossings into the wrong location will continue to cause issues
- Water crossings are one of the most likely to trigger compliance
- Water crossings are some of the biggest maintenance concerns, further reason to site them properly
- Crossing type depends largely on visitor and trail types

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WATER CROSSINGS TYPES

Natural Ford (at-grade)

- Easiest to build (its natural! But likely requires good approach and exits)
- Can be hardest to find/locate during planning/design
- Only feasible in certain situations, both terrain/landscape and compliance/regulatory
- May only be feasible for certain visitor types on specific trail types

Constructed/Armored Ford (at-grade)

- Simpler than bridges in most instances
- Generally need similar landscape situations as natural fords
- May require regulatory compliance (401/404)
- Typically the best option for ephemeral or seasonal drainages
- May only be feasible for certain visitor types on specific trail types

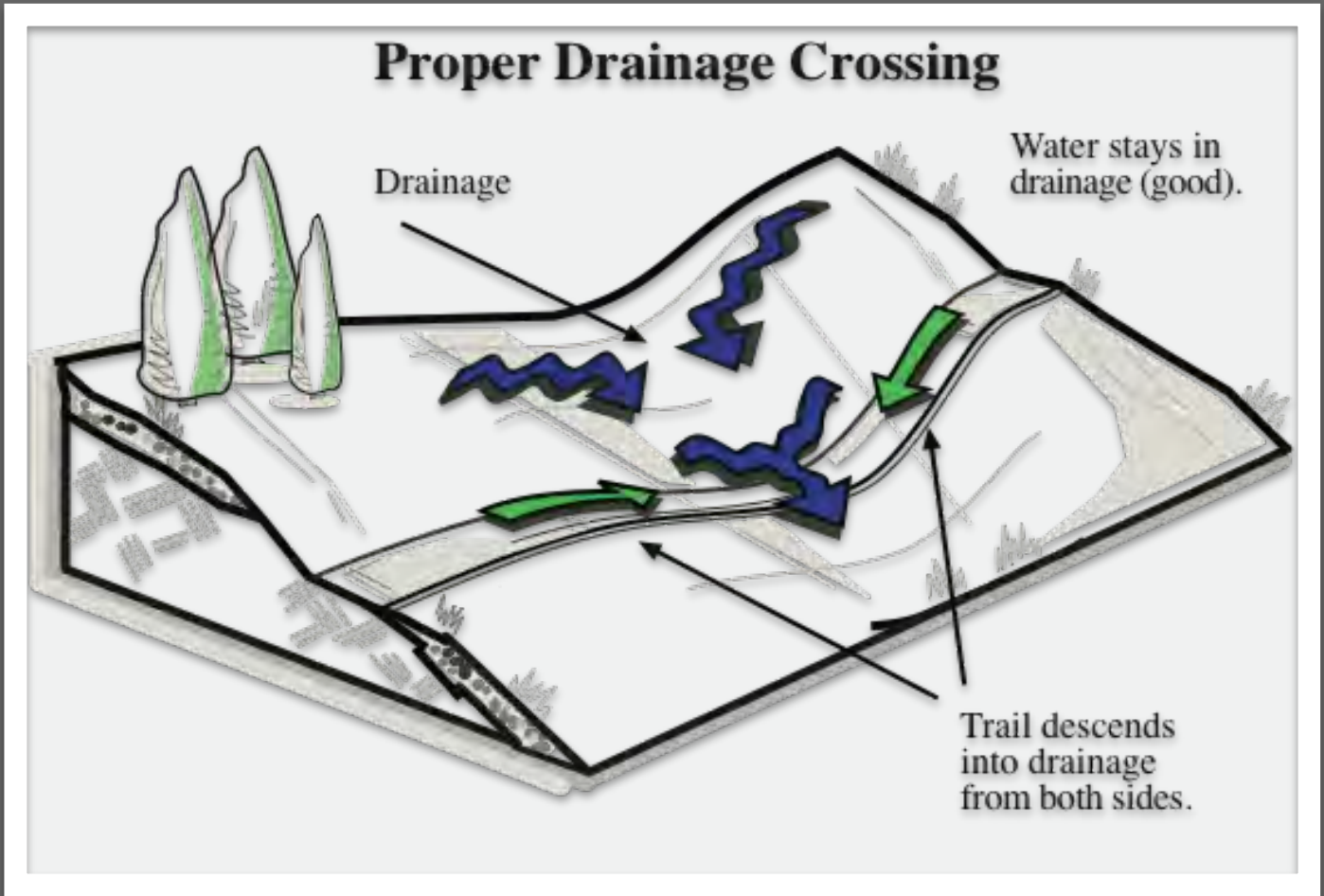
Bridge

- Typically requires the most design, regulatory compliance, and cost
- Typically used to cross wide or deep streams, rivers, and channels

Boardwalk

- Similar to bridges, these built structures can require expensive engineering, design, permitting, installation, and maintenance
- Typically used to cross wetlands or marshy areas.

WATER CROSSINGS



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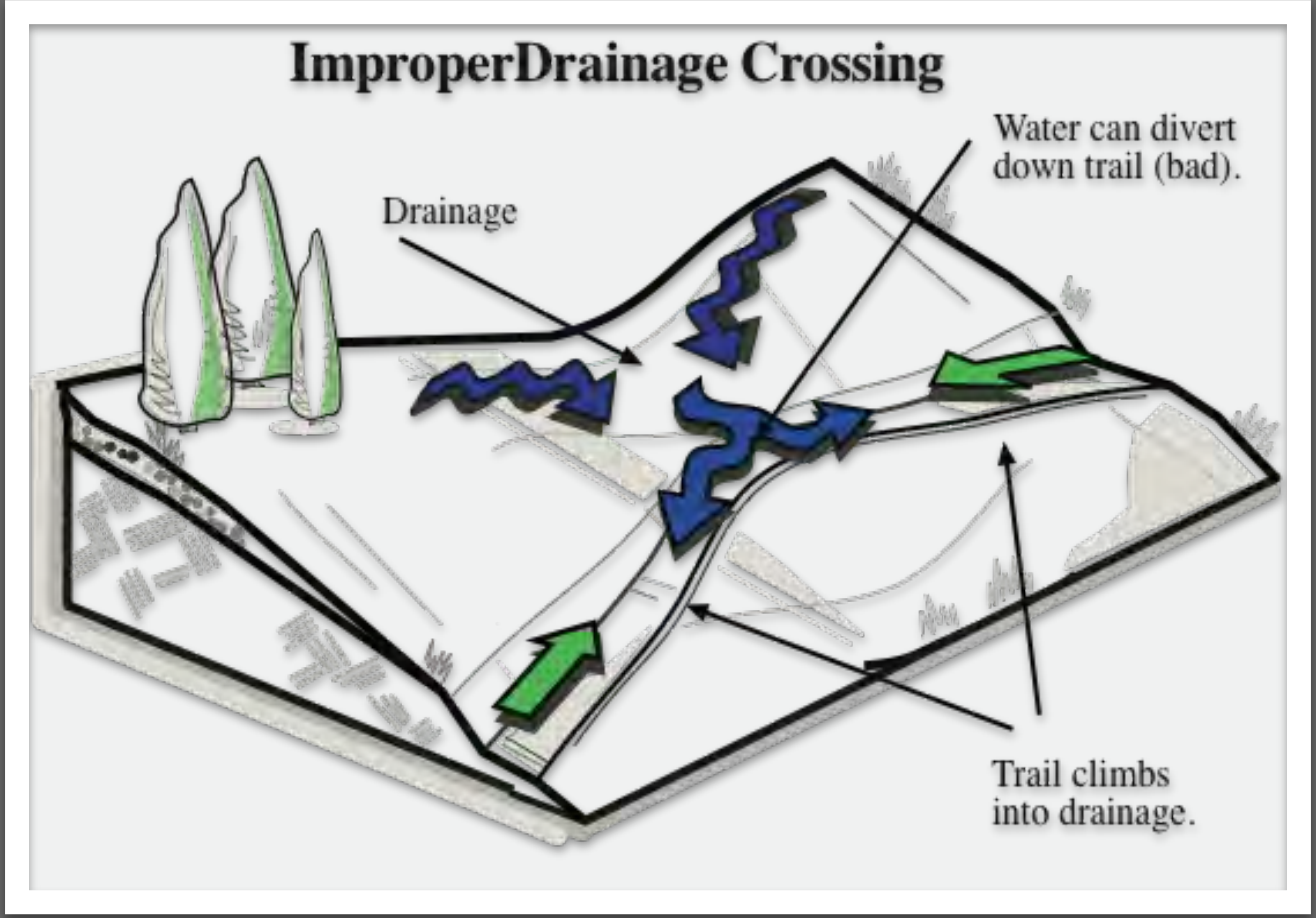
WATER CROSSINGS



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CROSSINGS FOCUSED WATER

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NATURAL FORDS

- Natural crossings (pictured) are rare both in terrain and compliance
- Generally these crossings will involve visitors getting wet at some point during the year
- These may provide useful options for equestrian crossings on shared-use trails that utilize another method (armored ford, bridge, etc.) for pedestrians and mountain bikers
- While the stream or channel bottom may be left intact, armored approach and exits will increase crossing lifespan and reduce nearby trail maintenance
- These crossing types are most appropriate in backcountry and remote settings, where crossing a water feature fits nicely with the aesthetic and experience

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ARMORED FORDS/CROSSINGS

- Armored fords and crossings (pictured) are generally some of the most prolific water crossing types
- These crossings may or may not be wet
- When armoring a drainage crossing it is important to ensure the armoring will not dam or constrict flow
- The lowest point should always match up the original channel and be on the downside edge of the trail tread
- Generally anchoring is recommended at the approach and exits to guide visitors over the armoring
- Approaches and exits much also be armored to increase lifespan and reduce nearby trail maintenance
- Largest rocks should anchor the entire armoring (more on this in rock armoring)

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ARMORED FORDS/CROSSINGS

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ARMORED FORDS/CROSSINGS




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ARMORED FORDS/CROSSINGS

- Grade reversal prior to crossing
- Lowest point in the channel/downside edge of trail tread
- Armored approach/exits
- Riprap below armoring to protect rocks/dissipate water energy

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SEEPS

- Seeps should be treated like armored fords and crossings
- Identifying seeps may be difficult during planning/design, in fact seeps may form over time due to trail construction and use
- Seeps should be armored to increase trail lifespan and reduce maintenance needs, while also increasing positive experiences for visitors

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