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Managing Degraded Off-Highway Vehicle Trails in Wet, Unstable, and Sensitive Environments

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Managing Degraded Off-Highway Vehicle Trails in Wet, Unstable, and Sensitive Environments

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Contents

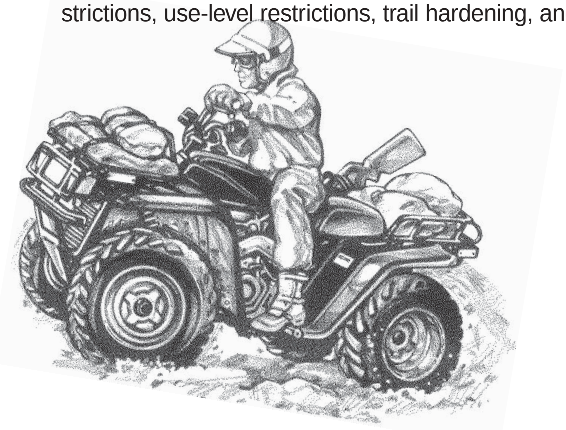
Introduction

Environmental impacts associated with the degradation of off-highway vehicle (OHV) trails have become a serious concern in many regions. Where OHV trails indiscriminately cross alpine areas, wetlands, steep slopes, and other areas with sensitive soil conditions, trails can become rutted, mucky, and eroded. Such areas are referred to as degraded trail segments. Degraded trails develop when trail use exceeds the trail's natural carrying capacity.

For land managers, degraded trails are a significant environmental problem because of their direct effects on vegetation, soils, and site hydrology. In addition, degraded trails may have indirect effects on wildlife, site esthetics, and other resource values. For trail users, degraded trails reduce the utility of trail systems and lead to a less enjoyable ride. Unfortunately, with increased use of backcountry resources by OHV enthusiasts and other trail users, the miles of degraded trails are increasing rapidly (figure 1).

Figure 1—A degraded trail in interior Alaska. Heavy use has stripped surface vegetation and exposed permafrost soils to accelerated melting, resulting in muddy, rutted trail surfaces, erosion, and deep muck holes.

This document provides land managers and trail users with an introduction to OHV trail degradation and outlines a framework for management responses. The information presented is based on work conducted by the author in southcentral and interior Alaska, but it also applies to degraded trails in other parts of the country. Some of the principles also apply to degraded foot, mountain bike, and horse trails. The document presents some fundamental concepts of soil and site characteristics, and the mechanics of trail degradation. It also offers inventory methods to document trail conditions and prepare stabilization "prescriptions." In addition, it outlines a number of management options including trail rerouting, seasonal and type-of-use restrictions, use-level restrictions, trail hardening, and trail closure.

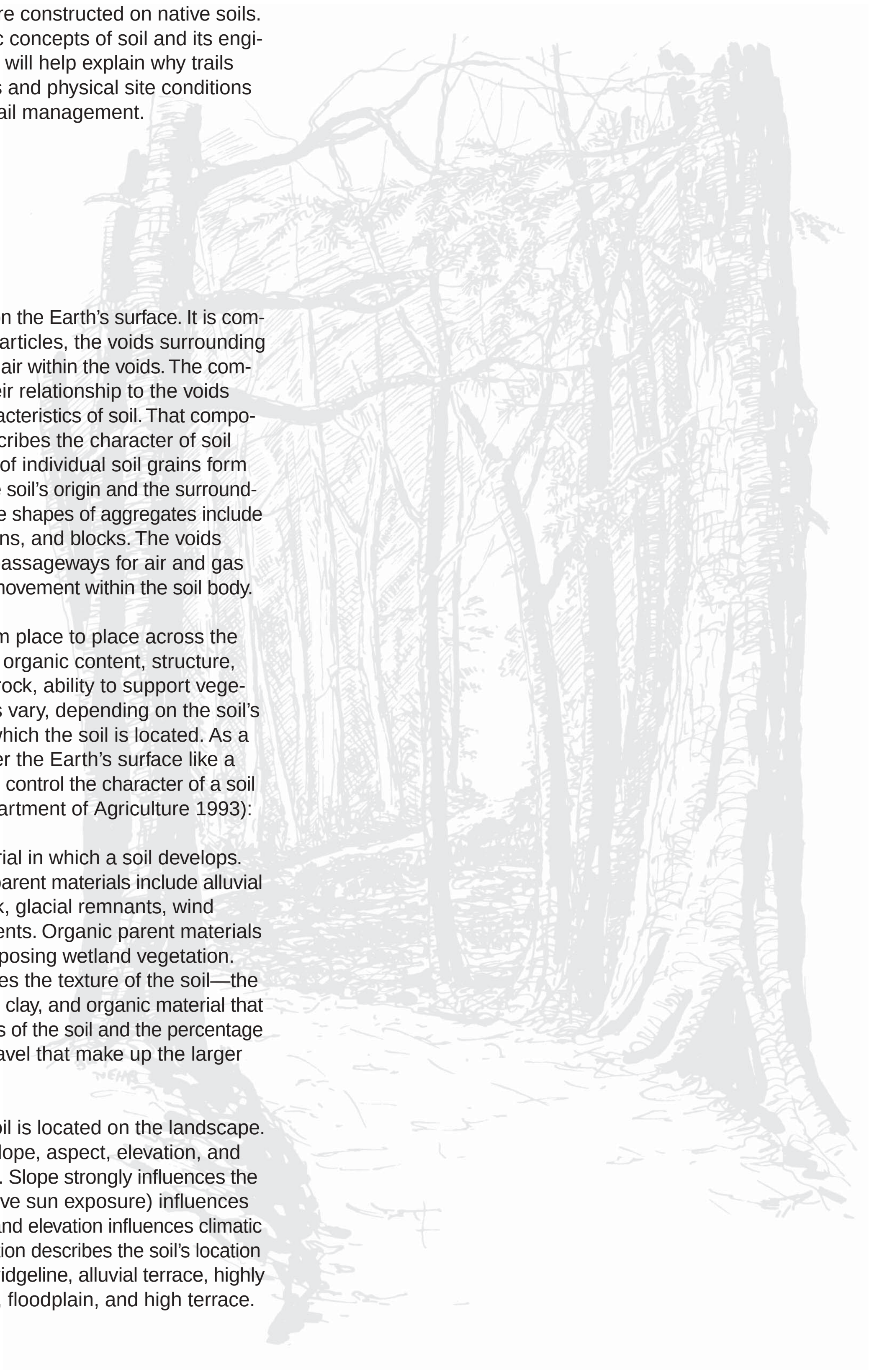


The information provided in this report is intended to stimulate additional research and networking among trail managers, trail users, and the conservation community. Only through the cooperative efforts of a wide range of public and private trail advocates can the environmental and social conflicts associated with OHV use be resolved. We hope that future efforts will lead to the development of a widely applied set of best management practices for OHV trail management.

We have used English units of measure instead of Standard International (SI), or metric units, throughout this report. The products discussed in this report are manufactured using English measurements and most trail workers are accustomed to English rather than metric units of measure. Appendix D includes conversions from English measurements to metric.

Soil—The Stuff Under Foot, Hoof, and Wheel

Most backcountry trails are constructed on native soils. A review of some basic concepts of soil and its engineering characteristics will help explain why trails degrade, and why soils and physical site conditions are important components in trail management.



Soils 101

Soil is unconsolidated material on the Earth's surface. It is composed of mineral and organic particles, the voids surrounding the particles, and the water and air within the voids. The composition of the particles and their relationship to the voids strongly affect the physical characteristics of soil. That composition, called soil structure, describes the character of soil aggregates. These aggregates of individual soil grains form unique shapes depending on the soil's origin and the surrounding environmental conditions. The shapes of aggregates include granules, plates, prisms, columns, and blocks. The voids between the aggregates form passageways for air and gas exchange, as well as for water movement within the soil body.

The character of soil varies from place to place across the landscape. A soil's mineral and organic content, structure, moisture content, depth to bedrock, ability to support vegetation, and other characteristics vary, depending on the soil's origin and the environment in which the soil is located. As a result, individual soil types cover the Earth's surface like a mosaic. Five soil-forming factors control the character of a soil at any given location (U.S. Department of Agriculture 1993):

- **Parent Material** is the material in which a soil develops. Examples of mineral-based parent materials include alluvial deposits, weathered bedrock, glacial remnants, wind deposits, and marine sediments. Organic parent materials include leaf litter and decomposing wetland vegetation. The parent material influences the texture of the soil—the relative amounts of sand, silt, clay, and organic material that make up the finer components of the soil and the percentage of boulders, cobbles, and gravel that make up the larger components.

- **Topography** is where the soil is located on the landscape. It includes the elements of slope, aspect, elevation, and landscape position of the soil. Slope strongly influences the risk of erosion, aspect (relative sun exposure) influences daily temperature variations, and elevation influences climatic environment. Landscape position describes the soil's location on the landscape—such as: ridgeline, alluvial terrace, highly dissected upland, foot slope, floodplain, and high terrace.

- **Time** is the period parent materials have been subject to weathering and soil-forming processes. In general, the older the soil, the greater the chemical and physical modification of the original parent material and the more developed a soil's internal structure. Through time, soils develop distinct layers. Soil scientists generally recognize four layers: 'O' for surface organic layers, 'A' for the organic-rich surface mineral layers, 'B' for the weather-altered subsoil, and 'C' for the unaffected parent material.

- **Climate** indicates the effect of local weather on soil development. Climate influences chemical weathering, soil temperature, and soil moisture levels. Within a localized area, topography moderates climate to some degree.

- **Organisms** are the plants, animals, and humans that affect soil development. This includes effects from vegetation growth, leaf litter accumulation, soil microorganisms, burrowing animals, and human agriculture, recreation, and construction. Organisms can dramatically affect a soil's development. Vegetation enriches soils by contributing organic material and aiding in the development of internal soil structure. Unfortunately, many human activities have a disruptive effect on soil development.

Starting with raw parent material, topography, time, climate, and organisms work together to weather, mix, and transport soil. Soil is continuously evolving and modifying its capacity to support plant, animal, and human use over time.

Soil's Characteristics as a Structural Component for Trails

Unlike bedrock, asphalt or concrete, soil is an unconsolidated material composed of loosely bonded particles and the voids surrounding them. The lack of solid bonds between particles means that soils are susceptible to impacts from trail use in a number of ways. These include crushing, lateral displacement, and erosion. A soil's ability as a structural component for trails is controlled by two factors, its bearing strength (its ability to support a load without being deformed) and its cohesion (the ability to resist displacement). Those abilities are primarily controlled by two related factors: the relative size of soil particles (soil texture) and the relative water content of the soil voids (soil moisture level).

Soil texture is the relative amount of organic matter, gravel, sand, silt, and clay in a soil. In general, soil texture can be broken into two major classes:

- Finely textured soils—those with high percentages of organic matter, silt, and clay

- Coarsely textured soils—those with high percentages of sand and gravel

In general, the coarsely textured soils have good bearing capacity. This is because of their large particle size, good drainage characteristics, and low shrink-swell potential. Conversely, finely textured soils generally have poor bearing capacity because of their small particle size, poor drainage characteristics, and a tendency to shrink or swell under different moisture conditions. Both classes of soils have moderate to poor cohesion, depending on other factors such as vegetation cover and roots that help hold individual soil particles in place.

Soil moisture level measures the relative amount of water in soil pores. A soil's texture controls the percentage of pores within a soil. Surprisingly, finely textured soils have more pore space than coarsely textured soils. Finely textured soils can have up to 60 percent void space, while coarsely textured soils typically have around 40 percent.

Soil moisture can range from bone dry to totally saturated. Because water acts as a lubricant for soil particles, the relative amount of water within a soil can dramatically affect its structural stability. While coarsely textured soils tend to have good bearing strength across a wide range of moisture conditions, finely textured soils have reduced bearing capacity as moisture levels increase. At saturation, when all soil voids are filled with water, finely textured soils typically have little bearing capacity. Finely textured soils store and retain water over long periods so their bearing capacity can be low for prolonged periods.

Besides soil texture and soil moisture, other environmental and site factors contribute to a soil's structural capability and suitability for trails. These include:

- Soil temperature
- Type of surface cover
- Root mass
- Depth to bedrock
- Slope
- Landscape position

These factors largely control how well a soil will support surface traffic. These characteristics also provide insights on how soil should be managed and on the options that might be employed to increase its suitability for use. Table 1 provides some general guidelines on broad categories of trail suitability based on these factors. The table segregates site characteristics into three classes of suitability for each soil factor: poorly suited (highly sensitive), limited suitability (moderately sensitive), and generally suitable (slightly sensitive).

The information in table 1 can help trail managers identify where they may have problems with existing or planned trail routes. For example, sites with all ‘generally suitable’ ratings shouldn’t pose any inordinate management or environmental concerns; those with ‘limited suitability’ ratings may require some special attention; and those with ‘poorly suited’ ratings may require significant attention and a high level of management. Poorly suited sites should be avoided during new trail construction. Existing trails with “poorly suited” ratings should be assessed for environmental impacts and evaluated for relocation.

Table 1—General guidelines on trail site suitability and sensitivity to impact.

	SUITABILITY/SENSITIVITY CLASS		
Soil factor	**Poorly suited (highly sensitive)**	**Limited suitability (moderately sensitive)**	**Generally suitable (slightly sensitive)**
Soil texture	All organic soils; soils with an organic surface layer thicker than 4 inches	Silt greater than 70 percent or clay greater than 40 percent in the soil surface layer; sand component is greater than 80 percent in the surface layer	Soils with a high percentage of gravel or rock in the surface layer
Soil temperature	Ice-rich permafrost is within 40 inches of the surface; soils at or near freezing	Low ice permafrost within 40 inches of the surface	Deeply frozen soils (winter activities)
Soil moisture	Poorly or very poorly drained soils; the water table is within 12 inches of the surface; water is ponded at the surface; soils are at or near saturation	Somewhat poorly drained soils; the water table is between 12 and 24 inches of the surface	Well- and moderately well-drained soils; the water table is deeper than 24 inches below the surface
Type of surface cover	All wetland vegetation communities; permafrost-influenced vegetation communities; alpine tundra communities		
Root mass	Fine, thin, poorly developed root mass	Root mass that is 2 to 6 inches thick, primarily fine roots	Root mass is more than 6 inches thick with a high percentage of woody roots
Soil depth	—	Less than 2 feet to bedrock	More than 2 feet to bedrock
Slope	Slopes steeper than 40 percent if the slope length is longer than 50 feet; slopes 20 to 40 percent if the slope length is longer than 100 feet	Slopes between 6 and 20 percent (with appropriate water control)	Slopes less than 6 percent (with appropriate water control)
Landscape position	North-facing aspects in some climatic conditions	Ridgelines (if shallow soils); foot and toe slopes (if wet or there are seep zones); floodplains (seasonal flooding); slopes (depending on percent of slope, see above)	South-facing aspects; gravel bars, terraces, and alluvial benches; outwash plains; alluvial fans (depending on slope)

How Soils Are Degraded

Trail use damages soils when the type and level of use exceed the soil's capacity to resist impact. A soil's capacity to resist impact varies depending on textural class, moisture level, and other environmental and site characteristics, but the processes by which soils are impacted are generally the same. Trail use damages soils directly by mechanical impact from surface traffic and indirectly by hydraulic modifications, soil transport, and deposition.

Direct mechanical impact has several components: abrasion, compaction, shearing, and displacement.

➢ Abrasion strips surface vegetation and roots.

➢ Compaction reduces soil voids and causes surface subsidence.

➢ Shearing is the destructive transfer of force through the soil.

➢ Displacement results in the mechanical movement of soil particles.

Indirect impacts include hydraulic modifications, such as the disruption of surface water flow, reductions in infiltration and percolation, surface ponding, and the loss of water-holding capacity. Other indirect impacts include those associated with erosion—both the loss of soil particles by wind or water erosion and deposition of transported particles. An associated impact is the hydraulic pumping that occurs when a destructive flow of water is forced through a saturated soil.

Both direct and indirect impacts degrade trail segments. The impacts generally occur in the following progression:

Abrasive loss of protecting surface vegetation and root mass (direct impact)
⮟
Compaction and surface subsidence (direct impact)
⮟
Hydraulic disruption (indirect impact)
⮟
Breakdown of soil structure from shearing and pumping (direct impact)
⮟
Soil particle erosion and deposition (indirect impact)

While most of the stages in this progression are familiar concepts, the shearing and pumping components may not be as familiar to some readers.

Shearing describes a transfer of force through a soil. When an applied force exceeds the capacity of the soil body to absorb it, a portion of the soil body can be displaced along a shear plane—that place where soil particle cohesion is weakest. The most common example is when the passage of a wheeled vehicle forms ruts. The downward force of the wheel shears—or displaces—the soil beneath it, forcing the soil to bulge upward beside the wheel. This process is illustrated in figure 2. The shearing action destroys soil structure by crushing soil peds (natural soil aggregates) and collapsing voids. Shearing is most likely to occur on finely textured soils under moist to saturated conditions. It is uncommon in coarse soils.

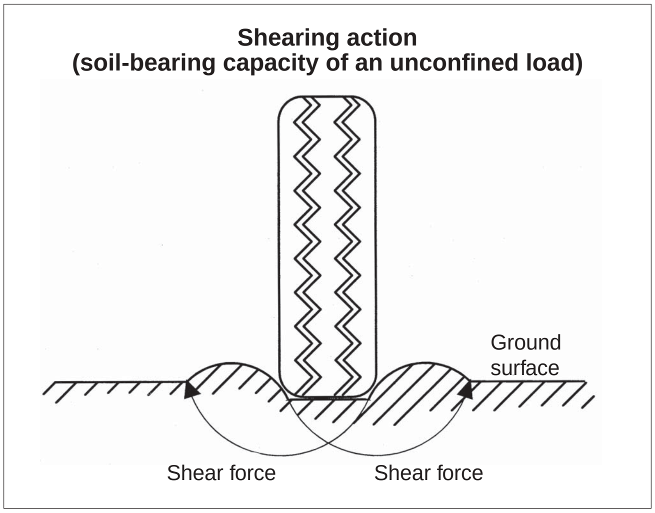


Figure 2—Diagram of shearing action.

Pumping action occurs when soils are saturated with water. Saturated soils are most common in wetlands, but may occur on other sites during spring thaw, periods of high rainfall, or where water is ponded. Pumping occurs when the downward pressure of a passing force—such as a vehicle wheel—forces water through soil voids and passages. When the pressure is released, water rushes back into the vacuum. This process is illustrated in figure 3. The force of this rapid water flow erodes internal soil structure and clogs soil voids with displaced sediment. Pumping occurs within all soils, but is most damaging to finely textured soils because of their fragile internal structure.

Shearing and pumping actions reduce soils to a structureless or "massive" condition. This condition is characterized by the loss of distinguishable soil structure and a reduction in pore space voids, and interped passages (the space between peds). An example of soil in a massive state is a dried mud clod or an adobe brick. In a massive state, soils have significantly reduced infiltration rates, percolation, water storage capacity, and gas exchange. This reduces a soil's ability to support vegetation growth, leads to surface ponding of water, and increases the soil's sensitivity to additional impacts.

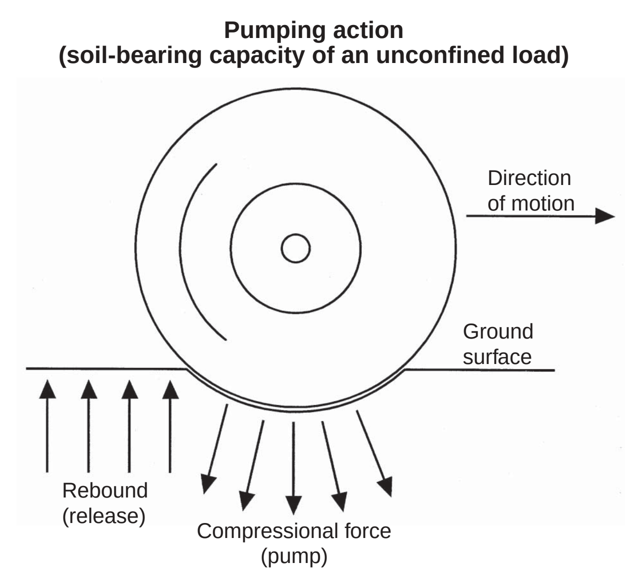


Figure 3—Diagram of pumping action.

Surface Erosion, Surface Failure, and Trail Braiding

Trail use has a predictable path of surface impact. The degree of impact is modified only by the natural resilience of the soil and the intensity of trail use. In an ideal situation, a natural balance is maintained between soil resilience and use, and trail use occurs without significant degradation. However, on sites with wet, unstable, and sensitive soils, that equilibrium is easily upset. Even low levels of trail use can have significant environmental consequences.

Typically, trail degradation follows one of two pathways: surface erosion or surface failure. Surface erosion occurs when wind or water displaces exposed trail surfaces. This usually occurs on steep terrain or on sandy soils that are susceptible to wind erosion. Surface failure occurs when trail surfaces degrade into muddy tracks with deep muck holes. This usually occurs on flat areas with organic or finely textured soils. Either pathway can lead to significant environmental impacts that are extremely difficult to stabilize or reverse. Without stabilization, a destructive cycle of degradation can begin that expands the impact to adjacent surfaces. That cycle begins with the widening of trail surfaces as users avoid degraded surfaces and expands to the development of multiple parallel trails.

The two degradation pathways are diagrammed in table 2.

Table 2—Trail degradation pathways.

Both pathways of impact begin when:

Surface vegetation and roots are stripped by surface traffic.
↓
Exposed soil is compacted and the trail surface subsides relative to the adjacent surface.
↓
Compaction and subsidence destroy soil structure and disrupt internal drainage patterns.
↓

Impact follows one of two paths:

Surface erosion	**Surface failure**
↓	↓
Exposed surface is eroded by wind scour or	Water collects on the trail surface.
↓	↓
Water drains onto the trail surface.	Water pools in low areas.
↓	↓
Water is channeled along the trail surface.	Pooled water saturates the soil.
↓	↓
Water erodes the trail surface.	Shearing and pumping damage the soil structure.
↓	↓
Deep erosion ruts form.	Muddy sections and deep muck holes form.

↓

The impact continues:

Trail segments develop rutted or muddy sections.
↓
Trails widen as users avoid degraded sections.
↓
Trail users abandon degraded sections.
↓
New routes are pioneered on adjacent soils.
↓
Vegetation and roots are stripped by traffic along the new route.
↓
Soil is compacted and the soil structure is destroyed, leading to surface erosion and/or surface failure.

And so the cycle repeats itself.

The first consequences of pioneering a trail across a virgin landscape are the stripping of surface vegetation, the abrasion of roots, and the compaction of surface soil layers. These impacts destroy soil structure, reduce water infiltration, and break bonds between soil particles. Soil particles are more vulnerable to displacement and loss from wind or water erosion. Soil compaction also leads to surface subsidence—the lowering of the trail relative to the adjacent ground surface. Trails become entrenched. This lower surface intercepts and drains water from adjacent surfaces and channels that flow along the trail. This dramatically increases the risk of water erosion on sloped areas and the pooling of water in low-lying sections. As trail surfaces degrade due to rutting or the formation of muck holes, users widen the trail and seek new routes, usually on adjacent soils where environmental conditions are identical to the original impact site. As this new route degrades, it is abandoned. A third route is pioneered, and then a fourth—until finally the area is scarred with a number of routes in various stages of use and abandonment. This condition is called trail braiding. Trail braiding significantly expands the environmental impacts of trail use. Trail braiding occurs because trail use levels repeatedly exceed the carrying capacity of soils to support that use. Figures 4a and 4b illustrate the process.

Figure 4a—Ponded water in ruts and muck holes prompt riders to pioneer new routes in adjacent undisturbed areas.

Figure 4b—Results are an adjacent degraded alignment and the development of a braided trail.

In braided trail sections, abandoned trail segments may slowly recover from impact through natural revegetation. However, the impact has usually dramatically altered the site's thermal, soil, and hydrologic characteristics. These changes affect the composition and structure of vegetation that can grow on the disturbed site. For example, a site that supported shrubs and grass before disturbance may only support sedges or other water-tolerant plants after disturbance. Abandoned routes may also recover enough to support subsequent trail use, but they are generally more sensitive to impact than virgin sites.

The impacts associated with braiding are a major concern for land managers because they dramatically increase the area of impacts associated with trail use (figure 5). Studies conducted in one area of Alaska documented that the average OHV trail had an impact area 34.6 feet wide (Connery 1984)—that's four times the width necessary for a single OHV track. Using that average width (34.6 feet), each mile of trail affects 4.2 acres. A single-track trail (8 feet wide) of the same length would affect just 0.97 acre per mile. Braided trail sections more than 200 feet wide are not uncommon within Alaska. For resource managers, the increase in area affected by braiding is significant in terms of resource destruction, habitat loss, and esthetics.

Figure 5—A braided trail in Alaska. More than a dozen separate routes have been pioneered in this section crossing a wetland. Note the wet trail conditions and numerous potholes. At this site, trail impacts affect an area more than 250 feet wide. Braiding significantly extends the area of impact by modifying vegetation cover, surface hydrology, and soil characteristics.

In Alaska, the cycle of degradation is well studied and documented (Connery 1984; Connery, Meyers, and Beck 1985; Ahlstrand and Racine 1990, 1993; and Happe, Shea, and Loya 1998). Responding to the impact has been more difficult. The problem is also compounded by rapidly expanding OHV use and increased OHV trail mileage. One study conducted by the Bureau of Land Management documented a 76-percent increase in miles of trail from the early 1970s to the late 1990s (Muenster 2001). Significant increases have also been observed in many other areas of Alaska. These increases in trail mileage and their associated environmental impacts on soil, vegetation, habitat, and water resource values have given resource managers a legitimate reason to be concerned about the impacts associated with degraded OHV trails.

Trail Management—Responding to Trail Degradation

Mlanagement Components

The task of trail management ranges from planning, designing, and constructing trails to maintaining them. In an ideal world, every trail would have a formal, well thought-out management plan and a staff dedicated to its implementation. Unfortunately, that is not the case. In Alaska, the term 'orphan trail' has been coined to describe active trails that receive no management oversight at all. Trail management should include elements from these five basic building blocks:

- Trail location documentation
- Trail condition assessment
- Trail improvement prescriptions
- Trail improvement implementation
- Trail maintenance and monitoring

Trail Location Documentation

Trail location documentation is plotting the location of the trail in a geographic database. A simple sketch of a trail location on a U.S. Geological Survey topographic map is better than no location data, but documenting the alignment with a mapping-grade global positioning system (GPS) unit is best. The GPS unit can record geographic coordinates of a trail alignment that can overlay digital topographic maps or be downloaded into a geographic information system (GIS). The GIS allows trail locations to be plotted over other geographic databases such as land ownership, soils, and terrain. Accurate trail location information is also critical for obtaining a legal right-of-way easement for a trail alignment.

Trail Condition Assessment

Condition assessment is an inventory of the physical character of a trail alignment. It documents conditions and problems and provides a baseline for monitoring changes over time. This assessment can be used to set priorities for trail prescription mapping (next section) and provide general information for future trail improvement work.

The assessment should evaluate the entire trail length, not just problem sites. This ensures that the assessment will provide a basis for evaluating condition trend during future monitoring efforts. Condition assessments can be conducted with manual data collection using a measuring wheel, tape measure, or odometer in the traditional "trail log" approach. The author has developed a simple alphanumeric system to classify individual trail segment conditions (table 3).

Table 3—Trail impact classes.

Impact class	Subclass	Description
A	1	Minor loss of original surface vegetation (over 80 percent remaining)
	2	Moderate loss of original surface vegetation (40 to 80 percent remaining)
B	3	Most original surface vegetation stripped away (less than 40 percent remaining)
	4	Exposed roots on trail surface
C	5	Almost total loss of root mass
	6	Only exposed mineral or organic soil at surface
	7	Erosive loss of less than 2 inches of soil, or compaction and subsidence less than 2 inches deep
D	8	Erosive loss of 2 to 8 inches of soil, or compaction and subsidence 2 to 8 inches deep
F	9	Erosive loss of 9 to 16 inches of soil, or compaction and subsidence 9 to 16 inches deep
	10	Erosive loss of more than 16 inches of soil, or compaction and subsidence more than 16 inches deep
	11	Trail segment intermittently passable during dry conditions
	12	Trail segment impassable at all times

For quick assessments, trail segments can be classified using classes A to F. For more detailed assessments, the numeric subclass designators can be used.

Trail segments with class A impacts have yet to experience significant degradation. Class B segments are generally new trails or lightly traveled routes. Segments with class C impacts display the beginnings of detrimental impacts, but have not yet been seriously degraded. Monitoring these sites should be a high priority. Segments with class D impacts display degradation due to poor site conditions or excessive use. Mitigation may be needed to stabilize impacts. Segments with class F impacts are seriously degraded trails, probably with significant environmental impacts. These sites should receive a high level of management attention. Methods to respond to the degradation of classes D and F trail segments are detailed later.

While table 3 presents a classification system for manual assessment, a much more powerful and descriptive assessment can be made by using a mapping-grade GPS receiver that attaches line, point, and area descriptors with collected trail alignment coordinates. The author has developed a trail condition mapping legend (table 4) that can be used with standard mapping-grade GPS software and equipment. The legend contains a fairly complete list of trail condition attributes, and it can be used as the starting point to develop a customized legend appropriate for any specific trail system. When the data elements in table 4 are loaded into a menu-driven GPS mapping system, they can be collected easily during trail condition mapping.

Table 4—Trail condition mapping legend (bold text identifies the more important data fields).

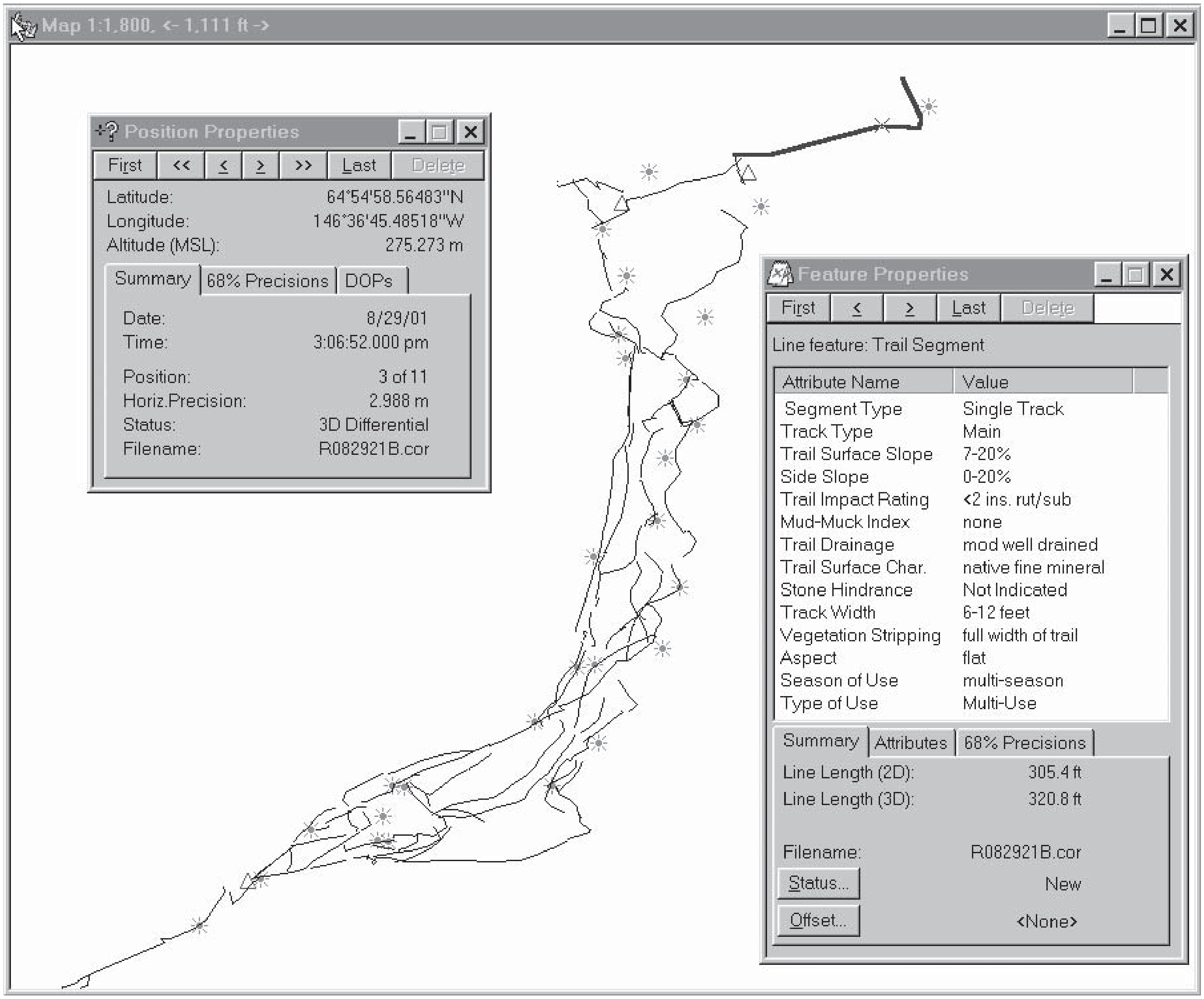
Feature element	Menu selection options
LINE FEATURE	
TRAIL SEGMENT	
Trail segment type (feet)	**Single track, double track, or multibraid 6 to 20, 21 to 40, 41 to 80, 81 to 160, 161 to 320, 321 to 480, wider than 480**
Trail track type	**Main, secondary, abandoned, access, cutoff, spur**
Trail surface grade (percent)	**Zero to 6, 7 to 20, 21 to 40, steeper than 40**
Side slope (percent)	Less than 20, 21 to 60, 61 to 100, steeper than 100
Trail surface	**Vegetated, native organic, wetland vegetated, floating organic, native fine mineral, mixed fines and gravel, sand, gravel, cobble, imported gravel, gravel over geotextile, wood chips, timbers/planking, corduroy, paved, porous pavement panel, rock, water crossing, other**
Trail impact rating	**None** **Loss of surface vegetation** **Exposed roots** **Less than 2 inches erosive loss or surface subsidence** **2 to 8 inches erosive loss or surface subsidence** **9 to 16 inches erosive loss or surface subsidence** **17 to 32 inches erosive loss or surface subsidence** **33 to 60 inches erosive loss or surface subsidence** **More than 60 inches erosive loss or surface subsidence**
Mud-muck index	**None, muddy, extremely muddy, muck hole, multiple muck holes, seasonally impassable, impassable at all times**
Trail drainage	**Well drained, moderately well drained, poorly drained, saturated, ponded, water running across surface**
Stone hindrance (percent)	None, less than 10, 11 to 25, 26 to 75, 76 to 100
Track width (feet)	**One to 3, 4 to 6, 7 to 12, 13 to 20, 21 to 30, 31 to 40, 41 to 60, over 60**
Vegetation stripping	**Single track, wheel track only, full width of trail**
Type of use	Multiuse, foot only, motorized only
Season of use	Multiseason, winter only, thaw season only
ROAD SEGMENT	
Road type	**Access, primary, secondary, subdivision, unimproved, other**
Road surface	Paved, gravel, dirt
Road width (feet)	8 to 12, 13 to 16, 17 to 20, 21 to 30
LINE GENERIC	
Line type	**Text entry**

Continued —>

Table 4—continued (bold text identifies the more important data fields).

Feature element	Menu selection options
POINT FEATURE	
WATER MANAGEMENT	
Type	**Water bar, grade dip, rolling dip, round culvert, box culvert, open drain, sheet drain, check dam, ditch**
Condition	**Serviceable, poor**
Culvert size (inches)	Numeric entry
STREAM CROSSING	
Type	**Unimproved ford, improved ford, bridge, culvert**
Stream name	Text entry
Stream width (feet)	Numeric entry
Approximate flow (cubic feet per second)	Numeric entry
PHOTO POINT	
Frame/reference No.	**Numeric entry**
Bearing (degrees)	**Numeric entry**
ANCHOR POINT	
Type	**Beginning, middle, intersection, angle, end**
REFERENCE POINT	
Type	**Milepost, trailhead, trail marker, survey marker, property marker, road crossing, junction, gate or barrier, other**
Mileage	Numeric entry
POINTS OF INTEREST	
Type	Scenic vista, pullout, shelter, campsite, cabin, structure, powerline, fence, staging area
HAZARD	
Type	**Text entry**
SIGNS	
Type	Informational, directional, regulatory, warning
Text	Text entry
POINT GENERIC	
Type	**Text entry**
AREA FEATURE	
PARKING AREA	
BRAIDED IMPACT AREA	
GENERIC AREA	

Figure 6 displays a GPS plot of a complex trail system with a large number of braided trail segments. Note the highlighted trail segment at the top of the image. The 'Feature Properties' data frame to the right of the screen lists the characteristics of that trail segment as it was mapped in the field. Similar data detail can be extracted for every line segment, point, or area feature displayed on the screen. The 'Feature Properties' box shows the location, date of data acquisition, and precision of the data collected.



Latitude: 64°54'58.56483"N
Longitude: 146°36'45.48518"W
Altitude (MSL): 275.273 m

Date: 8/29/01
Time: 3:06:52.000 pm
Position: 3 of 11
Horiz.Precision: 2.988 m
Status: 3D Differential
Filename: R082921B.cor

Line feature: Trail Segment

Attribute Name	Value
Segment Type	Single Track
Track Type	Main
Trail Surface Slope	7-20%
Side Slope	0-20%
Trail Impact Rating	<2 ins. rut/sub
Mud-Muck Index	none
Trail Drainage	mod well drained
Trail Surface Char.	native fine mineral
Stone Hindrance	Not Indicated
Track Width	6-12 feet
Vegetation Stripping	full width of trail
Aspect	flat
Season of Use	multi-season
Type of Use	Multi-Use

Line Length (2D): 305.4 ft
Line Length (3D): 320.8 ft
Filename: R082921B.cor
Status... New
Offset... <None>

Figure 6—This computer screen display shows the mapping legend for a complex trail system with a large number of braided trails. The feature properties (data box on the right) relate to the bolded trail segment at the top of the display.

Data collected with this level of sophistication should be downloaded into a GIS system. While a GIS requires a relatively high level of technical support, it can have tremendous payoffs for trail management. Once downloaded, the data can be subjected to a wide variety of map and tabular analysis, including overlay with other geographic information such as soils and terrain. Attribute values can be used to generate trail segment impact ratings and to identify critical problem areas. The length and area of trail segments can be calculated to help estimate mitigation and maintenance costs. When the condition inventory is incorporated into a GIS, it provides a baseline of trail conditions that can be used to plan and track monitoring efforts, evaluate trail performance across varying soils and landscape units, and plan future work.

Based on the author's experience and some limited contract work conducted by the Bureau of Land Management in Alaska, about 8 miles of trail can be mapped per day by a two-person crew mounted on OHVs using the GPS-based system. Production rates vary depending on trail conditions, weather, access, staff experience, and equipment performance. Office support work is required in addition to the field work. Allow about twice as much time in the office as in the field to set up equipment, load data dictionaries, download data, edit data, and integrate the data into a GIS.

Trail Improvement Prescriptions

Trail prescriptions focus on identifying locations for specific treatment applications, such as surface improvements, ditches, brush control, water management, and water-crossing structures.

The crew preparing trail prescriptions needs to be knowledgeable of the treatments available for specific trail ailments. Unlike condition mapping, which requires just a basic knowledge of field inventory technique, prescription mapping requires expertise in trail planning, construction and maintenance, and knowledge of the trail construction and maintenance resources that are available.

Prescription mapping can be greatly assisted by GPS/GIS technology. Table 5 is a prescription mapping legend developed by the author. It identifies a wide range of treatments and can be adapted readily for use on any trail systems.

Table 5—Trail prescription mapping legend (bold text identifies the more important data fields).

Feature element	Menu selection options
LINE FEATURE	
TRAIL SEGMENT	
Trail type	Active, inactive, new segment, access, water crossing, other
Surface treatment	**No treatment, light water management, heavy water management, grading/leveling, gravel cap, gravel/geotextile, porous pavement, corduroy, turnpike, puncheon-boardwalk, abandon—no treatment, abandon with light rehabilitation, abandon with heavy rehabilitation**
Gravel cap depth (inches)	**None, 2 to 4, 5 to 8, 9 to 12, 13 to 18, deeper than 18**
Trail width (feet)	**Numeric entry**
Surface treatment priority	High, medium, low
Ditching	None, left (outbound), right (outbound), both
Ditching priority	High, medium, low
Brush control	None, left, right, both
Brushing priority	High, medium, low
Root removal	None required, required
Cut-and-fill section (percent side slope)	None, less than 15, 16 to 45, 46 to 100, more than 100
LINE GENERIC	
Type	**Text entry**
POINT FEATURES	
ANCHOR POINT	
Type	**Beginning, middle, intersection, angle, end**
REFERENCE POINT	
Type	**Milepost, trailhead, trail marker, survey marker, gate or barrier, road crossing, fence crossing, other**
Mileage	**Numeric entry**
WATER MANAGEMENT	
Type	**Water bar, grade dip, rolling dip, culvert (diameter in inches, less than 8, 9 to 16, 17 to 36, larger than 36), check dam, open drain, other**
WATER CROSSING	
Type (feet)	**Unimproved ford, improved ford, bridge (shorter than 12, 13 to 24, longer than 24)**

Continued —>

Table 5—continued (bold text identifies the more important data fields).

Feature element	Menu selection options
POINT FEATURE (continued)	
PHOTO POINT	
Reference number	Numeric entry
Bearing	Numeric entry
POINT-OF-INTEREST DEVELOPMENT	
Type	Scenic vista, pullout, shelter, campsite, cabin
FIX HAZARD	
Type	**Tree removal, stump removal, rock removal, guardrail, fill hole, other**
SIGN NEEDED	
Type	Informational, directional, regulatory, warning
Text	Text entry
SIDE SLOPE FEATURE	
Type	**Switchback center point, climbing turn center point**
GRAVEL SOURCE	
TIMBER SOURCE	
STAGING AREA	
POINT GENERIC	
AREA FEATURE	
GENERIC AREA	

A prescription inventory collected with a GPS system provides an excellent basis for cost and labor estimates, but it does not have the familiar '1+00' trail log references typically associated with trail inventory work. Therefore, ground location reference points should be established before or during the inventory. Markers every one-quarter mile—or every 1,000 feet—are not too close for detailed surveys. Measuring wheels and OHV odometers are common measuring devices for establishing approximate milepost locations. Labeled flagging, lath, or metal tags should be placed at these standardized reference points. The more permanent the markers, the better.

Trail Improvement Implementation

Improvement implementation is planned trail maintenance, stabilization, or mitigation based on a trail improvement prescription. Improvement actions should be based on standard design specifications or commonly accepted management practices. Commonly accepted practices are best described in the following Federal and private publications:

Building Better Trails. 2001. International Mountain Bicycling Association, P.O. Box 7578, Boulder, CO 80306. Phone: 303–545–9011; e-mail: *info@imba.com*; Web site: *http://www.imba.com*. May be purchased both in HTML and PDF formats from the Web site or the IMBA office. 64 p. in printed book format.

Installation Guide for Porous Pavement Panels as Trail Hardening Materials for Off-Highway Vehicle Trails. 2001. Kevin G. Meyer. USDI National Park Service—Rivers, Trails, and Conservation Assistance Program Technical Note, 2525 Gambell St., Anchorage, AK 99503 (attached as appendix B).

Lightly on the Land—The SCA Trail Building and Maintenance Manual. 1996. Robert C. Birkby. The Mountaineers, 1001 SW. Klickitat Way, Seattle, WA 98134.

Off Highway Motorcycle & ATV Trails Guidelines for Design, Construction, Maintenance and User Satisfaction. 2d Ed. 1994. Joe Wernex. American Motorcyclist Association, 13515 Yarmouth Dr., Pickerington, OH 43147. Phone: 614–856–1900; fax: 614–856–1920, e-mail: *ama@ama-cycle.org*; Web site: *http://www.ama-cycle.org*.

Trail Building and Maintenance. 2d Ed. 1981. Robert D. Proudman and Reuben Rajala. Appalachian Mountain Club, 5 Joy St., Boston, MA 02108.

Trail Construction and Maintenance Notebook. 2000. Woody Hesselbarth and Brian Vachowski. Tech. Rep. 0023–2839–MTDC. United States Department of Agriculture, Forest Service, Missoula Technology and Development Center, 5785 Hwy. 10 West, Missoula, MT 59808–9361.

Wetland Trail Design and Construction. 2001. Robert T. Steinholtz and Brian Vachowski. Tech. Rep. 0123–2833–MTDC. United States Department of Agriculture, Forest Service, Missoula Technology and Development Center, 5785 Hwy. 10 West, Missoula, MT 59808–9361.

In addition to these references, supplementary information is available from the Missoula Technology and Development Center. Call 406–329–3978 to request the latest list of recreation publications and videos. Many of these are available through the Federal Highway Administration's Recreational Trails Program. To obtain a list of publications and an order form, go to Web site: *http://www.fhwa.dot.gov/environment/trailpub.htm*.

Each of these documents provides valuable information on trail design, construction methods, maintenance, or general trail management. While some may be regional in nature or focus on specific types of trails, their basic concepts can be adapted to OHV trails.

Trail Maintenance and Monitoring

Each trail alignment should receive regular maintenance at least once a year, preferably early in the season of use. Primary activities should include maintaining water-control structures, ditches, and culverts, and clearing fallen timber. Periodic inspections also should be made of bridges, especially after spring breakup or floods. Maintenance crews also should report on problem areas and maintenance concerns. In many cases, periodic, systematic maintenance can head off major trail degradation.

Monitoring to detect changes in trail conditions, including a complete condition assessment, should be conducted about every 5 years, depending on levels of use and a trail's soil and terrain characteristics. This frequency could be increased if significant environmental values are at risk, but enough time should pass between assessments to filter out changes due to seasonal effects, weather effects, or the subjectivity of inventory crew personnel. The same inventory classification system should be employed during each monitoring with key components such as trail surface character, trail impact rating, trail drainage, mud-muck index, and track width recorded from identical menu selection options.

Management Response to Severely Degraded Trails

Managing severely degraded trails presents a formidable challenge to resource managers. Severely degraded trails tax traditional trail management techniques and sometimes force managers to investigate and test innovative management methods, refining them for local conditions. No single set of responses can meet every situation, but a framework can help guide the process.

The trail degradation issue must be addressed on several fronts. The National Off-Highway Vehicle Conservation Council (NOHVCC), a nonprofit OHV advocacy group, uses an approach they call the Four Es. They are:

- Education
- Evaluation
- Engineering
- Enforcement

Education is needed to teach users about responsible riding and appropriate environmental ethics. In addition, resource managers and technicians need to be educated about effective trail management practices. Evaluation is necessary to develop methods to document use, assess impact, and evaluate mitigation methods. Engineering is necessary to develop trail improvement techniques and equipment modifications to reduce impacts. Enforcement is necessary to manage use within acceptable impact limits. In many locales, enforcement isn't a viable option. In those areas, enforcement may be implemented as "encouragement," encouraging users to conduct their activities in a sustainable manner. This might best be achieved by providing trail location maps that direct users to sustainable trails and trail signs that encourage appropriate use.

I would also add a fifth E: 'Enculturation' (the process of modifying human behavior over time). Enculturation can only be accomplished by the steady application of education, appropriate evaluation techniques, progressive engineering, appropriate enforcement, and encouragement.

The five Es show how broadly the issue of degraded trails must be addressed. Unfortunately, this report addresses a only a few of the five Es. It is intended as a tool to help educate trail managers and users about OHV trail degradation. In addition, the section on trail condition inventory presents an important evaluation component, and the following section identifies engineering solutions within a range of management options. These options include:

- ➢ Trail rerouting
- ➢ Seasonal or type-of-use restrictions
- ➢ Controlled use (traffic volume restrictions)
- ➢ Trail hardening
- ➢ Trail closure

By evaluating these options and developing a forum with users, advocacy groups, and the environmental community, trail managers can resolve many of the conflicts between degraded trails and environmental resources.

Trail Rerouting

Few OHV trails are planned trails where a full range of environmental considerations was carefully weighed before construction. In fact, few trails are specifically constructed for OHV use. Most OHV trails developed as individual riders followed game or foot trails or passed through natural corridors to remote fishing, hunting, or cabin sites. In Alaska, many OHV trails develop along routes that originally served as dogsled or snowmobile trails.

Because of the unplanned nature of OHV trails, many of them cross soils and sites poorly suited for the level of use occurring on them today. For example, a trail that originally developed from a game trail may not be suitable as a primary access route into a heavily used recreation area. A winter route across snow-covered wetlands doesn't necessarily provide a good alignment for a summer OHV route.

When numerous segments of a trail have been significantly degraded by the level of use, trail managers need to ask the following questions:

- ➢ Do opportunities exist to reroute the trail onto better soils and terrain?
- ➢ If yes, what is the cost of stabilizing the existing route compared to constructing a new trail alignment and rehabilitating the old one?

In some cases, moving a trail or segment may be an effective method of responding to trail degradation. For example, moving a trail from a foot slope to a side slope may significantly reduce trail wetness. Moving a trail from an open wetland to an adjacent woodland may stop trail braiding. Figure 7 shows an example where rerouting should be considered.

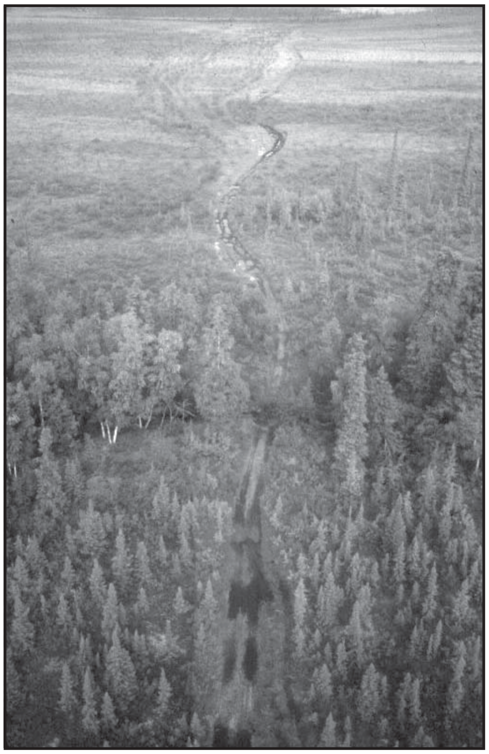


Figure 7—A heavily used OHV trail in Alaska crosses two distinct soil types. In the foreground, the trail passes through a mixed forest ecosystem where the soils support use along a single track. In the background, the trail crosses degraded wetland soils where users have created a braided trail. Managers should consider rerouting the trail to stay within the forest system.

A rerouting assessment should follow this process:

- ➢ Obtain and evaluate aerial photography of the trail alignment.
- ➢ Obtain soils data for the area surrounding the trail. Soil survey reports are available from the USDA Natural Resources Conservation Service.
- ➢ Conduct a site visit. Take available aerial photography and soils data with you. Visit the site during the primary season

of use. Evaluate the trail conditions on the ground to identify relationships between vegetation communities, terrain, soil conditions, and trail performance. Table 1 may be of some assistance. Use aerial photographs to identify adjacent areas that might support trail use. Identify alternative trail routes on aerial photographs and flag those routes on the ground.

- ➢ Identify the long-term benefits of the new route compared to continued use of the existing route.
- ➢ Develop a trail design for the alternative route. Develop a detailed construction plan. Identify any stabilization or reclamation work that is needed on the abandoned trail alignment. Identify methods to redirect use onto the new alignment using barriers, markers, or signs.

Decisionmakers and environmental groups may object to constructing new alignments where existing trails have failed, so it is important to have photos documenting the difference between trail segments on degraded sites and trail segments on more suitable sites. Illustrate the sustainability of the proposed new location to build consensus for the reroute option.

Table 6—Activities that have the potential to impact trails.

Impact	Use	
Generally slight	WINTER, WITH FROZEN GROUND AND ADEQUATE SNOW COVER:	
	Nonmotorized (Minimum snow cover 6 inches)	**Motorized** (Minimum snow cover 12 inches)
↓	Skiing/snowshoeing	Snowmobiling
	Dog sledding	
	SUMMER, WELL-THAWED GROUND:	
to	**Nonmotorized** Hiking	**Motorized** Light, tracked vehicles
	Mountain biking	Motorcycle riding
↓	Horseback riding	OHV riding (less than 1,500 pounds gross vehicle weight)
Potentially heavy		Unlimited off-highway vehicle use

Seasonal or Type-of-Use Restrictions

Seasonal-use restrictions are another option for responding to trail degradation. Because soils are most sensitive to impact when they are wet, restricting use of sensitive trails during spring breakup or periods of high rainfall may significantly reduce trail degradation. Also designating winter-season trails that cross wetlands as ‘WINTER ROUTES ONLY’ would significantly reduce impacts on sites that are extremely sensitive to impact by motorized vehicles during summer months.

Type-of-use restrictions limit the kind of equipment allowed on trails. For example, restricting gross vehicle weight to less than 1,500 pounds could significantly reduce the size of equipment operating on a trail. This would allow managers to build trails to a much lower design specification than when weight is unlimited.

In general, the potential of trail activities to create impacts ranges from slight to heavy as shown in table 6.

Reducing the types of use would lessen the potential for impact. Successfully restricting trail use requires user cooperation and enforcement. Signs, gates, and barriers aren’t enough to discourage some users, so public education and development of alternative routes on more resilient trails are needed to encourage compliance.

Controlled Use (Traffic Volume Restrictions)

Controlled use is another management option when responding to trail degradation. Trail degradation occurs when use exceeds the ability of the trail surface to resist impact. Controlling the level of use can be a powerful tool in reducing impacts. Determining the appropriate level of use can be difficult, especially since a trail’s resistance to impact can change with weather and type of use. Good decisions require knowledge of existing trail conditions, patterns and levels of use, and trail condition trends. If trail conditions are stable under existing loads, no volume restrictions may be necessary. If trail conditions are deteriorating, traffic volume may have to be decreased or trail surfaces may need to be modified to support the increased use.

Managing trails through controlled use is complicated because there may not be a linear relationship between use levels and impact. Typically, after a certain level of impact is reached, trails will continue to degrade without any further use. This is clearly the case when vegetation stripping exposes soils to erosion. Finding the balance between appropriate levels of use and acceptable impacts is a resource management art form, ideally backed up with good monitoring of the level of use and resource damage.

Controlled use also requires an authorized and determined enforcement presence. This may not be readily available. But where it is, monitoring impact and setting the allowable use may be a good management approach to controlling degradation problems.

Trail Hardening

Another management option is trail hardening. Trail hardening is a technique of modifying trail surfaces so they will support use without unacceptable environmental impacts to vegetation, soils, hydrology, habitat, or other resource values. Trail hardening should be considered under the following conditions:

- ➢ Existing trail impacts are causing or are projected to cause unacceptable onsite or offsite impacts, and
- ➢ More suitable alternative trail locations are not available, or
- ➢ Alternative trail locations are not environmentally acceptable or economically feasible.

Trail hardening provides the following benefits:

- ➢ Defines a single trail alignment for vehicle travel.
- ➢ Stabilizes surface soil conditions along the hardened trail section.
- ➢ Provides a stable, durable trail surface for OHV traffic.
- ➢ Halts trail widening and the development of braided trail sections.
- ➢ Allows formerly used trail alignments to naturally stabilize and revegetate.
- ➢ May provide for vegetation growth (or regrowth) within the hardened trail surface that helps to reduce visual impacts, maximizing site stability and increasing site productivity.

Trail hardening seeks to improve trail surfaces by one of three methods:

- ➢ Replacing or capping unsuitable surface soils.
- ➢ Reinforcing or augmenting existing soil structure.
- ➢ Providing a ‘wear and carry’ surface over unsuitable soils.

The goal of trail hardening is to reinforce soils so they will support a specified level of use under all environmental conditions. Because of the range of trail-hardening methods available, a trail manager must select a method that provides maximum utility for the investment in time, labor, and cost. Utility includes site stabilization, resource protection, and suitability for use as a surface for OHV traffic (figure 8).

The following section introduces a number of trail-hardening techniques.

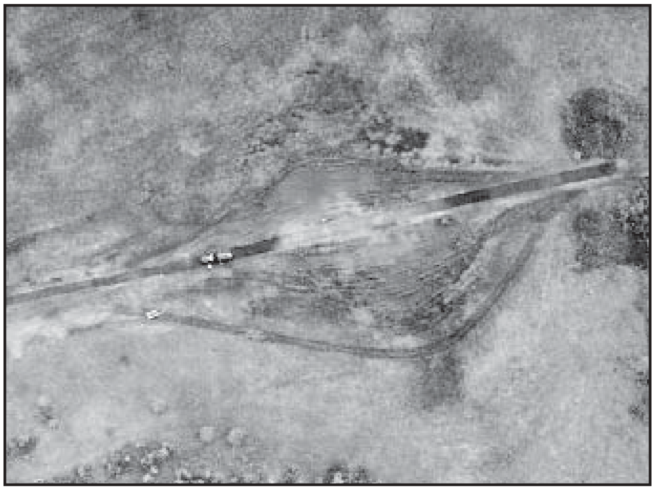


Figure 8—This aerial image shows a recently installed section of hardened trail crossing a wetland in southcentral Alaska. The new trail alignment defines a single route of travel that will prevent the continued development of braided trails.

Replacing or Capping Unsuitable Soils—Replacing unsuitable soils is the most intensive, trail-hardening technique. Problem soils are excavated and removed until a subbase of competent subsoils or gravel has been exposed. High-quality material is placed over the subbase to bring the trail surface up to the trail’s original level. This process is appropriate for trails with a suitable subbase close to the surface and a convenient source of high-quality fill. The work generally requires heavy equipment. It is most appropriate near trailheads and along highways where heavy equipment can be used to good advantage.

Where a suitable subbase is not close to the surface or excavation work needs to be minimized, geotextile fabrics may be used to provide a base for surface capping. The use of geotextile materials extends the application of capping to many areas where removal of substandard surface soils is impractical.

Geotextiles, also known as construction fabrics, are widely used in roadways, drains, embankments, and landfills. They are constructed of long-lasting synthetic fibers bonded by weaving, heat, extrusion, or molding. They come in a wide variety of types including fabrics, sheets, or three-dimensional materials. They can be pervious or impervious to water passage.

Geotextiles provide four important functions in road and trail surface construction:

- ➢ Separation
- ➢ Stabilization
- ➢ Reinforcement
- ➢ Drainage

These functions are illustrated in figures 9a, 9b, and 9c. Geotextiles work as separation fabrics when they are placed between gravel caps and underlying soils to prevent the materials from mixing. The geotextile serves to maintain the original thickness and function of the gravel cap as a load-bearing layer. Geotextiles increase soil stabilization by maintaining the load transfer capability of the gravel cap. This increases effective bearing capacity and prevents subsoil pumping. Geotextiles reinforce soils by providing a structure to bond the gravel cap and underlying soils. The geotextile fabric locks the two materials together and allows the soil to receive a load across a broader footprint. Geotextiles also help maintain the drainage characteristics of the gravel cap. In addition to use in trail tread, geotextiles can have important applications in erosion control, drainage interception (sheet drains), and ditch liners.

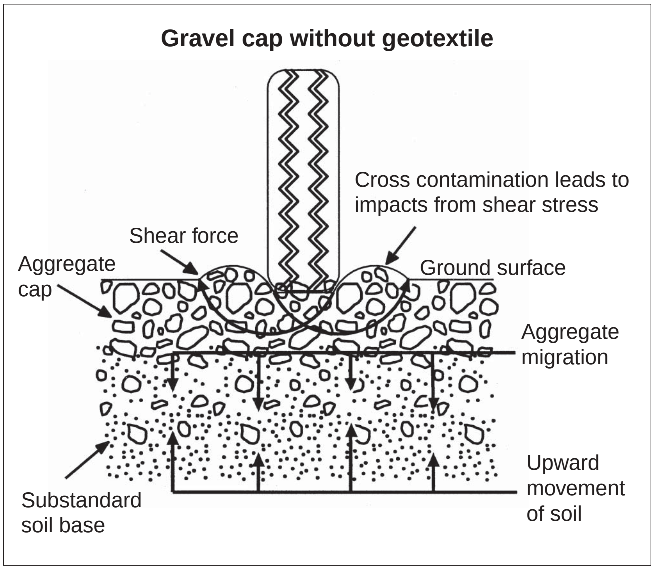


Figure 9a—Gravel cap without geotextile. The aggregate cap will lose strength as the gravel is contaminated by the subbase.

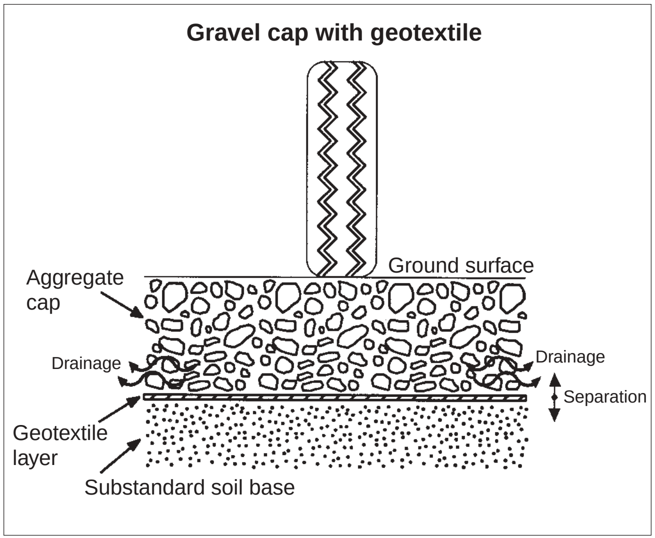
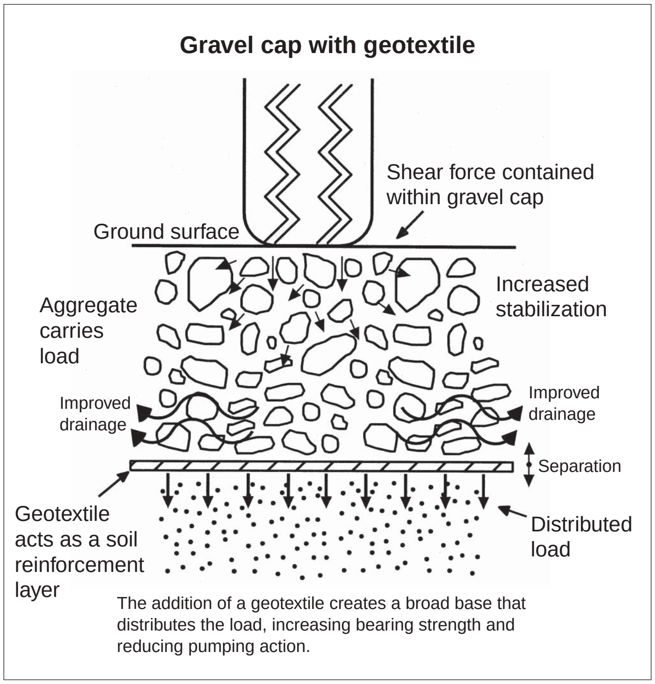


Figure 9b—Gravel cap with geotextile. The geotextile layer prevents the migration and contamination of the surface gravel cap by underlying poor-quality soils.



The addition of a geotextile creates a broad base that distributes the load, increasing bearing strength and reducing pumping action.

Figure 9c—Gravel cap with geotextile. Using a geotextile enhances trail performance through separation, stabilization, reinforcement, and drainage.

Site conditions such as soil texture, moisture, depth to foundation materials, and the type of use indicate when a geotextile fabric should be used. Because gravel is difficult and expensive to deliver onsite, the use of a separation fabric makes good economic sense to protect the function of the gravel cap. The use of a geotextile fabric requires adequate capping (a minimum of 6 inches) and regular maintenance to maintain the cap. Regular maintenance prevents the geotextile fabric from being exposed at the surface.

The National Park Service experimented with the use of geotextile and gravel placement during the summer of 1999 on degraded trail segments of a former mining road connecting two administrative sites in the Yukon-Charley Rivers National Preserve (Meyer 1999a). About 678 feet of geotextile with a 4- to 6-inch gravel cap was installed over soils in areas that crossed melted permafrost soils. Using this technique, the road alignment was reclaimed as an OHV trail.

Geotextile and gravel placement is relatively simple. The Yukon-Charley approach was adapted from Forest Service methods (Monlux and Vachowski 1995, figure 10). This technique provides a rim structure to minimize the loss of cap material (figures 11 and 12). A local source of suitable gravel was identified. One-half-cubic-yard belly dump trailers, loaded by a skid-steer loader and towed by 4x4 OHVs, transported gravel to trail construction sites.

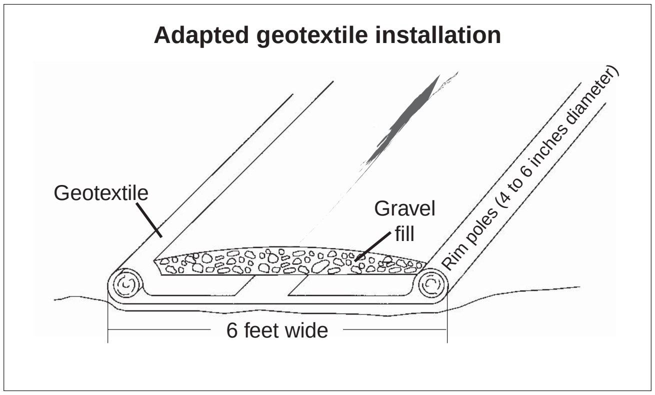


Figure 10—Adapted geotextile installation design.

About 45 labor days and 80 cubic yards of gravel were required to construct 678 linear feet of 6-foot-wide trail, roughly 45 work hours per 100 feet of hardened trail. Construction efficiency dropped considerably when construction sites were more than one-quarter mile from the gravel source because of the small size of the transport vehicles and the round-trip travel time. The loaded trailers, weighing about 2,000 pounds gross vehicle weight, also seriously degraded marginal trail segments along the haul route. Future operations at the site will use larger haul vehicles operating over frozen soils during the winter months.

The geotextile used on the project was AMOCO 2000, a light-grade woven synthetic fabric. The material cost about 5 cents per square foot, quite inexpensive, considering all other costs. Overall construction costs for the project were estimated at $3.60 per square foot using a labor rate of $18 per hour.

Figure 11—The author installing woven geotextile around a rim log in the geotextile gravel-capping test installation at the Yukon-Charley Rivers National Preserve in Alaska. The rim log held the gravel cap on the installation.

Figure 12—A geotextile and gravel-cap installation over permafrost-degraded soils in Yukon-Charley Rivers National Preserve in Alaska. Use of geotextile and a gravel cap on this trail allowed the National Park Service to construct a 6-foot-wide OHV trail over a 3- to 4-foot-deep muck hole.

Cellular Confinement Systems—Cellular Confinement Systems (CCS) are three-dimensional, web-like materials (figure 13) that provide structural integrity for materials compacted within the cell. They are engineered so cell walls limit the transfer of shear forces within the soil. Employed worldwide for a wide variety of uses, cellular confinement systems are a well-accepted soil engineering tool (Ron Abbott 2000). In Alaska, these systems have been used with success on military runways and remote radar sites, Arctic tank farms, construction sites, and boat ramps (Joseph Neubauer 2000). The systems also have been used when constructing shallow-water fords in the contiguous 48 States (Forest Service 1987).

A cellular confinement system consists of a surface-aggregate wear surface, the cell membrane, fill material, and an optional separation fabric (depending on site characteristics). Fill material is usually imported gravel, but onsite material can be used in

Figure 13—A cellular confinement system being installed on an experimental trail in southcentral Alaska. Four-inch-deep cells were formed by expanding the cellular product accordion style, then backfilling and compacting with a suitable fill material—in this case, sandy gravel. The sides of the installation were confined by a 6-inch-deep trench.

some circumstances (the use of onsite fill will be covered later). Installation of the system is labor intensive. The smallest cell commercially available is 4 inches deep. A minimum of 6 inches of fill material is required to fill the cells and provide a 2-inch wear surface, about 1 cubic yard of loose material per 6 linear feet of a 6-foot-wide trail. While the cell material alone costs about 70 to 90 cents per square foot, installation costs include the costs of any separation fabric, the fill, cap material, transportation of materials, cell panel connectors, and excavation of a trench or the construction of a curb or rim to confine the materials.

Test installations of cellular confinement systems for trail use in the contiguous 48 States have shown mixed results (Jonathan Kempff 2000). While the systems provided excellent structural reinforcement for soils, maintaining the surface wear cap to protect the cell membrane has been difficult. Without adequate curbing, capping material tends to erode from the cell surface. This is particularly true on sloped surfaces. With the loss of capping material, the cell membrane becomes exposed to damage by trail users. Although such damage usually doesn't significantly affect the cell's strength, exposed cells are unsightly and create a tripping hazard.

A somewhat similar problem occurred in the Bureau of Land Management's White Mountains District in Alaska. The agency reported mixed to poor results using cellular confinement systems on roadways in the Fairbanks area (Randy Goodwin 2001). Cellular confinement systems were used to cap four culvert installations on the Nome Creek road. The systems were installed in 50- to 200-foot segments to provide a stable fill road surface. Spring melt of overflow ice (aufeis), that typically plugs the culverts, scoured fill material out of the web cells each year. Replacing the fill without damaging the cell structure was difficult and time consuming.

Also in Alaska, about 900 feet of cellular confinement systems, with recycled asphalt fill and cap, were installed in 2000 on an access trail in the Turnagain Pass area by the Forest Service (Doug Blanc 2001). Based on the success of that installation, the Forest Service is planning another 3-mile installation adjacent to a visitor center. Both trails were designed to meet the requirements of the Americans With Disabilities Act and are not representative of remote OHV trails. A more representative installation is a 20-foot test installation at Palmer Hay Flats State Game Refuge (figure 13). Since its installation in August 2000, the trail surface has been performing well, but the capping material has begun to show signs of erosion (Colleen Matt 2001).

Cellular confinement systems are manufactured under a variety of trade names, including Geoweb, Envirogrid, and TerraCell.

➢ Geoweb is available from Presto Plastic Co., phone: 800–548–3424.

➢ Envirogrid is available from AGH, phone: 713–552–1749.

➢ TerraCell is available from WEBTEC, phone: 800–438–0027.

Reinforcing or Augmenting Soil Structure—Reinforcing or augmenting existing soil structure is a method that adds material to existing soil to improve its engineering characteristics. Unlike excavating and replacing substandard soils, this method works with the native in situ soil material. The two major types of material are soil binders and structural additives.

Binding agents come in two forms: chemical binders and physical binders.

Chemical Binders—The EMC SQUARED system is an example of a chemical binder. EMC SQUARED is a concentrated liquid stabilizer formulated to increase the density, cementation, moisture resistance, frost-heave resistance, bearing strength, shear strength, and stability of compacted earth materials. The highly concentrated product is diluted in water and applied as soil materials are mixed and compacted. The product is activated by biological catalyst fractions. According to the manufacturer, it is an environmentally friendly product. The system is supposedly effective with a wide range of aggregate and recycled materials, as well as clay and silt soils.

The primary binder in the EMC SQUARED system is Road Oyl, which has been used extensively as an aggregate binder for resin pavement mixtures. Road Oyl has demonstrated considerable success on urban and accessible trails for the

Forest Service, National Park Service, and other governmental and private organizations. Paul Sandgren, superintendent of the south unit of the Kettle Moraine State Park in southeastern Wisconsin, reports good success with Road Oyl in binding aggregate-capped mountain bike trails. The park's south unit, which receives heavy mountain bike use from surrounding urban areas, found annual applications of the binder worked well in reducing the displacement of a surface cap of $^3/_4$-inch crushed limestone (Paul Sandgren 2001).

Test applications of chemical binders in Alaska have proved disappointing. The municipality of Anchorage experimented with the use of a chemical binder on an urban access trail with poor results. The material failed to set up properly. In areas where the material set up, the surface was very slick. Whether the problem was caused by climate or improper installation was never resolved (Dave Gardener 2001). Denali National Park and Preserve has also experimented with a variety of chemical binders as dust suppressants on a gravel road that serves as the primary access for the park. To date, results have been disappointing (Ken Karle 2000)

Chemical binders such as Road Oyl have the greatest potential application in urban areas and at trailheads where high-quality gravel or recycled materials are available. They have yet to be tested on degraded OHV trails in remote locations where unsuitable soil materials, high moisture levels, inability to use heavy equipment, and severe climatic conditions would present challenges for this technique.

The EMC SQUARED system and Road Oyl are available from Soil Stabilization Products Company, Inc., of Merced, CA. Phone: 209–383–3296 or 800–523–9992. Other chemical binders available on the market include:

- **Stabilizer** (4832 East Indian School Rd., Phoenix, AZ 85018. Phone: 800–336–2468).
- **Soil-Sement** (Midwest Industrial Supply, Inc., P.O. Box 8431, Canton, OH 44711. Phone: 800–321–0699).
- **Pennzsuppress D** (John Snedden, National Sales Manager, Pennzoil Products Co., 100 Pennzoil Dr., Johnstown, PA 15909).

Physical Binders—Fine-textured native soil is an example of a physical binder. It can be used where trails are constructed with coarsely textured aggregate or washed gravel. Soil material containing high sand- and silt-sized fractions is used to fill voids between gravel- and cobble-sized material. The fine materials help "bed" the larger material, reducing displacement, improving the quality of the travel surface, and helping vegetation to become established.

Structural Additives—Another method of augmenting an existing soil structure is to add a physical component to the soil body. This can be as an internal structural member or as a surface feature.

Internal Structural Member—The use of cellular confinement systems to reinforce sandy soils is an example of adding a physical component to an existing soil structure. The original soil is excavated and used as fill and cap material. The cells of the cellular confinement system add a structural component to the sand that prevents shear force transfer and soil failure. This method was tested by the U.S. Army Corps of Engineers (Webster 1984; Purinton and Harrison 1994) and applied during Operation Desert Storm to construct sand roads capable of carrying heavy military traffic. The technique has also been applied by an American oil company to build roads through the Algerian Sahara Desert (Presto 1991). Using a cellular confinement system would be an excellent method to stabilize trails that cross sandy soils.

Another method used by the Forest Service (Kempff 2000) and recommended by the American Motorcyclist Association (Wernex 1994) is to embed concrete blocks in the body of the soil. The concrete block, installed with the block walls in a vertical position, provides a hardened wear surface. The open cell structure of the block prevents shear force from being transferred. This method may have applications where blocks can be readily transported to degraded trail sites, but has limited application in remote locations. Blocks are available that are specially designed for OHV trails. They are not as thick as normal construction blocks, and have a different grid pattern.

Surface Feature—The geosynthetics industry has developed a class of materials known as 'turf reinforcement' materials. These products are designed for installation at or near the surface to reinforce the surface vegetation mat. The Park Service experimented with one of these materials in a series of test plots established as part of an OHV trail mitigation study conducted in the Wrangell-St. Elias National Park and Preserve in Alaska. In 1996, the Park Service installed four 40-foot test sections of a combination of a drainage mat (Polynet) with a turf reinforcement mat (Pyramat) over moderately degraded OHV trails. Polynet is a $^1/_8$-inch-thick polyvinyl chloride (PVC) material, resembling expanded metal decking. Pyramat is a $^3/_4$-inch-thick, finely woven polypropylene product in a pyramid-shaped microweave pattern (figure 14).

The manufacturer had extensively tested Pyramat as a soil-reinforcement product. The company had documented significant increases in resistance to erosion and shear stress after vegetation regrowth (Synthetic Industries 1999). The National Park Service tested both turf reinforcements to see whether they would support existing roots and cushion soil bodies from direct impact. Polynet provided a wear surface, while the open weave of Pyramat allowed for active plant growth and eventually was integrated into the soil surface layer.

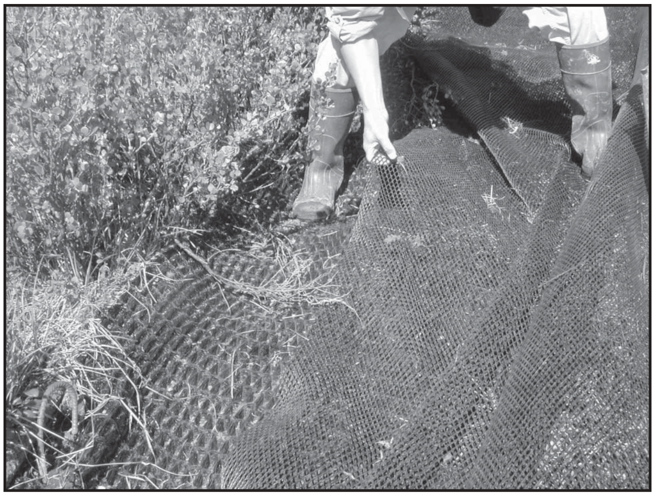


Figure 14—Polynet over Pyramat was used in this National Park Service installation to test the addition of a synthetic turf reinforcement mat. The Polynet, with its more durable wear surface, was installed over the less durable Pyramat.

The Park Service field tests were encouraging because the materials appeared to protect the underlying soils from impact. They stabilized degradation and provided a durable wear surface for OHV use. Vegetation regrowth on the sites increased from 54-percent cover at installation to 79.5 percent 3 years later (figure 15). On sites with a high percentage of sedge and cotton grass, the materials were well integrated into the root mass by the end of the second year.

Figure 15—A Park Service Polynet/Pyramat test installation after 3 years in a wetland area with a high percentage of sedge. By the third year, sedge had become well established and its roots well entwined with the Pyramat matting.

The products worked fairly well to stabilize trail degradation, but were difficult to install and maintain. They had a poor appearance. The material installation cost of the two products was $4 per square foot. It took 26 hours to install 100 linear feet of a 6-foot-wide trail. The full results of the test are detailed in the report, *All-Terrain Vehicle (ATV) Trail Mitigation Study: Comparison of Natural and Geosynthetic Materials for Surface Hardening* (Allen and others 2000).

Pyramat has also been used to reinforce foot trails and provide erosion control at a portage on Jim Creek, a tributary of the Knik River in the Matanuska Valley near Palmer, AK. Nancy Moore, who works for the Alaska Center for the Environment, coordinated the installation of a 90-foot-long by 8-foot-wide strip of Pyramat at the site in the summer of 2000. The mat was laid on the soil surface, capped with pit-run gravel and topsoil, and seeded to reestablish vegetation. According to Moore, the installation was successful in stemming erosion and improving trail conditions (Moore 2001).

Appendix A identifies the attributes of the Polynet/Pyramat combination and compares the combination with other products tested by the Park Service. While this combination of products may have utility in other applications, it is not considered suitable for hardening OHV trails because of the difficulty of installation and the limited durability of the wear surface.

Providing a Wear-and-Carry Surface Over Unsuitable Soils—The final method of trail hardening is to provide a wear-and-carry surface over unsuitable soils. Typically, this is accomplished by installing a semirigid structural component on the soil surface that provides a durable wear surface while distributing weight over a broad soil area. In this manner, the material “carries” the weight of the load, rather than directly transferring it to the underlying soil.

The methods of wear-and-carry, trail-hardening techniques for OHV trails discussed in this document include:

- ➢ Corduroy
- ➢ Wood matrix
- ➢ Puncheon
- ➢ Porous pavement panels
- ➢ Surface matting

These methods are expensive and labor intensive. It is not practical to use this method to harden the entire length of a trail. It should only be used to harden those segments that cannot be rerouted to more suitable locations or managed to reduce impacts.

Much of the following discussion is drawn from the author’s personal experience with trail hardening tests conducted in Alaska. This experience includes a formal study conducted in Wrangell-St. Elias National Park and Preserve, mentioned in a previous section (Allen and others 2000), data obtained from other test installations, independent research, and conversations with other professionals.

Corduroy—Corduroy has been commonly used to harden trails in Alaska. Many of the first wagon trails in the State were constructed as corduroy roads. It is not uncommon to see corduroy being excavated during roadwork today. In traditional road construction, the corduroy logs were covered with soil or a gravel cap to provide a smooth and durable road surface. Burying the poles beneath the surface cap also served to preserve them. This was especially true when the poles remained water-saturated under acidic soil conditions.

For most trail applications, corduroy is not covered with a surface cap. This is primarily due to the scarcity of quality cap material and the expense of hauling the material to installation sites. When corduroy is exposed to the air with frequent wet/dry cycles, its longevity is significantly shorter than if it was buried. Fastening the individual poles together is another challenge. Poles can be secured by weaving them with line, spiking them to sill or rail logs, or threading them with rope or cable. Corduroy provides a suitable, if somewhat rough, surface for OHV and foot traffic. Also, woven or threaded corduroy floats on water so it does not provide a stable surface for ponded areas.

The Park Service tested corduroy as one trail-hardening technique in the Wrangell-St. Elias study (Allen 2000). Although corduroy was somewhat labor intensive to install, the expense of installation was mitigated by the low cost of materials. The Wrangell-St. Elias study identified a material installation cost of about $1.75 per square foot. About 25 hours were required to install each 100-foot section of 6-foot-wide trail (figure 16).

Corduroy may also have an environmental cost if trees are harvested in sparsely timbered areas. Three to four poles are required for every linear foot of 6-foot-wide trail. The management tradeoff of harvesting trees to mitigate trail impacts needs to be evaluated for each installation site. Appropriate thinning methods can mitigate impacts of timber harvesting. Harvesting poles offsite can also mitigate impacts.

Appendix A has more detailed information about the benefits and drawbacks of corduroy. Corduroy is considered a suitable trail-hardening material for relatively short sections of trail when timber is available locally.

Wood Matrix—Wood matrix was another trail-hardening method tested by the Park Service in the Wrangell-St. Elias study (figure 17). The wood matrix was a wooden grid structure constructed of rough-cut, 2- by 4-inch timbers that were notched and fitted to form an 8- by 8-inch open grid. The surface of the grid formed the wear surface. The interlocked timbers carried and distributed the load across the soil surface. The technique was adapted from an approach developed in Britain (Shae 2000). The grid formed a rigid unit that had excellent load transfer characteristics, but was too inflexible to conform well to terrain. Although raw materials were cheap, preparing and fitting the joints was very labor intensive. The green, untreated lumber warped, was difficult to fit together in the field, and was subject

Figure 16—Spruce pole corduroy laid across permafrost soils in Alaska. These poles were imported to the site and secured by weaving them with three strands of $\frac{3}{8}$-inch nylon line.

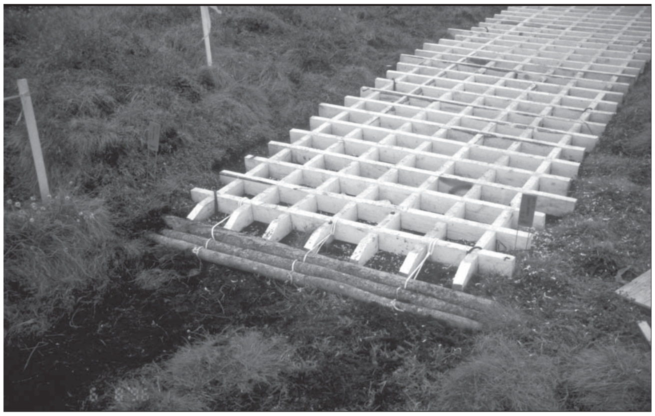


Figure 17—Wood matrix after installation in the Wrangell-St. Elias National Park and Preserve in Alaska. The wood matrix provided a suitable surface for OHVs, but had several characteristics that limited its suitability for future field applications.

to breaking at the joints. It was also subject to rot and showed visible signs of deterioration within the first year.

The installation cost for the wood matrix was $2.90 per square foot. About 70 hours were required to install a 100-foot section.

Additional information on the suitability of wood matrix for trail hardening is included in appendix A. Because a wood matrix installation entrapped wildlife in one case, it was removed from the Wrangell's test plots during the second season of the study. That concern and other factors of the material limit its suitability for future trail-hardening applications.

Puncheon—Constructing puncheon (a type of elevated boardwalk) for wet and muddy footpaths has been a standard construction technique for many years. Recently, its use in providing a hardened trail surface for ATVs has been pioneered by John Coila, an Alaska homesteader in the Kachemak Bay area of southcentral Alaska. Coila developed an installation similar to a standard Forest Service design called puncheon with decking (figure 18). Coila used locally available beetle-killed spruce and a portable bandsaw mill to produce the decking onsite.

Typically, Coila cuts timber adjacent to the trail from standing or recently fallen, beetle-killed spruce trees. Coila's slab-plank design uses two size classes of beetle-killed timber. Smaller diameter timber provides sills and stringers (figure 19). Larger diameter timber provides logs for planking. Sill timbers are 12 feet long and stringer timbers are 24 feet long. The minimum top diameter of logs used for sills and stringers is 7 to 8 inches. Bark is not typically stripped off the logs, nor are the sill or stringer logs milled in any fashion. The plank log diameter is controlled by the size the mill can accommodate. Plank logs are cut to 6-foot lengths to ease handling and are milled into 2-inch-thick slabs. Planks are not square edged. All round-faced slabs are discarded. Each plank provides an average of 1 linear foot of boardwalk (figure 20).

Coila estimates the expense of the installations at about $5 per linear foot, with a construction rate of 50 to 100 feet a day for a three-person crew when timber is close at hand. Installations have been in active service for longer than 15 years with the occasional replacement of a surface plank. An installation guide for the technique has been prepared and is available from the author (Meyer 2001a).

Porous Pavement Panels—Porous pavement panels (PPP) are three-dimensional, structural geotextiles designed to provide a durable wear surface and a load distribution system for driveways, parking areas, fire and utility access lanes, golf cart paths, and approaches to monuments, statues, and fountains. The panels are intended to be installed over a prepared subbase and filled with soil. They are designed to support grass growth and provide a reinforced turf surface for light or intermittent heavy traffic. In contrast to asphalt or concrete pavements, these porous pavement systems reduce surface runoff, increase infiltration, resist erosion, and enhance groundwater recharge.

The standard industrial installation technique is modified for hardening OHV trails. After surface leveling, the panels are installed directly over the existing trail surface. The grid cells are not backfilled unless fill material is readily available. After installation, the panel's surface provides a tread surface for vehicles, and the panel's structure distributes their weight. The open structure of the panels allows vegetation to grow through the panel after installation. On extremely muddy or boggy sites, a supplemental geotextile layer may be placed beneath the panels to increase flotation. Polynet PN3000, an open-grid drainage mat, has been used for that purpose in a number of test installations in Alaska.

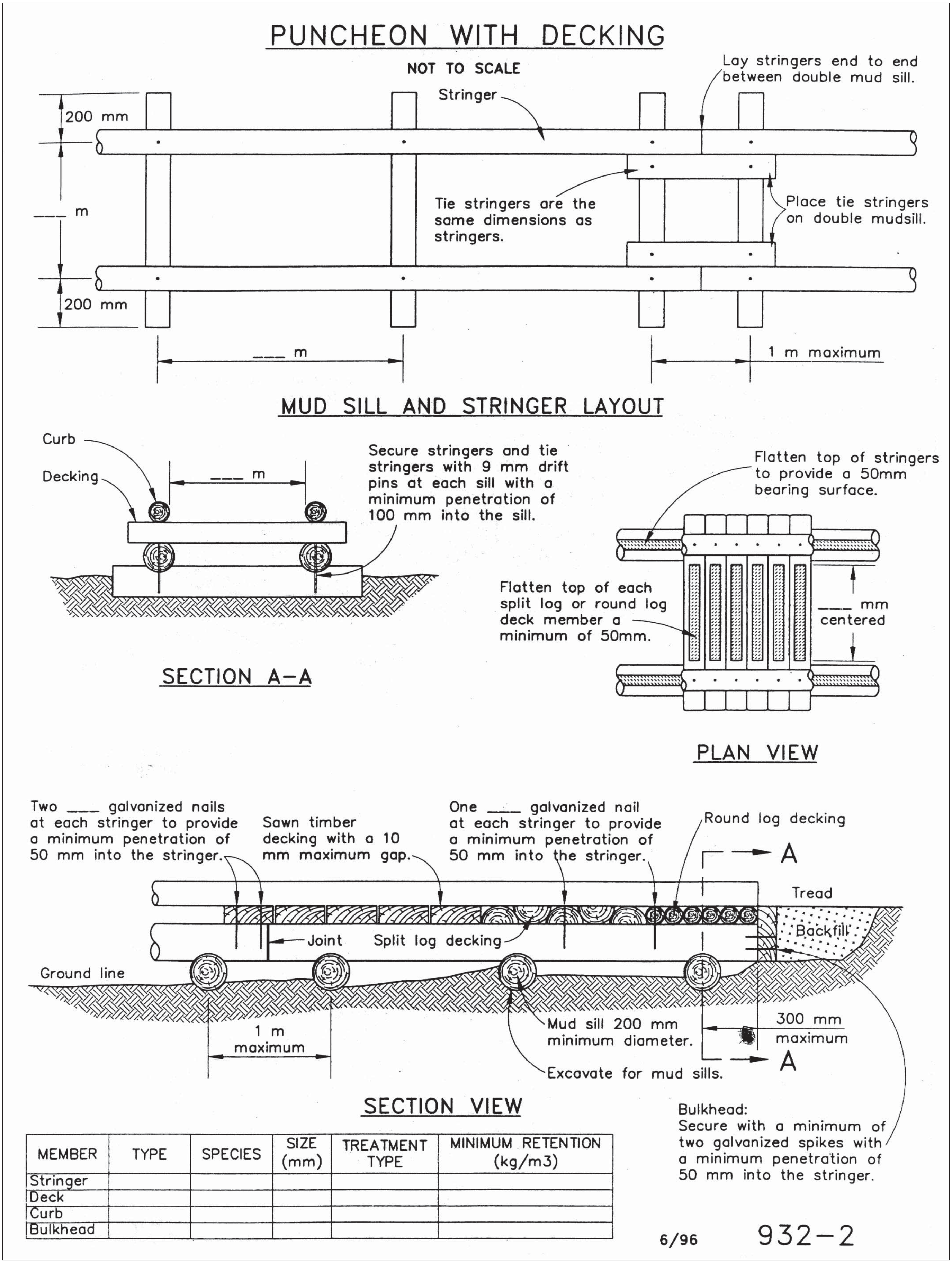
One advantage of the panel system is the light weight of the panels (about 2 pounds per square foot). The panels do not add any significant weight load to wetland surfaces and have little impact on surface hydrology. Their use can dramatically reduce the need for culverts or other water transfer structures along the trail.

Two porous pavement panel products have been the subjects of extensive field testing in Alaska. They are GeoBlock (figure 21) and SolGrid (figure 22).

GeoBlock is a commercially developed porous pavement system manufactured by Presto Products of Appleton, WI. GeoBlock has been on the market, in one form or another, since the early 1990s and was specifically tested in two earlier configurations by the Park Service in the Wrangell-St. Elias National Park and Preserve. Its primary industrial applications are emergency vehicle lanes, light service roads, and auxiliary parking areas.

SolGrid is a commercial porous pavement system developed by SolPlastics, of Montreal, Canada. SolGrid is a newer product. It has a unique configuration that makes it suitable for irregular terrain and sloped areas. Its primary industrial applications are walkways, bikeways, golf cart paths, and driveways.

Both products are partially recycled polyethylene plastic panels about 39 inches long, 19 inches wide, and 2 inches thick. GeoBlock has also been manufactured as a 1¼-inch-thick panel. The panels are stabilized with carbon black to help them resist degradation by ultraviolet light. Both GeoBlock and SolGrid are constructed with an open grid surface and interlocking edges. The GeoBlock products have a 3- by 3-inch-tall vertical grid reinforced by a base sheet perforated with 2¼-inch-diameter holes on a 3¾-inch spacing. About 44 percent of the base is open. The GeoBlock products form a rigid panel with good weight transfer between panels.



MEMBER	TYPE	SPECIES	SIZE (mm)	TREATMENT TYPE	MINIMUM RETENTION (kg/m3)
Stringer					
Deck					
Curb					
Bulkhead					

Figure 18—Forest Service Standard Drawing 932-2 of a puncheon with decking boardwalk trail. This design is similar to the one developed by an Alaskan homesteader to provide hardened trails for OHVs.

Figure 19—Rough layout of the sill and stringer timbers for puncheon trail construction over a wetland area in southcentral Alaska. Stringers are laid with tops meeting tops and butts meeting butts.

Figure 20—A finished puncheon trail. Note the placement of the plank taper to accommodate the curves along the trail.

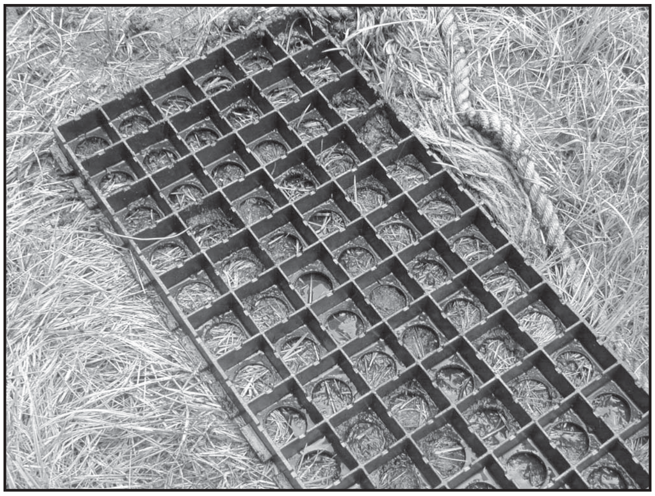


Figure 21—A GeoBlock panel. Note the edge tabs used to connect the panels and transfer loads between them.

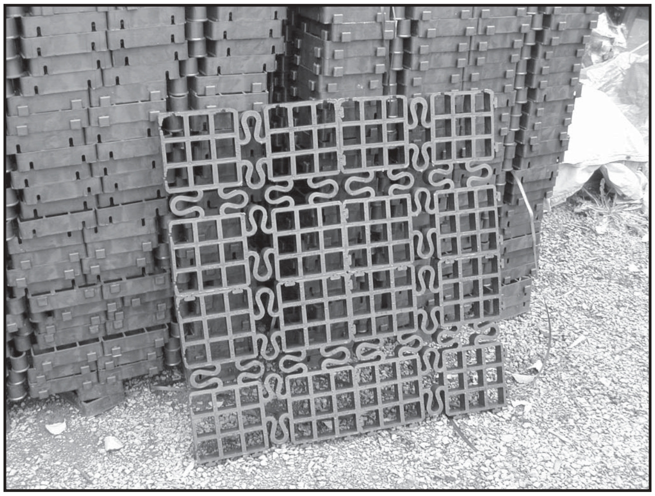


Figure 22—Two SolGrid panels. Note the U-shaped flex connectors between panel subsections.

The SolGrid product has a $2\frac{1}{2}$- by $2\frac{1}{2}$-inch-tall vertical grid pattern with an 8- by 8-inch subpanel. When assembled, subpanels form 16- by 16-inch weight-transfer panels. Flexible U-shaped connectors join the subpanels. There is no base sheet. About 85 percent of the grid surface is open for vegetation regrowth. Weight transfer between panels is poor because of the integrated flexible connectors. This can be mitigated somewhat by the use of supplemental geosynthetics underneath the panel. Polynet–PN3000 has been used for that purpose in Alaska and has demonstrated some benefit. The flexibility of the SolGrid panels increases their utility on irregular surfaces and on slopes. It also provides an integrated buffer for thermal expansion and contraction.

In 1996, earlier configurations of GeoBlock $1\frac{1}{4}$- and 2-inch panels were tested by the Park Service in the Wrangell-St. Elias trail mitigation study. The test demonstrated that the panels perform very well as trail-hardening materials. They provided a suitable wear surface for foot and OHV use and were easy to install. In addition, they readily facilitate vegetation regrowth.

Vegetation cover along two hardened trail segments increased on average from 70 to 90 percent and from 48.5 to 77.5 percent respectively, within the 4-year study period.

In 1996, the total installation costs for 100 feet of 6-foot-wide trail were:

1¼-inch GeoBlock	**2-inch GeoBlock**
• $6.67 per square foot	• $8 per square foot
• Installation, 32 hours	• Installation, 36 hours
• Panel costs with shipping, $3.14 per square foot	• Panel costs with shipping, $4.50 per square foot

Since 1996, GeoBlock panel costs have fallen to about $2.15 per square foot for the 2-inch panel, depending on volume. Presto no longer manufactures the 1¼-inch GeoBlock.

SolGrid costs about $1.60 per square foot, depending on volume. In some areas, SolGrid would require the use of a supplemental geotextile, such as Polynet PN-3000. This would add 15 to 25 cents per square foot to installation costs.

Both products have been tested in Alaska on OHV trails during 2000, 2001, and 2002. In 2000, two 100-foot test sections were installed on a dedicated recreation OHV trail in the Forest Service Starrigaven Recreation Area near Sitka. Several test sections of GeoBlock and one section of SolGrid were installed in cooperation with the Alaska Department of Fish and Game at the Palmer Hay Flats State Game Refuge near Palmer (figures 23 and 24). The Forest Service reports that the installations were more economical than the standard gravel cap placement and may be applied more widely in the future (LaPalme 2001).

The 2000 test project on the Palmer Hay Flats Game Refuge was successful enough for the department to install an 800-foot section in 2001. That installation included a 600-foot-long shallow underwater section that was supported by a base layer of geogrid and a gravel cap infill to ballast the installation to the pond floor. Also in 2001, the Bureau of Land Management sponsored test installations in the White Mountains National Recreation Area north of Fairbanks, AK, and the Tangle Lakes Archeological District west of Paxson, AK. More than 400 feet of hardened trail was installed at those two sites. In addition, a 300-foot test section was installed in the Caribou Lakes area on the lower Kenai Peninsula in Alaska. Average material costs ranged from $3 to $3.50 per square foot. Among the four sites, trail surfaces were constructed in 4.8-, 6.5-, and 8-foot-wide configurations. Labor requirements varied from 6.5 to 14 hours per 100 square feet, depending on site conditions, logistics, and layout configurations.

In the contiguous 48 States, GeoBlock was tested on the Wambaw Cycle Trail in the Francis Marion National Forest near Charleston, SC. Sections of the trail had extensive trail braiding due to wet soils. Fifty-five feet of GeoBlock was installed with a clay-sand fill and a 2-inch cap over a geofabric layer. The installation completely stabilized the soils at the site. More than 3,500 passes had been made over the installation by enduro-type motorcycles within the first 3 months of installation. According to the project manager, not one vehicle has ventured

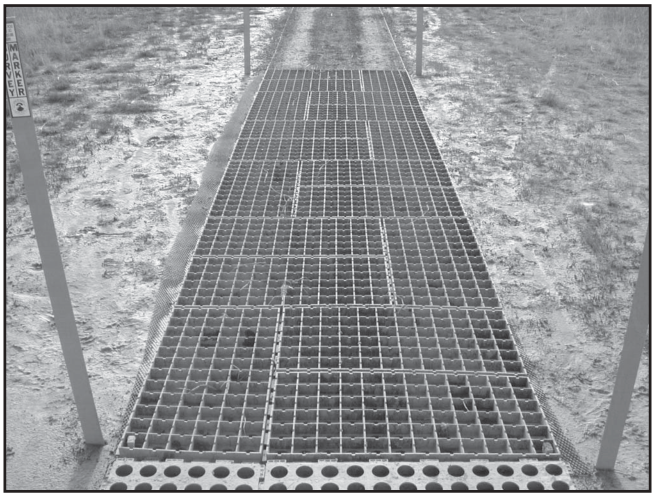


Figure 23—Test installation of 2-inch GeoBlock at the Palmer Hay Flats State Game Refuge in Alaska. This configuration of panels provided a 4.8-foot-wide trail. Note the interlocking tabs along the panel edges. These tabs transfer weight between panels. In this test, GeoBlock was installed over Polynet PN-3000.

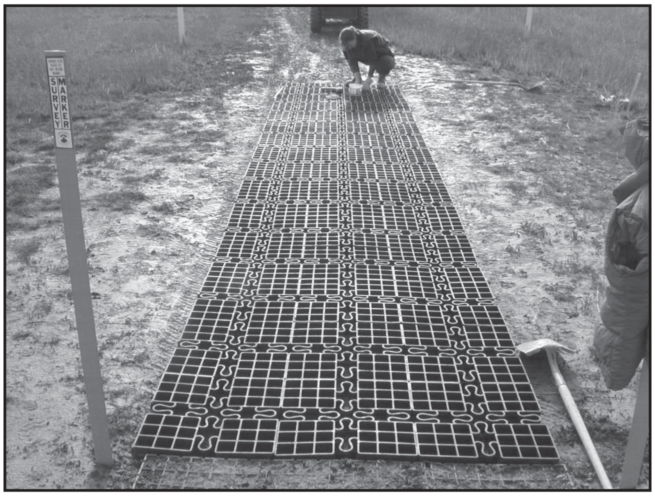


Figure 24—Test installation of SolGrid at the Palmer Hay Flats State Game Refuge in Alaska. Note the U-shaped flex joints between sub-panel sections. The SolGrid was tested without Polynet PN-3000 to test the characteristics of the product when installed on a soft, silty substrate.

off of the hardened trail to further impact the wetland site. Except for minor rutting of the surface cap, there has been no noticeable wear to the surface of the GeoBlock panels (Parrish 2001).

Appendix A provides an evaluation of the two products. GeoBlock is highly suitable for use as a trail-hardening material. The 1¼-inch product, if available, would be suitable for most installation sites, while the 2-inch product could be used for extremely degraded segments, for crossing large ponded areas, and possibly for shallow water fords. SolGrid, which is still undergoing field tests, is suitable for irregular terrain and sloped areas, but is not as suitable for extreme conditions because of its limited ability to transfer lateral loads.

GeoBlock is available from Presto Plastics, Inc., P.O. Box 2399, Appleton, WI 54913. Phone: 800–548–3424; Web site: *http://www.prestogeo.com*

SolGrid is available from SolPlastics, 1501 des Futailles St., Montreal, PQ, Canada H1N3P. Phone: 888–765–7527; Web site: *http://www.solplastics.com*

Appendix B provides an installation guide for these products.

Matting—Matting is another method of wear-and-carry trail hardening. Metal matting was used extensively during World War II to reinforce soft soils during airport construction on tropical islands and at remote sites in Alaska. Some of those installations are still in place. The military stopped stocking metal matting in the 1950s and it is no longer manufactured. Its availability as a surplus material is very poor; therefore, it is not considered a viable material for trail hardening.

Matting available in the commercial market today is typically plastic decking or industrial antifatigue matting made from PVC or rubber. Plastic decking costs too much for trail hardening and is not discussed further. Rubber and PVC matting are somewhat more cost effective and are readily available. In contrast to the rigid porous pavement systems, matting is generally thinner and more flexible. It drapes across the terrain and provides an excellent wear surface, but has a limited ability to transfer lateral loads.

PVC Matting—Safety Deck was a commercially available PVC mat tested in the Wrangell-St. Elias mitigation study. Safety Deck is a high-density, semirigid, open-grid PVC mat that is ¾-inch thick. It was supplied in 20-inch-square tiles that were laced together with parachute cord (figure 25). Safety Deck was installed on moderately impacted trail surfaces so the need to transfer lateral loads wasn't too extreme. In this less demanding condition, Safety Deck provided an excellent surface for all forms of use. However, it was expensive to procure and time consuming to install. Safety Deck had good vegetation regrowth values with an increase from 69 to 91 percent mean cover over the 4-year study period.

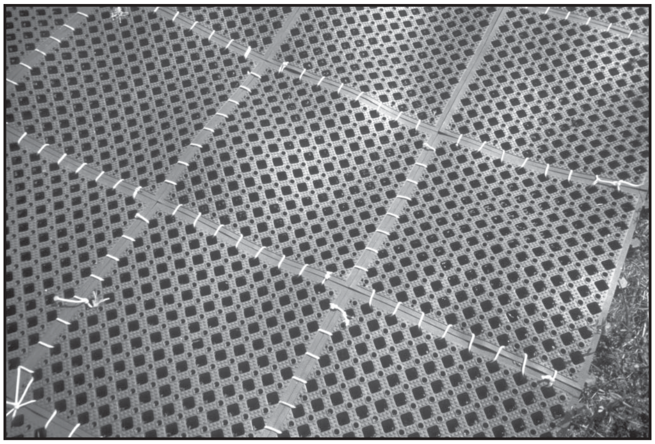


Figure 25—Safety Deck installed across a tundra surface in Wrangell-St. Elias National Park and Preserve in Alaska. Individual 20- by 20-inch tiles were lashed together with parachute cord and fishnet line. This time-consuming task drove up installation costs. The material performed very well on moderately degraded trails and provided an excellent surface for most uses.

Safety Deck was the most expensive material tested in the Wrangell-St. Elias study. Costs were $7.50 per square foot, including shipping. Forty-three labor hours were required to install a 100-foot-long, 6-foot-wide section of trail, for a total cost of $5,274 per 100 feet.

Appendix A shows the positive attributes of PVC Safety Deck. Although Safety Deck is a strong performer for moderately impacted sites, its high cost limits its use for most OHV trail-hardening applications. It may have excellent application on foot or horse trails where the volume of material is much reduced, or in providing a surface for accessible trails where the costs might be better justified.

Safety Deck is no longer commercially available. It was originally purchased from The Mat Factory, Inc., of Costa Mesa, CA, phone: 800–628–7626. The company carries a similar product called Dundee Grass Retention & Erosion Control Mat. That product sells for about $5.33 per square foot. Other PVC matting products may also be available.

Rubber Matting—Rubber antifatigue matting is commonly available in discount and hardware supply stores. Rubber mats are typically available in 3- by 3-foot panels, are ¾-inch thick and have an interlocking system along their edge (figure 26).

Omni Grease-Proof Anti-fatigue Mat (manufactured by Akro Corp. of Canton, OH) and Anti-fatigue Mat (manufactured by Royal Floor Mats of South Gate, CA) were tested in a preliminary field trial in the spring of 2000 by the National Park Service and the Alaska Department of Fish and Game at the Palmer Hay Flats State Game Refuge. The mats protected the soil surface and conformed well to surface terrain, but provided

Figure 26—A section of rubber antifatigue mat undergoing preliminary field trials at the Palmer Hay Flats State Game Refuge in Alaska. The large panels install quickly, but the rubber's flexibility limits the panels' ability to transfer lateral loads.

no lateral load transfer. The wheel track was noticeably lower after 10 passes by an OHV on a silty substrate. The low rigidity of the rubber products and their inability to transfer load across the mat's surface limit their application for all but the lightest of impact areas.

A typical rubber mat sells for about $3.20 per square foot. Estimated installation time would be about 14 hours per 100 linear feet of 6-foot-wide trail.

Appendix A identifies a number of positive attributes of the rubber matting. Rubber matting is not suitable for trail-hardening applications on degraded trails because of its extremely low ability to transfer lateral load. Rubber matting would not prevent shear impacts on wet, finely textured soils. The material may have some limited applications before sites become degraded or could provide a temporary wear surface for special events.

Cost Comparisons for Trail-Hardening Techniques—Table 7 compares installation materials and labor costs for the trail-hardening methods discussed. The costs and hours of labor were developed for data in the Wrangell-St. Elias OHV mitigation study and other Park Service projects. These figures are rough estimates to assist in project scoping. Actual cost and the hours of labor depend on site conditions, logistics, and project design.

The test installations were small scale. Larger projects would benefit from volume discounts on materials and labor efficiencies. This is especially true when considering shipping costs of raw materials. The unit cost of shipping large quantities of bulky materials, such as the porous pavement products, can be much less than the cost of shipping small quantities.

Another important consideration is the cost of labor. The figures presented use an $18 per hour labor rate. This represents the cost of a typical government wage-grade seasonal maintenance worker in Alaska. The installation of trail-hardening materials is well suited for summer field crews, such as fire crews, Student Conservation Association crews, or volunteer crews. The work is relatively simple and doesn't require extensive use of power equipment. Fire crews filling in between fire calls or seeking early season training would be excellent sources of labor. The availability of cheaper labor could significantly reduce installation costs.

Table 7—Materials and labor costs of different trail-hardening methods.

Material	Cost per square foot ($)	Cost per 100 linear feet[1] ($)	Hours to install per 100 linear feet[1]	Labor costs per 100 linear feet[1] at $18 per hour	Installation cost per square foot ($)	Installation cost per 100 linear feet[1] ($)
Corduroy	1.00	600	25	450	1.75	1,050
Wood matrix	0.80	480	70	1,260	2.90	1,740
Onsite puncheon	0.83	500	24	432	1.55	932
Gravel/geotextile	2.25+[2]	1,350+[2]	45	810	3.60+[2]	2,160+[2]
GeoBlock, 1¼ inch	2.75	1,650	38	684	3.89	2,334
GeoBlock, 2 inch	3.50	2,100	40	720	4.70	2,820
SolGrid	2.25	1,350	40	720	3.45	2,070
PVC matting	7.50	4,500	43	774	8.79	5,274
Rubber matting	3.50	2,100	14	252	3.92	2,352

[1] Trails are 6 feet wide. [2] Depends on gravel source and haul distance.

Trail Closure

The final management option to be discussed is trail closure. As a last resort, resource managers may close a trail to protect threatened resources. This would halt direct trail impacts, but might not halt secondary impacts, such as erosion and sedimentation. A trail identified for closure needs to be assessed and stabilized or reclaimed as necessary.

Closing a trail is seldom popular with trail users. Before the action is taken, the proposed closure should be discussed at a public forum. Alternatives to the closure—such as reroute options, seasonal or type-of-use restrictions, controlled use, trail hardening, or other surface improvements—should be addressed and evaluated. Agency budgetary and workforce limitations that may restrict implementation of alternatives should be discussed. User groups may offer to accept some of the responsibility of maintaining or implementing necessary trail improvements to avoid losing access.

In the contiguous 48 States, user advocacy groups such as the American Motorcyclist Association and National Off-Highway Vehicle Conservation Council have often been able to help facilitate projects that protect trail access while assuring resource protection. These on-the-ground projects have rallied a large response from volunteer groups and individuals who develop a certain “ownership” of the trail resources they are working to protect. Often the energy generated by a resource conflict has been harnessed by land management agencies to generate support for work that has prevented trail closure.

Status of Research

Research on the response to trail degradation issues is badly needed in all four aspects of OHV management: education, evaluation, engineering, and enforcement. In Alaska, the National Park Service's Rivers, Trails, and Conservation Assistance (RTCA) program is involved in research on several aspects of the trail degradation issue, including documentation of trail conditions, development of prescriptions, and trail hardening. The RTCA, in cooperation with a number of agencies, is conducting research on the use of porous pavement systems and is interested in investigating new products as they become available.

The RTCA program is also actively seeking information from other OHV research efforts with the hope of adapting proven techniques to the Alaska environment. In addition to conducting new investigations, the RTCA program is documenting past trials, experiments, tests, and temporary fixes. A wealth of information is available from those who have worked in the field through the years. Unfortunately, there has been a limited forum to document that information, exchange ideas, and share experiences. One of the goals of the Alaska RTCA program is to create that forum by conducting research, documenting work on the ground, and distributing information.

Appendix C lists projects the Alaska RTCA program was involved with during 2000, 2001, and 2002. Information on those projects is available for review. The RTCA staff hopes that the project list will grow longer, project reports will flourish, and the information generated will improve management response to trail degradation. The RTCA program invites all interested parties to contribute to that process.

Summary

Management of degraded OHV trails presents a significant challenge to resource managers. Degraded trails are already a serious problem in many parts of the country, and the mileage of degraded trails increases year by year. The degradation is fueled by an increase in OHVs and the limited number of areas that can sustain increased levels of use. The Specialty Vehicle Institute of America is a national nonprofit trade association representing manufacturers of all-terrain vehicles. According to the institute, the ATV industry has experienced double-digit growth for the past 5 years (Yager 2000).

The increased use of OHVs to provide access to the backcountry is having a dramatic effect on many trail systems. This is especially true in Alaska and other States with sensitive trail environments.

Simple observation of backcountry trails provides somber testimony to the conflict that is arising from the use of these vehicles across permafrost, wet or steep terrain, or other sensitive areas. It is well documented that a few passes can begin a pattern of degradation that is difficult—if not impossible—to stop. Increasingly, environmental observers are voicing concern over the expansion of OHV impacts: extended trail systems, degraded trail surfaces, and braided trail sections. Recently, concerns about secondary impacts have been voiced. These impacts include the effects of sediment on water quality, destruction of fish habitat, and threats to irreplaceable archeological values.

Responding to these impacts requires understanding the sensitive nature of onsite resources, particularly the soil. It requires understanding the dynamics of impact—how sites are affected and the patterns of degradation. It also requires the development of management components, such as documentation of baseline trail conditions and prescriptions for trail stabilization and recovery. Most importantly, it requires the development of alternative management options, such as trail rerouting, seasonal or type-of-use restrictions, use limitations, trail hardening, and trail closure.

This document provides an introduction to these topics. In college terms, it is ‘Degraded Trails 101.’ Unfortunately, there is no ‘Degraded Trails 102’ that answers all of the questions and solves all of the problems. At best, this document will stimulate resource managers who are struggling to respond to this issue in their own areas of responsibility. At worst, it will document some of the challenges faced by their contemporaries. In either case, the information is provided in the hope that it contributes to resolving the problems of trail degradation.

The author would appreciate receiving information from fellow trail managers on their experiences with managing degraded trails. Please send comments on management elements described in this document and descriptions of your field experiences—your successes and failures. Your contributions will bring us a little closer to developing a set of best management practices for OHVs that protect environmental values and access for OHV users.

The final photo (figure 27) shows Park Service geologist Danny Rosenkrans standing at the beginning of a 40-foot test installation of 2-inch GeoBlock installed in 1996 on the Reeve Field Trail in the Wrangell-St. Elias National Park and Preserve. The trail is unprotected in front of the installation and beyond it. The hardened trail section is supporting more than 90-percent vegetation cover with no detrimental impacts to the sensitive permafrost soils at the site. This is impressive, considering that the protected trail section had just received heavy OHV use. Unprotected sites farther down the trail were impassable. While all attempts to harden trails will not be as successful as this one, the photo clearly documents that options are available to address the problems of trail degradation.

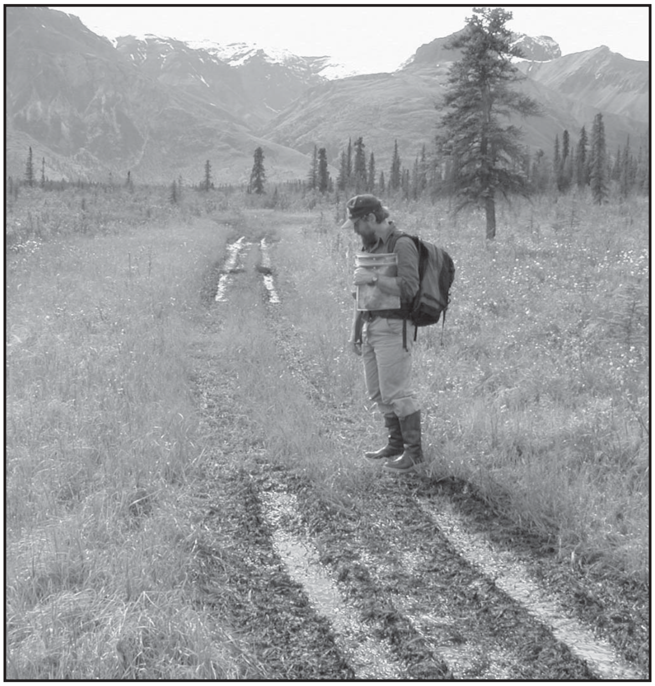


Figure 27—A hardened, protected section of trail 4 years after installation.

Recommendations

The following list of recommendations for research, funding, and interagency coordination would advance the responses to trail degradation.

Research

- ➢ Conduct watershedwide trail system evaluations on representative areas to develop demonstrations of management approaches to trail degradation issues.
- ➢ Conduct large-scale installation tests of selected trail-hardening methods to develop efficient installation methods and strategies to reduce costs.
- ➢ Conduct additional tests of trail-hardening materials to explore uses of new products or adapt existing products to new uses.
- ➢ Conduct tests on the use of sheet drains in soil surface capping applications.
- ➢ Test the use of trail-hardening materials on slopes.
- ➢ Develop methods of constructing shallow-water fords and low-cost bridges.
- ➢ Conduct change-detection mapping at selected sites, using historic aerial photography to document the pattern of trail development and impacts over time.
- ➢ Conduct a wetland impact study to document species composition changes with impact and recovery rates and patterns.
- ➢ Develop relocation case sites where trails could be relocated from sensitive to more resilient sites.
- ➢ Investigate offsite and secondary impacts of degraded trails.
- ➢ Document the number of OHV vehicles purchased and used in each State, the patterns of use, and present and future socioeconomic effects.

Funding

- ➢ Develop funding sources to sponsor research and test installations.
- ➢ Identify grant programs, including Federal, recreation, and transportation programs.
- ➢ Develop volunteer labor pools to assist with installations.
- ➢ Explore section 404 of the Clean Water Act as a possible revenue source for wetlands mitigation.

Interagency Coordination

- ➢ Conduct statewide workshops on trail management.
- ➢ Develop work groups including representatives of Federal, State, and local governments and OHV users to address OHV impacts.
- ➢ Establish networks of interested parties.
- ➢ Establish Web sites to host trail-related ‘Technical Notes.’
- ➢ Increase coordination among Federal and State agencies involved in trail management.

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Appendix A—Subjective Evaluation of Off-Highway Vehicle Trail Treatment Options for Alaska

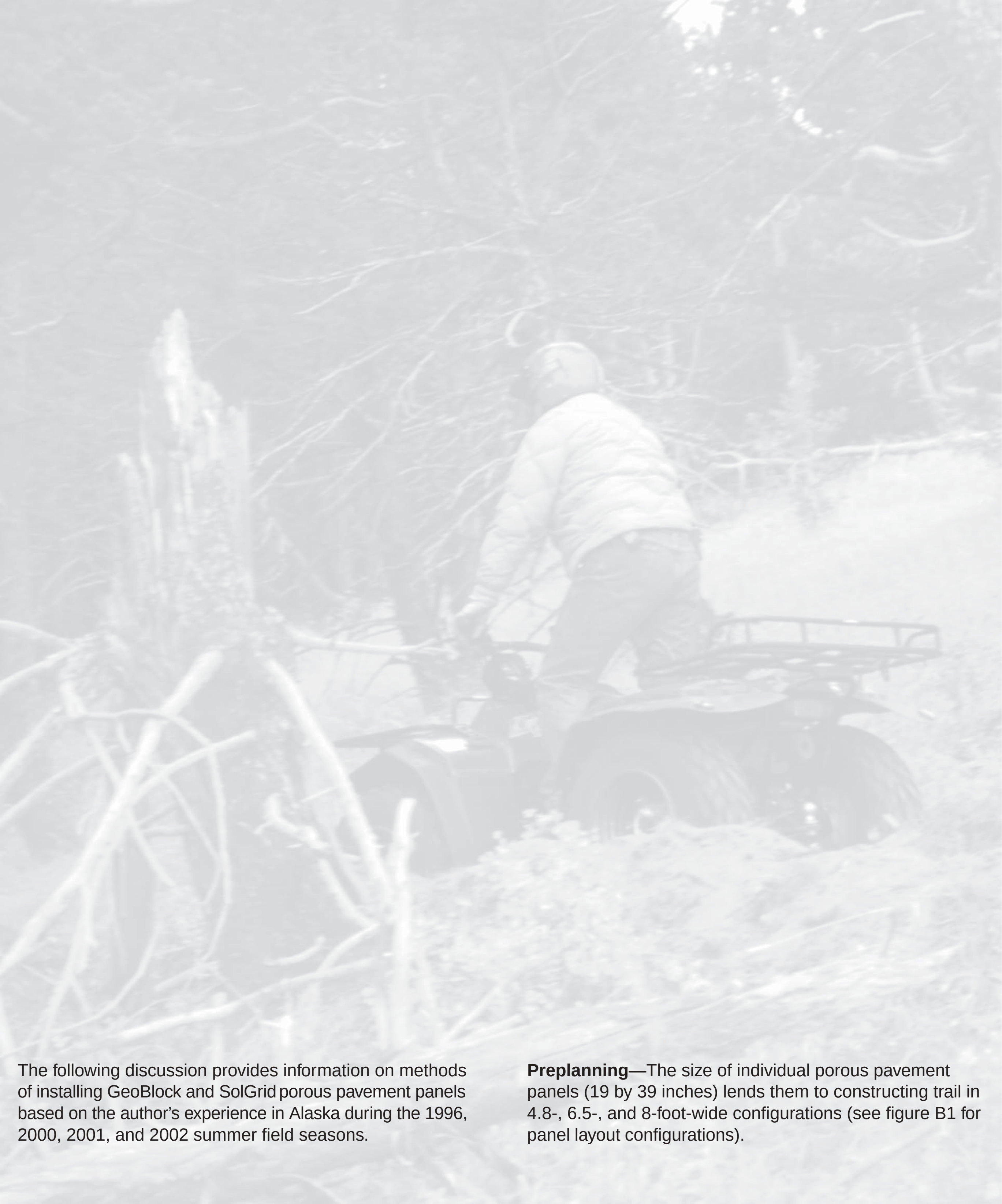
Evaluation factors	Polynet/ Pyramat	Wood matrix	1¼- and 2-inch GeoBlock	SolGrid	PVC mat	Rubber matting	Woven corduroy	Onsite material-puncheon	Gravel/ geo-textile	GeoWeb
Ability to stabilize trail degradation	Fair	Good	Very good	Good	Very good	Poor	Excellent	Very good	Good	Good
Ability to promote trail regeneration	Fair	Good	Very good	Very good	Good	Poor	Poor	Fair	Very poor	Very poor
Suitability for vegetation regrowth	Fair	Good	Very good	Very good	Fair	Fair	Poor	Poor	Very poor	Very poor
General quality of traffic surface:										
• For OHV use	Fair	Fair	Good	Good	Excellent	Excellent	Good	Good	Good	Good
• For foot traffic	Poor	Poor	Fair	Fair	Excellent	Excellent	Fair	Good	Good	Good
• For heavy track vehicles	Poor	Good	Fair	Fair	Good	Good	Fair	Very poor	Good	Good
• For horses along trail	Poor	Very poor	Poor	Poor	Good	Good	Poor	Very poor	Good	Good
• For large wildlife crossing	Fair	Very poor	Fair	Fair	Good	Good	Fair	Very poor	Good	Good
Slipperiness of surface when wet	Fair	Good	Good	Good	Good	Good	Fair	Fair	Good	Good
Ability to provide level surface	Poor	Good	Good	Fair	Fair	Fair	Good	Good	Good	Good
Ability to conform to terrain	Fair	Poor	Fair	Very good	Excellent	Excellent	Good	Good	Good	Good
Suitability for installation on slopes	Fair	Good	Fair	Excellent	Excellent	Good	Fair	Fair	Fair-Poor	Poor
Ability to facilitate trail curves	Poor	Poor	Good	Good	Very good	Good	Very poor	Good	Fair	Poor
Ability to install over center hump	Good	Good	Fair	Good	Good	Good	Fair	Good	Good	Good
Ease of installation	Poor	Very poor	Good	Excellent	Fair	Very Good	Poor	Good	Fair	Poor
Ease of installation over existing vegetation	Poor	Good	Good	Good	Fair	Fair	Good	Good	Fair	Poor
Ease of transport to installation site	Excellent	Poor	Good	Good	Fair	Fair	Poor	Excellent	Fair-poor	Fair-poor
Weight of material/surface area	Low	Heavy	Low	Low	Low	Low	Heavy	Heavy	Heavy	Heavy
Susceptibility to displacement	High	Low	Low	Low	Low	Low	Low	Low	Low	Very low
Natural appearance	Poor	Fair	Fair	Fair	Fair	Fair	Good	Good	Fair	Fair
General esthetics of installation	Poor	Fair	Good	Good	Good	Good	Good	Good	Fair	Fair
Visual "contrast" on installation	Moderate	Moderate	Moderate	Moderate	High	High	Mod	High	High	high
Visual "contrast" after revegetation	Good	Good	Good	Good	Fair	Fair	High	High	High	High
Public perception	Poor	Poor	Fair	Fair	Good	Good	Good	Good	Good	Good

continued —>

Appendix A—Subjective Evaluation of Off-Highway Vehicle Trail Treatment Options for Alaska

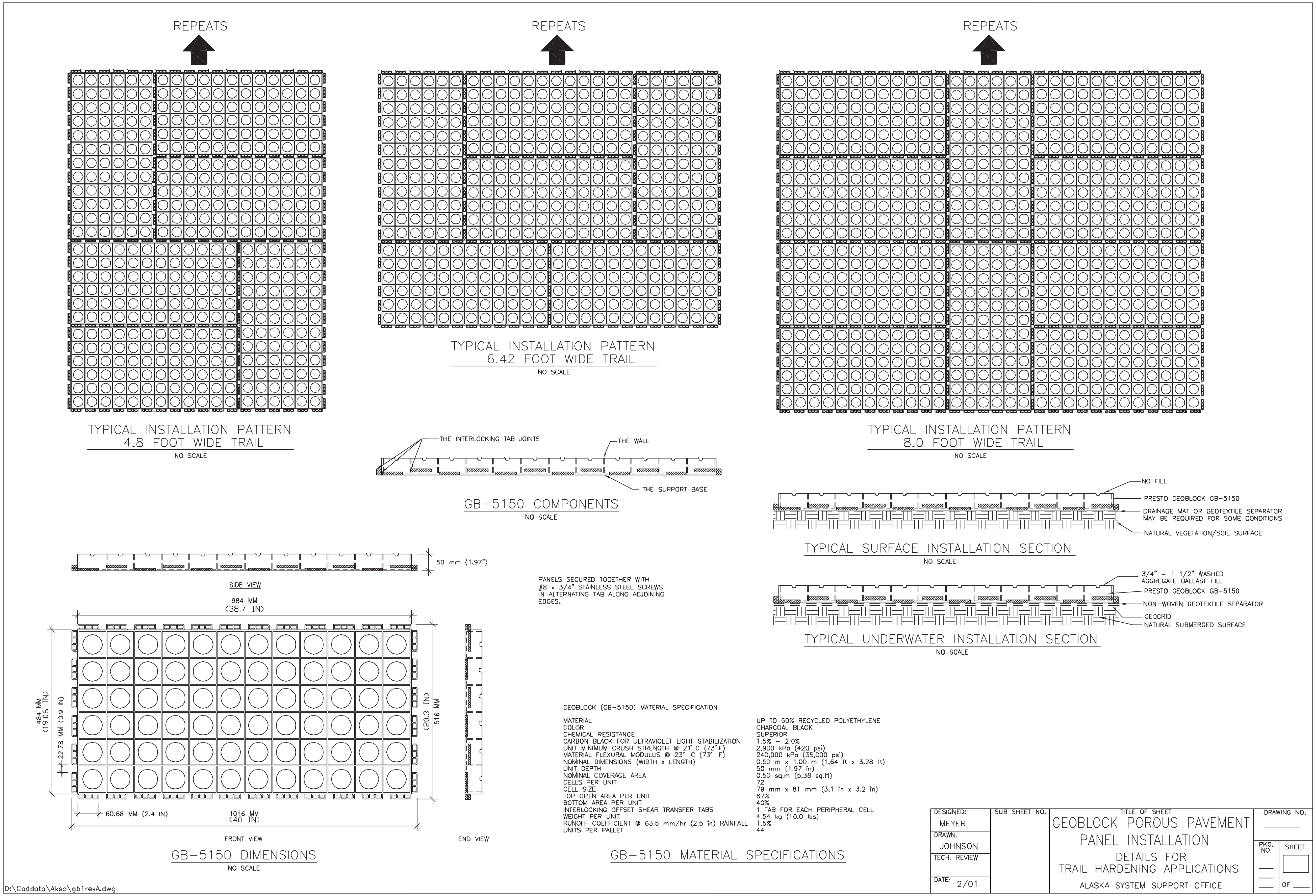
Evaluation factors	Polynet/ Pyramat	Wood matrix	1¼- and 2-inch GeoBlock	SolGrid	PVC mat	Rubber matting	Woven corduroy	Onsite material- puncheon	Gravel/ geo- textile	GeoWeb
Negative effect on permafrost	None	None	None	None	None	None	None	None	None	None
Suitability for under-water application	Poor	Poor	Good	Poor	Fair	Poor	Poor	Fair	Fair	Poor
Longevity of product	Fair	Poor	Good	Good	Good	Good	Fair	Fair	Good	Good
Strength of material	Poor	Fair	Excellent	Excellent	Excellent	Fair	Good	Good	Fair	Good
Transfer of lateral load	Poor	Excellent	Very good	Poor	Fair	Poor	Good	Excellent	Good	Good
Maintenance requirements	High	High	Low	Low	Low	Medium	Medium	Medium	Medium	Low
“Environmental” cost of material	Low	Low	Low	Low	Low	Low	High	Low	Low	Low
Installation labor time	High	High	Low	Very low	High	Low	Medium	Low	High	High
Cost of material	Low	Low	Medium-high	Medium	High	Low	Low	Low	Medium-high	Medium-high
Suitable for use: L-M-H impacted areas	Light	Heavy	Heavy	Moderate	Moderate	Light	Heavy	Heavy	Heavy	Heavy
Overall suitability for use	Poor	Poor	Very good	Good	Good	Poor	Conditional	Site dependent	Good	Conditional

Appendix B—Installation Guide for Porous Pavement Panels as Trail-Hardening Materials for Off-Highway Vehicle Trails



The following discussion provides information on methods of installing GeoBlock and SolGrid porous pavement panels based on the author's experience in Alaska during the 1996, 2000, 2001, and 2002 summer field seasons.

Preplanning—The size of individual porous pavement panels (19 by 39 inches) lends them to constructing trail in 4.8-, 6.5-, and 8-foot-wide configurations (see figure B1 for panel layout configurations).



GEOBLOCK (GB-5150) MATERIAL SPECIFICATION

MATERIAL	UP TO 50% RECYCLED POLYETHYLENE
COLOR	CHARCOAL BLACK
CHEMICAL RESISTANCE	SUPERIOR
CARBON BLACK FOR ULTRAVIOLET LIGHT STABILIZATION	1.5% - 2.0%
UNIT MINIMUM CRUSH STRENGTH @ 21° C (73° F)	2,900 kPa (420 psi)
MATERIAL FLEXURAL MODULUS @ 23° C (73° F)	240,000 kPa (35,000 psi)
NOMINAL DIMENSIONS (WIDTH x LENGTH)	0.50 m x 1.00 m (1.64 ft x 3.28 ft)
UNIT DEPTH	50 mm (1.97 in)
NOMINAL COVERAGE AREA	0.50 sq.m (5.38 sq.ft)
CELLS PER UNIT	72
CELL SIZE	79 mm x 81 mm (3.1 in x 3.2 in)
TOP OPEN AREA PER UNIT	87%
BOTTOM AREA PER UNIT	40%
INTERLOCKING OFFSET SHEAR TRANSFER TABS	1 TAB FOR EACH PERIPHERAL CELL
WEIGHT PER UNIT	4.54 kg (10.0 lbs)
RUNOFF COEFFICIENT @ 63.5 mm/hr (2.5 in) RAINFALL	1.5%
UNITS PER PALLET	44

Figure B1—Typical panel layouts.

Table B1 provides information for ordering material, based on typical installation configurations.

Table B1—Material layout specifications. (All prices depend on volume and are subject to change.)

PANELS	Dollars per square foot	Dollars per panel	Square feet per panel	Panels per pallet	Square feet per pallet
GeoBlock, 2 inch	2.15	11.57	5.38	44	236.72
SolGrid	1.53	7.83	5.12	78	399.36

	Linear feet per pallet at 4.8 feet wide	Dollars per linear foot at 4.8 feet wide	Linear feet per pallet at 6.4 feet wide	Dollars per linear foot at 6.4 feet wide	Linear feet per pallet at 8 feet wide	Dollars per linear foot at 8 feet wide
GeoBlock, 2 inch	49.11	10.37	36.87	13.81	29.48	17.27
SolGrid	83.20	7.34	62.40	9.79	49.92	12.23

18 panels per 20 linear feet at 4.8 feet wide • 24 panels per 19 linear feet at 6.4 feet wide • 30 panels per 19 linear feet at 8 feet wide

UNDERLAYMENT	Dollars per square foot	Dollars per roll	Roll size in feet	Linear feet per roll, 4.8 feet wide	Linear feet per roll, 6.4 feet wide	Linear feet per roll, 8 feet wide
Polynet PN-3000	0.32	1,527	14.4 x 300	600	600	450
Geogrid, Tensar 1100	0.25	540	13.1 x 164	328	328	164
Geogrid, Tensar 1200	0.40	854	13.1 x 164	328	328	164
Nonwoven geotextile 4545, 4-ounce	0.06	265	12.5 x 360	720	640	540
Nonwoven geotextile 4551, 6-ounce	0.08	360	15 x 300	600	560	500
Nonwoven geotextile 4553, 8-ounce	0.08	360	15 x 300	600	560	500

SCREWS	14 screws per linear foot for 4.8 feet wide 18 screws per linear foot for 6.4 feet wide 28 screws per linear foot for 8 feet wide
CABLE TIES	About 100 ties per 100 feet of trail
GRAVEL	Requires 1 cubic yard of gravel per 14 linear feet at 4.8 feet wide Requires 1 cubic yard of gravel per 10.5 linear feet at 6.4 feet wide Requires 1 cubic yard of gravel per 8.5 linear feet at 8 feet wide

A typical installation requires the following:

Supplies
- ¾- to 1-inch No. 8 or 10 Phillips-head screws, galvanized or stainless steel (No. 8, 1-inch truss-head screws are generally the least expensive.)
- Quik Drive screws (TRSD34S) 2,500 screws per box (for use with Quik Drive system)
- Zip ties, 11-inch, 120-pound test (Catamount L-11-120-0-C or equivalent)
- One ½-inch sheet of CDX plywood to help join panel sections (cut down to 24 inches wide and 1 foot longer than the installation width)
- ¾-inch CDX or all-weather plywood for joints (cut into 8-inch-wide strips the width of the installation)
- One 2 by 4 by 8 piece of lumber
- One 2 by 6 by 8 piece of lumber

Equipment
- At least two 400 cc or larger ATVs for transporting workers and equipment
- At least one flatbed or large-box ATV trailer for hauling panels
- At least one small-tub ATV trailer for hauling equipment and supplies
- Miscellaneous straps and tiedowns for trailers
- 5-gallon gas can
- Chain saw with chain oil and mix gas, or a portable circular saw for cutting panels
- Gas-powered weed trimmer with blade option
- Shovels, pulaskis, and rakes
- At least three portable drill drivers with extra battery packs (18 volts recommended)
- One Quik Drive automatic screw gun (modified No. PHD18R with head for ¾- to 1-inch screws)
- Utility knife
- Leatherman tool for clearing screw jams
- Tool belts, knee pads, drill holsters, and waterproof tool storage containers
- 100-meter tape measure, lath, flagging, marker pens
- First-aid kit, communications equipment, water, sunscreen, insect repellent, rain gear, and similar items

Labor
- Calculate 3 to 6 hours per 100 square feet for onsite installation. The actual time will depend on site conditions, logistics, and installation design.
- Ideal crew size, two to four teams of three; one supervisor, one runner

Here is an example of the supplies and labor needed for a 4,800-square-foot installation, 6.5 feet wide by 800 feet long:

- About 850 GeoBlock panels
- About 140 SolGrid panels
- Four boxes of Quik Drive screws (TRSD34S, 2,500 screws per box)
- 2,000 screws
- 1,500 zip ties Catamount, L-11-120-0-C
- 5 days labor with an eight-person crew

Supplemental geotextiles and membranes are required in some locations to increase the flotation of installations in extremely muddy conditions, to support installations over long expanses of weak ground, or to help contain fill material. Table B2 lists the most commonly used materials and their purpose.

Table B2—Supplemental geotextiles and membranes.

Type of material	**Application**
Open-cell drainage mat	Reduces size of openings, increases flotation on extremely muddy sites
Nonwoven separation fabric	Eliminates openings, provides separation layer when filling cells
Geogrid	Provides lateral support of panels across ponded areas

The author has used Polynet PN-3000 (or equivalent) as a suitable open-cell drainage mat. It decreases the size of openings to less than ¼ inch and also reduces the total opening by roughly 30 percent. This increases the flotation of the panels on extremely muddy sites and still allows for vegetation regrowth. A nonwoven separation fabric in an 8-ounce material weight can be used to completely eliminate openings when flotation needs to be maximized. Nonwoven fabric delays vegetation regrowth unless cells are filled with a growth medium. Vegetation regrowth helps anchor and stabilize the installation, integrate it into the environment, and improve site productivity. Tensar BX 1100 (or equivalent) has been used as a geogrid underlayment for installations longer than 100 feet in ponded areas. The geogrid provides a lateral membrane that helps prevent joint failure. Because the panels are neutrally buoyant and will float just below the surface in pooled areas, they should be filled with aggregate as a ballast when the trail crosses long ponded sections. A separation fabric should be used to contain the ballast gravel within the cells. In many cases, cells do not have to be filled because the grid cell provides an adequate traffic surface for most applications. Fill can increase regrowth in some cases, help integrate the installation, and provide a buffer for thermal contraction and expansion of the panels. High-quality fill is not required because the cell walls carry the load. Any readily available growth medium can be used. Gravel fill may also be necessary where tracked vehicles or snow machines with cleats will operate on panel surfaces. The gravel will help protect the soft plastic grid cell walls from crushing and abrasion.

Site Preparation—New trail locations should be cleared of trees, shrubs, rocks, and large tree roots. Tussocks and thick clumps of grass should be sheared off at ground level. It is generally not necessary to strip the site to mineral soil because vegetation growth through the open cells is desirable. For existing trails, the surface should be leveled to the extent practicable and center humps between wheel tracks and along trail edges should be roughly level to the depth of wheel ruts. Potholes should be filled to the extent that is practical. The installations handle variations in terrain *along* the course of the trail better than *across* the trail. An undulating surface is okay, but there shouldn't be more than a 4-inch variation *across* the surface. The smoother and more nearly level the surface, the cleaner the installation will look and the better the panels will be able to transfer load from one to another. Simple handtools such as shovels and grubbing tools (such as pulaskis) can be used for site preparation. Small backhoes, bulldozers, and/or tillers and weed trimmers may have application at some sites.

Staging—After the pallets of panels have been delivered to the trailhead, they can be broken down and shuttled to the staging areas with ATVs and small ATV trailers. Using double-axle ATV trailers to haul larger loads will increase the efficiency of shuttle operations and minimize trail impacts between the trailhead and staging areas. Machines that are 400 cc or larger are recommended for these operations.

Staging areas should be located along the identified alignment every 500 feet or so. Trail conditions may require that the trail be hardened before heavy loads can be shuttled to distant staging areas. If so, only stage enough panels to construct trail to the next staging area. Stock the staging areas as the trail extends to them. The staging areas should be relatively level and large enough to accommodate stacked panels and assembly areas. An area 20 by 30 feet is usually adequate. If a helicopter will be used to carry the panels, be sure to site the staging areas with clear approaches and leave extra room for drop zones.

Subsection Assembly—It helps to assemble panels into subsections before installing them. Stack panels neatly to the outside of the trail corridor, leaving room to assemble subsections on the trail side of the staging area. With the GeoBlock panels *upside down* on a flat, level surface, assemble the panels (refer to figure B1 for the panel layout configurations). For a 4.8- or 6.5-foot-wide trail, six panels will form a subunit. For an 8-foot-wide trail, 10 panels will form a subunit. Assembling the panels upside down places the edge tabs closer to the surface, making it easier to screw the panels together.

Either screw the panels together using individual screws or use a automatic-feed screw gun. A Quik Drive No. PHD18R (figure B2) with Quik Drive $^3/_4$-inch TRSD34S screw strips has been used successfully in Alaska. The Quik Drive gun has limited capability to countersink screws, so the panels must be upside down when using this tool. The tool must be slightly modified to allow it to countersink an additional $^1/_8$ inch. To do this, grind off the small raised area on the base collar to increase the depth of drive. Screws should be driven through the center of the overlapping tabs between panels (figure B3). It is not usually necessary to place screws in every tab, but tabs should be fastened in adjacent pairs to pin the panels. At a minimum, a pair of tabs should be fastened on each side

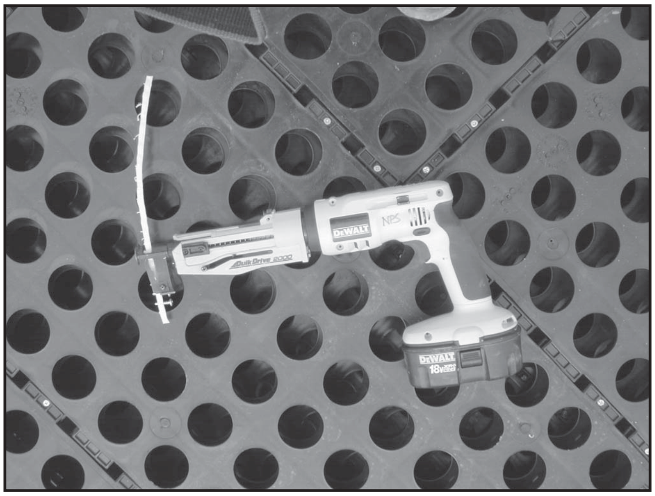


Figure B2—The Quik Drive automatic-feed screw gun speeds assembly of the panel subsections.

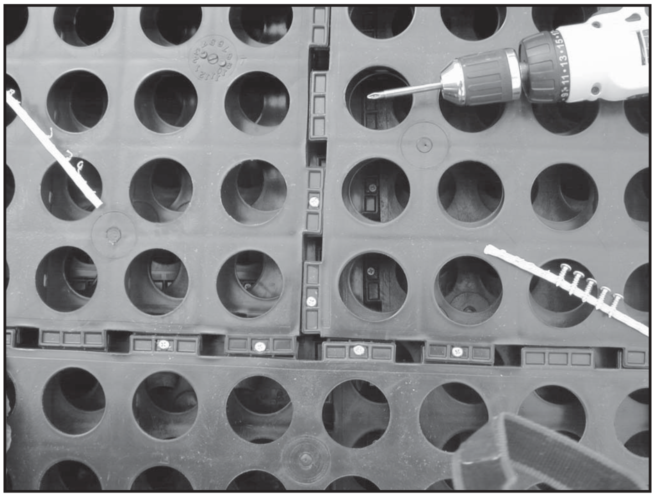


Figure B3—Illustration of the tab-fastening screw pattern at panel joints.

of a joint and along the outside edge. Along interior joints, screw a pair of tabs together along every 6 inches of the panel's length.

Subsections should be assembled on top of each other so that the underlying panels provide a pattern for consistent assembly and a smooth and level base for constructing subsections. Repeat the same panel pattern with each successive layer (figure B4).

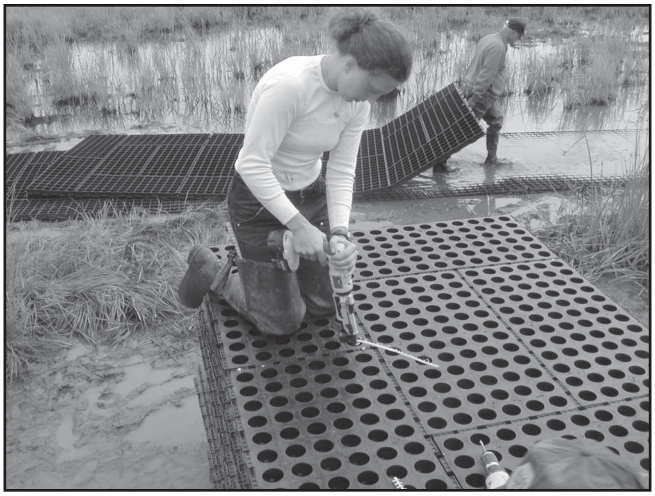


Figure B4—Assembling the subsections with the Quik Drive drill system. Using this tool and a standard 18-volt cordless drill, two people can assemble 32 six-panel subsections in 1½ hours. In the background, a worker drags a three-section assembly along an installed trail segment.

Three-Section Assembly—Once a good stock of subsections is stockpiled, they can be assembled into three-section units. On an adjacent smooth surface, join three or more of the subsections together. Leave them upside down and use the same screw pattern along the joint as in the subsection assembly. Make sure that the subsections are oriented so that the panel pattern repeats itself in the proper sequence. This should be automatic if the subsections are placed in the same orientation as they were constructed. Again, assemble the three-section units one section on top of another until all the available subsections have been assembled into full three-section units.

Expansion Sections—Because unfilled GeoBlock panels tend to expand and contract under changing temperatures (up to 12 inches per 100 feet were documented in Alaska with a temperature variation of –20 °F to 90 °F), expansion sections are required whenever installations longer than 40 feet are placed in an exposed location. This includes areas where the panels are to be placed directly on soil or vegetation that is not shaded by overhead vegetation, where the panels are not ballasted with gravel or filled with soil, and sites where vegetation regrowth cannot be expected to provide adequate shading during the first year of installation.

To construct the expansion sections, assemble sections of SolGrid panels the same width as the GeoBlock subsections. The SolGrid panels interconnect with a slot and tab joint system (figure B5). Carefully lay out the panels so all of the tabs are aligned along the leading and right edges. This will take a few minutes to work out. Carefully repeat the pattern with subsequent sections. Lock the joints together with screws by screwing through the panel sidewall in the cell between the tabs. Stockpile enough SolGrid subsections to place one between every three three-section GeoBlock units (about every 40 feet).

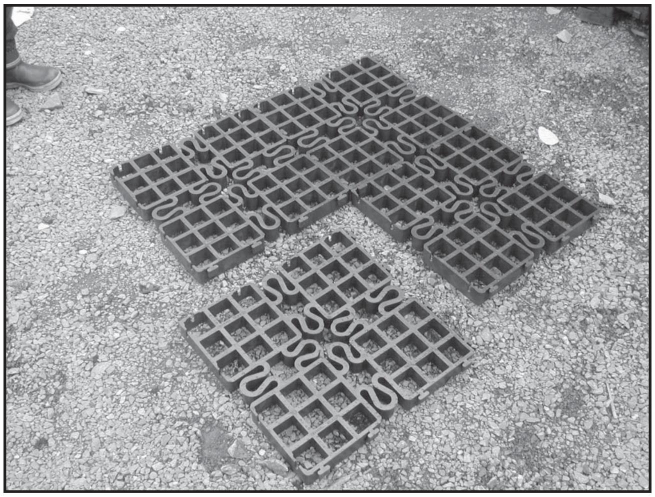


Figure B5—Two SolGrid panels. Note the slot and tab fasteners along the edges and the intergrated U-shaped expansion components.

Trail Panel Layout—Any required underlayment should be placed along the trail alignment before skidding the assembled panels into place. This may include a drainage net, nonwoven geotextile, and/or geogrid. Once those materials (if any) are in place, the assembled three-section units are flipped over and skidded into place. Temporarily place a 2-foot-wide piece of ½-inch CDX plywood at the joint to help the tabs along the joint match (figure B6). Starting at one edge, "zip" the tabs into place. One worker at the far end of the new section can assist by shifting the panel from one side to another and applying pressure as required.

Once the panels match, they are fastened together through the overlapping tabs from the top, using a standard cordless drill gun with a 2½-inch-long No. 2 Phillips bit (figure B7).

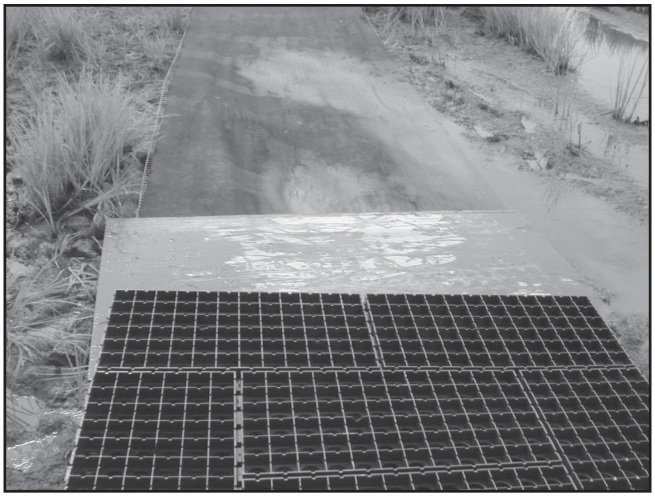


Figure B6—A ½-inch sheet of CDX plywood should be placed at section joints to provide a flat surface to help join the panels.

Figure B7—Joining the sections using a screw gun. Note the underlying plywood.

Additional assembled sections are then skidded into place and fastened. More screws and cable ties are used to reinforce panel joints along the outside edges and anywhere additional strain might be encountered, such as areas where the terrain is irregular. Cable ties are also used to connect panels to the underlying Polynet.

Expansion Joint Connections—Expansion joint sections are fitted between every three full GeoBlock sections. Because the SolGrid panels do not provide the same degree of load transfer as the GeoBlock panels, a geotextile underlayment such as Polynet or a geogrid should be placed beneath the expansion joint section extending 1 to 2 feet beneath the adjoining GeoBlock sections.

Trim the end tabs of the GeoBlock and SolGrid panels where the panel sections join. Butt the panel sections together and screw the panels together through the cell sidewalls. Screw from both sides to secure the joint. Use cable ties to further reinforce the joint.

An alternative expansion joint can be provided by leaving a 3- to 4-inch space between three-section assemblies. An 8- to 12-inch-wide piece of ¾-inch plywood can be attached under one panel edge and allowed to slide under the other panel if the gap needs to be reinforced.

Facilitating Curves—The size and configuration of the panels do not lend themselves to the construction of smooth radius curves. Curves must be facilitated with angular turns (figure B8). Fortunately, a wide range of angles can be constructed.

Angles are constructed by overlapping full three-section assemblies. The end edge tabs of the lower panel are trimmed off with a chain saw or other cutting tool. The overlying panel section is laid over the end of the first section and is carefully aligned in the new trail direction. A 2 by 4 is placed between the two panels to provide clearance for the saw blade, and the top panel is cut off parallel with the joint. A chain saw or other cutting tool can easily make the cut. Be careful not to cut into any screws! Eleven-inch-long, 120-pound-test zip ties (Catamount L-11-120-0-C or equivalent) are used to join the panel edges. Then place an 8-inch-wide strip of ¾-inch CDX plywood equally beneath each panel edge and screw through the base plate to further secure the joint (figure B9).

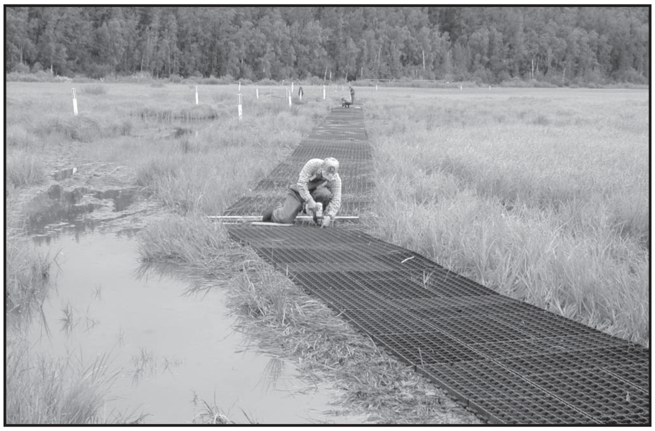


Figure B8—Angular cuts in the panel sections help form the turns in the trail.

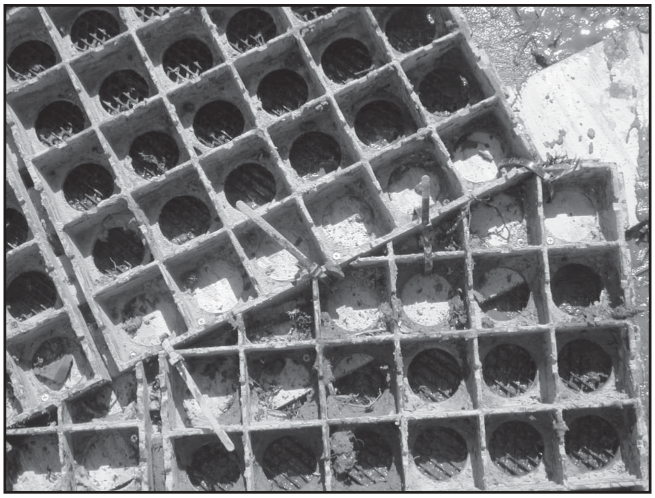


Figure B9—Corner joint showing cut, underlying plywood, and cable ties. Note the screws through the panel's plastic baseplate that secure the panels to the plywood.

Finish—Use cable ties to connect panels to underlying Polynet or geogrid geotextile about every 3 feet along both sides of the installation. Place fill in cells as available or specified. No other anchoring is required.

Maintenance and Monitoring—Inspect the installation on a regular basis during the first season of use and annually thereafter. Reinforce joints with screws and cable ties as necessary. If joints separate, place an 8-inch-wide strip of $^3\!/_4$-inch CDX plywood beneath them and secure with screws through the baseplate. If joints buckle and overlap, cut away the overlapping panel section and reattach it using cable ties, screws, and underlying plywood.

Material Sources

GeoBlock
Presto Products Co.
Geosystem Products
P.O. Box 2399
Appleton, WI 54913–2399
Phone: 800–548–3424 or 920–738–1118
Fax: 920–738–1222
E-mail: info@prestogeo.com
Web site: *http://www.prestogeo.com*

SolGrid
Sol Plastics, LP
1501 des Futailles Str.
Montreal, PQ, Canada HIN3P1
Phone: 888–SOL–PLAS or 514–254–8525
Fax: 514–254–6325
Web site: *http://www.solplastics.com*

Ecogrid
Pro-Seal Products, Inc.
16541 Redmond Way, Suite C
Redmond, WA 98052–4463
Phone: 800–349–7325
Fax: 425–821–1006
Web site: *http://www.prosealproducts.com*

Polynet and geogrid
Any geotextile supply business

Appendix C—National Park Service Rivers, Trails, and Conservation Assistance Program Cooperative Research on Trail Hardening for Degraded Trails in Alaska

Locations Undergoing Field Tests of Trail-Hardening Systems

Wrangell-St. Elias National Park and Preserve—Three 40-foot test plots installed in 1996 of: corduroy, wood matrix, 1¼- and 2-inch GeoBlock, PVC matting, and a combination of two drainage mats. Detailed monitoring on thermal effect, revegetation, cost, and structural performance. Final report available (Allen 2000).

Palmer Hay Flats State Game Refuge—Four 20-foot test plots of 6½-foot-wide GeoBlock in a variety of configurations along with one 20-foot test plot of SolGrid and one 20-foot test plot of Geoweb on a estuarine area that provides ATV access to a waterfowl hunting area. One 60-foot test plot of GeoBlock was installed as a shallow-water ford in the same location. Installed fall 2000. Ongoing monitoring.

Nine-hundred-foot installation of GeoBlock with a 600-foot shallow-water ford. Installed 2001. Contact refuge manager Colleen Matt, Alaska Department of Fish and Game (Phone: 907–267–2189).

Tongass National Forest, Sitka—Test of 100 feet of 2-inch GeoBlock and 100 feet of SolGrid on the Starrigavan Valley Recreation Area dedicated ATV trail system near Sitka, AK. Installed December 2000. Contact recreation planner Ann Marie LaPalme, Sitka Ranger District (Phone: 907–747–4209).

Tangle Lakes Archeological District—100-foot installation of 8-foot-wide GeoBlock and 100 feet of 8-foot-wide SolGrid on degraded OHV trails to protect cultural resources. Bureau of Land Management, Glenallen District. Installed August 2001. Contact John Jangala (Phone: 907–822–3217).

White Mountains National Recreation Area—200-foot test installation of 6½-foot-wide GeoBlock and SolGrid on an alpine OHV trail. Installed July 2001. Bureau of Land Management, Fairbanks, AK. Contact outdoor recreation planner Randy Goodwin (Phone: 907–474–2369).

General State lands, Homer, AK—300-foot installation of 4.8-foot-wide GeoBlock and SolGrid in test installation on degraded recreational OHV trails. Installed October 2001. Contact Homer Soil and Water Conservation District (Phone: 907–235–8177).

Glenallen District, Bureau of Land Management—1,000-foot demonstration installation of 8-foot-wide GeoBlock and Solgrid with partial gravel fill on degraded OHV trail segments along the Middle Fork trail, mile 169, Richardson Highway. Installed July 2002. Contact Rod Holbrook, trail coordinator, Glenallen District, Bureau of Land Management (Phone: 907–822–3217).

Kodiak, AK—700-foot installation of 6½-foot-wide GeoBlock on the Summit Lake trail. Installed August 2002. Contact Sam Christian, Kodiak Soil and Water Conservation District (Phone: 907–486–9451).

Nancy Lake State Recreation Area—65-foot installation of 6½-foot-wide GeoBlock on the multiuse Red Shirt Lake trail. Installed June 2002. Contact John Wilber (Phone: 907–495–6211).

General State lands, Homer, AK—Proposed 2½-mile, 6-foot-wide puncheon OHV trail for the Caribou Lake trail. Tentative installation date is summer 2003. Contact Lindsay Winkler, Homer Soil and Water Conservation District (Phone: 907–235–8177, ext. 5).

Appendix D—Metric Conversions

To convert from this unit	To this unit	Multiply by
inch	millimeter	25.4*
inch	centimeter	2.54*
foot	meter	0.3048*
yard	meter	0.9144*
mile	kilometer	1.6
millimeter	inch	0.039
centimeter	inch	0.394
centimeter	foot	0.0328
meter	foot	3.28
meter	yard	1.09
kilometer	mile	0.62
acre	hectare (square hectometer)	0.405
square kilometer	square mile	0.386*
hectare (square hectometer)	acre	2.47
ounce (avoirdupois)	gram	28.35
pound (avoirdupois)	kilogram	0.45
ton (2,000 pounds)	kilogram	907.18
ton (2,000 pounds)	megagram (metric ton)	0.9
gram	ounce (avoirdupois)	0.035
kilogram	pound (avoirdupois)	2.2
megagram	ton (2,000 pounds)	1.102
ounce (U.S. liquid)	milliliter	30
cup (inch-pound system)	milliliter	247
cup (inch-pound system)	liter	0.24
gallon (inch-pound system)	liter	3.8
quart (inch-pound system)	liter	0.95
pint (inch-pound system)	liter	0.47
milliliter	ounce (U.S. liquid)	0.034
liter	gallon	0.264
liter	quart	1.057
degrees Fahrenheit	degrees Celsius	(°F – 32) ÷ 1.8
degrees Celsius	degrees Fahrenheit	(°C x 1.8) + 32

**These items are exact conversion factors for the units—the others give approximate conversions.*

About the Author

Kevin G. Meyer is an environmental specialist/soil scientist for the National Park Service in Anchorage, AK. He earned a bachelor's degree in soil science from the University of Wisconsin-Madison in 1976 and a master's degree in forestry from Colorado State University in 1985. Meyer has been a working professional for the Department of the Interior in Alaska since 1977. He has churned through a multitude of muck holes in his quest to formulate effective management responses to degraded trail issues and is an avid promoter of research and development of best management practices for OHV trails.

About the National Park Service Rivers, Trails, and Conservation Assistance Program—The Rivers, Trails, and Conservation Assistance (RTCA) program is a branch of the National Park Service that helps State, local, and nonprofit organizations develop, protect, or enhance river and trail systems and open space in the United States. The program's work has helped local communities establish organizations for trail advocacy and planning, map trails to help establish dedicated easements, and develop community-led trail plans. The RTCA also provides technical assistance in trail design, construction, and maintenance. To locate a RTCA contact in your area, visit: *http://www.ncrc.nps.gov/programs/rtca/index.html*

Library Card

Meyer, Kevin G. 2002. Managing degraded off-highway vehicle trails in wet, unstable, and sensitive environments. Tech Rep. 0223-2821-MTDC. Missoula, MT: U.S. Department of Agriculture, Forest Service, Missoula Technology and Development Center. 48 p.

Describes techniques that have been used to manage off-highway vehicle trails in Alaska. The report explains why off-highway vehicle trails become degraded and suggests management options to prevent degradation. It also reports the results of tests comparing different options for hardening off-highway vehicle trails. Appendixes provide installation instructions for porous pavement panels and a list of locations where trail-hardening systems are being tested in cooperation with the National Park Service Rivers, Trails, and Conservation Assistance program.

Keywords: all-terrain vehicles, geogrid, geosynthetics, geotextiles, mechanized recreation, national parks, porous pavement panels, recreation management, soil additives, soil properties

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You can order a copy of this document using the order form on the FHWA's Recreational Trails Program Web site at: *http://www.fhwa.dot.gov/environment/trailpub.htm.* (Electronic copies may also be available at this site.) Fill out the order form and fax it to the distributor listed on the form. If you do not have Internet access, you can fax a request to 202–366–3409, or mail a request to:

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Washington, DC 20590

Forest Service and Bureau of Land Management employees may obtain additional copies from:

USDA FS, Missoula Technology and Development Center
5785 Hwy. 10 West
Missoula, MT 59808-9361
Phone: 406–329–3978
Fax: 406–329–3719
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For additional technical information, contact Kevin Meyer at:

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Anchorage, AK 99503
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