

equestrian Trail

GUIDELINES

CONSTRUCTION AND MAINTENANCE

Nathan Kyle Tabor

Kathleen M. Trauth, Ph.D., P.E.

George W. Hartman, certified wildlife biologist

INTRODUCTION

Missouri is a horse rich state, with a herd size that is the seventh highest in the nation. Missourians owned more than 281,000 horses valued at \$420 million in 2005. More than 145,000 of these horses were used primarily for recreational riding. The total economic impact of these recreational users has been valued at \$673 million (American Horse Council Foundation, 2005).

Recreational trail riding is the premier pastime of most of our state's recreational horse owners. Equestrian trails on state and federally owned lands provide countless hours of relaxation and enjoyment. Unfortunately, most equestrian trail development has come about in one of two ways: 1) through the formalization of existing trails created by riders who have meandered through an area or 2) through the designation of trails along existing traces such as old roadways or logging roads. Neither method of trail establishment considers soil types, slopes or erosion hazards. Neither did managers consider the behavior of trail riders in going around wet spots, deep ruts and fallen trees, thus creating braided trail networks and an ever-expanding corridor for the trail. Equestrian trail maintenance also has not been a high priority as agency budgets are reduced and external funding sources become more scarce. All these factors—throughout decades of trail use—have created a system of trails that has deteriorated beyond acceptable limits by both trail riders and the government agencies that manage the trails.

Such was the case within the Missouri Department of Conservation (MDC) in autumn 2003. Land managers realized the need for well-designed trails and effective trail maintenance standards, because equestrian trail-riding activity has increased during the past several years and deterioration of existing trails has accelerated. To address this problem, MDC land managers requested help in determining the best sites and maintenance techniques for managing equestrian trails.

A graduate study, completed in 2007, used engineering expertise from the Department of Civil and Environmental Engineering at the University of Missouri-Columbia. That study is the basis for the guidelines within, which are intended as an aid to land managers within MDC and other Missouri land-management agencies. This study examined soil associations and topographic features found in this state. University and MDC engineering staff provided input and guidance throughout the project. Major trail renovations and design features still will require the expertise of engineers. However, by using the information here, land management personnel should be able to devise basic trail layouts and resolve problem areas within a trail system.

The design of trails based upon soils and topography is basic to erosion control and lower maintenance costs. However, as with any user group, trail riders have behavioral preferences for themselves and their horses that also need to be considered within a trail management program. A partial list of behavioral topics to consider along with the engineering aspects for the trail system is included in Appendix A. This list is not extensive, so managers are encouraged to incorporate area users or organized horse trail groups in the trail-planning process. The best-designed and best-constructed trail system is for naught if riders will not use or stay on the trails.

The information gained by this two-year study was greatly enhanced by and drew heavily upon prior work reported by the USDA Forest Service—Hoosier National Forest (HNF) and by the International Mountain Biking Association (IMBA). Although IMBA trails information pertains to mountain bike trails, much of the information they have published is applicable to equestrian trails. The HNF study was conducted during a seven-year period by the Virginia Polytechnic Institute and State University Department of Forestry.

Other recommended trail-building references:

Trail Solutions: IMBA's Guide to Building Sweet Singletrack Available at www.imba.com/resources/trail_building/Natural_Surface_Trails_by_Design. 2004. Troy Scott Parker. Naturescape. Boulder, Colorado
Trail Construction and Maintenance Notebook USDA Forest Service, 4E42A25-Trail Notebook
Geosynthetics for Trails in Wet Areas. 2000. S. Monlux and B. Vachowski. USDA Forest Service Technical Report 0023-2838-MTDC

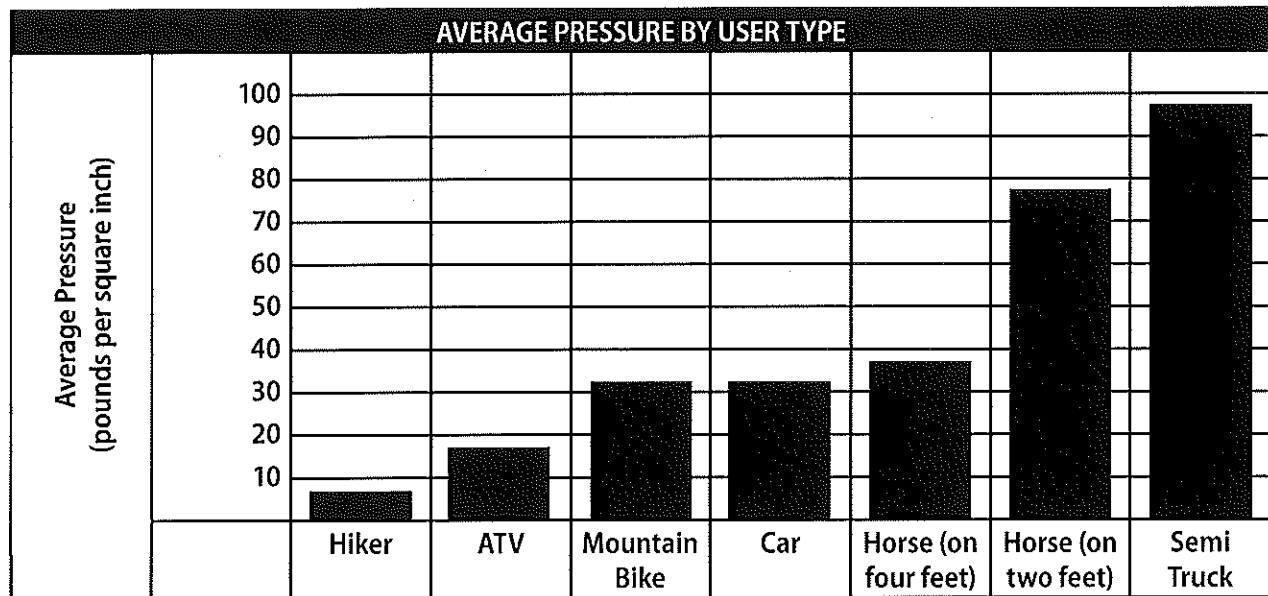


Figure 2. Pressure exerted on a surface by user type

While soil disturbance and the subsequent erosion is related to the pressure applied by users, the extent of erosion has an unexpected relationship to use. It takes only a few users to significantly loosen the top layer of the soil. Increased use increases disturbance only up to a certain point, to a threshold. After that threshold has been reached (where the soil has been disturbed), additional use does not cause additional disturbance until precipitation runoff has removed that top layer of loose soil. The disturbance process then begins again.

Resisting Forces

The disturbing forces of water and use are resisted by either erosion resistance or wearing resistance. Erosion resistance comes from the size and weight of the soil particles. Larger and heavier particles are more difficult to transport via flowing water. Size and/or weight can be a property of the material itself, as with gravel. Clays are not individually large or heavy, but their cohesive properties—which bind the particles together—make them resistant to movement. Sands—neither large, heavy nor cohesive—are more subject to erosion.

Wearing resistance is the ability to resist the disturbing action of use and is produced by the strength of the soil. Soil strength is determined by the texture, density and moisture content of the trail's soil or alternative surface. See additional details on the resisting forces in Chapter 2.

Effective limits on the trail steepness and tread length are associated with soil type, and recommendations are found in Table 2. Steep trails need to have shorter tread lengths between water diversion structures. This requirement is more pronounced for materials that are more susceptible to erosion—silt, for example.

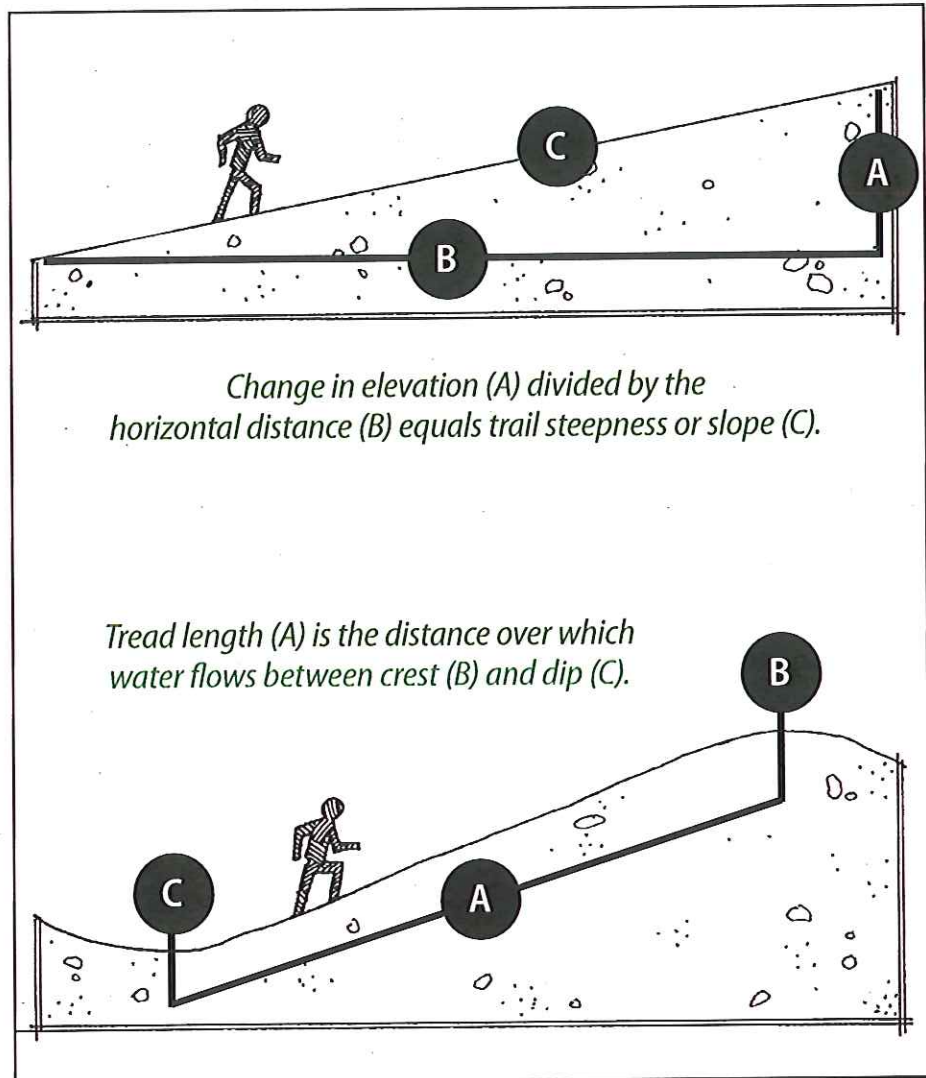


Figure 5. Trail steepness and tread length

General recommendations for Missouri soils							
Soil Type	Trail Steepness (%)						
	2%	4%	6%	8%	10%	12%	14%
* Clay	100 ft.	80 ft.	65 ft.	45 ft.	25 ft.	15 ft.	N/A
Silt	50 ft.	40 ft.	30 ft.	15 ft.	N/A	N/A	N/A
Sand	40 ft.	35 ft.	20 ft.	10 ft.	N/A	N/A	N/A
Loam	90 ft.	70 ft.	60 ft.	40 ft.	15 ft.	N/A	N/A
Gravel Loam	100 ft.	80 ft.	65 ft.	40 ft.	30 ft.	20 ft.	N/A
1"-minus Gravel	80 ft.	60 ft.	40 ft.	40 ft.*	40 ft.*	40 ft.*	30 ft.*
* Needs ditching to intercept surface water for diversion or additional structural protection.							

Table 2. Tread-length limits in feet based on steepness and soil type

I HAVE HEARD INCREASING THE BACKSLOPE WILL DECREASE SUBSURFACE FLOW ON TO THE TRAIL - NOT SURE?

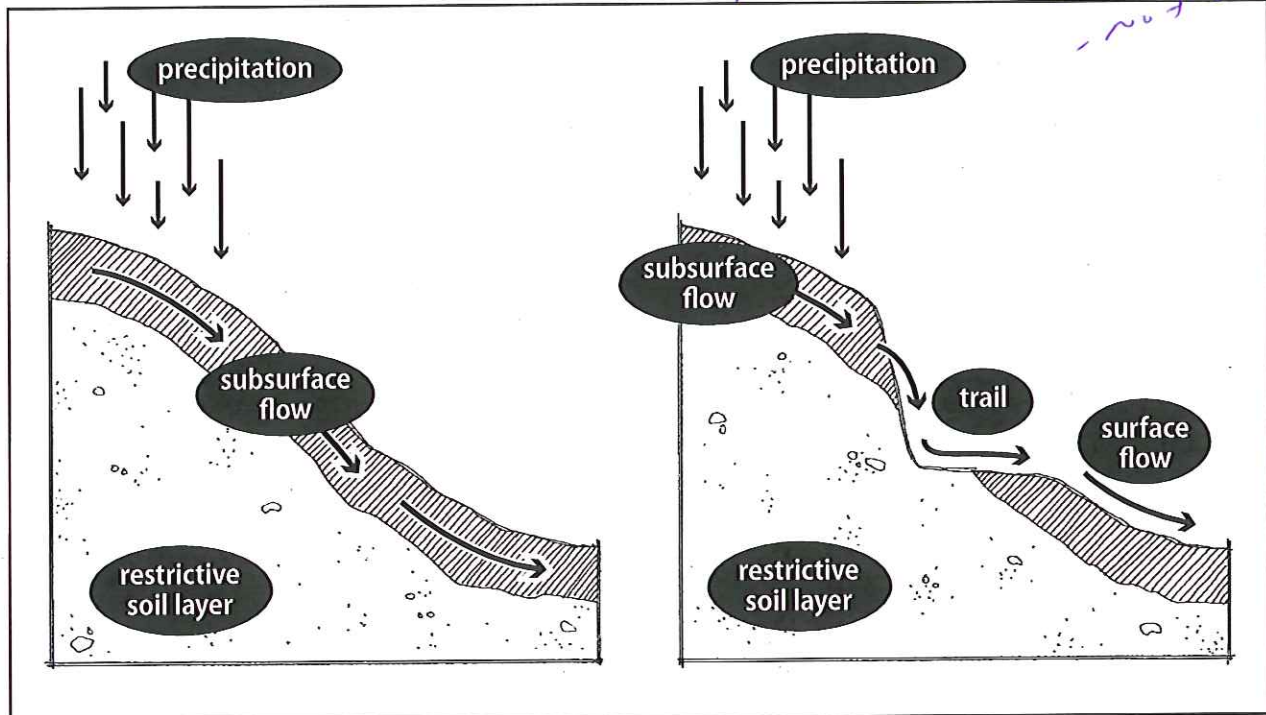


Figure 7. Restrictive soil layer with water seepage onto trail

B. WATER-DIVERSION STRUCTURES AND TRAIL-SURFACE SHAPE: REMOVING WATER FROM TRAILS

Once a trail has been designed to minimize water flow onto it, the next thing to consider is how to remove water that does make its way there. This is accomplished by shaping the trail surface and using water-diversion structures to force water off the trail.

Trail-Surface Shapes

There are three recommended shapes for the trail surface (tread): outsloped, insloped and crowned (Figure 8). The shape designation indicates how water will be directed off the trail.

Outsloped Tread (tread tilted toward downhill side of trail)

A trail with an outsloped tread directs water immediately off it. This is highly effective with benched trails (those cut into a sideslope) on steep sideslopes where water diversion is easy. Immediate diversion with the benched trails is important because the cutting associated with benched trails may result in the subsurface seepage of water onto the trail.

Insloped Tread (tread tilted towards the uphill side of the trail that intercepts and collects water over a given distance before the water can reach the trail surface)

The insloping prevents the water from affecting the trail surface. Any water collected in the channel created by the insloped surface and the hill slope can be managed and diverted away from the trail at specific points, such as waterbars or grade dips.

Crowned Tread (trail surface is both raised above the normal ground surface and shaped to be higher in the middle and lower on the trail edges)

A crowned tread prevents runoff from reaching the trail surface and immediately sheds any rain that falls on it. This shape is effective in flat areas where water diversion is difficult.

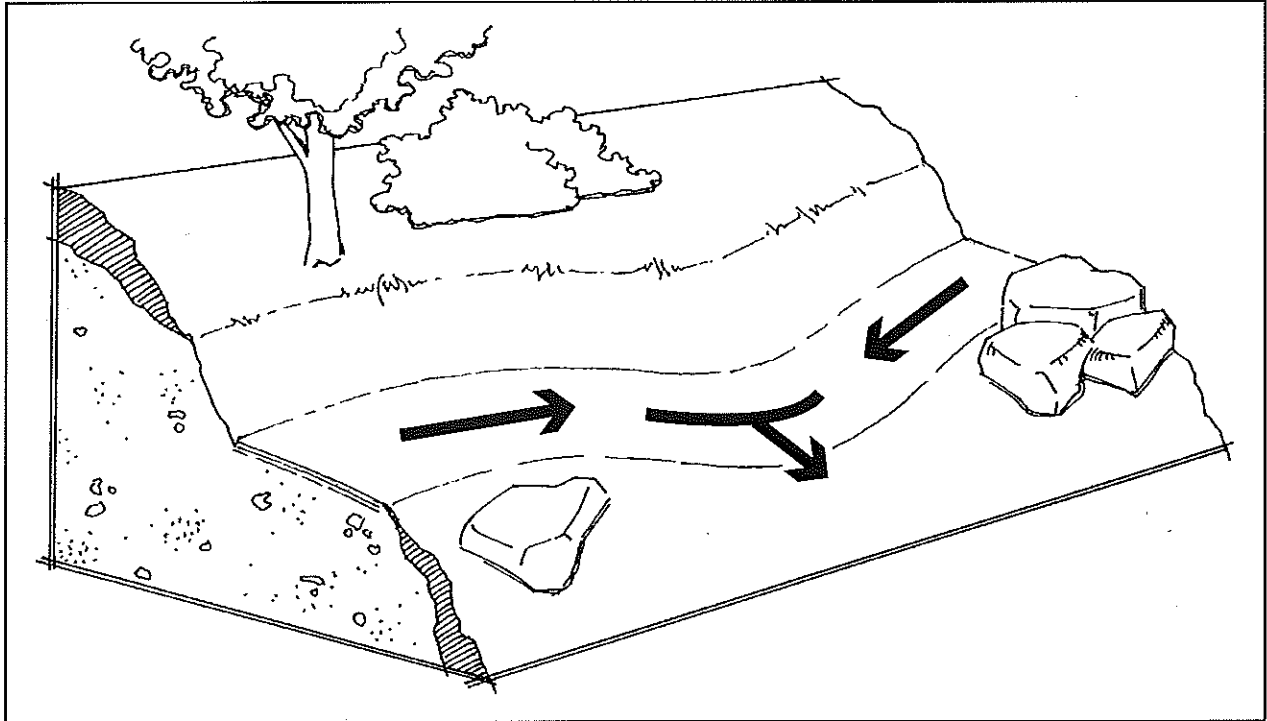


Figure 10. Grade dip

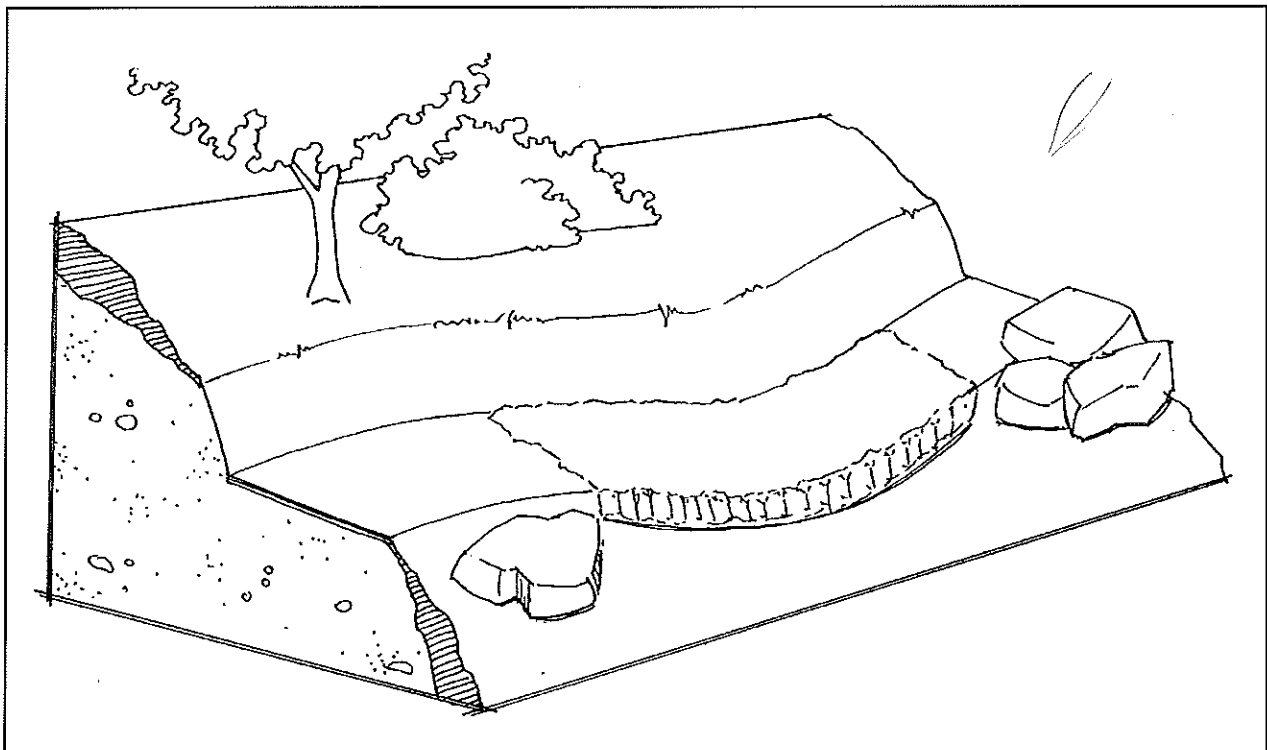


Figure 11. Grade dip with geocell reinforcement

C. THE RIGHT WEARING SURFACE: HARDENING THE TRAIL SURFACE

The selection of the wearing surface complements the previous design steps of trail layout (keeping water off a trail) and water-diversion structures (removing the water that does end up on a trail). The wearing surface must be able to withstand the combination of use and environmental factors. Choosing the right wearing surface depends on soil type, landscape location and water potential. Silts and sands are highly erosive, but if a trail is located where water will not significantly affect it, they can be adequate trail surfaces. Table 4 summarizes the use of a few trail surface stabilization techniques.

Natural Soil Surfaces

Natural soil surfaces are the cheapest and easiest to use for trails. However, due to the intense impact from equestrian use, not all soil types will provide an adequate surface for sustainable trails. Soil types such as clays and silts are greatly affected by water and are weak when wet. Sandy soil types are easily disturbed and are also highly erosive. Soil types with a high gravel content are strong and can resist heavy trampling, which reduces the potential for erosion.

Gravel Surface

Gravel-wearing surfaces offer increased erosion resistance and surface strength. Gravel is a strong material that easily can support the pressure from horses. When compacted, well-graded gravel surfaces are erosion resistant because the larger particles are harder for water to carry away.

Stabilization Technique	Soil applicability	Pros	Cons
Gravel Surface	Highly erosive soils: silts and sands	Easy application; relatively cheap	Susceptible to rutting on fine-grained soils: silts and clays
Gravel with Geotextiles	Wet, fine-grained soils	Increased strength; longer life cycle than gravel alone	More expensive than gravel alone
Geocells	Very weak, wet fine-grained soils; steep slopes	Very high strength; very low rutting potential	Expensive; intensive construction process

Table 4. Trail-surface stabilization techniques: pros and cons

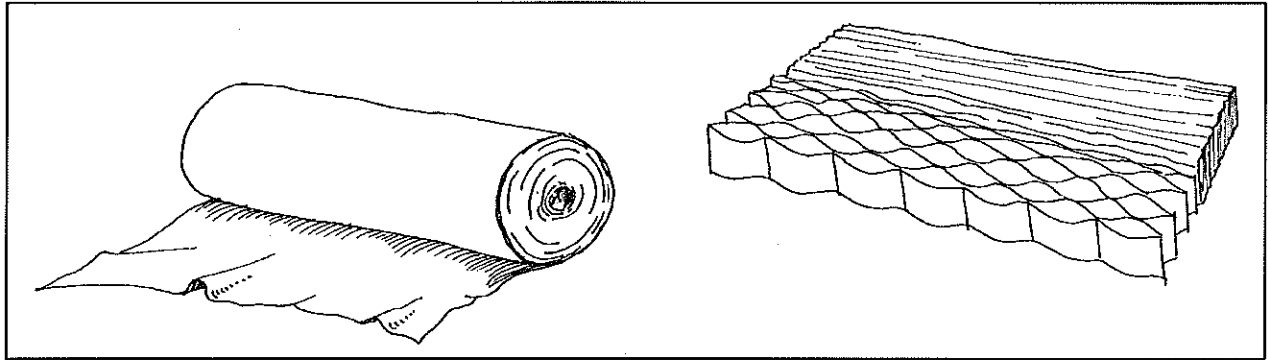


Figure 13. Geosynthetic examples: geotextiles (left) and geocells (right)

Geosynthetics

Geosynthetics (Figure 13) are synthetic materials, such as fabrics and frames, that are used to improve soil strength by providing separation and water drainage. These materials are used to separate gravel of different sizes and to reinforce and contain trail-construction materials.

Water drainage is impeded, in part, by the small pore size of some soil types. Geosynthetics can increase water drainage by keeping small particle sized soils from mixing with the larger sized particles of a trail surface. The geosynthetic frames can hold gravel in place, while the fabric separates gravels from the upward migration of small particles (fines) that can clog the drainage area and create muddy conditions. The reinforcement of trail materials helps them stay in place so that they can function properly. Gravel-wearing surfaces can be paired with geosynthetics to increase strength. These combinations provide strong surfaces in areas with weak soils, require less material and increase the life of a trail.

Geotextiles

Geotextiles (Figure 15) are fabric sheets of synthetic fibers that provide separation and reinforcement between a natural soil surface and a gravel-wearing surface. The fabric allows water, but not soil, to flow through the material. On gravel roads, rutting often occurs when gravel mixes with the soil below. With geotextile separation the materials do not mix, and the result is a stronger surface that requires less gravel and prevents rutting (Figure 14).

Geotextiles can be used in two different applications (Figure 15): as a single-layer (non-wrapped) section or as a wrapped section. In a single-layer application, one layer of the fabric is covered by gravel.

In a wrapped section, the geotextile fabric encapsulates free-draining gravel that is then covered with a surface gravel. The geotextile fabric provides soil separation and reinforces the encapsulated gravel in this application. The wrapped section, with two layers of geotextile, has more strength than the single-layer section.

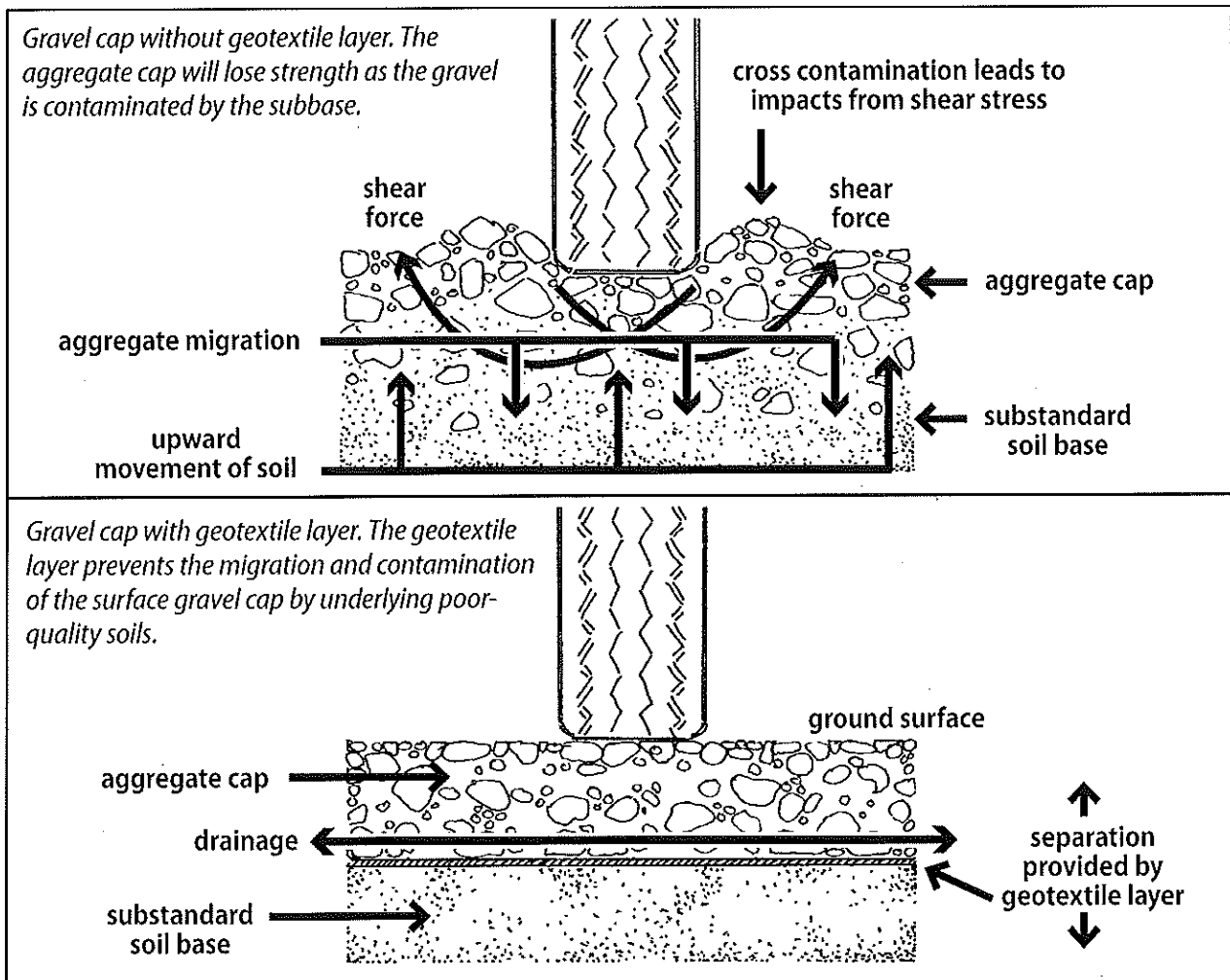


Figure 14. Bearing capacity increase with geosynthetic reinforcement example

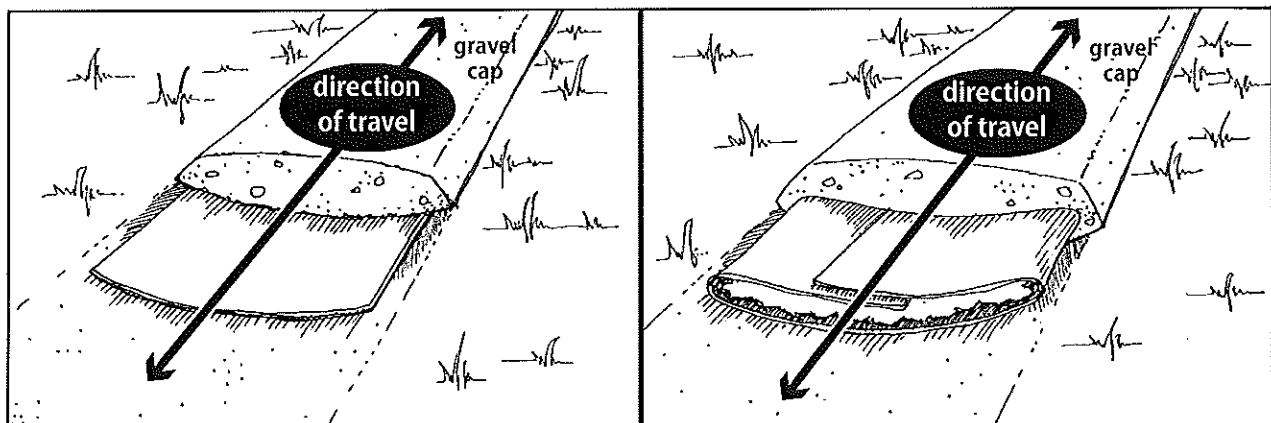


Figure 15. Geotextile non-wrapped (left) and wrapped (right) sections

Geocells

Geocells (Figure 16) are plastic strips that are bonded together to create a honeycomb type of structure. The individual cells are installed in an excavated section, filled with gravel and covered with an additional layer of gravel. The gravel and geocells act together to spread out loads over a wider area, essentially reducing the load over a unit area and increasing the strength of the system. In addition, geotextile fabric is placed underneath the geocells to separate the fill material from the soil underneath. The result is increased surface strength that requires less fill material.

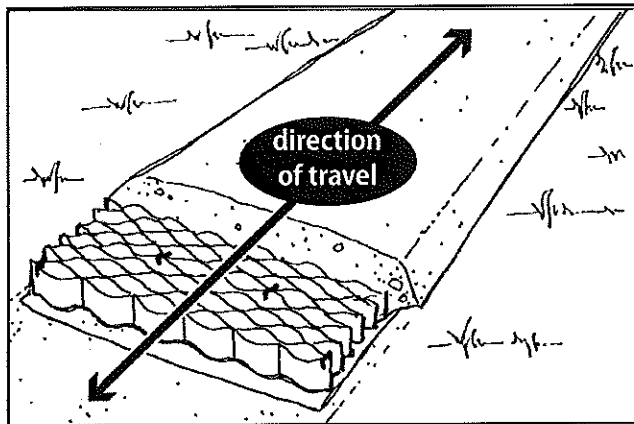


Figure 16. Geocell trail

*Looks
Good***Specifications for rock**

Surface aggregate: 1-inch minus base
Largest particle size: 1 inch
Well-graded with fines
Fines (<#200 sieve) should not be greater than 30 percent by weight.

Drainage Aggregate: 1-inch clean aggregate – No fines

Geotextile-reinforced waterbar**Construction process:**

1. Dig out dip. Align the water bar at an angle of 45 degrees from the trail.
2. Lay fabric on soil surface, downhill from dip.
3. Fill fabric with clean draining rock.
4. Wrap ends of fabric around rock.
5. Cover the wrapped fabric with surface aggregate.

Tips: Pull fabric wrap as tightly as possible. Overlap fabric at least 12 inches. Cover fabric wrap with more than 3 inches of surface aggregate.

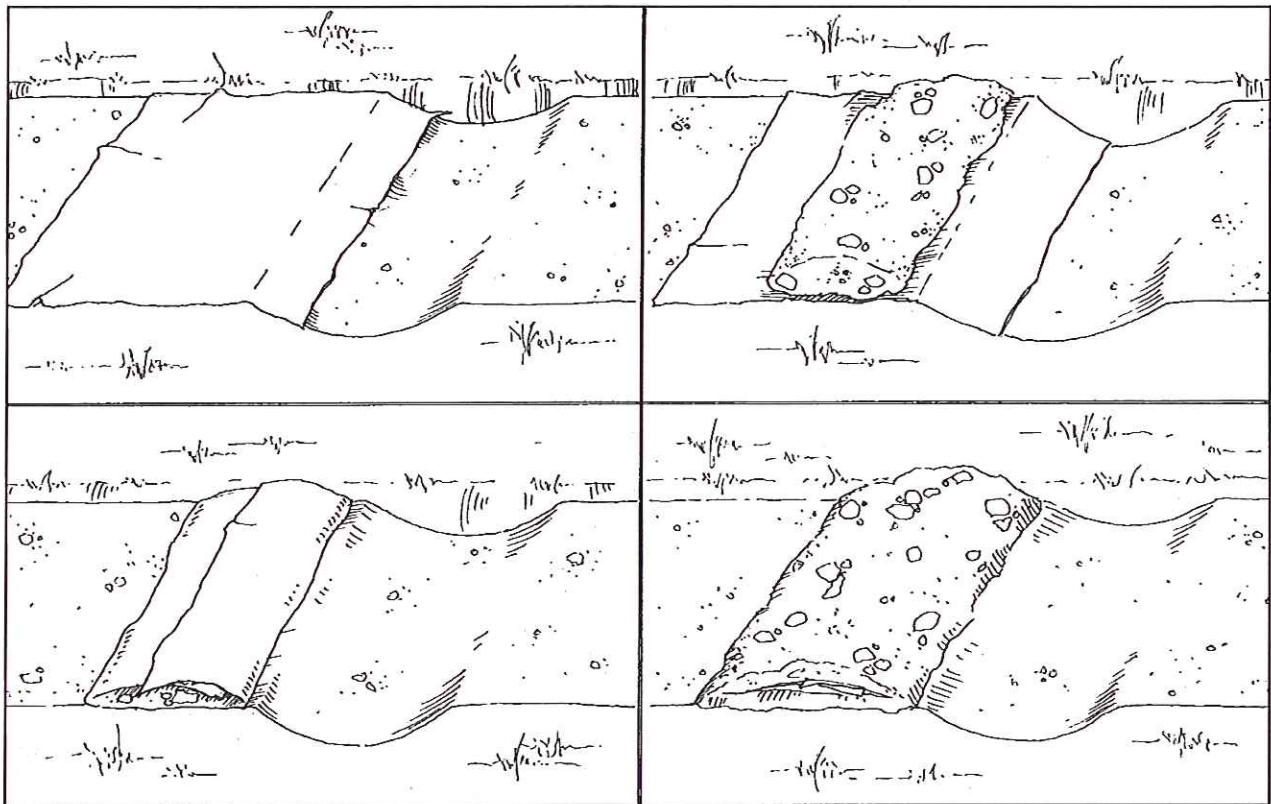


Figure 22. Geotextile-reinforced waterbar construction

Geotextile trail segments (wrapped or double layer)

Construction process:

1. Cut roll of fabric to more than two times the desired width of trail.
2. Roll out fabric roll along trail surface; be sure to prevent wrinkles in the fabric.
3. Place clean aggregate on top of geotextile fabric. Width should be desired width of trail. If depth of aggregate is not even, use hand tools to even trail surface.
4. Overlap excess fabric over the clean aggregate. Minimum overlap should be 12 inches.
5. Place surface aggregate on top of the overlapped fabric. Minimum thickness should be 2 inches, with a maximum of 4 inches.
6. Compact trail surface with equipment. If possible, use a mechanical roller.

Tips: Do not drive equipment over bare geotextile fabric; the fabric will rip and lose separation integrity.

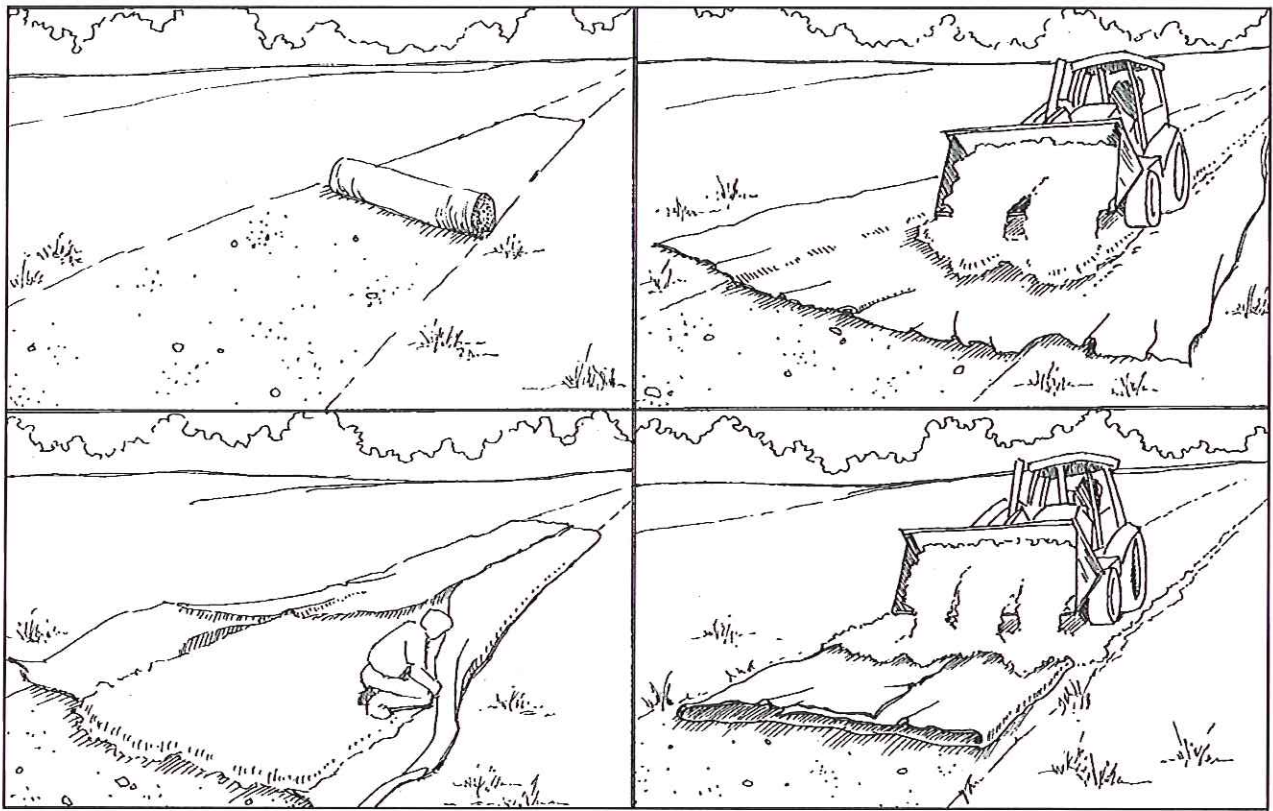


Figure 24. Geotextile-wrapped section construction

MIGHT BE GOOD
FOR LOW AREAS
FILL WOULD NOT BE LOST

Geocell segments

Construction process:

1. Roll out geotextile fabric along trail surface.
2. Open and place geocells to desired width of trail surface.
3. Once the desired width is met, stake one end of the geocells with at least five stakes.
4. Pull the rest of the geocells along the trail until desired width is reached. Stake along the sides of the geocells, keeping them tight and not allowing deformation. Use approximately 25-30 stakes per segment to secure the geocells in place.
5. If additional sections of geocells are needed, connect the ends of two geocell segments together. Use additional stakes, heavy-duty staples or twine to connect the sections together.
6. Begin to place clean aggregate inside the geocells. Fill each cell with clean aggregate up to the top of each cell. If aggregate is being placed by equipment, be sure the drop height does not exceed 3 feet. When placing aggregate with equipment, it is hard to distribute aggregate evenly. Therefore, the excess aggregate needs to be spread out with rakes or other hand tools.
7. Once the clean aggregate has been placed and spread into each cell, place the surface aggregate on top. A minimum surface aggregate thickness of 2 inches is needed, with a maximum of 4 inches.

Tips: Be sure to use equipment with low ground pressure, such as tracked skid loaders or ATVs with dump-bed attachments. Do not drive equipment over the geocells until the cells have been filled to the top with aggregate.

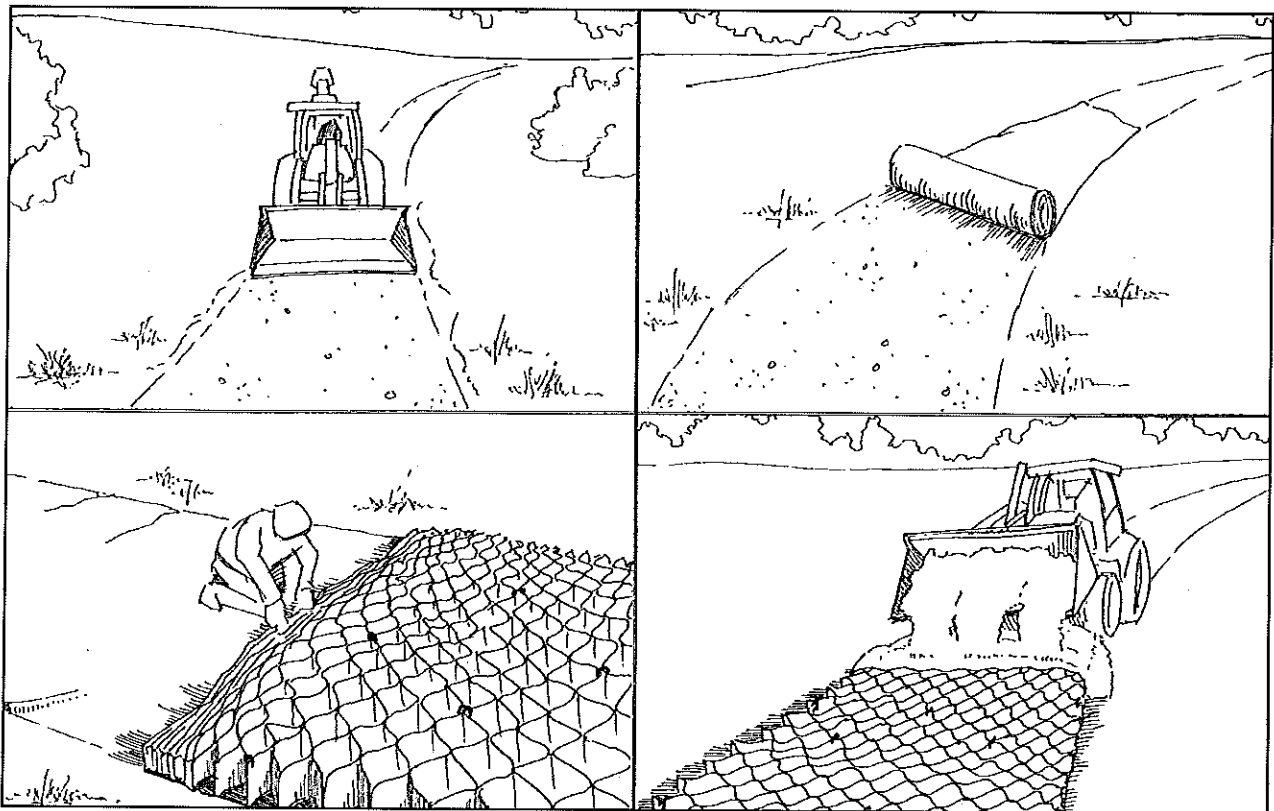


Figure 25. Geocell segment construction

Geocell-reinforced stream crossings

Construction process:

1. Excavate a section of stream bottom to make room for placement of geocells. Depth of excavation should be 8 inches deep along the stream bottom. Width of excavation should match the desired trail width over the crossing. The finished surface should be level with the existing stream bed.
2. Excavate ditches for placement of rip-rap. Location should be outside the desired width of trail. Depth should be 3 to 5 feet. Place large rip-rap stones in the ditches.
3. Roll out geotextile fabric along the planned crossing.
4. Open and place geocells to desired width of trail surface.
5. Once the desired width is met, stake one end of the geocells with at least five stakes.
6. Pull the rest of the geocells along the trail until desired width is reached. Stake along the sides of the geocells, keeping them tight and not allowing deformation. Use approximately 25-30 stakes per segment to secure the geocells in place.
7. If additional sections of geocells are needed, connect the ends of two geocell segments together. You may use additional stakes, heavy duty staples or twine to connect the sections together.
8. Begin to place clean aggregate inside the geocells. Fill each cell with clean aggregate up to the top of each cell. If aggregate is being placed by equipment, be sure the drop height does not exceed 3 feet. When placing aggregate with equipment, it is hard to distribute aggregate evenly. Therefore, spread out the excess aggregate by hand with rakes or other hand tools.
9. Once the clean aggregate has been placed and spread out into each cell, the surface aggregate can be placed on top. You will need a minimum surface aggregate thickness of 2 inches and a maximum of 4 inches.
10. Place rip-rap stones on downstream side of the crossing. Maximum height should be 3 inches above the stream bottom. This will create a small pool of water that will prevent scour of the surface.

Tips: Be sure to use equipment with low ground pressure, such as tracked skid loaders or ATVs with dumped attachments. Do not drive equipment over the geocells until the cells have been filled to the top with aggregate.

would be ok for wet areas perhaps but not streams

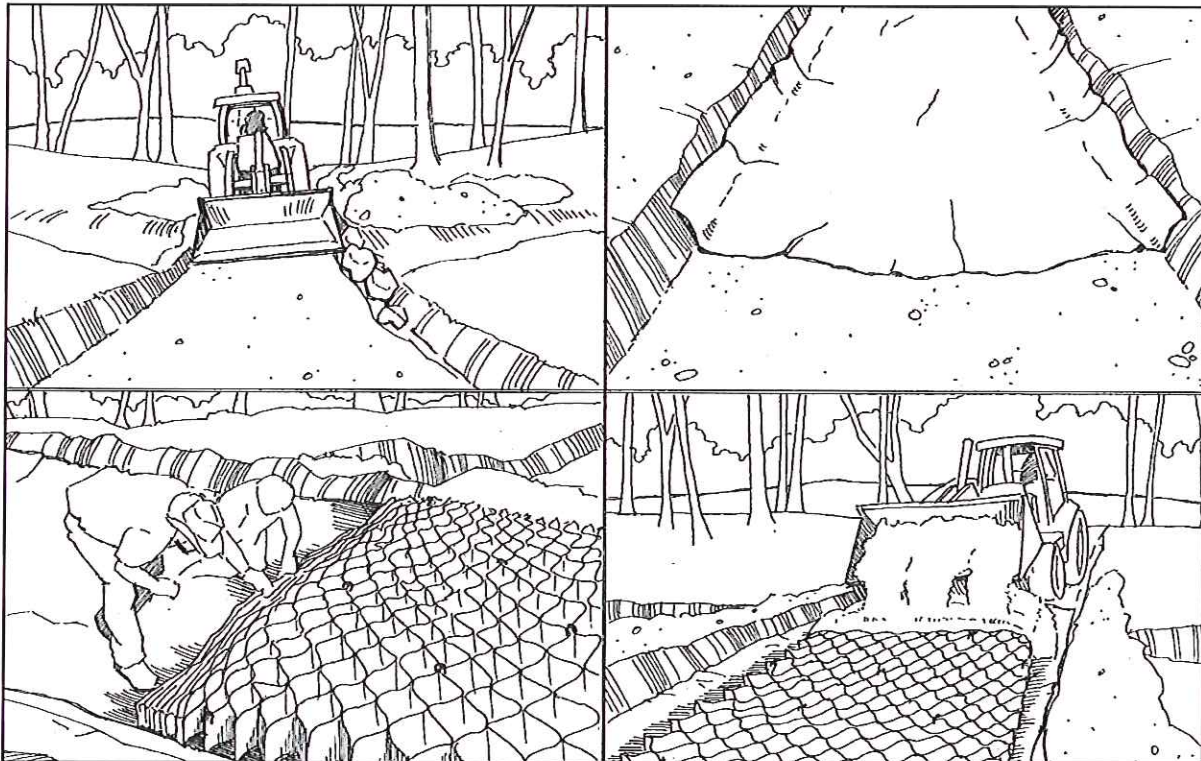


Figure 26. Geocell-reinforced stream crossing

APPENDIX A

TRAIL-RIDER AND HORSE BEHAVIORS TO CONSIDER IN TRAIL-CONSTRUCTION PROJECTS

offered by George Hartman

With a keen interest in both horse and trail-rider behaviors, I offer these observations from 10 years on the trail. Consider these suggestions for working with the equine-using public when and where they will enhance your trail-construction and -maintenance program.

Rider Behaviors

Most problems from horse-trail users result from riders' perceptions of what their horses want, horses that lack training or riders who are inadequately trained to handle their horses. There is, of course, a wide variety of personalities and abilities among trail riders. If you consider these behaviors when designing or correcting existing trail problems, your constituents will be more satisfied and your trails may last longer.

Different trails for different types. You cannot make all riders happy with one type of trail, so manage for the best trail types suited to your soils and topography. Whatever trail surfaces and widths fit your management program, be assured that at least a segment of the trail riders will enjoy them.

Trail riders go to water. Horses do not need or want to drink every time they come to water, but some riders will take their horses to water at every opportunity. Consider this when a planned trail crosses a flowing or intermittent stream or passes close to a pond or lake. Screen the trail from the water, make access to the water difficult or develop a watering area that will withstand usage by horses.

Decrease temptation. If riders can see another trail or something of interest from the backs of their horses, some will ride over to investigate or to reach the other trail. That is how many unauthorized trails begin. Consider the line of sight from your trail at a height of about 8 feet (rider on horse). This is especially important on switchback trails or where trails pass close to an attraction such as a cave, stream or scenic overlook. If you want riders to access these attractions, provide an access. Otherwise, don't tempt riders to leave the existing trail. They will.

Keep them clear. Riders will go around low-hanging branches and may get off the trail. They will ride around downed trees, wet areas or deep ruts—all actions that cause a braided trail. Be vigilant about keeping the trail height and width open and dry so that riders can follow the designated trail.

Horse Behaviors

Under the best of circumstances, a horse—as an evolutionary prey species—has some behaviors that will show up in all but the most well-trained trail animals. They have evolved with their sight, hearing and smell to warn them of danger and their legs to get them away from any real or perceived danger. Their response to anything out of the ordinary is to perceive it as a potential threat. Any trail situation that could impede their escape from a predator also makes them anxious.

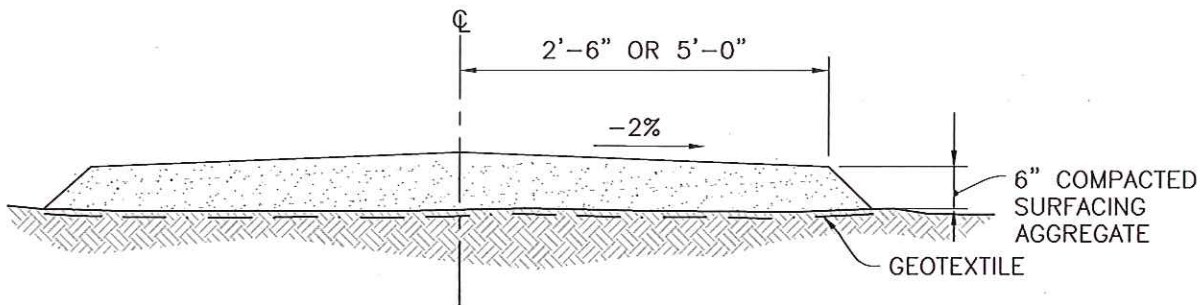
The following horse behaviors or responses to stimuli cannot be avoided. However, if they are addressed whenever practical, the chances of horses giving their riders control problems will decrease.

Tender feet. Some horses are more tender-footed than others, even with shoes. When a horse is on rocks that are either painful to its feet or that make walking more difficult, they perceive their ability to escape from predators as restricted. This will make some horses more nervous. I recommend the top coating of trails to be one-inch minus-sized materials and, preferably, packed down.

Attention getters. Horses show concern toward things that move quickly, such as flapping bags, tarps or flags. They also notice objects that stand out from their surroundings, such as contrasting colors of construction materials.

Noises make them nervous. Horses are excited by out-of-the-ordinary noises, such as engaged construction equipment or the sound of their own feet walking over a bridge.

What's in there? If a horse sees something that looks like a den or hiding place, it may be wary. Road culverts, where the openings are visible from either approach, could be harboring danger—in a horse's mind.

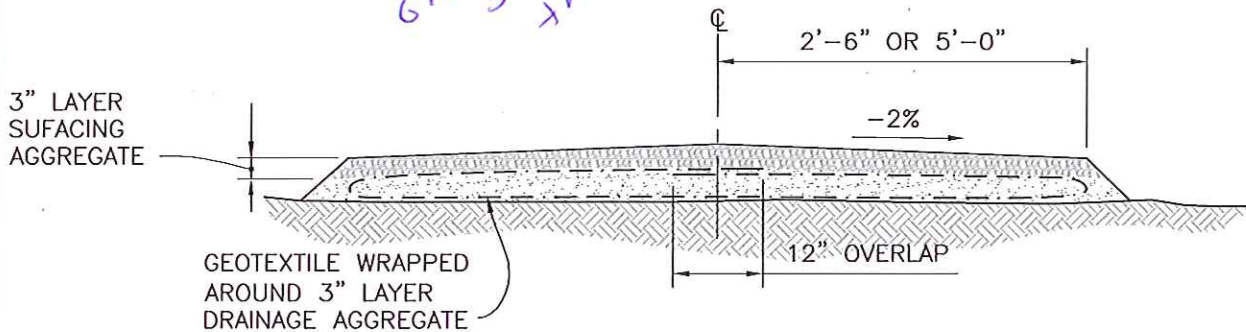


1
2

CROWNED AGGREGATE SURFACING

NTS

*I would worry about
Gravel sliding off
the fabric*



2
2

CROWNED ENCAPSULATED AGGREGATE SURFACING

NTS

NOTE: THE FIRST LAYER OVER THE GEOSYNTHETIC MUST BE PLACED BY END DUMPING AND SPREADING IN WITH LIGHT MACHINERY (2.5-3.0 PSI CONTACT PRESSURE) TO PREVENT DIRECT WHEEL OR TREAD CONTACT.

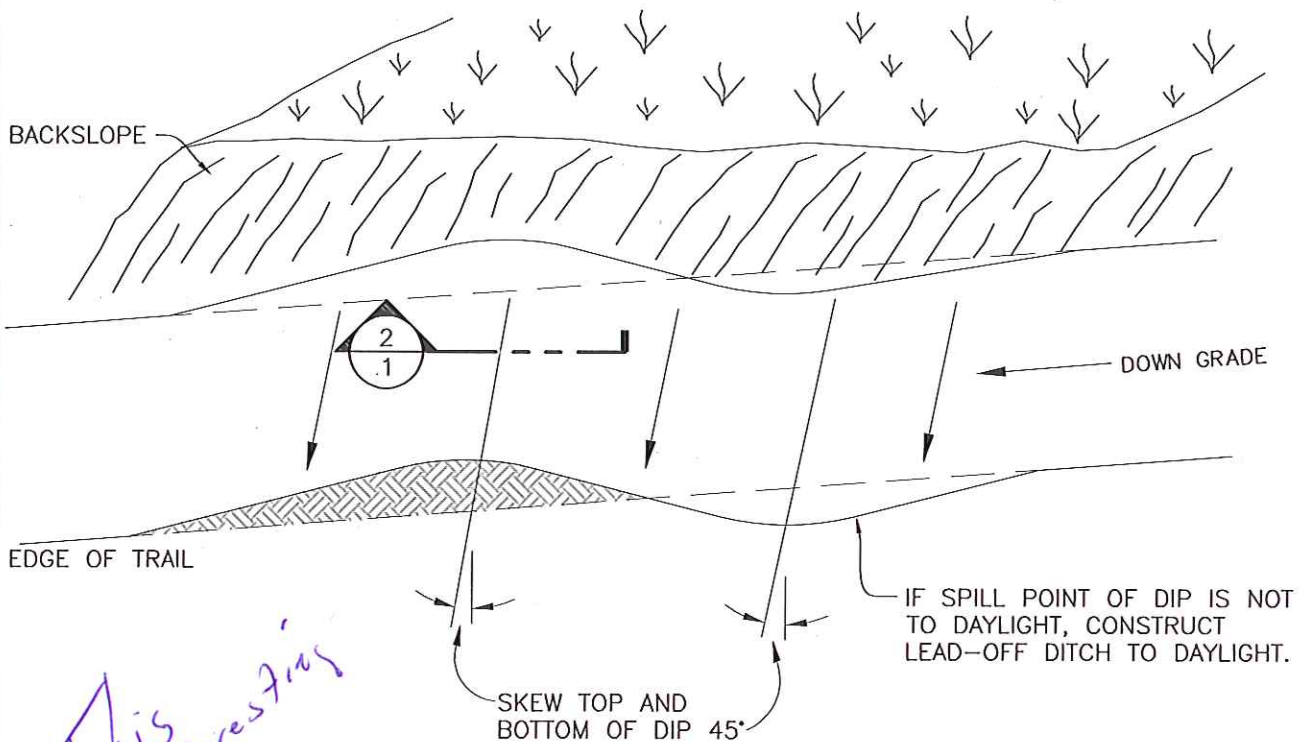
MISSOURI DEPARTMENT OF CONSERVATION
DESIGN & DEVELOPMENT

EQUESTRIAN TRAIL - DETAILS

AGGREGATE SURFACING SECTION CONTINUED

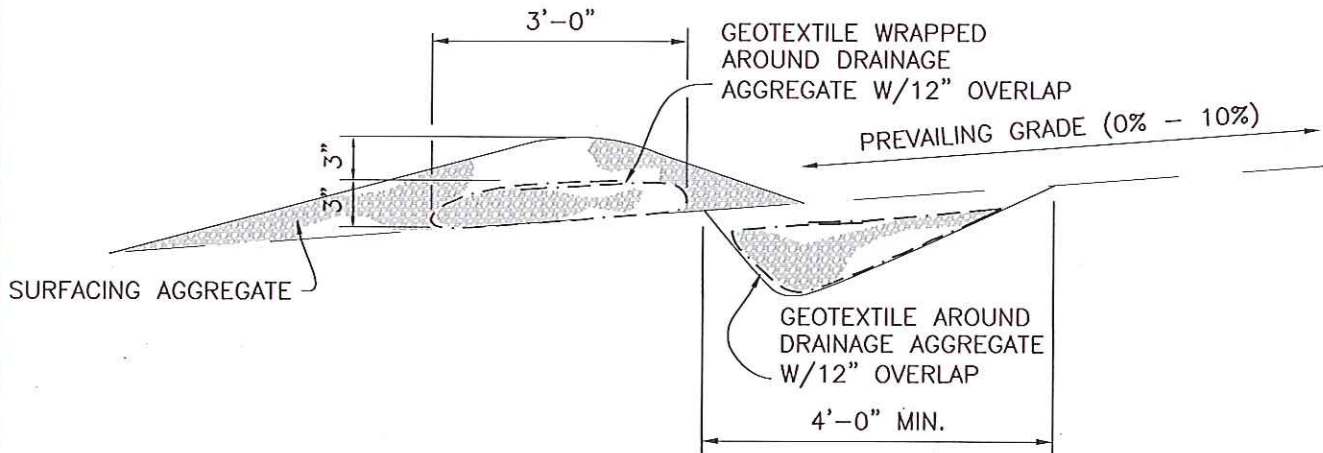
SHEET 2 of 2





INFILTRATION BAR PLAN

NTS



INFILTRATION BAR SECTION

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MISSOURI DEPARTMENT OF CONSERVATION
DESIGN & DEVELOPMENT

EQUESTRIAN TRAIL - DETAILS

INFILTRATION BAR

SHEET 1 of 1

