

**ALL-TERRAIN VEHICLE (ATV) TRAIL MITIGATION STUDY:
COMPARISON OF NATURAL AND GEOSYNTHETIC MATERIALS
FOR SURFACE HARDENING**

within

Wrangell-St. Elias National Park and Preserve, Alaska.

Wrangell-St. Elias National Park and Preserve Research and Resource Management Report

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Photo A. Trail braiding on ATV trails in Wrangell-St. Elias National Park and Preserve.



Photos B and C. Thermokarst ponding and bog formation resulting from excessive ATV use on trails with permafrost.

EXECUTIVE SUMMARY

Purpose of Study

Studies have documented the potential and existing environmental degradation due to all-terrain vehicle (ATV) use in sub-arctic terrain (Sparrow, Wooding and Whiting 1978, Ahlstrand and Racine 1990, Cook 1990a and 1990b, Happe, Shea and Loya 1998). Impacts include vegetation damage or destruction, changes in vegetation community composition and structure, substrate thermal change and permafrost thaw, and soil erosion and subsequent development of thermokarst features and terrain degradation (Slaughter et al. 1990). One of the most evident effects of prolonged ATV use in sub-arctic and arctic tundra is the development of extensive trail braiding (Photo A). Trail braiding results from alternate trails that are created by users in order to avoid mud bogs and standing water (ponding) that develop on ATV trails which are underlain by ice ridge permafrost (Photos B and C).

One option for mitigating the effects of ATVs is to use surface hardening materials to stabilize trail degradation on ATV trails. This study tests the practicality, effectiveness and feasibility of several geosynthetic and natural trail hardening materials in sub-arctic environments in Wrangell-St. Elias National Park and Preserve, Alaska. This report documents the results of the mitigation phase of a Natural Resource Preservation Program (NRPP) funded study: the Assessment and Mitigation of ATV Impacts Project within Wrangell-St. Elias National Park and Preserve (Happe 1994).

This study test natural and geosynthetic materials for their ability to mitigate impacts on all-terrain vehicle (ATV) trails in mixed shrub-sedge tussock vegetation communities underlain by permafrost. In 1996, six hardening materials were installed in test sections (6' x 40' per material) in four study sites in the Nabesna District of Wrangell-St. Elias NP/P. Experimental hardening materials included 1) Corduroy; 2) Wood Matrix (frame of 2"x4"s); 3) Geoblock® 2"; 4) Geoblock® 1 1/4"; 5) Safety Deck® and 6) Polynet PN-3000/Pyramat™. Floatation and separation geosynthetics were used under the hardening materials. Untreated trail control plots and unaffected (non-trail) control plots were also established at each site to use as a comparison.

The hardening materials were compared in terms of the material, installation costs, and maintenance needs. Soil characteristics were compared among heavily impacted, moderately impacted and unaffected test sites. Soil thaw depths, subsidence depths and soil temperatures were monitored the first two years after installation, to measure trail stabilization in terms of thermal regime. Vegetation and ground cover were measured pre-installation, one year after, and four years after installation, to determine the change in vegetation cover and composition among the different material types and control plots.

Study Results

Of the six materials tested, Polynet PN-3000/Pyramat™ had the lowest cost in terms of materials, shipping and labor in 1996, followed by Corduroy. The costs per linear foot of material calculated in 1996 are shown in the Table A. However, the costs of materials have changed since the initial purchase date, updated prices can be determined by contacting the product distributors (available in Appendix D). In addition, changes to the Geoblock® product now allow for easier installation, which could reduce the costs in labor. Safety Deck® and Geoblock® 1 1/4" are no longer produced. An overview and photo of each material type is provided in the Summary of Materials section below.

Table A. The 1996 costs per linear foot (6' width) of trail hardening material and installation are shown below. Labor costs were estimated from the actual number of labor hours required for prep and installation multiplied by the average wage of one WG-7 and two WG-5 (\$18.00/hr) in 1996. Additional Materials includes the cost of rebar, anchoring devices and underlayment separation materials.

Hardening Material	1996 Cost Per Linear Foot of Material (6' width)				
	Transportation Helicopter Sling	Labor	Materials & Shipping	Additional Materials	TOTAL
Corduroy	\$7.00	\$11.00	\$5.80	\$3.30	\$27
Wood Matrix	\$10.00	\$19.50	\$4.80	\$3.50	\$38
Geoblock® 2"	\$4.00	\$14.00	\$27.00	\$3.30	\$48
Geoblock® 1 ¼"	\$4.00	\$13.50	\$18.80	\$3.30	\$40
Safety Deck®	\$7.00	\$14.50	\$43.70	\$2.60	\$68
Polynet PN-3000 /Pyramat™	\$4.00	\$11.00	\$8.40	\$1.00	\$24

Trail stabilization was measured in terms of the level of ponding, changes to the thermal regime and subsidence depths. Soil compaction and churning by ATV's can result in decreased water holding capacity of the soil and disrupted drainage. Over time as the thaw depth increases, subsidence increases leading to trail rutting, surrounding areas drain into the trail ruts and ponding occurs. Over four years the hardening material test plots generally had unchanged or reduced ponding, while the untreated plots had increased ponding.

During the two years that soil thaw depths were monitored, the thaw rates did not change significantly (reduce or increase) for most of the test plots, including the untreated controls. There was a general increase in thaw rates and a significant increase in maximum thaw depths between 1996 and 1997 for all of the plots, including the unaffected control plots. This was probably due to annual temperature variations or an unintended affect from the bi-monthly monitoring. The researchers recognize that two years probably does not allow for changes in the thermal regime to take affect and that longer periods of monitoring are recommended.

All of the materials provided a certain level of re-vegetation, which provides soil insulation and stabilization. Between 1996 and 2000 there was an increase in average total vegetation cover for all of the treatment plots, including the control plots (shown in Figure A). By 2000, most of the hardened study plots had vegetation cover comparable to the Unaffected Control Plots, although species composition still remained different. At all three sites, the unprotected Heavy Control plots still had significantly lower vegetation cover than the Unaffected areas. Geoblock ® 2" had the greatest increase in vegetation cover, while Polynet/Pyramat and Corduroy had the lowest increase. Cotton grass (*Eriophorum* spp.) was the most common species of vegetation to increase for most of the sites.

One problem developed from the project study design which probably influenced the increase in vegetation cover at two of the sites. The hardening material test plots were installed in 12 m (40 ft) lengths, with non-protected trail sections between the test plots. These non-protected areas and the heavy and moderate control plots degraded and resulted in impassible trails for ATVs and hikers. Between 1998 and 2000, alternate trails were developed by users to avoid mud bogs that formed in between the study plots. However, the increase in vegetation was evident at the Reeve Field site, which had continuous ATV use throughout the study and had periods of heavy ATV use during 1999 and 2000. Although the abandonment of the study site trail segments influenced some of the study results, it demonstrated the need to install materials in lengths that span the impacted areas.

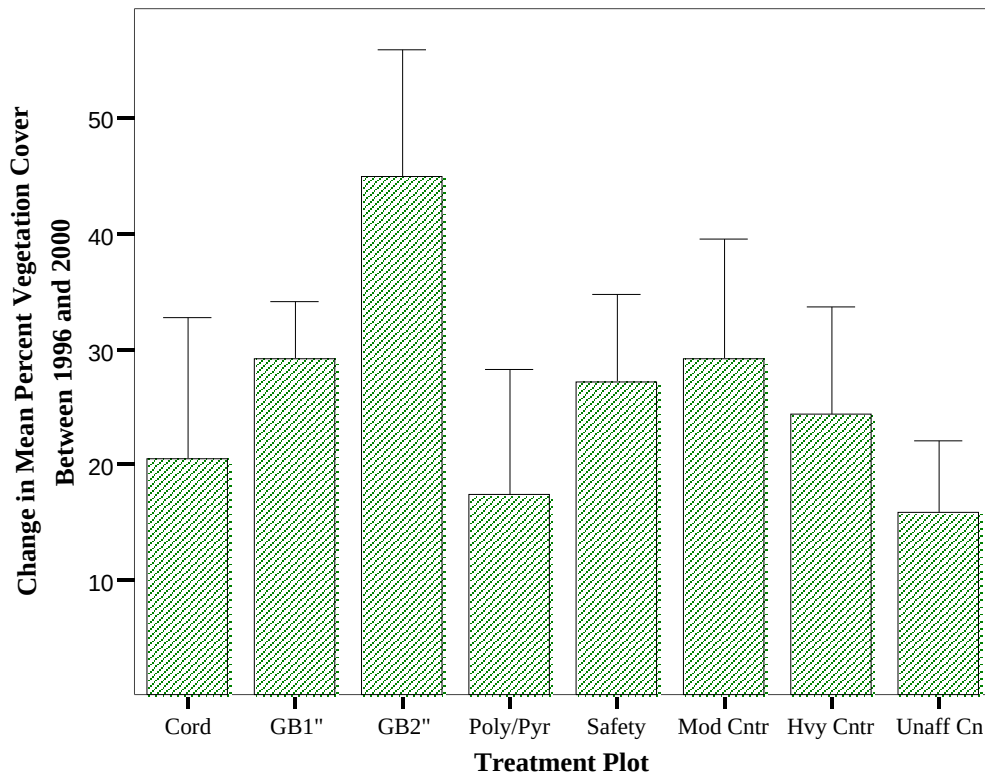


Figure A. The average change in total percent vegetation cover for each plot type between 1996 and 2000. Averaged over the three study sites, excluding Tanada Lake site because vegetation was not measured in 2000. Wood Matrix is not shown, because this material was removed in 1997. A positive bar indicates the vegetation cover increased. Treatment plot acronyms used in the graph are: Cord = Corduroy, GB2''= Geoblock® 2'', GB1'' = Geoblock® 1 ¼'', Poly/Pyr = Polynet/Pyramat, Safety = Safety Deck®, Mod Cntr = Moderate Control, Hvy Cntr = Heavy Control, and Unaff Cn = Unaffected Control.

Summary of Material Types

Corduroy

Corduroy worked well in terms of trail stabilization and support for all-terrain vehicle use. Corduroy did not re-vegetate as well as other materials, but the logs may contribute to soil insulation similar to vegetation. In this study, corduroy was constructed using nylon rope to weave the logs together (Figure B). In areas of heavy ponding (standing water), the corduroy floated over the water and presented unstable walking conditions. The material costs and labor costs for corduroy were low in this study. The labor crew considered this material the easiest to install: leveling of the trail was only necessary at one of four sites for installation and the materials were pre-cut, limbed, measured and packaged as part of the original purchase cost of the material. The purchase of pre-cut and prepared logs significantly reduced the labor time in the field normally associated with using raw on site materials. However, after four years, the logs have begun to show signs of weathering and rot at all of the sites. Therefore, the longevity of this material appears shorter than the geosynthetics. This material provides a good, but short term option for trail stabilization.



Figure B. Woven Corduroy tested for ATV trail mitigation in Wrangell-St. Elias National Park and Preserve.

Geoblock®

Both Geoblock® 1 ¼" and 2" (Figure C) provided good trail stabilization, riding surface and re-vegetation potential. The initial purchase of the materials was expensive, and was somewhat labor intensive to install. The material is fairly rigid and does not conform to the terrain readily. Therefore, excavation and leveling was required at sites with uneven terrain and extensive thermokarst features. However, this material provided excellent stability and appears to be more durable than Corduroy or Polynet/Pyramat. The current dimensions and specifications of the Geoblock® 2" allow for easier installation than the material that was used in 1996. Except for the initial cost, this material provides a good option for long term trail hardening.

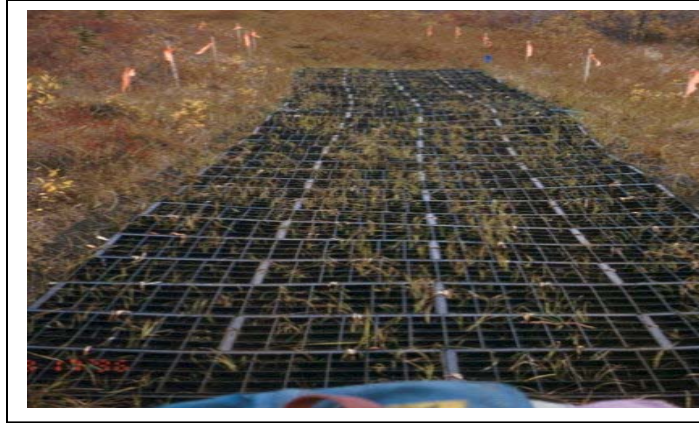


Figure C. Geoblock® material tested for ATV trail mitigation in Wrangell-St. Elias National Park and Preserve

Polynet PN-3000/Pyramat™

Polynet PN-3000/Pyramat™ (Figure D) had the lowest cost for materials, conformed well to the terrain and required minimal trail leveling to install. It provided moderate trail stabilization if re-vegetation occurred. However, it had a low rating in terms of ability to support ATV use, maintenance and safety. Due to its flexibility and light weight, the material had a tendency to bunch up and catch under ATVs, even when anchored with rebar and duckbills (a j-hooked anchoring device held by cables). In areas underlain with permafrost, the anchoring materials frequently frost jacked and caused trail hazards. These materials work well as an underlaying drainage or flotation material, but does not provide a suitable trail surface when used separately.



Figure D. Polynet PN-3000/Pyramat™ tested for ATV trail mitigation in Wrangell-St. Elias National Park and Preserve

Safety Deck®

Safety Deck® (Figure E) was the most expensive material to purchase initially and was fairly labor intensive to install because the 19 ¾" x 19 ¾" size tiles were woven together both lengthwise and crosswise with nylon parachute cord. Safety Deck® material conformed well to uneven terrain and required minimal site preparation for installation. The material provided an excellent riding and walking surface, stabilized trail degradation and allowed for vegetation regeneration. It was the most popular material among surveyed trail users. Unfortunately this material is no longer available.



Figure E. Safety Deck® material tested for ATV trail mitigation in Wrangell-St. Elias National Park and Preserve.

Wood Matrix

Wood matrix (Figure F) had the poorest performance in terms of labor costs, maintenance and safety. The construction from raw materials was time consuming, and the green, untreated lumber showed signs of wear within the first year (broken joints and rot). Concern was voiced by users that the 8" x 8" open grid presented a risk of entrapping the hooves of wildlife and horses. The material did provide a stable, although rough, ride and supported vegetation re-growth within the first year.



Figure F. Wood Matrix material tested for ATV trail mitigation in Wrangell-St. Elias National Park and Preserve.

Recommendations

Evidence from this study and others has shown that trails in mixed shrub-sedge tussock vegetation do not readily support ATV use, due to thermokarsting and soil instability. Suitable trail substrates and vegetation types that support ATV use were identified in the ATV assessment study (Happe, Shea and Loya 1998) and other studies (Teare and Meyers 1984). One mitigation option, not addressed in this study, is to consider re-routing the trail to suitable substrates or vegetation types. If re-routing is not a viable option, such as in areas where no suitable substrate occurs or the environmental impacts of developing an alternative route are high, hardening materials provide an alternative to mitigating the effects of ATV use. Trail hardened surfaces define a stable corridor for passage across sensitive sites and prevent the development of additional parallel tracks and braiding. Previously used tracks have the opportunity to naturally stabilize and begin recovery. In addition, the ability of the installations to support re-vegetation provide for site recovery and habitat restoration on the trail surface itself.

Additional work is required to develop appropriate methods for field application. During the study untreated trail segments quickly degraded and ATV users were forced to create alternative routes that bypassed other hardened trail segments. Hardened trail segments need to be “anchored” to suitable sites, provision made for constructing approach aprons and for spanning degraded soils. Selection of materials should be weighed in terms of longevity of materials, cost and conditions of the sites. While locally derived materials such as corduroy poles may have been appropriate in the past, the use of modern geosynthetics may be more cost effective and efficient for larger scale installations.

ATV use and trail degradation is going to be an ongoing management concern in Alaska. We recommended the following actions to address these concerns in Wrangell-St. Elias National Park and Preserve.

1. Treatment materials should remain installed since the materials are promoting re-vegetation and stabilization of soils. The materials should be monitored for safety over time. If the materials are not creating a hazard they should not be removed since removal may cause more damage to the soils and vegetation. Additionally, the treatments will have value for long-term assessment of re-vegetation and soil stabilization at the sites.
2. An assessment of alternative routes should be conducted. If alternative routes are feasible with respect to soils and vegetation, the costs of establishing and maintaining these routes needs to be evaluated. This process will involve developing a soils and vegetation base map with associated ATV impact ratings. In addition, a trail prescription protocol will need to be developed.
3. An assessment of significant changes in trail widths could be made by comparing 1986 aerial photography with current aerial photography and/or by re-reading the 1984-1985 ATV assessment trail widths (Connery, Beck and Meyers 1985).
4. While re-routing or closure of trails may not be feasible in the near future, trails should be protected from further degradation. One option for protecting these trails is to install longer sections of treatment material that span the extent of unsuitable soils. Longer sections of treatment will promote the use of one main track and will prevent the establishment of additional trail braids.
5. This study has been recognized as pioneering by other land managers in the state and has stimulated research into the use of geosynthetic materials. These materials will be tested on State, Forest Service and BLM lands at five different localities in Alaska beginning in summer 2001 (Meyer 2000). Results from these studies will be valuable in developing installation

methods, costing and in identifying alternatives for trail treatments in WRST. In addition, an Alaska working group is being formed to address ATV trail management issues. The park is encouraged to contribute to the state-wide effort to address the issues associated with ATV use.

Conclusions

All the materials were successful in terms of re-vegetation, an important factor in soil and thermal stabilization. Additionally, all of the materials but one (Polynet/Pyramat) provided an adequate riding surface for ATV traffic. None of the materials had a negative impact on the thermal regime within the first year after installation and there was no observed evidence of negative impacts to the thermal regime during the period of the study. Two of the materials are not recommended for use in trail hardening due to safety concerns and maintenance requirements: Wood Matrix and Polynet/Pyramat. The wood constructed materials (Corduroy and Wood Matrix) appeared to have a shorter life span than the geosynthetics. Material cost and labor varied widely between the products tested and larger installation efforts would be more economical on a per unit basis. This study indicates that geosynthetic trail hardening materials, although expensive, are effective in preventing further degradation to trail conditions while providing for site stabilization and recovery in sites where soil and vegetation are sensitive to impacts from ATV use.

INTRODUCTION

All-terrain vehicles (ATVs) have become a common mode of transportation in roadless areas of Alaska. Prior to the establishment of Wrangell-St. Elias National Park and Preserve in 1980, a wide range of mechanized vehicles (primarily track vehicles) created a network of trails within the current Park boundaries to access private property, mining claims, subsistence and recreational hunting and fishing areas, and seismic exploration sites. The Alaska National Interest Lands Conservation Act (ANILCA), the enabling legislation for Wrangell-St. Elias National Park and Preserve, requires the National Park Service to provide for reasonable and feasible access to in-holders (43 CFR 36.10, ANILCA 1110) and subsistence users (36 CFR 13.46, ANILCA 811). This access is frequently by all-terrain vehicles.

The National Park Service Organic Act (1988) also mandates the National Park Service to preserve and protect resources and wilderness values, this is potentially in conflict with the National Park Service's requirement to provide access under ANILCA. Due to the potentially conflicting requirements of allowing access while protecting resources, it was necessary for Park management to gain a better understanding of the effects of ATV use across different vegetation and soil conditions in order to manage ATV use within the Park and Preserve (National Park Service, 1994, p.7:14). Information was needed on management options to minimize and mitigate ATV impacts in areas of documented trail deterioration (National Park Service, 1994, p. 7:15). In 1994, Wrangell-St. Elias National Park and Preserve received funding from the Natural Resources Preservation Program (NRPP) to initiate the Assessment and Mitigation of ATV Impacts Project.

History of ATV Assessment

Since the mid-1980's several studies have inventoried and assessed ATV use in Wrangell-St. Elias National Park and Preserve. Between 1984 and 1986 a park wide mechanized vehicle trail inventory and assessment was conducted (Connery 1984, Connery, Beck and Meyers 1986). The objectives of the study were to 1) map current, historic and seismic trails used by mechanized vehicles and 2) assess ecological impacts of mechanized vehicles on existing trails (Connery 1984). Over 600 mi. (965 km) of mechanized vehicle trails were mapped using aerial survey techniques. Of the 600 miles, 250 mi. (402 km) were active trails, 324 mi. (521.3 km) were historic trails and 46 mi. (74 km) were seismic trails. Field inventories were conducted to assess the condition of a sub-sample of the trails. Twenty-four of the 64 active (current) ATV trails were assessed on the ground, however their assessment methods did not stratify trails by vegetation types or soil types. Of the 24 trails surveyed, they found a 20% loss of vegetation cover, an 80% increase in surface subsidence and a 440% increase in ponding frequency in the affected trail area versus adjacent unaffected area. The average trail width of the active trails, which included braiding, was 10.54 meters, four times the average width of historic trails (2.65 m).

During 1984 an inventory and impact rating of the Kuskalana trail and Kotsina road were completed (Teare and Meyers 1984). In this study, the trail/road was stratified into 6 substrate types and 2 slope categories. The results demonstrated that several substrate-slope combinations supported ATV and 4-wheel drive vehicle use with relatively low impacts (gravel-cobble or gravelly silt loam soils in either slope category). Whereas trail segments with mucky silt loam and organic silt loam had the highest impact ratings, particularly if underlain with permafrost.

Another study took place in the Park during 1984 and 1985 to measure the effects of ATV use on shrub-tussock communities by type of vehicle, season of use and intensity of use (Ahlstrand and Racine 1990, Ahlstrand and Racine 1993). Four types of ATV machines made 10, 50 and 150 passes over separate 30 m test lanes, and were repeated again in 1985, for a total of 20, 100 and 300 passes. The tests were repeated over three seasonal periods: late spring, all-summer, and early autumn. The following measurements were made prior to and after the ATV passes: surface profile depths (depth of

tracks), percent of shrub injury and tussock compression, and the length of organic soil exposure along the 30 m lanes. Vehicles with the lightest ground contact - 3 wheel All-Terrain Cycles (comparable to current 4-wheel ATVs) had the shallowest tracks formed and lowest organic soil exposure, shrub injury and sedge tussocks compression. The shallowest tracks were formed during the late spring test, and deepest tracks were formed during the "all-summer" tests (mid-June – early-September). Plant disturbance varied by season and species type. In general, the low shrubs *Betula nana* and *Vaccinium uliginosum* suffered most injury, while the dwarf shrubs *Empetrum nigrum* and *Vaccinium vitis-idaea* were least affected.

Connery's (1984) assessment methods were used in 1987 to document the condition of mining access trails in the Gold Hill area of Nabesna (Beck 1987) in response to mandates from two mining access Environmental Assessments (United States Department of Interior, 1988, Appendix A, No. 5; United States Department of Interior, 1989). This assessment was expanded into monitoring along three of the trails during 1988 and 1989 (Cook 1990a and 1990b). The monitoring objectives were to identify and quantify specific environmental impacts along the access routes for mining operations. Transects were established in affected ATV trail areas and unaffected areas of the sub-arctic alpine tundra of Gold Hill and stratified by vegetation type. The results of this study indicated a loss of organic top soil, significant reduction in vegetation cover, increased ponding and soil erosion in the active ATV trails. Lichens and shrubs were most sensitive to disturbance while graminoids were least disturbed.

The assessment portion of this NRPP project investigated how subarctic vegetation and soil types responded to varying levels of ATV passage in the Nabesna and Gold Hill areas of Wrangell-St. Elias National Park and Preserve from 1994 to 1996 (Happe, Shea and Loya 1998). The study found that ATV impacts varied significantly between vegetation and soil types. Mesic herbaceous and low shrub vegetation communities, had the greatest number of trail braids, trail width, ponding, thaw depth and subsidence depth. These communities are found on cold and wet permafrost soils that are susceptible to churning and displacement of vegetation and organic matter from ATV use, and consequently have the least resistance to ATV impacts. Open forest communities, with soils that are well drained, were found to have a low number of braids, trail width, and ponding and intermediate thaw depth, demonstrating more resistance to ATV impacts.

ATV Management

These studies have documented the potential and existing environmental degradation from ATV use in sub-arctic terrain. ATV impacts included vegetation damage or destruction, changes in vegetation community composition and structure, substrate thermal change and permafrost thaw, and soil erosion and subsequent development of thermokarst features and terrain degradation (Slaughter et al. 1990). Most of the studies documented loss and damage to vegetation, which would be expected in most trails. However, the reduction in vegetation cover can cause changes in soil structure through increased bulk density and reduction in soil insulation. This can result in lower water-holding capacity, increased soil subsidence and increased depth to permafrost (Cook 1990, Happe, Shea and Loya 1998, Ahlstrand and Racine 1990). Eventually in soil types underlain by ice ridge permafrost, large mud bogs will form from overuse (Photos B and C). ATV riders and other trail users frequently develop alternate trails to avoid the mud bogs, resulting in trail braiding (Photo A). Aerial photography in 1994 showed a total of 85,000 meters (52 miles) of braided trails within the Nabesna trail system (excluding the Chisana area) in Wrangell-St. Elias NP/P. Approximately 30,000 meters (19 miles) of this was considered to have significant braiding (greater than 4 braids wide) (Happe, unpublished). One of the most evident effects of prolonged ATV use in sub-arctic tundra is the development of trail braiding, and the scarring on the landscape that can last for many years. Ideally an ATV trail should maintain the user on a single track, to reduce the level of braiding.

There are several ATV management approaches for mitigating these effects, including regulation and/or zoning ATV use, using terrain analysis and sensitivity mapping to select appropriate routes, training the vehicle operator, and surface protection and stabilization of existing ATV trails (Slaughter et. al. 1990). This study investigates traditional and alternative ATV trail surface protection by testing 6 surface hardening materials. Traditionally, native timber, sawn timber or old railroad ties have been laid on trails for surface protection (Slaughter et. al. 1990). Alternative materials, such as geosynthetics are currently available, but no studies have looked at the potential for using these materials as a mitigation tool on ATV trails.

Study Objectives

This report covers the mitigation phase of the Assessment and Mitigation of ATV Impacts within Wrangell-St. Elias National Park and Preserve project (Refer to Wrangell-St. Elias National Park and Preserve Research and Resource Management Report No. 98-1 for information on the impact assessment phase of this NRPP project). In this study natural and geosynthetic materials were tested for their ability to mitigate impacts on ATV trails in mixed shrub-sedge tussock vegetation communities underlain by permafrost in Wrangell-St. Elias NP/P. Six hardening materials (treatments) were installed in 1996 along four trail segments. The objectives of the study were 1) to compare the cost of materials and installation, and 2) to monitor the trail condition in terms of soil thermal regime and vegetation condition. The intentions were to monitor over a 7-10 year time span. The sites were monitored in 1996, 1997 and 2000. This report reviews the condition of the materials and trails after four year's time of exposure to the elements within a subarctic environment.

STUDY AREA AND METHODS

General Description

Wrangell-St. Elias National Park and Preserve is located in the eastern corner of South Central, AK (Figure 1). The study was conducted in the Nabesna district of the Wrangell-St. Elias National Park and Preserve (Figure 2). The Nabesna area is a wide relatively flat valley between the Mentasta Mountains to the north and Wrangell Mountains to the south. The valley holds the Copper River drainage, which flows west and south to the Gulf of Alaska, and the Nabesna River drainage, which flows west and north to the Yukon River watershed. Trailheads originate on the Nabesna road, or are extensions of other trails with road origins. Historically, portions of these trails were traditional Alaskan native routes, as well as links to mining trails of the Chisana area (Geoffrey Bleakley, personal communication). Present day ATV trail use includes access to in-holdings; subsistence access to hunting, fishing, trapping and gathering; and recreational access to hunting, fishing and general recreation.

Climate

The study area is in the subarctic climatic zone. The weather pattern is continental with influence to the north from the Mentasta/ Nutzotin mountain ranges, considered part of the Alaska Range, and to the south from the Wrangell Mountains. The Wrangell Mountains produce a secondary rain shadow, and precipitation drops to about 8 inches per year compared to the 130 inches received on the coast and to the 10-12 inches received by the lower elevation of the Copper River basin, which is considered a transition zone between maritime and continental climate (National Park Service 1986). The Alaska Range, northwest of the Mentasta and Nutzotin Mountains, also affects weather patterns in the study area by blocking some of the precipitation and cold air masses from the north. The study area is subject to extreme seasonal temperature variations, with lows down to -57°C (-70°F) and highs up to 27°C (80°F). The mean annual temperature for this area is -2°C (28°F), with a January mean temperature of -20°C (-4°F) and a July mean of 14°C (57°F) (Racine and Ahlstrand

1991). Precipitation data for the summer prior to the study and three summers of the study can be seen in Appendix A.

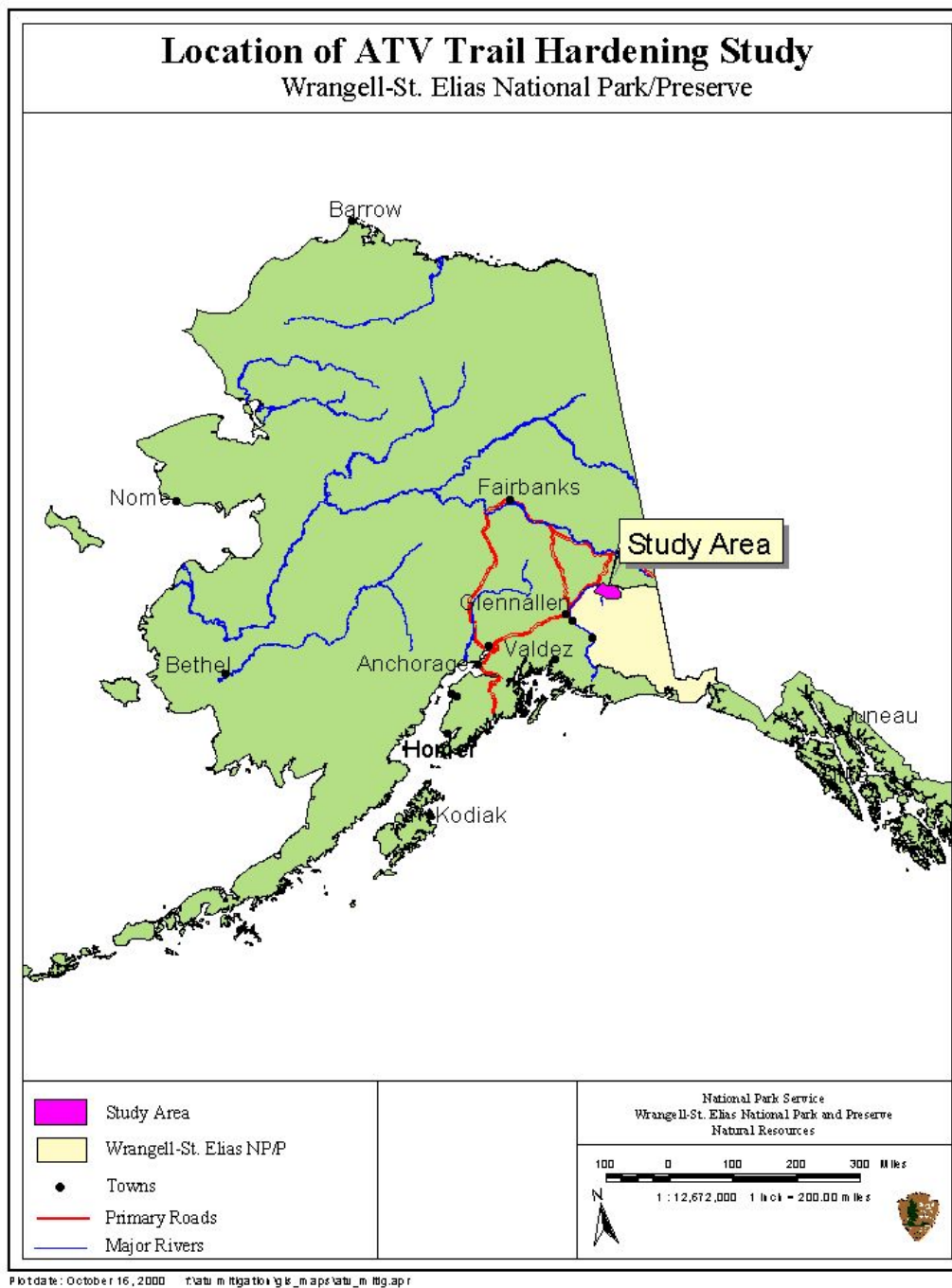


Figure 1. Location of ATV Trail Impact Assessment and Mitigation Study Area, in Wrangell-St. Elias National Park and Preserve, Alaska.

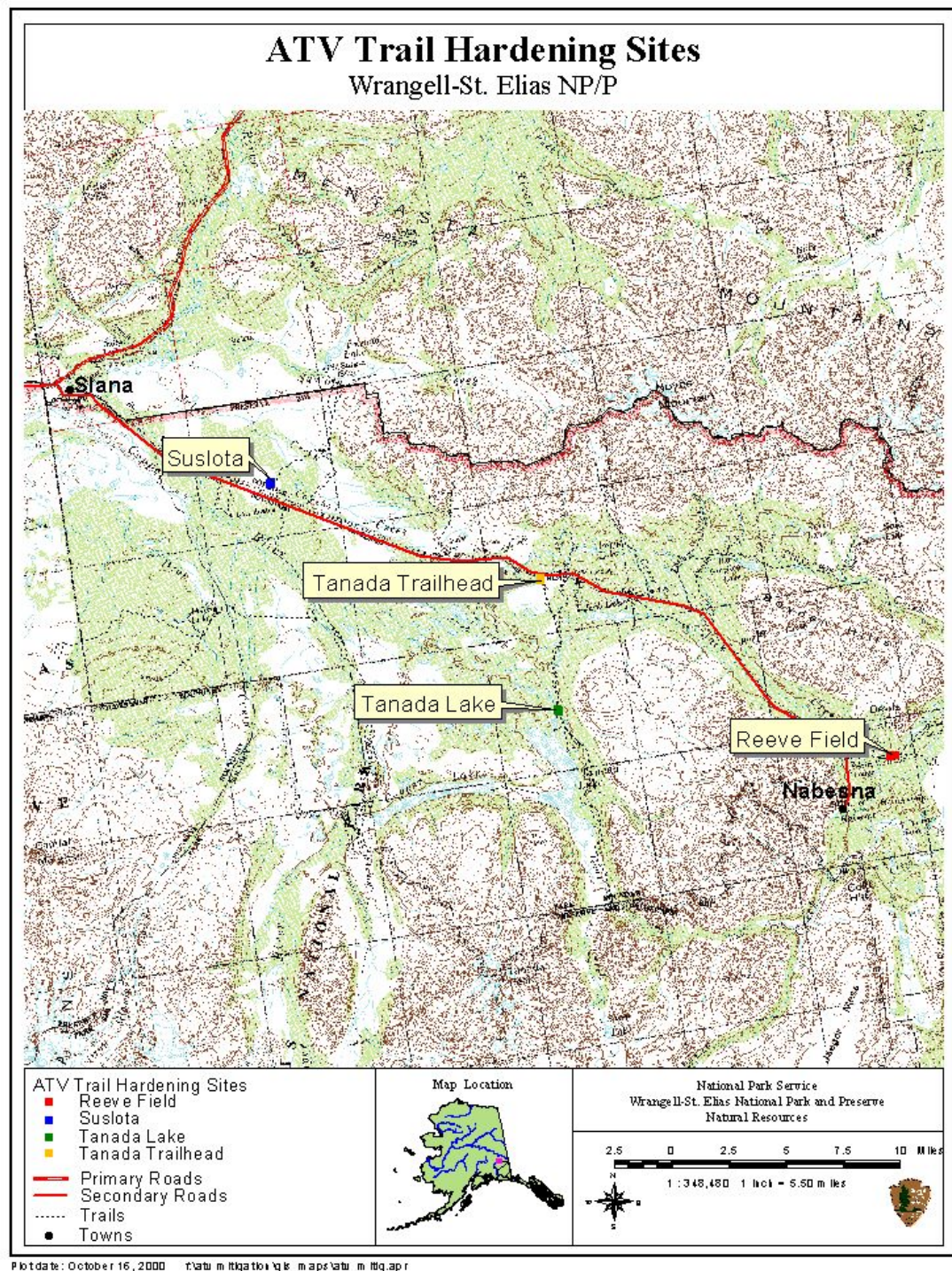


Figure 2. Location of ATV Trail Hardening Study sites in the Nabesna District of Wrangell-St. Elias National Park and Preserve, Alaska.

Study Sites

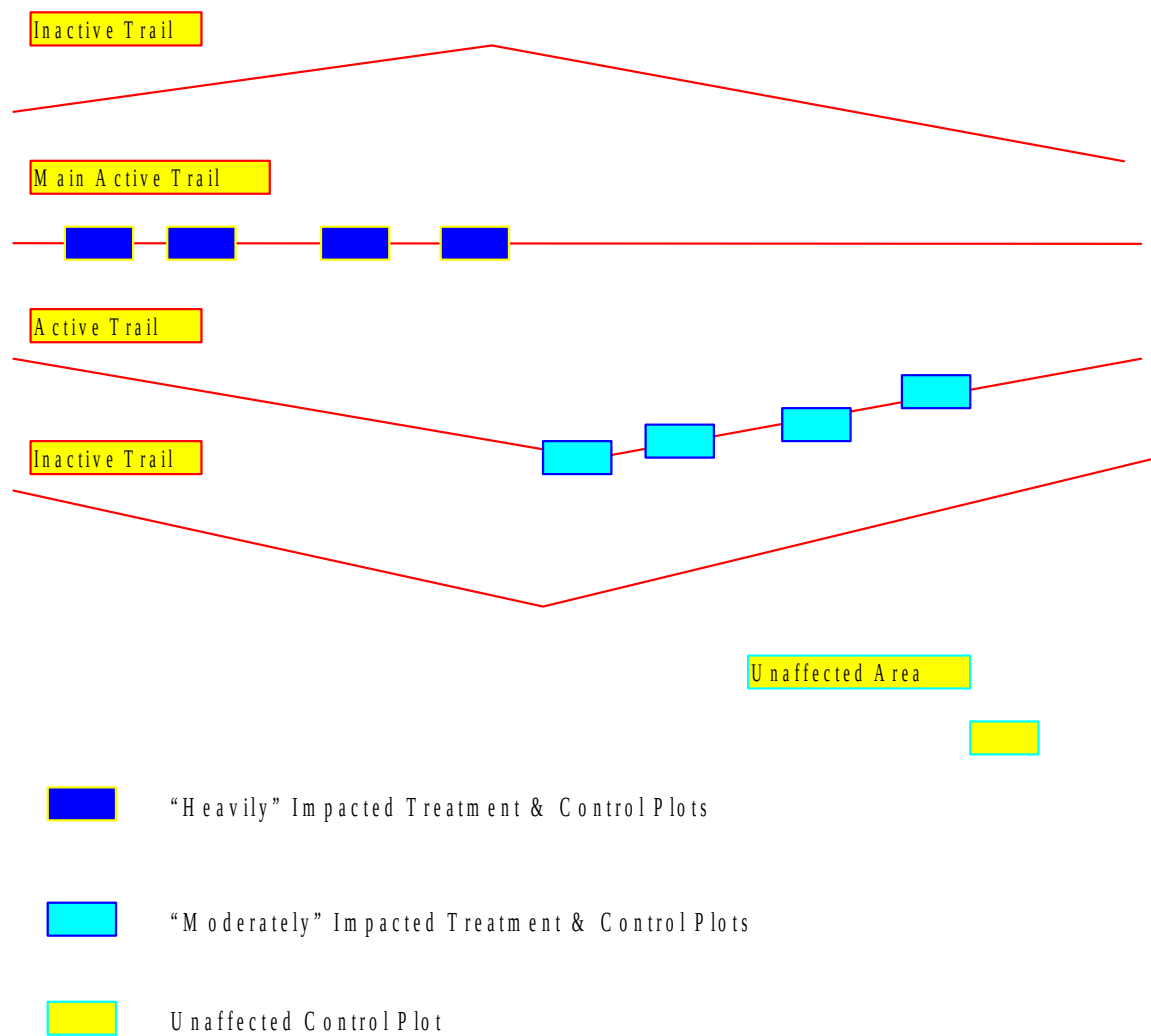
During 1996 hardening material and control test plots were established along four trail segments in the Nabesna District of Wrangell-St. Elias NP/P. Trails and plot locations were selected in a restricted randomized sampling block design. Due to time and budget constraints, test plots were restricted to areas that had reasonable access. Test plots were also restricted to the mixed shrub-sedge tussock bog vegetation type (Viereck *et al.* 1992), which was the dominant vegetation type in the study area (32% of the study area, or found along approximately 50 km out of a total of 155 km of trail). Mixed shrub-sedge tussock bog was also one of the most sensitive vegetation types to ATV impacts (Happe *et al.* 1998); with over 40% of the trails in this vegetation type braided (multiple ATV trails formed). Finally, sampling was restricted to lengths of trail that were large enough to fit all treatment plots within a suitable trail segment.

Four study sites were selected according to the aforementioned restrictions: Suslota, Tanada Trailhead, Reeve Field and Tanada Lake¹ (Fig. 2). The vegetation at the Suslota study site was influenced by the presence of black spruce (*Picea mariana*) from a nearby open black spruce forest. Tanada Lake study site was influenced by a small drainage transecting the trail creating wet pockets that were more herbaceous in nature. The Reeve Field study site had more low shrubs in the surrounding areas and was influenced by nearby white spruce (*Picea glauca*) and tall willow (*Salix* sp.) communities that occasionally border the trail site. However within the trail area of Reeve Field was more herbaceous.

Within each study site, four "heavily" and four "moderately" impacted plots within the trail corridor and one unaffected control plot near the trail were selected and marked with survey stakes at each study site. A modification of the Muskeg Research Institute, Vehicle Impact Rating Scheme was used to segregate surveyed plots in to moderate or heavy impact (Muskeg Research Institute, 1970) (Appendix B). Within each impact type, there were three trail treatments and one untreated trail control. Treatments and controls plots were randomly assigned within each impact site (Figure 3). Specific plot layouts for each site are shown in Appendix C. Monitoring plots were 12 m x 4 m in size, and the hardening materials were 12 m x 1.85 m in size.

Although the original study design was intended to compare the difference in vegetation recovery for moderately and heavily impacted plots with ATV use, the final vegetation analysis compares all plots together regardless of the original impact level, due to changing levels of ATV use among the study sites and between plots.

¹ As a result of heavy rains and flooding during the week of July 21 of 1997, a debris flow through the Tanada Lake Study Site covered several plots. This site was not monitored for vegetation in 2000, because of the changes due to the mud flow.



ATV Trail Impact Mitigation Study
Sampling Block Design
Wrangell-St. Elias National Park/Preserve

Figure 3. ATV Impact Mitigation Study, Sampling Block Design, Wrangell-St. Elias National Park and Preserve, Alaska.

Hardening Materials

Trail hardening materials were selected for their presumed ability to protect existing vegetation root mass and organic material, to stabilize surface soil, to allow re-establishment of native vegetation, and to contour the terrain. In addition portability, ease of installation and environmental compatibility were considered. To reduce disturbance to trails and surrounding areas and to reduce labor costs, materials that would lay on top of the trail and be anchored down with re-bar and duck bills were chosen. Gravel fill was considered incompatible with Park purposes and would have required excessive backcountry transportation and labor costs as well as NEPA permitting. Importing soils to use as fill materials was not considered feasible because of excessive backcountry transportation costs and labor costs. Both native and geosynthetic materials were selected for a wide-ranging comparison of material cost, installation labor time and cost, aesthetic qualities, wildlife interactions and long-term maintenance time and cost. All materials were known to be inert to biological and naturally occurring chemicals as well as non-toxic to plants and animals.

Three materials were selected to protect moderately impacted trails (Table 1): Geoblock® 1¹/₄“, a porous pavement system made from recycled fiber-reinforced polyethylene plastic; Safety Deck®, a pathway surfacing system made from recycled PVC; and Polynet PN-3000/Pyramat™, a profiled geonet made of extruded polyethylene strands forming a diamond shape. Three other treatments were selected to protect heavily impacted trails: Corduroy - straight tree poles 2” top diameter, 4” bottom diameter, 6’ length laid perpendicular to the trail and woven together with nylon rope; Wood Matrix² - a frame of 2”x 4”s sawn timbers; and Geoblock® 2” - a porous pavement system made from recycled fiber-reinforced polyethylene plastic (Table 1). Material specifications, purchasing information and installation methods can be found in Appendix D & E. All of the treatment materials, except Polynet PN-3000/Pyramat™, were underlain by two different floatation and separation geosynthetics, half of a treatment plot was underlain by Polynet PN-3000 and the remaining half underlain with Landlok® ECRM 450.

The trail hardening materials were installed at each site during the summer of 1996, after pre-installation vegetation and soils data were collected. Materials were installed at each site during the following time periods: 1) Tanada Trailhead, June 4-13; 2) Suslota, June 18-27; 3) Reeve Field, July 2-11; and 4) Tanada Lake, July 15-24.

Table 1. Each study site had the following treatments and control plots randomly established within each impact area along the trail segments. In addition an unaffected control plot was established at each site outside of the trail corridor.

Moderately Impacted Areas	Heavily Impacted Areas
Safety Deck®	Corduroy
Geoblock® 1 ¹ / ₄ ”	Geoblock® 2”
Polynet PN-3000/Pyramat™	Wood matrix ²
Moderate Control	Heavy Control

Data Collection Methods

Baseline soils data was collected for all sites in 1996. Following installation of materials, soil thaw depth and temperatures were monitored in 1996 and 1997 on a two week rotation per site. Vegetation cover and ground cover data were collected prior to installation of treatments in 1996, one

² The Wood Matrix treatment was removed early June of 1997 because it posed a potential threat of trapping wildlife in the open 8”x 8” grid, therefore the Wood Matrix data was removed from the soil and vegetation monitoring analyses.

year post installation (1997), and four years post installation (2000). Photo points of all treatments were taken during each sampling year.

Soils Baseline

Baseline data was collected in order to describe the soils at the four study sites. Soil assessments involved describing the soils for each plot, collecting soil samples from control plots for laboratory analysis, and measuring active layer thaw depth and surface subsidence. Soil descriptions at each study site were made for each treatment and control to document soil differences between sites and account for variability in future treatment results.

Soil descriptions involved digging a small pit and removing materials for examination. Pits were located in one of the ruts, near the center of the plot. The length and width of the pits was approximately 25 cm, the width of the “sharpshooter” shovel. Depth of pits depended on the depth of thaw. Following examination and description of the soil, materials were replaced in order to minimize impact. Standard field descriptions were made of the depth of horizons, horizon boundaries, color, texture, coarse fragments, structure, consistence, roots and soil moisture. Terminology followed abbreviations and definitions outlined in the Soil Survey Manual (Soil Survey Staff, 1951).

Soil samples were collected at the four ATV Trail Mitigation sites, from the Heavy Control, Moderate Control, and Unaffected Area plots to compare the bulk density, percent moisture and percent lost on ignition (% organic matter) among the impact areas. Location of sampling within each plot was selected randomly from points in the ruts that did not conflict with other monitoring transects. Three to six samples were collected in each plot. Samples were taken with a stainless-steel “sharpshooter” shovel, inserted into the soil 4 times to remove a square shaped soil sample. Sampling depth was approximately 20 cm. Each sample was measured and photographed with a graduated (centimeter) probe to show depth. Soil samples were then stored in plastic bags in a refrigerator until transferred to the laboratory.

Soils were analyzed at the University of Alaska Fairbanks’ Soil and Plant Analysis Laboratory in Palmer, Alaska. All procedures followed the Lab’s manual Methods of Soil and Plant Analysis (Michaelson et. al., 1993). For drying and moisture content, the samples were removed from the bags and cut into smaller sections. Each sample was carefully measured to determine volume for bulk density calculation. The samples were then placed in a drying oven at 100 degrees Celsius overnight (minimum 12 hours). The following day the samples were removed from the oven, placed in a desiccater for cooling, then weighed. The following calculations were made for Bulk Density and Percentage Moisture:

$$\text{Bulk Density} = \text{Weight of Oven-Dried Soil} / \text{Volume (L} \times \text{W} \times \text{H)}$$

$$\% \text{ Moisture} = [(\text{Weight of Wet Soil} - \text{Weight of Oven-Dried Soil}) / \text{Weight of Wet Soil}] \times 100$$

For each oven dried sample, a sub-sample was taken for determination of organic matter based on loss on ignition (LOI). Sub-samples were taken by collecting material from the edge of the oven dried sample along its length. Sampling along the length insured that any heterogeneity at depth would be represented. The sub-samples were placed in porcelain crucibles and loaded into a muffler furnace for ignition at 400 degrees Celsius overnight (min. 12 hours). The next day, the furnace was opened and allowed to cool to approximately 150 degrees before removal and weighing. The percentage lost on ignition (%LOI), representing the percentage of organic matter, was calculated with the following equation:

$$\% \text{ LOI} = [(\text{Weight of Oven-Dried Soil} - \text{Weight of Ignited Soil}) / \text{Weight of Oven-Dried Soil}] \times 100$$

Soils Monitoring

Active layer thaw depth and surface subsidence measurements were made to assess any effects the hardening materials may have on the rates and depth of thaw. Monitoring of soil temperatures as well as thaw depth and subsidence was conducted approximately every two weeks following installation and again in 1997. Treatments took two weeks to install at each site so monitoring was staggered starting with early June for Tanada Trailhead, late June for Suslota, early July for Reeves Field, and late July for Tanada Lake. Monitoring during 1997 began on June 9 and was conducted every two weeks through the week of September 15. Soils were not monitored in 2000.

Thaw depth and subsidence measurements were made by inserting a sharpened graduated steel probe into the ground and reading the depth at which the probe intercepted the ground surface and height at which it intercepted a reference line. The reference line was established by attaching a cord to survey stakes and inserting the stakes into the ground on opposite sides of the trail such that the string was 16 cm. above the surface at the staking point. Water present on the surface was included in the subsidence depth as ponding usually occurs in heavily subsided or rutted areas. The subsidence measurement was calculated by subtracting the depth at which the probe intercepted the ground from the height at which it intercepted the string. Three measurements were made across the treatment, one in each rut and one in the meridian. Two measurements were also made on each side of the treatment, at 33 cm. and 66 cm. from the edge, for a total of 7 measurements per transect (Figure 4). The transects established for vegetation sampling were used for thaw and subsidence sampling.

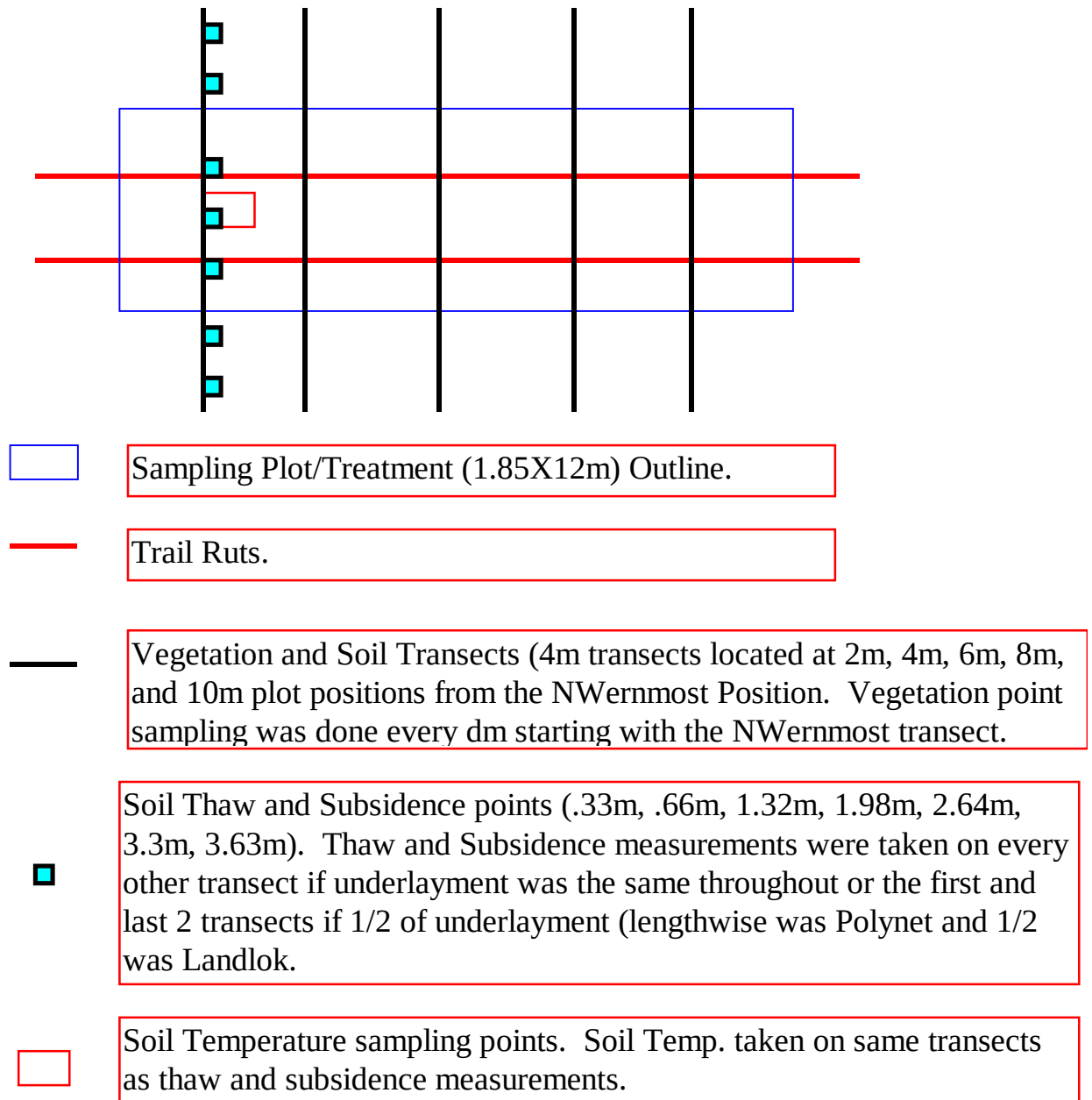
Temperatures were measured at the center of each transect selected for thaw depth and subsidence monitoring. Temperatures were obtained using an Omega Engineering HH-21 Digital Thermometer and stainless steel Type T thermocouple probe. Temperatures were measured at 2 cm and 15 cm depths below the surface. Values were recorded one minute after insertion of the probe to allow the reading to stabilize.

Vegetation Monitoring

Vegetation data was collected from the sampling sites in 1996 (pre-installation), 1997 and 2000; Table 2 lists the sampling dates. Five permanent 4m transects were established perpendicular to each plot at 2 meter intervals starting 2 m from the north-westernmost corner of the plot (Figure 4). Vegetation was sampled using the point intercept method and sampling every dm along transects. Vegetation by species and ground cover were recorded at each point intercept point. If a point had no vegetation, the point was labeled according to its ground cover as appropriate: organic matter (OM), mineral soil (MS), litter (LIT), ponding (POND), and treatment (TX). If a sampling point had only one intercept of vegetation the point was classified as VEG1, if a sampling point had two intercepts of vegetation the point was classified as VEG2, etc., where VEG1 was the upper most intercepted vegetation or ground cover. The data from VEG1 was used to determine the relative vegetation or ground cover for a plot. This report follows the nomenclature of Hultén (1969) for most vascular plants, Viereck and Little (1986) for willows, Vitt, Marsh and Bovey (1988) as well as Schofield (1992) for bryophytes and Thomson (1984) for lichens.

Table 2. Sampling dates for vegetation monitoring are shown for each site.

Site	1996 Vegetation Sampling Date	1997 Vegetation Sampling Date	2000 Vegetation Sampling Date
Reeves	July 1	July 10 – 11	August 2
Suslota	June 17	July 7	July 11 – 12
Tanada Trailhead	June 3 – 5	July 12 – 13	July 13 – 14



**ATV Trail Impact Mitigation Study
Sampling Plot Design
Wrangell-St. Elias National Park/Preserve**

Figure 4. ATV Trail Impact Mitigation Study, Sampling Plot Design, Wrangell-St. Elias National Park and Preserve.

Trail intercept

In 1996 and 1997, transect width intercept was taken measuring location of trail ruts, affected vegetation/soil, meridian (center line), unaffected vegetation/soil, and affected edge along the same transects established for vegetation sampling. Trail width intercept was taken by walking out parallel with and beyond the north-western most transect of each plot until the furthest trail braid was reached. Then using a walktax string or survey chain with one end of the string held by the recorder, the sampler walked back toward and beyond the mitigation plot being sampled measuring perpendicular widths of ruts and meridian of all braids of the trail being sampled as well as the unaffected vegetation between braids. This information was collected but analyses are not presented in this document.

Photo Monitoring

Photos were taken of all plots in 1996 (post-installation), 1997, and 2000. During 1996 and 2000 photos were taken in conjunction with vegetation measurements. During 1997 photos were taken of all plots and areas between plots every two weeks, which was done in conjunction with the soils monitoring. In 1998 photos were taken September 10 when TrailMaster units were serviced. Photos were taken from a point 4 meters from the ends of each plot for two aspects: north to south and south to north. An additional photo was taken at the third transect, 4 meters from the east edge of the plot looking west, except at Reeve Field where photos were taken from west to east due to the slope and vegetation.

Video documentation of pre-installation and post-installation conditions were taken during the following periods: 1) Tanada Trailhead, June 4-13; 2) Suslota, June 18-27; 3) Reeve Field, July 2-11; and 4) Tanada Lake, July 15-24. Video can be found on the '1996 ATV Trail Impact Mitigation Study' Tape I and II. Video of mitigation sites were taken post-installation during early summer (the week of May 14th, 1997), pre-hunting season (the week of Aug. 5th, 1997), and post hunting season (the week of Sept. 16th, 1997). All plots and areas between plots were video-ed with close-ups of ponding and subsidence as well as spans of east and west of trails. Video can be found on '1997 ATV Trail Impact Mitigation Study' tapes I, I (continued), II and III.

Trail Use

To quantify the amount and type of use on trails we used infrared trail counters with cameras (TrailMaster 1500, by Goodson and Associates, Inc., Lenexa, KS). The TrailMaster units were installed at the beginning of each study site on wooden posts approximately ½ meter above the ground, with the transmitter/counter on one side of the trail and the receiver and camera on the opposite side. Trail users passing by the TrailMaster break the infrared beam between the transmitter and the receiver, signalling the TrailMaster to record and store the date and time that the pass or event occurred, as well as activating the camera to take a photo at that moment. Data from the TrailMasters was collected every two weeks at the time of soils monitoring in 1996 and 1997 and every two weeks from June 23 to August 21 in 1998.

The following problems occurred with this method of assessing trail use. (1) Trail users often did not pass by the cameras and enter the test plots even though directed by flagging and notification of the purpose of the study at the trailhead. (2) Cameras and film were stolen throughout the study. Often the loss of the units was not noticed until the bi-monthly monitoring occurred. (3) Many false events were recorded. These may have been triggered by snowfall, leaf fall, bird use or wind. For these reasons, data and photos from the trail use monitoring has not be evaluated or presented in this report.

Data Analysis and Presentation

Material Overview

The hardening materials were assessed for their cost, installation, maintenance, durability and, functionality (ability to maintain and support ATV use on the trail, and prevent further ponding and thermokarsting). Labor preparation and installation costs, transportation costs, and material costs were used to determine an average cost per linear foot of trail. Treatment materials and anchoring devices were assessed visually through site visitation and photo monitoring to test each treatment's ability to withstand harsh environmental conditions and ATV use. In addition, public comment was solicited during 1996 and a qualitative review was completed by K. Meyer (1998) to assess the materials' functionality and durability.

Soils

Soil percentage lost on ignition, percent moisture, and bulk density means by Heavy Control, Moderate Control, and Unaffected Control were analyzed using multivariate analysis of variance (MANOVA) (SPSS Version 10.0.5) to determine the effect of impact level on these three parameters. This information will help to account for variability in treatment results and also help to gain a better understanding of the affect of ATVs on these soil parameters.

Permafrost thaw depth, soil temperature, and thaw subsidence were measured to determine treatment effectiveness. Thaw depth data was averaged by transect and treatment for each monitoring period at the four study sites. Thaw rate regression lines were then determined for each transect. The slope of the linear regression lines (thaw rates) were compared using a two-way Analysis of Variance (ANOVA) (SPSS Version 10.0.5) by year. This compared the difference in thaw rates among the study sites and among the treatments. A student's t-test was used to compare the slope differences (thaw rates) between 1996 and 1997 for each plot type at each site. Maximum thaw rate was tested using an ANOVA. Treatments were deemed effective if permafrost thaw was significantly less than pre-treatment thaw or was not significantly different from Unaffected Control thaw.

Vegetation

Preliminary analysis indicated there was a significant difference in vegetation cover and species composition among the trail sites, therefore each site was analyzed separately. Each site was first compared to determine if there was a significant difference in total vegetation cover among the three sampling years, using a one-way ANOVA (SPSS Version 10.0.5). One-way ANOVAs were then used to compare the difference in total vegetation cover among the test plots by sites for each sample year (1996, 1997 and 2000). The analyses compared each treatment to the moderate and heavy control plots and the unaffected control plot. Treatments were deemed effective if vegetation cover was significantly higher than the moderate or heavy control plots (if this cover was not derived from introduction of exotic species cover) or was not significantly different from Unaffected Control vegetation cover.

Data was also compared in terms of the change in vegetation cover one year after hardening treatment installation (Veg% 1997 – Veg% 1996) and four years after installation (Veg% 2000 – Veg% 1996). Treatments were considered effective if the change in vegetation cover was significantly higher than the change in vegetation cover in the control plots.

To assess species composition change over the years, percent vegetation and ground covers were calculated in the following categories: forbs, shrubs, grasses, bryophytes, lichens, *Eriophorum*, and *Carex*. Percent ground cover were calculated in the following categories: bare, litter (undecomposed, dead vegetation, woody debris or roots), ponding (standing water) and treatment

material. Graphical displays are presented of the data, followed by a discussion on species composition changes.

Trail Restrictions and Other Problems

During the time between 1997 and 2000, alternate trails were developed by users to avoid mud bogs that formed in between the study plots. The hardening material test plots were 12 m (40 ft) in length, with non-protected areas between the test plots. These non-protected areas and the heavy and moderate control plots degraded and resulted in impassible trails for ATVs and hikers. This influenced the study and the results of the study will be discussed in light of this problem.

Due to flooding from unusually heavy rainfall in the Nabesna area, ATV use on the Suslota Lake, Tanada Lake, and Reeves Field trails was restricted temporarily beginning Aug. 5th, 1997. The restriction on ATV use was lifted for Suslota Lake trail on 9/8/97 and for Tanada Lake and Reeves Field trails on 10/17/97.

It became evident early on in 1996 that the Reeves Field study site's Original Heavy Control (OHC) had become impassable. A New Heavy Control (NHC) was established on 7/11/96. The Reeves Field OHC was eliminated from analysis and the NHC was use in its place for analysis.

RESULTS

Material Overview

Costs

Table 3 provides a cost estimate of transportation, labor and materials by linear foot of trail (6 foot width) for each material type in 1996. A break down of costs by transportation, labor and material can be found in Appendix F. It is important to note that transportation costs were calculated using the cost of helicopter sling loads; labor costs were calculated from wages of a crew of 3 Wage Grade workers in 1996 (One WG-7 worker and two WG-5 workers); and material costs include shipping costs during 1996. The costs of the raw materials were determined from an order of approximately 160 linear feet of material (enough to cover the test plots at 4 sites), the cost for most materials would decrease with larger orders. The table below should be used as a general guideline for costs, since the costs and configurations of materials (which result in easier installation) have changed over the past four years. Current contacts for purchasing materials and current prices can be found in appendix D. In addition, two of the materials are no longer manufactured: Geoblock® 1 ¼” and Safety Deck®.

Table 3. The 1996 costs per linear foot (6’ width) of trail hardening material and installation are shown below. Labor costs were estimated from the actual number of labor hours required for prep and installation multiplied by the average wage of one WG-7 and two WG-5 (\$18.00/hr) in 1996. Additional materials cover the cost of rebar, anchoring devices and underlayment separation materials.

Hardening Material	1996 Cost Per Linear Foot of Material (6’ width)				TOTAL
	Transportation Helicopter Sling	Labor	Materials & Shipping	Additional Materials	
Corduroy	\$7.00	\$11.00	\$5.80	\$3.30	\$27
Wood Matrix	\$10.00	\$19.50	\$4.80	\$3.50	\$38
Geoblock® 2”	\$4.00	\$14.00	\$27.00	\$3.30	\$48
Geoblock® 1 ¼”	\$4.00	\$13.50	\$18.80	\$3.30	\$40
Safety Deck®	\$7.00	\$14.50	\$43.70	\$2.60	\$68
Polynet PN-3000 /Pyramat™	\$4.00	\$11.00	\$8.40	\$1.00	\$24

Installation

The installation methods are described for each material type in Appendix E. The number of labor hours spent by one WG-7 and two WG-5s on general installation per material type for all sites (158.4 ft of trail) was 57.75 hours, this included time spent for staging materials, site preparation, general material handling, and underlayment installation. This would equate to 36.5 hrs/100 linear ft of general material installation labor. Table 4 lists the additional hours needed to complete tasks specific to the material type.

Wood matrix was the most labor intensive, primarily due to the pre-installation handling time needed to build the matrix from raw 2 x 4’s. Wood Matrix was installed on heavily impacted sites, and it required ground leveling at three out of the four sites. Safety Deck® was the next most labor intensive, because the 19 ¾” x 19 ¾” square tiles were tied together during installation. However, Safety Deck® conformed well to the terrain and required minimal site leveling and preparation on moderately impacted sites. The Geoblock® materials used in 1996 were cut in half in order to alternate the pattern for greater strength and were tied together during installation, which was time

consuming. The current dimensions of the Geoblock® 2” eliminates the need for pre-installation cutting and screw tabs reduce the time of tying. The Geoblock® conformed to uneven terrain better than the Wood Matrix, but it still required site leveling. Two of the four sites in the moderately impacted areas (Geoblock® 1 ¼”) and three of the four sites in the heavily impacted areas with the Geoblock® 2” required site preparation. Polynet PN-3000 /Pyramat™ had low installation costs; it conformed well to the vegetation and uneven terrain and did not require lashing materials together. However it required additional excavation and time at all of the sites, in order to anchor the materials securely. In this study, Corduroy was the least labor intensive, because it required very little pre-installation handling i.e. trees were cut, limbed and banded together as part of the cost of the material. Corduroy required leveling for installation at only one of the four heavily impacted sites.

Table 4. The number of total labor hours per 100 linear foot of material installation, exceeding the 36.5 hours of general installation cost per material. Zero hours indicate no extra time was required for material, beyond the 36.5 hours of general labor time.

Hardening Material	Pre-installation handling	Material Distribution	Staging	Material Installation	Total Hours
Corduroy	0	2	0	23	25
Wood Matrix	38	4	1	27	70
Geoblock® 2”	4	2	1	36	43
Geoblock® 1 ¼”	4	2	1	32	39
Safety Deck®	0	1	0	43	44
Polynet PN-3000 /Pyramat™	4	0	0	21	26

Pre-installation handling = cutting, bending, fitting, or measuring materials prior to installation in field.

Material Distribution = distributing and organizing materials at site, post sling-load.

Staging = additional staging time for sling load operations, beyond normal sling load operation time calculated in Appendix F, Table F2.

Material Installation = laying polynet/landlok underlayment, leveling and excavation site, fitting, tying materials, and anchoring.

Maintenance

In this study, all of the materials were anchored using rebar and duck-bills (a j-shaped anchoring device that are stabilized by cables). The rebar was subject to frost jacking, due to the freeze, thaw cycle and permafrost. Weekly site visits per summer were required to keep the rebar in the ground and prevent trail hazards. Therefore it is not recommended in the future to use rebar for anchoring, except possibly for the first year. Most of the materials used do not require anchoring, except Polynet PN-3000 /Pyramat™, which requires some type of anchoring until re-vegetation occurs.

All of the materials, except Corduroy and Wood Matrix, appeared to have no structural integrity problems over the past four years. The Wood Matrix treatments were removed in 1997, but within the first year some of the joints had broken. The logs used in the Corduroy have begun to weather and rot in sections. The expected life span of untreated wood in a wet environment is approximately 15 years. Polynet PN-3000 /Pyramat™ required the most maintenance, due to its tendency to buckle and slide under ATV vehicle use (Figures D and 23). However, once re-vegetation occurred the Polynet PN-3000 /Pyramat™ became more stabilized.

Function

The likelihood of use, safety, and prevention of further trail degradation and ponding, were used to determine functionality of the hardening materials. Unfortunately, due to the ponding and mud bog holes that developed between the hardening materials, new trails were developed at two out of the four study sites (Suslota and Tanada Trailhead), and ATVs bypassed the test plot sections all together. Therefore it was not feasible to use the trail intercept data to determine if more braiding

occurred with specific material types. However, it was felt that this was not the result of the materials, but because of the study design. The comment cards summarized below give the best estimate of which materials were most favored by users for handling, mitigation of trails and aesthetics.

In 1996, comment cards on the ATV hardening experiment were distributed to trail users. The survey asked for the comments on the driveability and potential success of each hardening material and to record which material had the best drive and was most aesthetically pleasing. Only eight comment sheets were returned, and not all of the material types were rated. A tabular summary of the comments is presented in Table 5. Some interpretation was necessary for the scoring, since the survey was narrative.

Safety Deck® received the most ratings (57%) of excellent for driveability and potential, followed by the Geoblock with 25 % excellent and 75% good. Safety Deck® had a smooth and stable ride, and provided good traction. The Wood Matrix and Polynet/Pyramat had a range of opinions. In general it was felt that the Wood Matrix provided a stable, but rough riding surface. Several users commented on the problems related to Polynet/Pyramats flexibility and problems of catching under ATVs. Unfortunately only two comment sheets remarked on the Corduroy. However, it was found that in trail sections with standing water, the woven Corduroy floated over the water and did not provide a stable walking or riding surface. Safety Deck received the most overall votes for best drive and aesthetically pleasing (Table 5). Specific comments on each material are listed in Table 6.

Table 5. Summary of the comments from eight returned comment cards, regarding the driveability and potential for each material type. Not all surveys were completed for all types of materials, the “No. Surveyed” column indicates the number comments on the driveability and potential. The “best drive” and “aesthetically pleasing” were separate comments on the survey, some surveys selected more than one type of material as the best drive, etc.

Hardening Material	No. Surveyed	Driveability/Potential				Best Drive	Aesthetically Pleasing
		Excellent	Good	OK	Poor		
Corduroy	2	0	0	2	0	0	1
Wood Matrix	6	1	2	2	1	2	0
Geoblock® 2”	8	2	6	0	0	2	1
Geoblock® 1 ¼”	8	2	6	0	0	2	1
Safety Deck®	6	4	1	1	0	4	4
Polynet PN-3000 /Pyramat™	5	0	2	1	2	1	2

Table 6. Listed below are specific comments from survey cards about the hardening materials.

Corduroy Limited potential due to rot Time consuming to install Wood Matrix Rough with heavy load, but stable Bumpy for mountain bikes Good stability, but rough Potential tripping hazard for horses Short term potential due to rot (2 comments) Safety Deck Not applicable everywhere Very nice to drive on (ATV) Horses are not spooked	Geoblock 1 ¼” and 2” Easiest to drive over Good stability Horses spooked at first Somewhat expensive Polynet/Pyramat Easily hung up on ATV Short life span Not real stable or rigid, but helps with traction Too soft Horses spooked at first
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Wood Matrix and Polynet PN-3000 /Pyramat™ were the only two materials that posed a potential safety hazard. As mentioned in the comments, the Wood Matrix 8” x 8” open grids were large enough to trip a horse or trap a young moose or caribou hoof. Subsequently, Wood Matrix was removed from the study due to concerns about wildlife and horses. The Polynet/Pyramat if not anchored by vegetation, frequently pulled up and bunched under an ATV, and also caused hazards for walking.

Comparing the level of ponding and thaw rates for the different materials provided information on the materials ability to reduce ponding and trail degradation. It was possible to compare the change in ponding over the past four years using the vegetation monitoring data. Ponding on the ATV trails generally develops because of thermokarsting (melting of the permafrost), however it can also occur due to excessive rain and poor drainage. Regardless, it is generally undesirable and causes greater resource damage. The chart in Figure 5 shows the change in percent cover of ponding for each test plot between 1996 and 2000. Due to the stratification in to moderate and heavily impacted segments, not all of the sites originally had ponding. Overall, there was a significant increase in ponding for the unprotected Heavy Control plots at all sites, and at Suslota both the Moderate and Heavy control plots had increased ponding (Figures 17 - 24). On the other hand, the hardening materials either reduced ponding or did not significantly change it from 1996, which suggests that ponding did not worsen due to the materials. In 2000, there was a significant amount of rainfall previous to and during the sampling period, therefore it is not suspected that the decreases would be due to a drier season. Geoblock 2” showed the most significant decrease in ponding, of all the materials. Thaw rate analyses are presented under the soil monitoring section below.

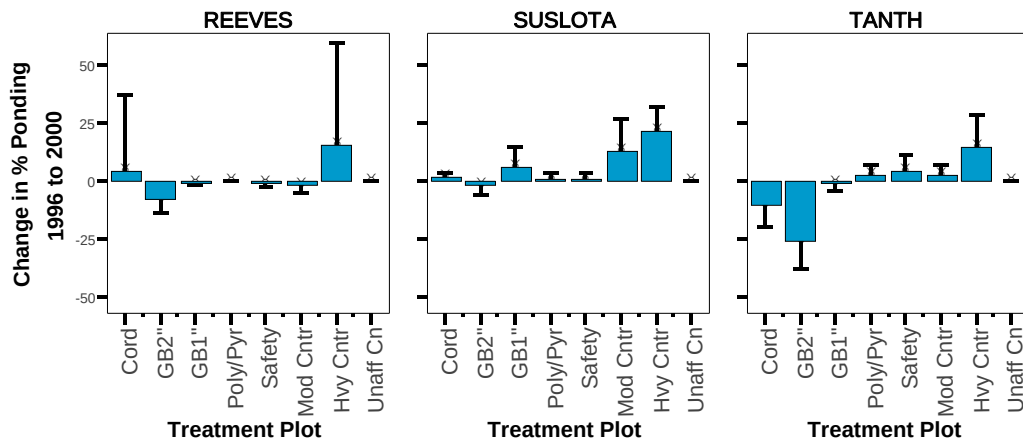


Figure 5. Bar graph showing the change in percent cover of ponding (standing water) from the vegetation monitoring plots between 1996 and 2000 at each study site (Tanth = Tanada Trailhead). A positive bar indicates the ponding had increased by 2000, a negative bar indicates the ponding had decreased by 2000. Treatment plot acronyms used in the graph are: Cord = Corduroy, GB2”= Geoblock® 2”, GB1” = Geoblock® 1 ¼”, Poly/Pyr = Polynet/Pyramat, Safety = Safety Deck®, Mod Cntr = Moderate Control, Hvy Cntr = Heavy Control, and Unaff Cn = Unaffected Control.

Soil Descriptions

Tanada Trailhead

Soils for the Tanada Trailhead test plots were described on June 4, 1996, prior to installation of the treatment materials. Soil descriptions for the unaffected area were made August 2, 1996 when the

active layer was thawed more deeply. Thaw depths for the treatment and control plots ranged from 21 to 37 cm. below the surface at the time of survey. Complete soil descriptions for each plot are presented in Table 7.

Due to the thickness of the organic horizons, these soils are classified as Histic Pergelic Cryaquepts. Subsurface materials are primarily alluvium from historic glacial outwashes, forming uneven terrain and allowing for deposition of finer sediments in depressions and bases of slopes, such as is found at the Tanada Trailhead test site (Richter & Schmoll, 1973).

Soils are characterized by organic matter over predominantly silty mineral soils, ranging in texture from silt loam to silt clay. However, the plot treated with Safety Deck® is underlain by clay and a fine sandy loam underlay the plot treated with Corduroy. In some plots it was not possible to determine the mineral texture as soils had not thawed to sufficient depth. Colors generally suggested saturated soil conditions (greys and olive greys) or the incorporation of organic matter into the upper mineral soil (dark browns).

Organic matter in the surface horizon for moderate impact plots was generally less decomposed than in the heavy impact plots. Organic horizons extended to between 15 and 37 cm. below the surface, with increasing percentages of mineral soil at depth. Live roots were observed throughout most of the soil profiles, although the surface had little or no live vegetation. Soils in the moderate and heavy plots were observed to be considerably wetter than in the unaffected area throughout the season.

Table 7. Soil Descriptions for Tanada Trailhead Test Plots and Unaffected Area.

Impact	Treatment	Horizon Depth		Horizon Boundary	Color	Texture	% Coarse			Roots	Wet.
		Top	Bottom				Fragments	Structure	Consistence		
Mod	Geoblock 1.25"	0	5	aw	2.5Y 2/1	peat				2m 2f 2vf	w
		0	16	ai	5YR 2.5/1	peat					w
		5	13	aw	5YR 2.5/1	p muck				2vf 1m	w
		13	23	froz	5YR 2.5/1	muck					w
Mod	Polynet/ Pyramat	0	2	aw	5YR 2.5/1	peat				1f	w
		2	5	aw	10YR 2/2	p muck				2f 2vf	w
		5	16	aw	5YR 2.5/1	m peat				2f 2vf	w
		16	21	froz	5YR 2.5/2	silty clay		massive		3vf	w
Mod	Safety Deck	0	5	aw	5YR 2.5/12	m peat				1c 1f 1vf	w
		5	21	froz	5YR 2.5/1	muck				3vf	w
		10	21	froz	5/5GY; 10YR 4/3	clay		massive	vs vp	1vf	w
Mod	Moderate Control	0	2	as	5YR 2.5/1	peat				1m 1f 2vf	w
		2	5	aw	5YR 2.5/1	p muck				2vf	w
		5	15	as	5YR 3/2	muck				1f 3vf	w
		15	31	froz	5Y 4/2	silt loam	33% gravel	2csbk	fr	2f 2vf	w
Heavy	Corduroy	0	2	aw	5Y 4/2	m peat				2vf 1f	w
		2	7	as	5YR 2.5/2	p muck				3vf	w
		7	23	froz	5Y 4/1	sandy loam		massive	so ps	2vf	w
Heavy	Geoblock 2"	0	3	as	5YR 3/1	m peat				1f 1vf	w
		3	9	as	5YR 3/1	p muck				1f 2vf	w
		9	37	froz	10YR 3/1	muck				3vf	w
Heavy	Wood Matrix	0	7	aw	10YR 2/1	peat				2c	w
		7	13	cw	10YR 2/1	p muck				2vf	w
		13	22	froz	5YR 3/1	muck				3vf	w
Heavy	Heavy Control	0	7	cs	2.5Y 2/1	p muck				1f 1vf	w
		7	21	froz	10YR 2/1	muck				1f 3vf	w
Unaff	Unaffected Area	0	8	aw	10YR 2/1	peat				2vf	m
		8	22	froz	5YR 3/1	muck				1f 2vf	sm

Suslota

Soils for the Suslota test plots were described on June 17, 1996 prior to installation of the treatment materials. Soil descriptions for the unaffected area were made on August 3, 1996 when the active layer had thawed more deeply. Thaw depth for the treatment and control plots ranged from 25 to 46 cm. below the surface at the time of survey. Complete soil descriptions for each plot are presented in Table 8.

Soils at the Suslota site fall into the classification of Pergelic Cryaquepts. Parent material for the soils is glaciolacustrine deposits of stratified clay, sand, and some gravel deposited in an extensive glacial lake and some post-glacial alluvial and pond deposits (Richter, 1976).

Soils are characterized by organic matter over silt or clay mineral soil. Mottling, indicated by gray and brown colors within a horizon, indicate reduction-oxidation conditions, and thus it appears that the clay horizons are subject to periods of saturation. Massive structure may be restricting root penetration, as very fine roots are present in the upper organic horizons but are less abundant in the lower mineral horizons. Boundaries between organic and mineral horizons are generally abrupt, although in some plots there appears to be some mixing of materials in the Corduroy treatment plot.

Organic materials in the upper horizon of the moderate control plots are less decomposed (peat) than in the heavy control plots (mucky peat and peaty muck), although the plot treated with Safety Deck® has only a thin horizon of mucky peat. Thickness of organic materials varies widely throughout all plots, ranging from 6 to 35 cm. Heavy impact plots tend to be wetter than the moderate impact plots.

Table 8. Soil Descriptions for Suslota Test Plots and Unaffected Area.

Impact	Treatment	Horizon Depth		Horizon		% Coarse			Roots	Wet.	
		Top	Bottom	Boundary	Color	Texture	Fragments	Structure			Consistence
Mod	Geoblock 1.25"	0	10	aw	5YR 3/2	peat				2vf	m
		10	16	aw	5YR 2.5/1	m peat				3vf	m
		16	43	froz	5YR 3/2	silt		2csbk	so po	1vf	m
Mod	Polynet/ Pyramat	0	17	as	10YR 2/1	peat				2f 3vf	m
		17	26	as	5YR 2.5/2	p muck				3vf	m
		26	37	froz	10YR 3/1, 10YR 4/1	clay		massive	ss pv	3vf	m
Mod	Safety Deck	0	9	as	10YR 2/2	m peat				1m 1f 1vf	w
		9	39	froz	5Y 3/1, 10YR 3/4	clay		massive	vs p	1vf	w
Mod	Moderate Control	0	5	as	5YR 2.5/2	peat				1f	m
		5	11	as	5YR 3/2	p muck				2vf	m
		11	17	aw	5YR 4/2	p muck				1vf	m
		17	25	froz	5YR 3/2	muck				1vf	m
Heavy	Cordoroy	0	15	aw	5YR 3/1	m peat				1vf	w
		15	35	aw	5YR 3/1	muck				1vf	w
		35	45	froz	2.5Y 4/2, 10YR 3/4	clay		massive	ss p	1vf	m
Heavy	Geoblock 2"	0	17	gs	5YR 2.5/2	p muck				3vf	w
		17	29	froz	5YR 2.5/2, 10YR 2/1	muck				3vf	w
Heavy	Wood Matrix	0	11	cs	5YR 2.5/2	m peat				2m 2vf	w
		11	20	cs	5YR 3/1	muck				3vf	w
		20	35	froz	10YR 2/1	silt		2csbk	so ps	2vf	w
Heavy	Heavy Control	0	6	as	5YR 3/1	m peat				2vf	w
		6	46	froz	10YR 4/1, 10YR 3/4	clay		massive	vs p	1vf	m
Unaff	Unaffected	0	5	aw	5YR 2.5/2	p muck				1f 2vg	m
		5	10	aw	5YR 2.5/1	muck				1f 2vg	m
		10	20	froz	2.5Y 4/1	clay		massive	ss p		m

Reeve Field

Soils for the Reeve Field test plots were described on July 1, 1996 prior to installation of the treatment materials. Soil descriptions for the unaffected area were made on August 4, 1996 when the active layer had thawed more deeply. Thaw depths for the treatment and control plots ranged from 44 to 52 cm. below the surface at the time of survey. Complete soil descriptions for each plot are presented in Table 9.

Soils at the Reeve Field are Pergelic Cryaquepts. The soils are formed on alluvium from slopes coming from adjacent uplands. This alluvium covers fluvioglacial and glacial deposits consisting of unconsolidated but commonly stratified silt, sand, gravel, and boulder deposits up to 140 meters thick (Richter, 1971).

The active layer was thawed sufficiently deep at the time of survey to examine the mineral soil in all plots. Organic materials dominated the upper 20 cm. of the soil, with less decomposed materials (peat) at the surface of the moderate control plots than in the heavy treatment plots (mucks). Mineral soil textures were clayey, including silty clay and very fine sandy clay. Soil colors had low chromas, and were described as dark grays and dark grayish browns, indicating reduced conditions as well as incorporation of organic matter. The structure of the mineral soil was generally sub-angular blocky or massive, with a slightly sticky and plastic consistence. Roots appeared throughout most profiles, including those with massive clay horizons. Moisture conditions tended to be very moist or wet, with moisture increasing with increasing impact.

Table 9. Soil Descriptions for Reeve Field Treatment Plots and Unaffected Area.

Impact	Treatment	Horizon Depth		Horizon Boundary	Color	Texture	% Coarse		Consistence	Roots	Wet.
		Top	Bottom				Fragments	Structure			
Mod	Geoblock 1.25"	0	12	cs	5YR 3/2	peat				3vf	m
		12	20	cs	5YR 2.5/1	p muck				1f 2vf	m
		20	45	froz	5YR 3/1	silty clay		2msbk	ss sp	1vf	m
Mod	Polynet/ Pyramat	0	2	aw	5YR 2.5/2	peat				3vf	m
		2	6	aw	5YR 3/2	p muck				3vf	m
		6	15	cw	5YR 2.5/1	muck				3vf	m
		15	30	as	10YR 3/1	loamy sand		2fabk	ss p	1vf	m
		30	47	froz	2.5Y 3/2	sandy clay		2msbk	ss p		m
Mod	Safety Deck	0	10	aw	5YR 3/2	peat				2f 3vf	m
		10	23	aw	5YR 2.5/1	muck				3vf	w
		23	49	froz	7.5YR 3/2	silty clay		massive	ss p	2vf	w
Mod	Moderate Control	0	11	cw	10YR 2/2	m peat				3vf	w
		11	23	cw	10YR 3/1	muck				2vf	w
		23	44	froz	10YR 3/1	silty clay		massive	s p	2vf	w
Heavy	Cordoroy	0	17	aw	10YR 2/2	muck				1m 2f 3vf	w
		17	44	froz	10YR 4/1	clay		massive	s p	2vf	m
Heavy	Geoblock 2"	0	8	cw	10YR 2/2	p muck				1f 3vf	w
		8	20	cs	5YR 3/1	muck				3vf	w
		20	26	cs	5YR 3/1	clay		3vf sbk	ss ps	2vf	w
		26	52	froz	5YR 3/1	silty clay		3mabk	s ps	2vf	w
Heavy	Wood Matrix	0	15	cw	5YR 3/1	muck				1f, 2vf	w
		15	25	aw	5YR 3/1	clay		2fsbk	ss p	2vf	w
		25	44	froz	10YR 3/2	silty clay		2vcsbk	s p	2vf	w
Heavy	Heavy Control	0	13	cs	5YR 3/1	m peat				3vf	w
		13	22	cs	5YR 2.5/1	muck				2vf	w
		22	52	froz	10YR 3/1	clay		2msbk	ss p	1vf	w
Unaff	Unaffected	0	5	aw	5YR 2.5/1	peat				1f 2vf	m
		5	17	cw	5YR 2.5/1	muck				1f 3vf	m
		17	20	froz	10YR 3/2	clay		2vf sbk	s po		m

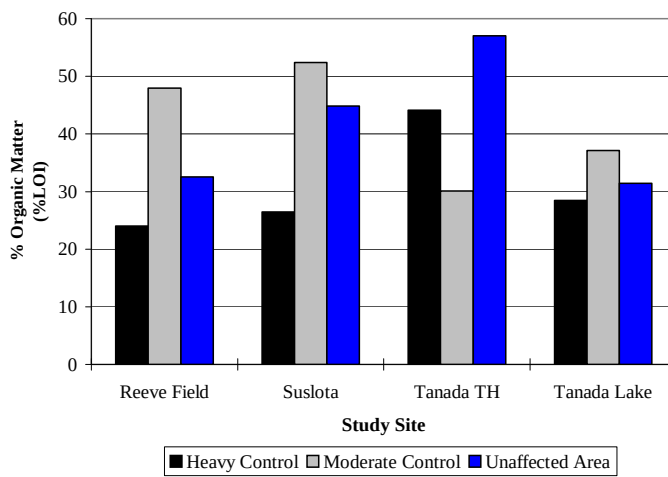
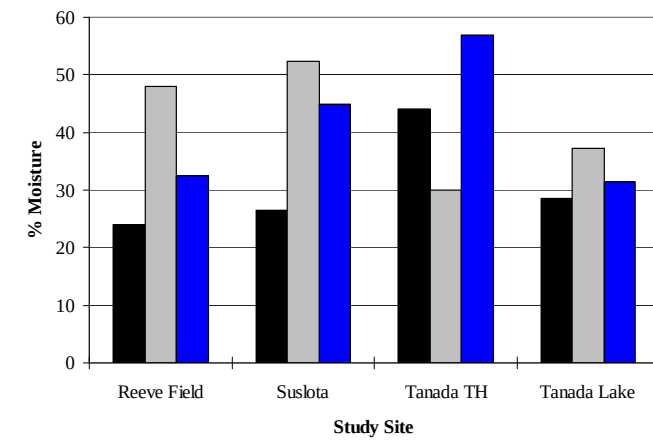
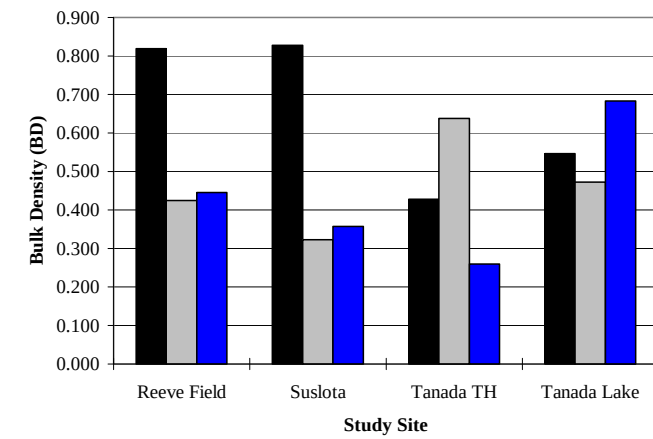


Figure 6. Average laboratory values for bulk density (BD), percentage moisture (%MOIST), and percentage lost on ignition (%LOI) for soil samples within each control plot at each site.

Laboratory Analysis of Soils

Laboratory values for bulk density (BD), percentage moisture (%MOIST), and percentage lost on ignition (%LOI) were averaged within each control plot sampled at each trail. Values are presented in Figure 6. Multivariate analysis of variance was used to test the effect of the level of impact (heavy, moderate, or unaffected) on BD, %MOIST, and %LOI values. No significant differences were detected at the <.05 level. The effects of depth and proportion of soil textural types between impact levels were also analyzed for significance. Again, there were no significant differences. However, some general trends can be observed in the data.

Heavily impacted plots generally had higher BD values than the unaffected area, except at the Tanada Lake site (Figure 6). Soils with higher BD values naturally had lower %MOIST values and lower %LOI values. At the Tanada Lake and Tanada Trailhead sites, soils in the heavy control plots appear to be generally lower in BD in comparison with the other two sites, and higher in moisture. Lower %LOI values were also found in heavy control plots in comparison to moderate control and unaffected area plots, except at Tanada Trailhead where the moderate control plot had less organic matter than both the heavy control and unaffected area plots. Bulk density is the mass of soil in a given volume. Higher levels of organic matter (estimated by % LOI) in a soil tend to decrease bulk density because organic material weighs less than minerals. Organic matter promotes aggregation of soil, resulting in a more porous soil structure, which allows for the soil to hold water and also allows for water to move through the soil. Soil compaction and loss of organic matter due to loss of vegetation will result in an increase in bulk density and increase in ponding.

The absence of significant differences in BD, %MOIST, and %LOI between the heavy, moderate and unaffected plots is likely the result of variations that exist in microtopography in mixed shrub-sedge tussock bog vegetation communities. Some areas have naturally thinner organic horizons, such as in inter-tussock spaces, while tussocks and hummocks represent thicker accumulations of organic matter.

Thaw Depth

Permafrost thaw depth and subsidence data was collected and analyzed as a means to measure the affect of treatments to the soil's thermal regime. Thaw depth data was averaged by transect and test plot for each monitoring period at the four study sites. Thaw rate regression lines were determined for each transect. Thaw rate and maximum average thaw depth variables were analyzed using untreated trail and Unaffected Controls as a means of comparison with treatments. Thaw rates were compared between 1996 and 1997 for each test plot and site. Soil temperature measurement and subsidence data were collected, but were not analyzed in this report.

Thaw Rates

Average thaw depths of all sites for the 1996 and 1997 monitoring periods are depicted in Figure 7 for the heavily impacted plots and Figure 8 for the moderately impacted plots. Linear regression lines were compared in order to determine differences in the thaw rates for each treatment or control plot for each study site. Table 9 lists the average thaw rates (slopes) for each test plot by site for 1996 and 1997. Greater slopes (higher numbers) indicate a faster thaw rate and more rapid melting of the soils.

The data from 1996 and 1997 were initially compared separately to detect differences among the test plots and study sites, from year to year. There was a significant difference in thaw rates among the study sites during both 1996 and 1997 (Tables 10 and 11). In general, Suslota and Tanada Trailhead had greater rates of thaw than Reeve Field and Tanada Lake. There was also a significant difference in thaw rates among the test plots during 1996 and 1997. In 1996, all of the trail plots had significantly greater thaw rates than the Unaffected Control plots. However, in 1997, the thaw rate for the untreated Heavy Control and Geoblock® 1 ¼" plots were not significantly greater than those in the

Unaffected areas, but the remaining plots still had significantly greater rates of thaw when compared to the Unaffected plots. Comparing thaw rates between 1996 and 1997 the trend was an overall increase in thaw rates, including the Unaffected Control Plots. This may be due to seasonal variation, average temperatures were warmer in 1997 than 1996 (Appendix A). Student's t-tests were used to statistically compare the thaw rates (slopes) between 1996 and 1997 for each test plot at each site, shown in Table 9. Only Polynet/Pyramat at Tanada Trailhead showed a significant increase in thaw rates between 1996 and 1997.

Maximum Thaw

The maximum average thaw depth was calculated by determining the average thaw depth for each monitoring period by transect for each test plot, then selecting the maximum value for each test plot for the sampling year. Figure 9 shows the average maximum thaw depths averaged across the study sites. To assess changes within plots between years, comparisons were made between 1996 and 1997 maximum thaw depth for each treatment or control type. There was a significant difference in thaw depths by sample year, with 1997 having greater thaw depths than 1996 and among the test plots (Table 12). Maximum average thaw depths were then compared by year for each plot type. During 1996, there was a significant difference in maximum thaw depth among the plots ($P = 0.04$) (Table 13). The post-hoc analysis indicated that only Geoblock® 2" (average maximum thaw depth of 95.3 cm) had significantly greater thaw depths than the Unaffected Control (50.2 cm). By 1997, although the Unaffected Plots still had lower maximum thaw rates, there was no significant difference among the maximum thaw depths among the test plots (Table 14).

There was no clear pattern (positive or negative) on thaw depth or thaw rate within the period of monitoring. Monitoring over two years was probably not long enough to see significant changes in the thermal regime, due to the thermal buffering in the surrounding permafrost. Factors that would affect thaw depth in the long term are most likely associated with characteristics of the surface (i.e. thickness of covering vegetation mat and organic mat) and surface hydrology (ponding). Even with significant vegetation recovery, thaw patterns set in motion from prior disturbances may take 10 – 15 years or more to recover to the thermal patterns of an unaffected site.

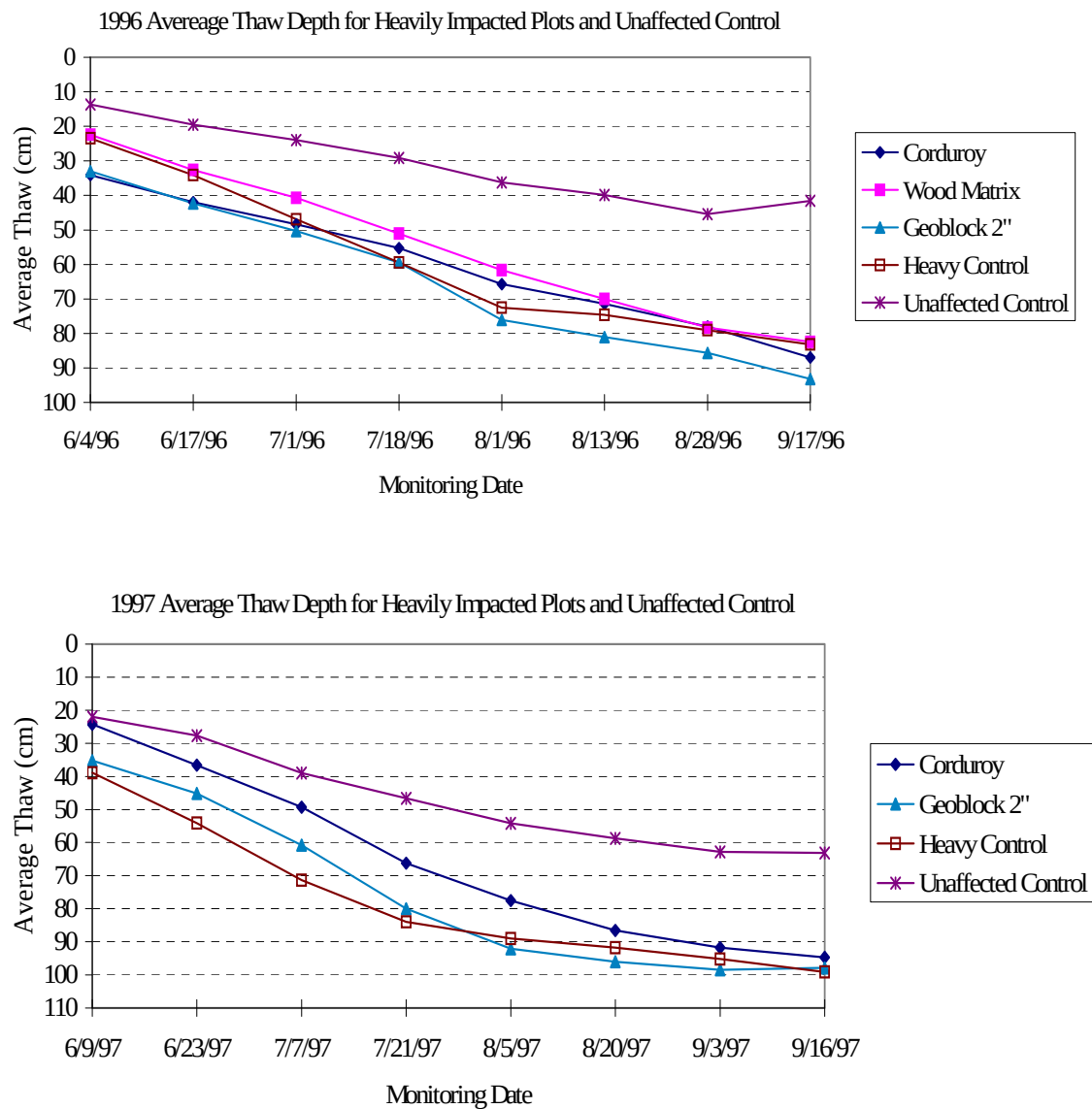


Figure 7. Average thaw depths for the heavily impacted test plots during the 1996 and 1997 monitoring periods. Averaged across all four sampling sites.

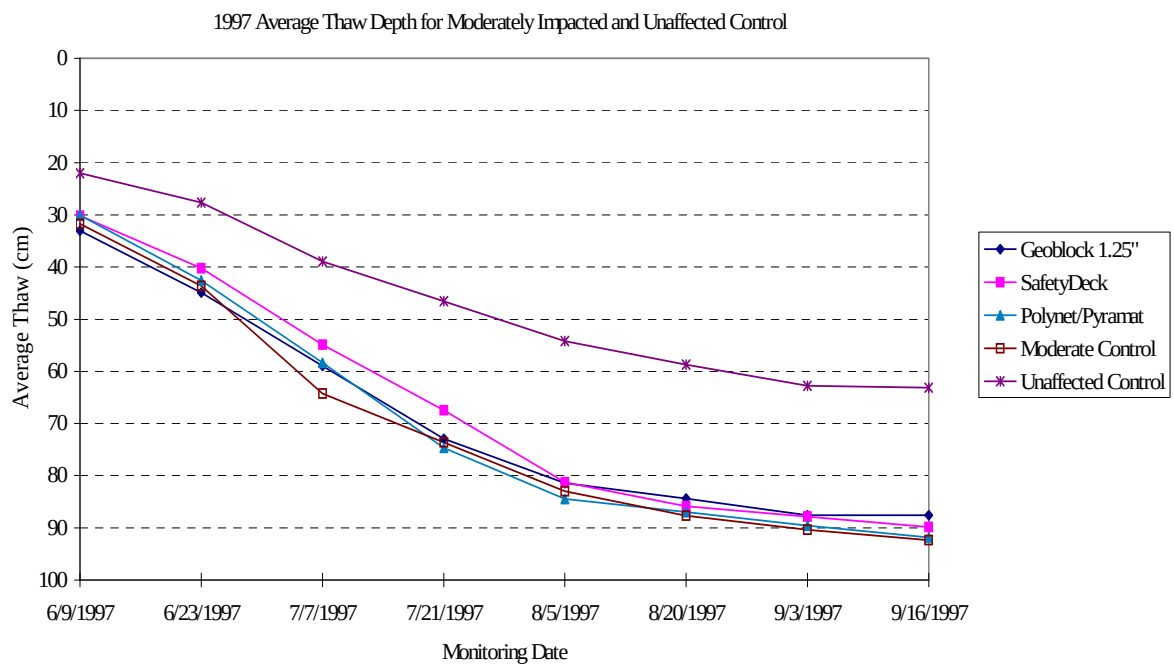


Figure 8. Average thaw depths for moderately impacted test plots during the 1996 and 1997 monitoring periods. Averaged across all four sampling sites.

Table 9. The average thaw rates (slopes) determined from linear regression analyses for each plot by site for 1996 and 1997 are shown below. Trail impact level are indicated by M for moderate, H for heavy, and U for Unaffected. The probability that the slopes are different between 1996 and 1997 for each test plot were calculated with a Student's t-test. P-values less than or equal to 0.05 indicate a significant difference in the thaw rate between 1996 and 1997.

Imp-act	Test Plots	Trail Study Site	1996 Thaw Rate	1997 Thaw Rate	t Value	v	P > [t]
U	Unaffected Control	Reeve Field	0.241	0.440	0.756	38	> 0.50
		Suslota	0.283	0.464	1.243	41	> 0.50
		Tanada Lake	0.352	0.526	0.291	35	> 0.50
		Tanada Trailhead	0.276	0.340	0.497	44	> 0.50
M	Moderate Control	Reeve Field	0.412	0.539	1.232	38	> 0.50
		Suslota	0.445	0.544	0.349	41	> 0.20
		Tanada Lake	0.562				
		Tanada Trailhead	0.739	0.768	0.479	43	> 0.50
M	Geoblock 1 ¼"	Reeve Field	0.363	0.575	0.992	40	> 0.50
		Suslota	0.782	0.693	-0.949	42	> 0.50
		Tanada Lake	0.389	0.437	0.118	38	> 0.50
		Tanada Trailhead	0.498	0.537	0.470	44	> 0.50
M	Polynet/Pyramat	Reeve Field	0.390	0.580	0.513	38	> 0.50
		Suslota	0.494	0.566	0.899	41	> 0.20
		Tanada Lake	0.515				
		Tanada Trailhead	0.629	0.800	3.311	44	< 0.002
M	Safety Deck®	Reeve Field	0.381	0.554	1.333	38	> 0.50
		Suslota	0.549	0.568	0.100	41	> 0.50
		Tanada Lake	0.272	0.641	1.682	23	> 0.50
		Tanada Trailhead	0.617	0.703	1.168	44	> 0.20
H	Heavy Control	Reeve Field	0.327	0.586	0.424	32	> 0.50
		Suslota	0.639	0.58	-0.679	41	> 0.50
		Tanada Lake	0.333				
		Tanada Trailhead	0.592	0.565	-0.258	44	> 0.50
H	Corduroy	Reeve Field	0.376	0.582	1.305	40	> 0.20
		Suslota	0.545	0.849	1.407	42	> 0.50
		Tanada Lake	0.571	0.633	0.251	38	> 0.50
		Tanada Trailhead	0.737	0.913	1.469	44	> 0.10
H	Geoblock® 2"	Reeve Field	0.337	0.462	0.833	40	> 0.50
		Suslota	0.971	1.017	0.329	42	> 0.50
		Tanada Lake	0.508	0.537	0.219	38	> 0.50
		Tanada Trailhead	0.661	0.793	1.011	39	> 0.50
H	Wood Matrix	Reeve Field	0.394				
		Suslota	0.747				
		Tanada Lake	0.469				
		Tanada Trailhead	0.595				

Table 10. The results of a two-way ANOVA, comparing the thaw rates among the test plots (Treatment) and study sites (trail) for 1996.

Tests of Between-Subjects Effects^b

Dependent Variable: JULDATE

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	2.683 ^a	35	7.665E-02	5.187	.000
Intercept	22.608	1	22.608	1529.947	.000
TRAIL	.911	3	.304	20.548	.000
TREATMEN	.841	8	.105	7.112	.000
TRAIL * TREATMEN	1.011	24	4.214E-02	2.852	.001
Error	.828	56	1.478E-02		
Total	26.199	92			
Corrected Total	3.510	91			

a. R Squared = .764 (Adjusted R Squared = .617)

b. YEAR = 96

Table 11. The results of a two-way ANOVA, comparing the thaw rates among the test plots (treatment) and study sites (trail) for 1997.

Tests of Between-Subjects Effects^b

Dependent Variable: JULDATE

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	2.587 ^a	28	9.239E-02	9.025	.000
Intercept	34.141	1	34.141	3335.142	.000
TRAIL	.448	3	.149	14.574	.000
TREATMEN	.937	7	.134	13.080	.000
TRAIL * TREATMEN	1.092	18	6.065E-02	5.924	.000
Error	.717	70	1.024E-02		
Total	42.058	99			
Corrected Total	3.303	98			

a. R Squared = .783 (Adjusted R Squared = .696)

b. YEAR = 97

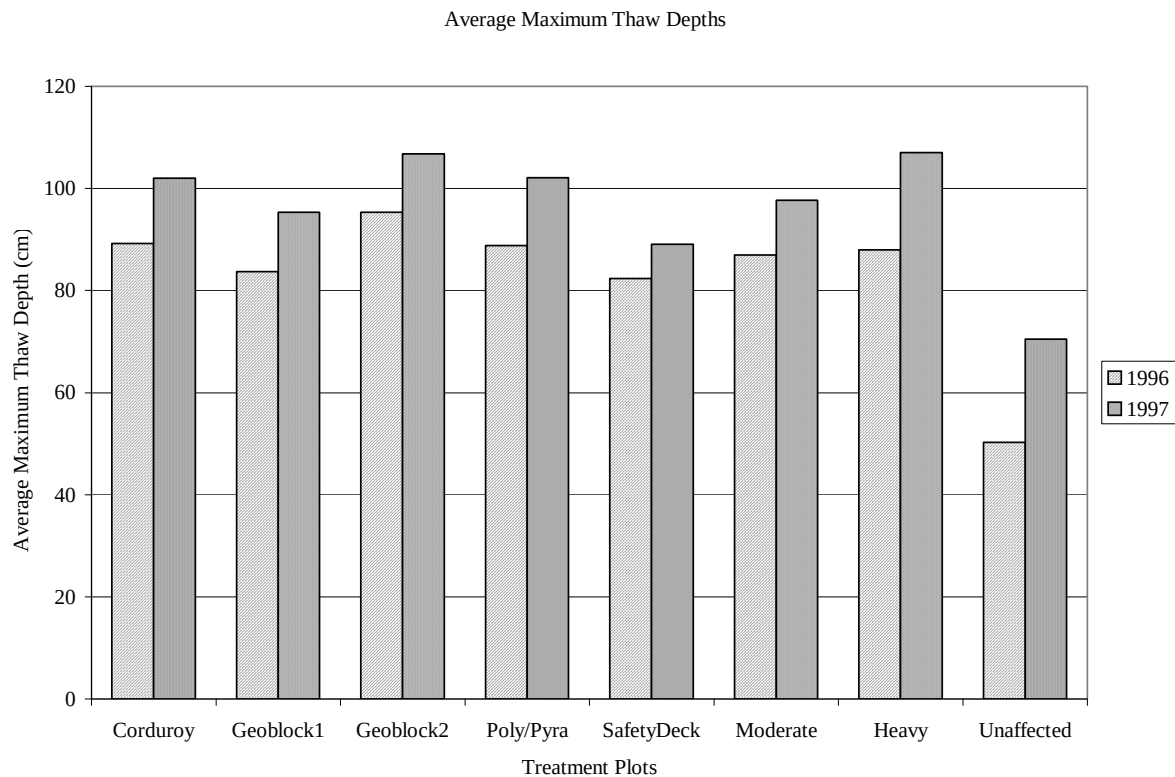


Figure 9. The average maximum thaw depth in centimeters for each plot type during 1996 and 1997. Thaw depths were averaged across sites.

Table 12. The results of a two-way ANOVA comparing the average maximum thaw depth between the two sample years, 1996 and 1997, and among the test plots.

Tests of Between-Subjects Effects

Dependent Variable: THAW_MAX

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	11735.529 ^a	16	733.471	2.305	.013
Intercept	506036.278	1	506036.278	1590.000	.000
YEAR	2635.803	1	2635.803	8.282	.006
TREATMEN	9002.807	8	1125.351	3.536	.003
YEAR * TREATMEN	263.685	7	37.669	.118	.997
Error	15276.565	48	318.262		
Total	539373.313	65			
Corrected Total	27012.094	64			

a. R Squared = .434 (Adjusted R Squared = .246)

Table 13. The results of a one-way ANOVA comparing the difference in maximum thaw depths for each test plot during 1996.

Tests of Between-Subjects Effects^b

Dependent Variable: THAW_MAX

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	5357.080 ^a	8	669.635	2.435	.040
Intercept	249319.908	1	249319.908	906.470	.000
TREATMEN	5357.080	8	669.635	2.435	.040
Error	7426.214	27	275.045		
Total	262103.201	36			
Corrected Total	12783.294	35			

a. R Squared = .419 (Adjusted R Squared = .247)

b. YEAR = 96

Table 14. The results of a one-way ANOVA comparing the difference in maximum thaw depths for each test plot during 1997.

Tests of Between-Subjects Effects^b

Dependent Variable: THAW_MAX

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	3880.966 ^a	7	554.424	1.483	.227
Intercept	263815.396	1	263815.396	705.717	.000
TREATMEN	3880.966	7	554.424	1.483	.227
Error	7850.352	21	373.826		
Total	277270.111	29			
Corrected Total	11731.318	28			

a. R Squared = .331 (Adjusted R Squared = .108)

b. YEAR = 97

Vegetation Results

Reeve Field

The dominant vegetation cover in the sampled trail plots at Reeve Field both prior to and four years after the installation of the hardening materials was *Carex aquatilis* (water sedge) and *Eriophorum angustifolium* (tall cotton-grass). Both of these species generally grow in shallow water - bordering ponds or bogs, indicating a relatively wet site. This section of the trail is located at the toe of a saturated slope, and the trail is entrenched forming a depression that collects water. The unaffected plot and area surrounding the trail plots was an open, shrub birch-willow community (Vioreck, 1992), predominately vegetated with shrubs: dwarf birch hybrid (*Betula* hybrid (*glandulosa* x *papyrifera*)) and willow (*Salix glauca* and *Salix planifolia*), and tussocks of *Eriophorum vaginatum*. The difference in general species composition between the unaffected plot and the trail plots can be seen in between Figure 11. Reeve Field was the only site that appeared to have continuous ATV use along the

test area throughout the four years. Secondary trails were probably not developed because of the heavy shrub cover adjacent to the trail, reducing the motorist's ability to create secondary trails.

At Reeve Field, there was significantly greater vegetation cover during 2000 across all of the plots ($P < 0.000$) in comparison to 1996 and 1997 (Table 15 and Figure 10). There was no significant difference in total vegetation cover between 1996 and 1997. In comparing the total percent vegetation cover among the eight plots there was a significant difference among all eight plots for the three years of data (Table 16). The post-hoc analysis revealed that five of the plots in 1996 had significantly lower total percent vegetation cover than the Unaffected control plot, these were: Corduroy, Polynet/Pyramat, Geoblock® 2", Moderate Control and Heavy Control. Four years later in 2000, only the Heavy Control plot had significantly lower vegetation cover than the Unaffected plot (See Table 17, Figure 10). A photo series of the Reeve Field test plots over time is presented in the Photo Series Section, and shows the changes in vegetation over time.

It is of interest to compare the relative change in vegetation cover to determine whether the hardening treatment plots had an increase or decrease in vegetation growth in comparison to the untreated trail controls or the unaffected control. As seen in Figure 11, the change in vegetation cover between 1996 and 1997 showed a drop in vegetation cover for several of the plots (Geoblock® 1 ¼", Safety Deck®, Polynet/Pyramat and Unaffected Control). However only Geoblock® 1 ¼" had a significant decrease in cover compared to heavy control, while Geoblock® 2" had a significant increase in cover when compared to the unaffected control. Although the overall cover increased by 2000, the amount of increase was not significantly different among the plots. Indicating there was a general increase, but it occurred throughout all of the plots (Figure 11). The majority of the vegetation increase was attributed to an increase in cotton grass, *Eriophorum* species (generally *E. angustifolium*), with a decrease in litter or *Carex* (Table 18).

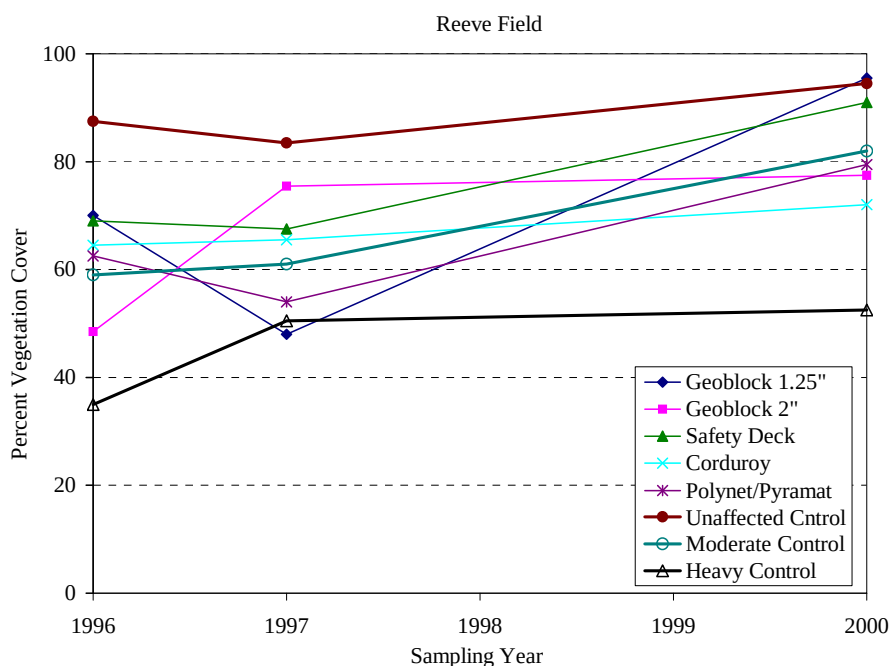


Figure 10. Display of the average percent cover of all vegetation by test plot type. Each point symbol represents the average percent cover taken during that sampling year for Reeve Field.

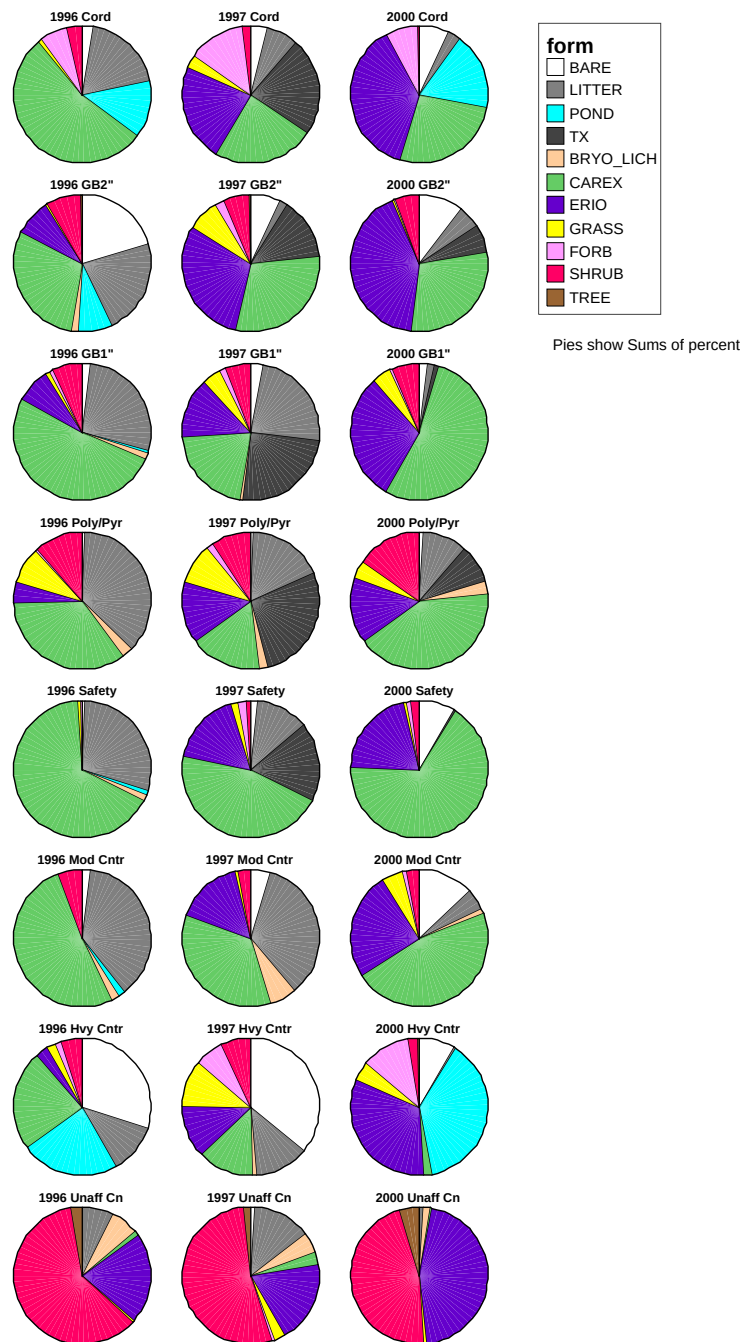


Figure 11. General species composition for major types of vegetation and ground cover, during 1996, 1997 and 2000 of each test plot at the Reeve Field study site. Pie slices represent the average percent cover of vegetation or ground cover of each test plot.

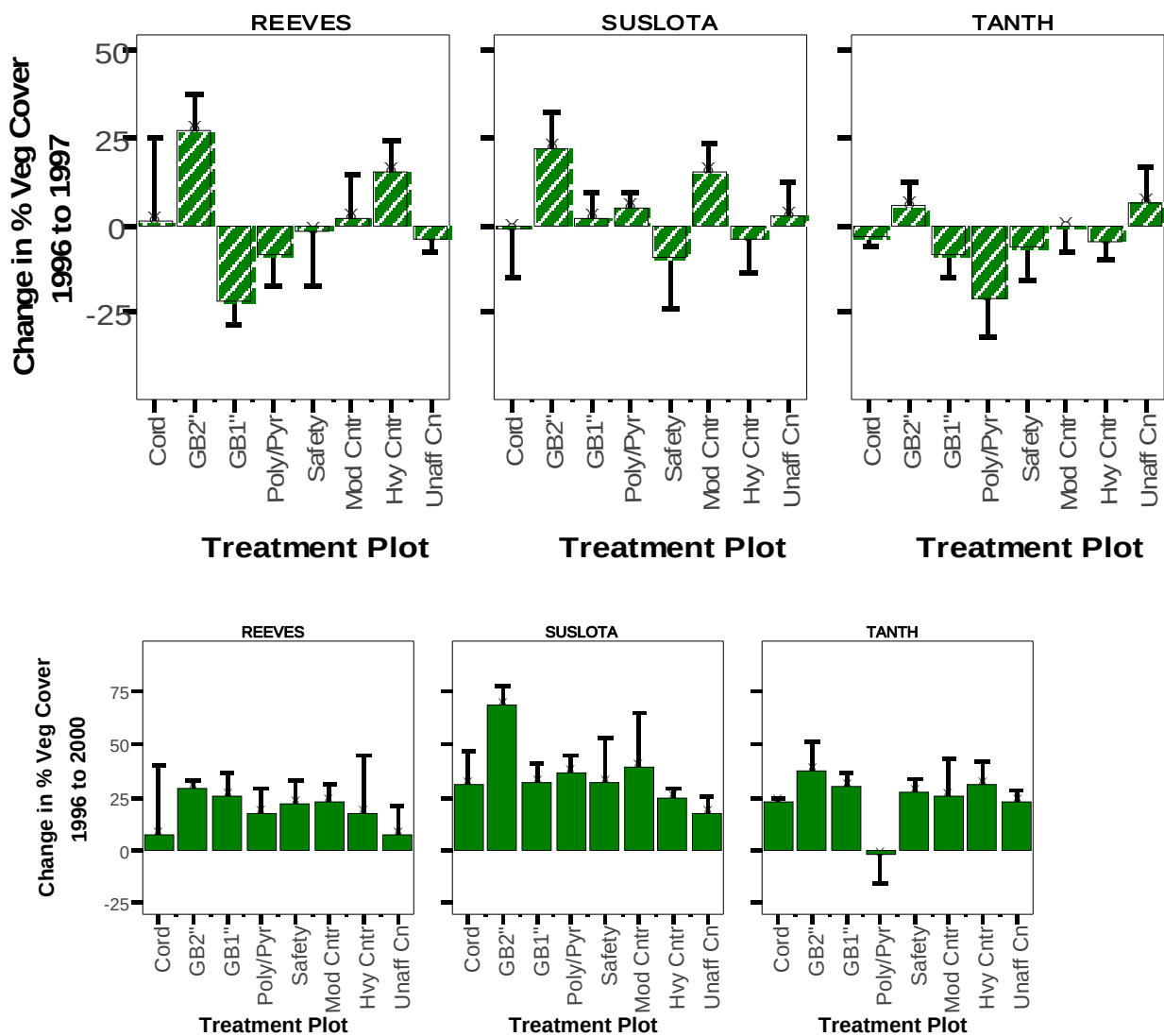


Figure 12. Bar graphs showing the average change in percent total vegetation cover for each test plot between 1996 to 2000 (top graph) and between 1996 to 2000 (bottom graph). A positive bar indicates the vegetation cover increased, a negative bar indicates a decrease in vegetation cover.

Table 15. The results of a 1-way ANOVA and Tukey's Post-Hoc comparison of the average percent vegetation cover for all Reeve Field ATV mitigation plots among the three years sampled.

ANOVA^a

VEG_TOT

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	8638.229	2	4319.115	13.706	.000
Within Groups	36870.938	117	315.136		
Total	45509.167	119			

a. BLOCK = REEVES

Average Percent Vegetation Cover^b

Tukey HSD^a

YEAR	N	Subset for alpha = .05	
		1	2
1996	40	62.0000	80.5625
1997	40	63.1875	
2000	40		
Sig.		.952	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 40.000.

b. BLOCK = REEVES

Table 16. The results of a 1-way ANOVA comparing the difference in total percent vegetation cover by year among the test plots at the Reeve Field.

Variable	Test	Sum of Squares	df	Mean Square	F	Sig.
1996 % Veg	Between Test Plots	8450.00	7	1207.14	10.226	0.000
	Within Test Plots	3777.50	32	118.05		
	Total	12227.50	39			
1997 % Veg	Between Test Plots	5344.84	7	763.55	4.120	0.002
	Within Test Plots	5930.00	32	185.31		
	Total	11274.84	39			
2000 % Veg	Between Test Plots	6998.59	7	999.80	5.023	0.001
	Within Test Plots	6370.00	32	199.06		
	Total	13368.59	39			

Table 17. Mean percent cover and standard deviation (in parentheses) for total vegetation by test plot and year. Asterisks indicate significantly different covers when compared to the unaffected control, see Table 16 for the ANOVA tables. N = 5 transects per test.

Test Plots	1996 Pre-Treatment	1997	2000
	Average Percent Total Vegetation Cover	Average Percent Total Vegetation Cover	Average Percent Total Vegetation Cover
Corduroy	64.5 (13.1)*	65.5 (20.2)	72.0 (21.2)
Geoblock 2"	48.5 (10.8)*	75.5 (20.4)	77.5 (11.6)
Geoblock 1 ¼"	70.0 (7.7)	48.0 (7.8)*	95.5 (5.1)
Polynet/Pyramat	62.5 (8.4)*	54.0 (2.8)*	79.5 (6.2)
Safety Deck	69.0 (9.8)	67.5 (7.5)	91.0 (3.8)
Moderate Control	59.0 (5.7)*	61.0 (12.9)	82.0 (10.9)
Heavy Control	35.0 (18.4)*	50.5 (18.6)*	52.5 (27.4)*
Unaffected Control	87.5 (7.3)	83.5 (4.5)	94.5 (7.4)

Table 18. List of the cover type with the greatest increase in cover and greatest decrease in cover between 1996 and 2000 vegetation monitoring at Reeve Field.

Treatment	Greatest Increase in Cover	Greatest Decrease in Cover
	1996 –2000	1996 –2000
Corduroy	<i>Eriophorum</i>	<i>Carex</i>
Geoblock 2"	<i>Eriophorum</i>	Litter
Geoblock 1 ¼"	<i>Eriophorum</i>	Litter
Safety Deck	<i>Eriophorum</i>	Litter
Polynet/Pyramat	<i>Eriophorum</i>	Litter
Heavy Control	<i>Eriophorum</i>	<i>Carex</i> and Bare Ground
Moderate Control	<i>Eriophorum</i>	Litter
Unaffected Control	<i>Eriophorum</i>	Low shrub

Suslota Lake Trail

In 1996, the Suslota trail plots were primarily barren of vegetation except along the edges of the trails, which had *Eriophorum vaginatum*, a tussocks forming cotton grass, and low shrubs (Figures 13 and 14). By 2000, there was a significant increase in vegetation cover within the trail plots, primarily *E. vaginatum*. The unaffected plot and adjacent vegetation to the trail was an open low mixed shrub-sedge tussock tundra community (Viereck 1992), predominately vegetated with tussocks *Eriophorum vaginatum* and approximately 30% dwarf birch, *Betula glandulosa/nana*. A photo series of the Suslota test plots over time is presented in the Photo Series Section.

During 1996 and 1997 there was documented ATV use over the study site trail segments. However, sometime after 1997, the study site trail segments were by-passed by ATVs. Several areas between the test plots became impassable due to large mud-bogs that developed between the treatment plots and within the control plots. Currently the trail segment is totally abandoned and an alternate trail has formed. It is estimated that very little ATV or foot traffic occurred over the study site trail segment since 1997 (personal comm. Vickie Rood). Therefore, this site best estimates the vegetation condition after two years of trail use followed by two years of little or no use.

Similar to Reeve Field, there was significantly greater vegetation cover in 2000 compared to 1996 and 1997 (Table 19 and Figure 14). There was no significant difference in total vegetation cover between 1996 and 1997. In 1996 all of the plots at Suslota had significantly lower total vegetation cover than the Unaffected Control in 1996, as seen in Figure 14 and Table 21.

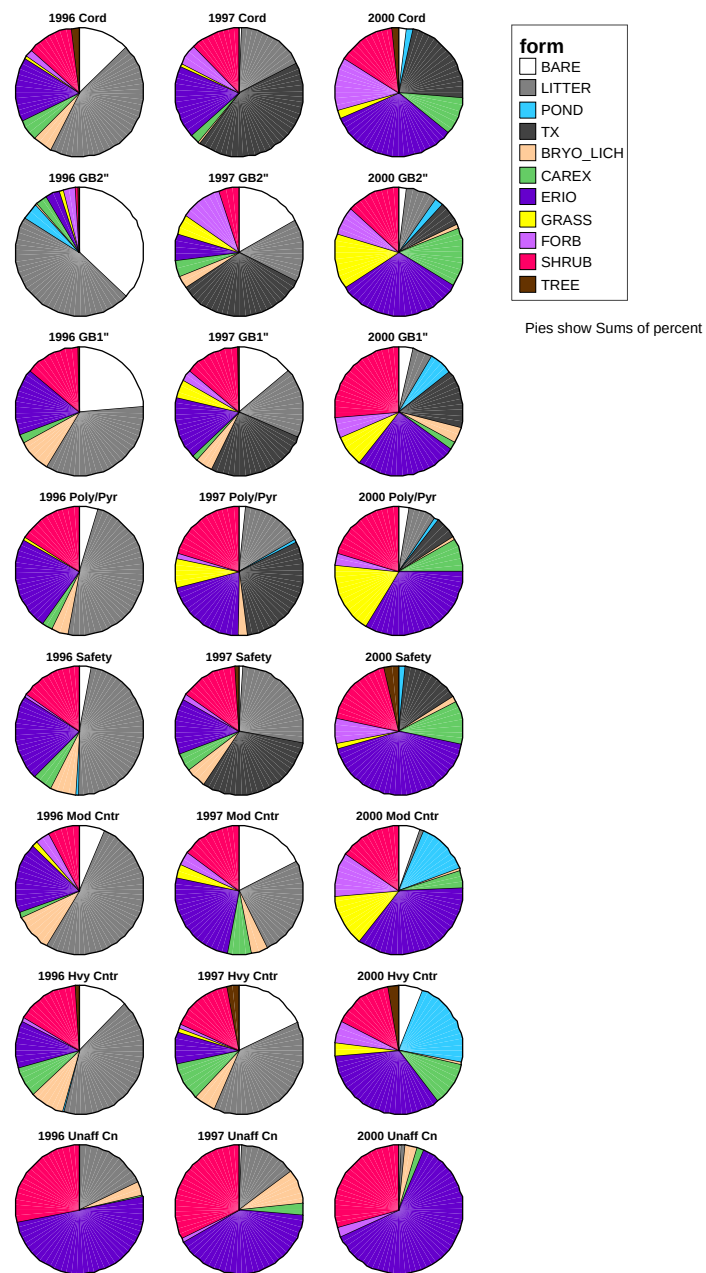


Figure 13. General species composition for major types of vegetation and ground cover, during 1996, 1997 and 2000 of each test plot at the Suslota study site. Pie slices represent the average percent cover of vegetation or ground cover of each test plot.

Four years later in 2000, only three of the plots had significantly lower vegetation cover than the unaffected plot (Corduroy, Geoblock 1 ¼" and Heavy Control). This suggests a significant recovery in vegetation growth, however all of the plots, including the moderately and heavily impacted plots, appeared to have an increase in vegetation growth by 2000 (Figure 12). In comparing the change in vegetation cover from 1996 to 2000, only Geoblock 2" had a significant increase in vegetation when compared to the control plots (moderate, heavy and unaffected). Figure 22 A -C in the photo series section clearly shows the increase in vegetation cover for Geoblock 2" at Suslota from 1996 to 2000. It should be noted that the initial vegetation cover was very low for this plot, and that there was more potential for increased vegetation.

The majority of the vegetation increase for all of the plots was attributed to an increase in tussocks cotton grass, *Eriophorum vaginatum*, with a decrease in litter (Table 22). From Figure 13 it can also be seen that several of the plots showed a slight increase in grasses – primarily *Calamagrostis canadensis* and *Arctagrostis latifolia*. Slough grass, *Beckmannia erucaeformis*, also increased in cover.

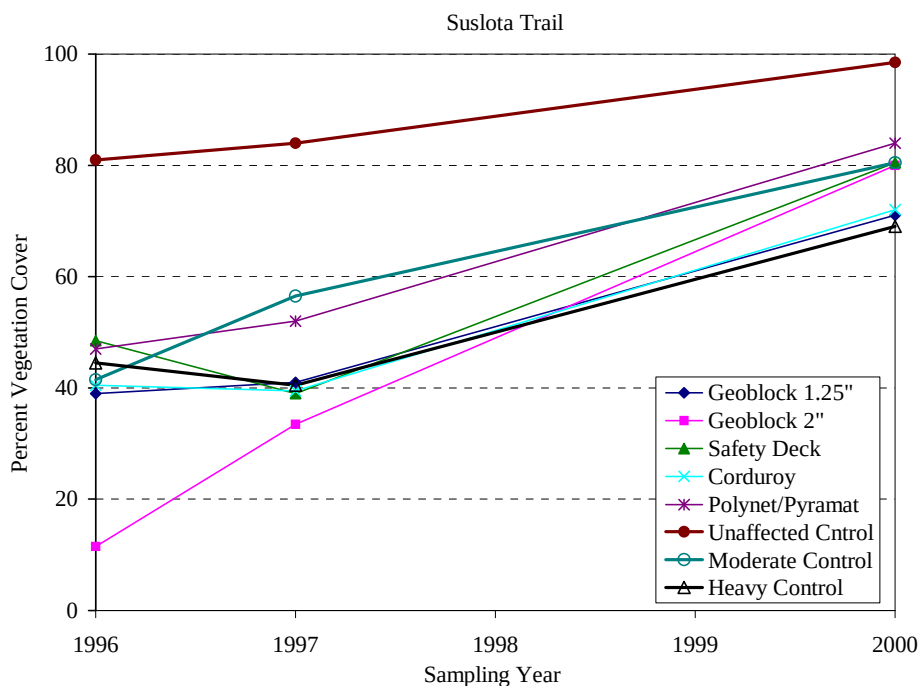


Figure 14. Display of the average percent cover of all vegetation by test plot at Suslota study site. Each point symbol represents the average percent cover measured for the sampling year.

Table 19. The results of a 1-way ANOVA and Tukey's Post-Hoc comparison of the average percent vegetation cover among the three years sampled for all ATV mitigation plots at Suslota Trail.

ANOVA^a

VEG_TOT

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	29756.354	2	14878.177	54.059	.000
Within Groups	32200.938	117	275.222		
Total	61957.292	119			

a. BLOCK = SUSLOTA

Average Percent Vegetation Cover^b

Tukey HSD^{*}

YEAR	N	Subset for alpha = .05	
		1	2
1996	40	44.1875	79.4375
1997	40	48.2500	
2000	40		
Sig.		.519	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 40.000.

b. BLOCK = SUSLOTA

Table 20. The results of a 1-way ANOVA comparing the difference in total percent vegetation cover by year among the eight treatment plots at Suslota.

Variable	Test	Sum of Squares	df	Mean Square	F	Sig.
1996 % Veg	Between Test Plots	12489.8	7	1784.2	18.629	0.000
	Within Test Plots	3065.0	32	95.78		
	Total	15554.8	39			
1997 % Veg	Between Test Plots	9262.5	7	1323.2	29.924	0.000
	Within Test Plots	1415.0	32	44.2		
	Total	10677.5	39			
2000 % Veg	Between Test Plots	3111.1	7	444.4	4.977	0.001
	Within Test Plots	2857.5	32	89.3		
	Total	5968.6	39			

Table 21. Mean percent cover and standard deviation (in parentheses) for total vegetation by treatment plot and year. Asterisks indicate significantly different covers when compared to the unaffected control, see Table 20 for the ANOVA tables. N = 5 transects per treatment.

Treatment	1996	1997	2000
	Average Percent Total Vegetation Cover	Average Percent Total Vegetation Cover	Average Percent Total Vegetation Cover
Corduroy	40.5 (15.9)*	39.5 (6.9)*	72.0 (4.4)*
Geoblock 2"	11.5 (10.8)*	33.5 (5.2)*	80.0 (3.9)
Geoblock 1 ¼"	39.0 (7.2)*	41.0 (7.2)*	71.0 (7.2)*
Polynet/Pyramat	47.0 (6.9)*	52.0 (7.8)*	84.0 (4.2)
Safety Deck	48.5 (7.2)*	39.0 (9.1)*	80.5 (13.5)
Moderate Control	41.5 (9.3)*	56.5 (4.2)*	80.5 (18.4)
Heavy Control	44.5 (10.1)*	40.5 (6.9)*	69.0 (9.1)*
Unaffected Control	81.0 (7.4)	84.0 (4.2)	98.5 (2.2)

Table 22. List of the cover type with the greatest increase in cover and greatest decrease in cover between 1996 and 2000 vegetation monitoring at Suslota.

Treatment	Greatest Increase in Cover	Greatest Decrease in Cover 1996 -
	1996 -2000	2000
Corduroy	<i>Eriophorum</i>	Litter
Geoblock 2"	<i>Eriophorum</i>	Litter
Geoblock 1 ¼"	Low Shrub	Litter
Safety Deck	<i>Eriophorum</i>	Litter
Polynet/Pyramat	<i>Eriophorum</i>	Litter
Heavy Control	<i>Eriophorum</i>	Litter
Moderate Control	<i>Eriophorum</i>	Litter
Unaffected Control	<i>Eriophorum</i>	Litter

Tanada Trailhead

The vegetation at the Tanada Trailhead test site was fairly similar to that of the Suslota site. The unaffected area was a mixed shrub-sedge tussock tundra (Viereck *et al.* 1992), with *Eriophorum vaginatum* and dwarf birch, *Betula glandulosa*. In 1996, the active trail plots were primarily barren (ponding, litter or bare ground) with low shrubs and tussocks on the inactive edges (Figure 15). Over the four years, there was an increase in *Eriophorum* or *Carex*.

The seismic and photo monitoring detected ATV use through 1997. Field notes report that during 1998 an alternate trail was being used, and the test area trail was less traveled due to the mud bogs that developed between the hardening test plots and within the trail control plots. It is uncertain how much ATV use the Tanada TH plots received from 1998 to 2000, but observations from 2000 note that ATV use seemed to be split between alternate routes and the test area trail. Therefore this site could be considered to have light to moderate use.

Again, there was a significant increase in vegetation cover in 2000, compared to 1996 and 1997 (Table 23 and Figure 16). There was no significant difference in total vegetation cover between 1996 and 1997. In 1996 only three of the plots (Geoblock 1 ¼" and 2" and Heavy Control) had significantly lower vegetation cover than the unaffected control plot (Tables 24 and 25). In 1997 all of the plots had lower vegetation cover than the Unaffected Control, probably due to the cover caused by the hardening materials. But by 2000, only Polynet/Pyramat and Heavy Control plots had

significantly lower vegetation cover than the Unaffected Control. The change in vegetation cover between the sampling years is shown in Figure 12. In comparing the change in vegetation cover from 1996 to 2000, it was found that Polynet/Pyramat had a significant decrease in vegetation when compared to the control plots (moderate, heavy and unaffected).

The type of vegetation increase varied among the plots, but included *Eriophorum angustifolium* and *Eriophorum vaginatum*, low shrubs (*Betula*) and *Carex* (Table 26 and Figure 15). From Figure 15 it can also be seen that Heavy Control and Safety Deck plots had an increase in grasses – primarily slough grass, *Beckmannia eruaeformis*, which is a weedy annual, although not introduced.

Photo Monitoring

Of the photos taken for the photo monitoring, two photo series are presented here to demonstrate the changes that occurred to the trails over the duration of the study. The Reeve Field study site, shown in Figures 17- 20 was selected because it represents a site that has had continuous ATV use over the monitoring period. The Suslota study site was selected to show the changes in vegetation and ponding on a two year old abandoned trail section (Figures 21 – 24).

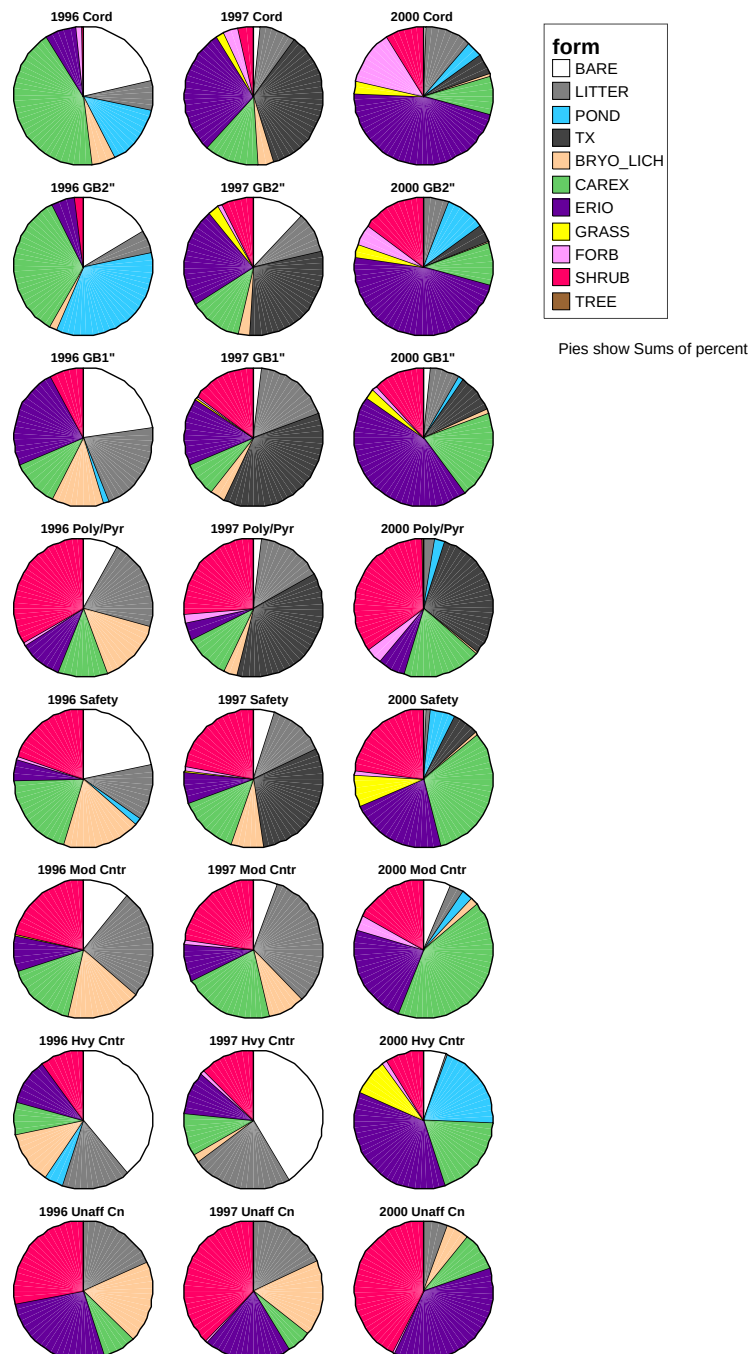


Figure 15. General species composition for major types of vegetation and ground cover, during 1996, 1997 and 2000 of each test plot at the Tanada Trailhead study site. Pie slices represent the average percent cover of vegetation or ground cover of each test plot.

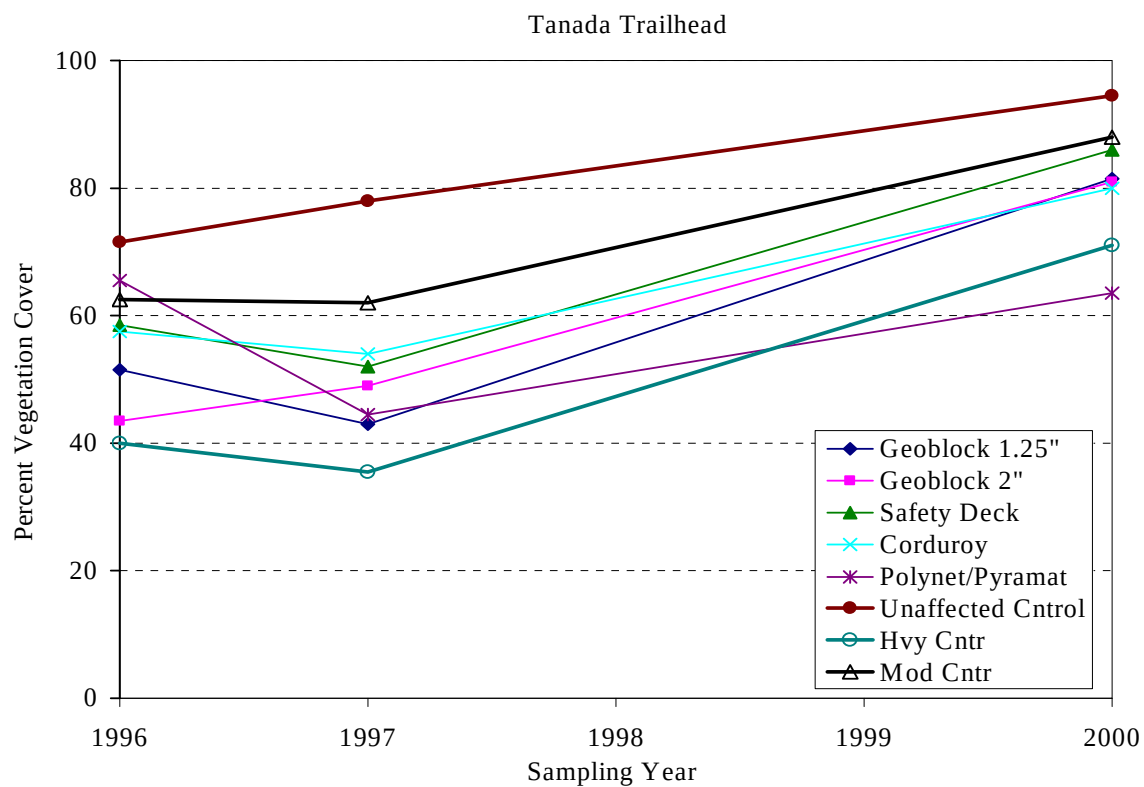


Figure 16. Display of the average percent cover of all vegetation by test plot at Tanada Trailhead. Each point symbol represents the average percent cover measured for the sampling year.

Table 23. The results of a 1-way ANOVA and Tukey's Post-Hoc comparison of the average percent vegetation cover among the three years sampled for all ATV mitigation plots at Tanada Trailhead.

ANOVA^a

VEG_TOT

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	18924.479	2	9462.240	55.121	.000
Within Groups	20084.688	117	171.664		
Total	39009.167	119			

a. BLOCK = TANTH

Average Total Vegetation Percent for all Plots^b

Tukey HSD^a

YEAR	N	Subset for alpha = .05	
		1	2
1997	40	52.2500	80.6875
1996	40	56.3125	
2000	40		
Sig.		.351	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 40.000.

b. BLOCK = TANTH

Table 24. The results of a 1-way ANOVA, testing the difference in the percent vegetation cover among the 8 plots, during 1996,1997 and 2000 at Tanada Trailhead.

Variable	Test	Sum of Squares	df	Mean Square	F	Sig.
1996 % Veg	Between Test Plots	4064.8	7	580.7	6.763	0.000
	Within Test Plots	2747.5	32	85.8		
	Total	6812.3	39			
1997 % Veg	Between Test Plots	5990.0	7	855.7	13.640	0.000
	Within Test Plots	2007.5	32	62.7		
	Total	7997.5	39			
2000 % Veg	Between Test Plots	3314.8	7	473.5	7.731	0.000
	Within Test Plots	1960.0	32	61.2		
	Total	5274.8	39			

Table 25. Mean percent cover and standard deviation (in parentheses) for total vegetation by treatment plot and year. Asterisks indicate significantly different covers when compared to the unaffected control, see Table 24 for the ANOVA tables. N = 5 transects per treatment.

Treatment	1996	1997	2000
	Average Percent Total Vegetation Cover	Average Percent Total Vegetation Cover	Average Percent Total Vegetation Cover
Corduroy	57.5 (9.3)	54.0 (7.2)*	80.0 (9.3)
Geoblock 2"	43.5 (10.7)*	49.0 (5.7)*	81.0 (6.2)
Geoblock 1 ¼"	51.5 (5.7)*	43.0 (4.1)*	81.5 (10.2)
Polynet/Pyramat	65.5 (10.5)	44.5 (4.8)*	63.5 (6.8)*
Safety Deck	58.5 (9.5)	52.0 (8.7)*	86.0 (6.5)
Moderate Control	62.5 (14.2)	62.0 (7.8)	88.0 (5.4)
Heavy Control	40.0 (6.4)*	35.5 (9.3)*	71.0 (11.4)*
Unaffected Control	71.5 (2.8)	78.0 (12.4)	94.5 (3.2)

Table 26. List of the cover type with the greatest increase in cover and greatest decrease in cover between 1996 and 2000 vegetation monitoring at Tanada Trailhead.

Treatment	Greatest Increase in Cover	Greatest Decrease in Cover
	1996 -2000	1996 -2000
Corduroy	<i>Eriophorum</i>	<i>Carex</i>
Geoblock 2"	<i>Eriophorum</i>	<i>Carex</i>
Geoblock 1 ¼"	<i>Eriophorum</i>	Bare ground
Polynet/Pyramat	Low Shrub	Litter
Safety Deck	<i>Eriophorum</i>	Bare ground
Moderate Control	<i>Carex</i>	Litter
Heavy Control	<i>Eriophorum</i>	Bare ground
Unaffected Control	Low Shrub	Litter



Figure 17. Photo series of Corduroy (A-C) and Safety Deck (D-F) hardening material plots between 1996 and 2000 at Reeve Field study site in Nabesna District, Wrangell-St. Elias National Park and Preserve, Alaska.



Figure 18. Photo series of Geoblock® 2" (A-C) and Geoblock® 1 1/4" (D-F) hardening material plots between 1996 and 2000 at Reeve Field study site in Nabesna District, Wrangell-St. Elias National Park and Preserve, Alaska. This study site had ATV traffic for all four years.



Figure 19. Photo series of Polynet PN-3000/Pyramat™ (A-C) hardening material plot and Moderate Control (D-F) untreated trail plot between 1996 and 2000 at Reeve Field study site in Nabesna District, Wrangell-St. Elias National Park and Preserve, Alaska. This study site had ATV traffic for all four years.



Figure 20. Photo series of the Heavy Control untreated trail plot (A-C) between 1996 and 2000 and Unaffected Control plot in 1997 (D) and 2000 (E) at Reeve Field study site in Nabesna District, Wrangell-St. Elias National Park and Preserve, Alaska. This study site had ATV traffic for all four years, excluding the unaffected area



Figure 21. Photo series of Corduroy (A-C) and Safety Deck (D-F) hardening material plots between 1996 and 2000 at Suslota Lake study site in Nabesna District, Wrangell-St. Elias National Park and Preserve, Alaska. This study site had ATV use during 1996 and 1997; an alternative trail was developed in 1998 that by-passed the study plots.

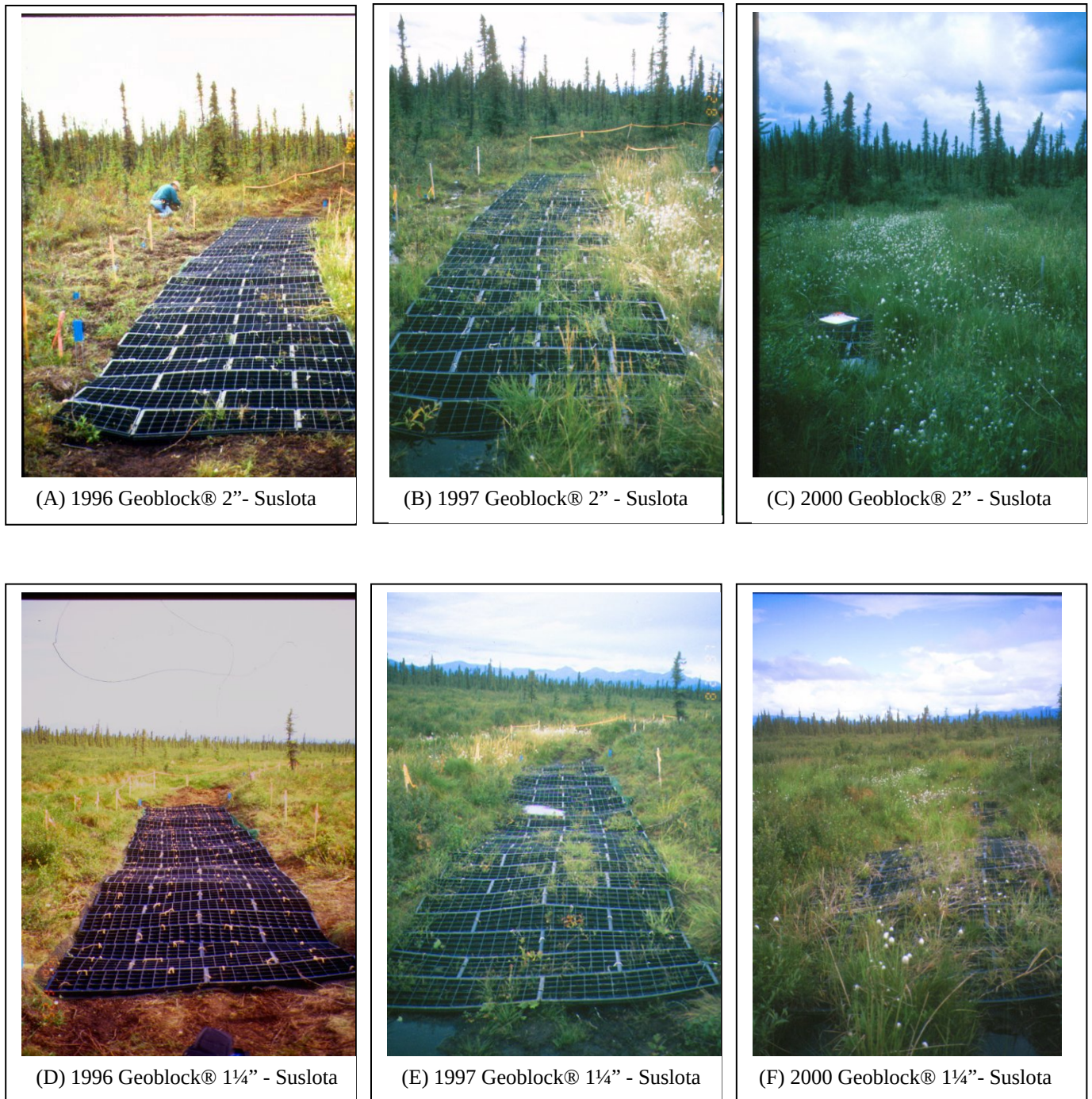


Figure 22 Photo series of Geoblock® 2" (A-C) and Geoblock® 1 1/4" (D-F) hardening material plots between 1996 and 2000 at Suslota Lake study site in Nabesna District, Wrangell-St. Elias National Park and Preserve, Alaska. This study site had ATV use during 1996 and 1997; an alternative trail was developed in 1998 that by-passed the study plots.



Figure 23. Photo series of Polynet PN-3000/Pyramat™ (A-C) hardening material plot and Moderate Control (D-F) untreated trail plot between 1996 and 2000 at Suslota Lake study site in Nabesna District, Wrangell-St. Elias National Park and Preserve, Alaska. This study site had ATV use during 1996 and 1997; an alternative trail was developed in 1998 that by-passed the study plots.



Figure 24. Photo series of the Heavy Control untreated trail plot (A-C) between 1996 and 2000 and Unaffected Control plot in 1997 (D) and 2000 (E) at Suslota Lake study site in Nabesna District, Wrangell-St. Elias National Park and Preserve, Alaska. The unaffected control photo from 1997 was taken to the east of the 2000 photo. This study site had ATV use during 1996 and 1997; an alternative trail was developed in 1998 that by-passed the trail study plots.



Figure 25. The vegetated and non-rutted sections along the trail (noted by the arrows) are areas with hardening material protection at Reeve Field.

CONCLUSIONS

The purpose of this study was to test the practicality, effectiveness and feasibility of four geosynthetic and two natural trail hardening materials on segments of all-terrain vehicle (ATV) trails in Wrangell-St. Elias National Park and Preserve. Specifically, cost, structural integrity, trail degradation (soil parameters) and re-vegetation were compared among the six materials. The sites were monitored in 1996, 1997 and 2000. At the time of this report, four of the materials were considered successful in terms of structural integrity, safety and stabilizing trail degradation: Corduroy, Geoblock 2", Geoblock® 1 1/4" and Safety Deck®, of these only the Corduroy and Geoblock® 2" are still available.

Six hardening materials were installed in test plots along four trail segments, with control plots at each study site. The test plots were established along segments of ATV trails in mixed shrub-sedge tussock communities, a common vegetation type along the trails in the Nabesna District of the Park. The NRPP ATV Assessment Report identified this community type as having the greatest number of trail braids, width of braids and ponding cover (Happe, Shea and Loya 1998). The hardening material test plots were installed in 12 m (40 ft) lengths, with non-hardened trail sections between the test plots. Controlling ATV use through the test plots proved difficult. Traffic through these non-hardened areas and the heavy and moderate control plots degraded and resulted in impassible trails for ATVs and hikers. Between 1998 and 2000, two of the four study sites were abandoned as active trails, and alternate routes were developed by users to avoid mud bogs that formed in between the individual test plots. The abandonment of the trail study sections influenced some of the results and intentions of the study. This problem demonstrated the need for hardening materials to be installed in longer spans and to have anchor points in adequate substrates that support

ATV use. Despite the lack of traffic across two of the test sites, this study provides valuable information for managers to assess the use of hardening materials as a mitigation tool on ATV trails.

Material Overview

The study provided a review of the cost of materials and installation, plus maintenance needs of the hardening materials. The costs of the raw materials varied greatly (\$5.40/linear foot for Corduroy to \$35.00/lf for Safety Deck®). In four years since the original purchase of the materials in 1996, prices have changed, material specifications have changed, and two of hardening materials are no longer commercial available (Safety Deck® and Geoblock® 1 ¼"). See Appendix D for current manufacture contacts, material specifications and costs.

Wood Matrix and Corduroy had the lowest initial purchase cost. The low cost of the raw materials for the Wood Matrix was countered by the high labor costs of constructing the materials. The Wood Matrix treatment was removed from the study because of concerns over trapping or tripping wildlife and horses in the 8"x 8" open grid. Corduroy provided a low cost method of trail hardening that worked well to stabilize trails and provide a tread suitable for all-terrain vehicle and foot traffic over non-ponded areas. In trail sections with standing water the woven Corduroy floated over the water and did not provide a stable walking or riding surface. Using off-site, prepared logs significantly lowered the labor costs of installation and prevented harvesting local trees creating secondary environmental effects in a park setting. Moderate amounts of site preparation was necessary for installation. One significant draw-back to Corduroy is the short service life of the material. Within four years, the Corduroy logs were showing signs of weathering and rot at all of the sites.

Polynet PN-3000 /Pyramat™ had the lowest cost for materials with installation. It conformed well to the terrain and required minimal trail leveling to install. It provided moderate trail stabilization if re-vegetation occurred. However, it had a low rating in terms of ability to support ATV use, maintenance and safety. The material had a tendency to bunch up and catch under ATVs, even when well anchored. In areas underlain with permafrost, the anchoring materials frequently frost jacked and created trail hazards. These materials work well as underlayment and flotation material, but did not prove to be suitable for hardening ATV trails when used separately.

The two Geoblock® materials (1 ¼" and 2" thick) were fairly expensive to purchase and install. The rigidity of the material required leveling at those sites with uneven terrain and extensive thermokarst features. However, the material provided excellent stability and was more durable than the Wood Matrix, Corduroy or Polynet/Pyramat. Changes in the dimension and panel joints of Geoblock® 2 currently on the market, increase the utility of the product for trail hardening installations.

Safety Deck® was the most expensive material to purchase and was fairly labor intensive to install. Safety Deck® conformed well to uneven terrain and required minimal site preparation for installation. The material provided excellent riding and walking surfaces, stabilized trail degradation and allowed for vegetation regeneration. It was the most popular material among surveyed trail users. Unfortunately this material is no longer available.

Trail Stabilization

Trail stabilization was measured in terms of the level of ponding and changes to the thermal regime. Between 1996 and 2000, the hardening materials did not significantly change or reduce ponding, while the heavily impacted sites had increased ponding. This suggests that the hardening materials stabilized the level of ponding within the monitored time frame.

During the two years of soil thaw depths monitoring, only one test plot displayed any signs of significant change in soil thaw rate. There was an overall trend of increased thaw rates and maximum

thaw depths for all of the plots including the unaffected control plots between 1996 and 1997. This may have been due to seasonal variation or due to impacts from monitoring.

The short amount of time monitored (2 years) probably does not allow for changes in the thermal regime to be detected, nor provide a long enough time frame to understand seasonal variation. The lack of ATV use on two of the trail sites, and the loss of one site to a mudslide, effected the decision to discontinue monitoring. Thermal regime may be one of the most important factors in terms of trail stabilization in permafrost soils, and it would be recommended to monitor thaw depths in future studies. The methods of monitoring used in this study should be reviewed and possibly revised. Specifically the use of the same insertion points for the probe.

Vegetation Reclamation

Repeated ATV use on trails generally results in the destruction of the surface organic horizon (plants, roots, organic litter, etc.) and compaction of the soil. This disrupts the drainage pattern and reduces water holding capacity of the soils and eventually results in ponding water in the trail ruts. Since standing water has a greater heat absorption capacity than bare soil or vegetation, the melting of underlying permafrost is accelerated.

All of the materials provided a certain level of re-vegetation as shown in Figure 25. Vegetation provides soil insulation and structure that can help stabilize trail destruction. Between 1996 and 2000 there was an increase in average total vegetation cover for all of the treatment plots, including the control plots. By 2000, most of the hardened study plots had vegetation cover comparable to the Unaffected Control Plots, although species composition still remained different. At all of the sites, the unprotected Heavy Control plots still had significantly lower vegetation cover than the Unaffected areas. Geoblock® 2" had the greatest increase in vegetation cover, while Polynet/Pyramat and Corduroy had the lowest increase in vegetation. Cotton grass (*Eriophorum* spp.) was the most common species of vegetation to increase for most of the sites.

The increase in average vegetation cover may have resulted from the abandonment of the trail segments at two of the study sites. Never the less, Reeve Field demonstrated that even under heavy use, the hardening materials provided protection for soils and roots while allowing vegetation to re-grow as shown in Figure 25.

RECOMMENDATIONS

Evidence from this study and others have shown that trails in mixed shrub-sedge tussock and mesic herbaceous tundra do not readily support ATV use, due to thermokarsting and soil instability problems. Suitable trail substrates that supports ATV use have been identified by the ATV assessment study (Happe, Shea and Loya 1998) and other studies (Teare and Meyers 1984).

Managers should explore the option of re-routing trails located on substandard soils and associated vegetation types (Happe, Shea and Loya 1998). Terrain analysis and soils mapping can be used to evaluate alternative routes. In some areas, re-routing short sections to avoid wetlands or inappropriate substrates may resolve trail problems. In other cases, a complete re-route or moving of the trail may be necessary. In either case, the environmental impacts of developing a new trail versus the cost of hardening a new trail need to be considered. Evidence from this study and the assessment study indicate that vegetation can re-colonize abandoned trails. However, the structure and species compositions of the inactive trails were not equal to the unaffected trail vegetation and on average, there was no recovery of thaw depth or reduction in ponding.

If re-routing is not a viable option, such as in areas where no suitable substrate occurs or other resource issues may prohibit re-routing, hardening materials provide an excellent alternative to mitigating the detrimental effects of ATV use. Two of the materials tested in this study are viable

options for hardening trails and are currently available (Corduroy and Geoblock® 2"). Other products are currently being tested by NPS Rivers, Trails and Conservation Assistance Program (K. Meyer, personal communication). Selection of materials should be weighed in terms of longevity of materials, cost and conditions of the sites. This study clearly shows the importance in spanning the affected or potentially affected areas of the trail and anchoring materials in suitable substrate. Further in-park studies are warranted to test larger scale installations.

Other important ATV trail management considerations which were not addressed in this study, but should be considered in any ATV trail management program, are the options of regulating the number of user or types of ATVs, applying seasonal restrictions or permanently closing trails.

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APPENDICES

Appendix A. Climate of the Slana and Nabesna area.

Table A1. Average Maximum and Minimum Temperatures (F) and average Precipitation (cm) at Slana (elev. 667m (2192 ft.)) and Nabesna (elev. 880m (2901ft)) at either end of the Nabesna Rd.

	Year	Month	Mean Temperature (F)	Departure from normal (F)	Total Precipitation (inches)	Departure from Normal (inches)
Slana	93	Jan	-5.3M	-3.2	1.16	0.36
		Feb	7.7M	2.3	0.24M	M
		March	16.3M	0.2	0.06	-0.66
		April	33.7M	4.0	0.00M	M
		May	46.9M	3.8	0.58	-0.34
		June	53.1M	0.3	2.52	0.26
		July	58.4M	1.6	1.89	-0.68
		Aug	52.2M	-0.3	4.07	1.97
		Sept	40.6M	-1.8	2.01M	M
		Oct	28.5	2.0	0.64	-0.50
		Nov	7.8	1.9	3.54	2.76
		Dec	1.3M	1.7	1.2	.12
	94	Jan	2.2	4.7	0.27M	M
		Feb	-2.3	-7.7	0.59M	M
		Mar	16.7	0.6	0.05	-0.67
		April	34.5	4.8	0.08	-0.46
		May	43.3M	0.2	3.08	2.16
		June	52.0M	-0.8	1.51	-0.75
		July	56.6M	-0.2	0.92	-1.65
		Aug	57.1M	4.6	.34M	M
		Sept	38.6M	-3.8	1.78	-0.07
		Oct	23.1M	-3.4	0.24	-0.90
		Nov	-0.5M	-6.4	1.44	0.66
		Dec	-5.2M	-4.8	0.35	-0.73
	95	Jan	-2.7M	-0.2	0.00T	-0.80

	Year	Month	Mean Temperature (F)	Departure from normal (F)	Total Precipitation (inches)	Departure from Normal (inches)
	96	Feb	5.8M	0.4	0.48	-0.17
		March	8.4M	-7.7	0.00T	-0.72
		April	35.9M	6.2	0.11	-0.43
		May	46.3M	3.2	1.15	.23
		June	53.9M	1.1	2.39	0.10
		July	56.0M	-0.8	2.76	0.19
		Aug	50.2M	-2.3	1.85	-0.25
		Sept	M	M	M	M
		Oct	27.5M	1.0	0.51M	M
		Nov	7.6	1.7	0.69	-0.09
		Dec	-3.8M	-3.4	0.14M	M
		Jan	-21.5M	-19.0	0.00M	M
	97	Feb	4.0M	-1.4	1.80	1.15
		Mar	14.2M	-1.9	1.57	0.85
		April	30.8M	1.1	0.00T	-0.54
		May	42.0M	-1.1	1.37	0.45
		June	51.9M	-0.9	0.43	-1.83
		July	M	M	M	M
		Aug	49.4M	-3.1	1.15	-0.95
		Sept	34.3M	-8.1	M	M
		Oct	M	M	2.08M	M
		Nov	M	M	0.35	-0.43
		Dec	-5.4M	-5.0	0.19	-0.89
		Jan	-8.69M	-6.19	0.26	-0.54
		Feb	12.10M	6.7	0.20	-0.45
		Mar	8.91M	-7.19	.51	-0.21
		April	29.22M	-0.48	0.27	-0.27
		May	44.63M	1.53	.52	-1.30
		June	54.5M	1.70	1.30	-0.96
		July	58.18M	1.38	2.45	-0.12

	Year	Month	Mean Temperature (F)	Departure from normal (F)	Total Precipitation (inches)	Departure from Normal (inches)
Nabesna	93	Aug	53.45M	0.95	4.69	2.59
		Sept	43.02M	0.62	0.10	-1.75
		Jan	-4.8	M	0.25M	M
		Feb	6.6M	M	0.00M	M
		Mar	16.2	M	0.27	M
		April	33.7	M	0.23	M
		May	45.8	M	1.60M	M
		June	51.4	M	3.11	M
		July	55.7	M	1.22	M
	94	Aug	50.5	M	1.59	M
		Sept	40.7	M	0.60M	M
		Oct	27.5	M	0.94	M
		Nov	8.0	M	1.15	M
		Dec	0.9M	M	0.53	M
		Jan	-3.7	M	0.15	M
		Feb	-6.8	M	0.76M	M
		Mar	14.9	M	0.00T	M
		April	32.2	M	0.06	M
		May	41.0	M	1.54M	M
		June	50.3	M	1.42	M
		July	54.4	M	1.63	M
		Aug	55.6	M	0.71	M
		Sept	38.1	M	0.27M	M
		Oct	19.5M	M	0.40	M
		Nov	-1.8	M	1.11	M
		Dec	-6.4M	M	M	M
	95	Jan	-5.9	M	0.06	M
		Feb	3.9	M	0.50M	M
		Mar	5.4	M	0.02	M
		April	32.2M	M	0.83	M

	Year	Month	Mean Temperature (F)	Departure from normal (F)	Total Precipitation (inches)	Departure from Normal (inches)
	96	May	45.8	M	0.41	M
		June	52.5	M	3.21	M
		July	54.9	M	2.45	M
		Aug	49.0	M	3.02	M
		Sept	45.3M	M	0.63	M
		Oct	23.4	M	0.12	M
		Nov	-1.9M	M	0.34M	M
		Dec	-7.5M	M	0.00T	M
		Jan	-20.1M	M	0.03	M
		Feb	3.6	M	M	M
		Mar	14.3M	M	0.38	M
		April	26.9M	M	1.41	M
	97	May	41.8	M	1.08M	M
		June	49.8M	M	0.35M	M
		July	53.2M	M	1.12	M
		Aug	47.5	M	1.98	M
		Sept	37.5M	M	0.20	M
		Oct	12.6M	M	0.08	M
		Nov	-2.8M	M	0.06M	M
		Dec	-10.0M	M	0.36M	M
		Jan	-16.63	-8.00	0.06	-0.06
		Feb	13.45	11.62	0.05	-0.27
		Mar	7.03M	-5.67	T	-0.17
		April	30.05	-1.2	0.06	-0.57
		May	42.66	-0.94	0.33	-0.83
		June	51.80	0.80	0.67	-1.35
		July	55.74	1.22	4.47	2.87
		Aug	52.29	1.64	3.10	1.28
		Sept	41.79	1.39	T	-0.43

M=Missing data. T = Trace Precipitation. Appears with monthly data when less than 10 days are missing and it appears alone if > 9 days are missing. It appears with annual data, when derived from months with miss data. * Departure from normal taken from average of 1993-1996 data.

Appendix B. Vehicle Impact Rating Scheme.

This rating system was modified from one developed by the Muskeg Research Institute (Muskeg Research Institute, 1970). Sum rating score for trail. If score is equal to a number between 1-8 then designate trail as low impact, between 9-16 then designate trail as moderate impact, between 17-24 then designate trail as heavy impact

Codes for Active Trails

Vegetation

- 1 Undamaged; no discernible change.
- 2 Slight compression; leaves or stems temporarily bent or rearranged; vehicle passage barely perceptible.
- 3 Mosses, graminoids and other herbaceous species compressed and leaves flattened; shrubs stems becoming compressed.
- 4 Leaves or mosses and lichens torn or removed; woody shrub stems flattened, with some breakage and abrasion.
- 5 11-25% of original vegetation composition not discernible.
- 6 26-50% not discernible.
- 7 51-75% not discernible.
- 8 76-100% not discernible.

Soil

- 1 None exposed.
- 2 1-5% exposed.
- 3 6-10% exposed.
- 4 11-25% exposed.
- 5 26-50% exposed.
- 6 51-75% exposed.
- 7 76-90% exposed.
- 8 91-100% exposed.

Microrelief

- 1 No discernible change or depression of the surface.
- 2 Tracks evident but not with less than half of track depressed 2.5 cm; slight compression of tussocks or hummocks.
- 3 Surface depression less than 2.5 cm over majority of track; slight to moderate compression of tussocks or hummocks.
- 4 Track depressed 2.5-5 cm; moderate tussock or hummock compression.
- 5 Track depressed 5-10 cm; moderate to severe tussock or hummock compression.
- 6 Track depressed 10-15 cm; severe tussock or hummock compression.
- 7 Track depressed 15-20 cm; severe compression or destruction of tussocks or hummocks.
- 8 Depressions or ruts greater than 20 cm deep; tussocks or hummocks completely flattened or destroyed.

Codes for Inactive Trails

Vegetation

- 1 Vegetation percent cover and species composition are approximately equal to unaffected vegetation.
- 2 Veg percent cover is approx. equal to unaffected veg; species composition 75-90% similar to unaffected.
- 3 Veg percent cover is approx. equal to unaffected veg; species composition 50-75% similar to unaffected.
- 4 Veg percent cover is approx. equal to unaffected veg; species composition 25-50% similar to unaffected.
- 5 Veg percent cover 75-90% of unaffected veg; species composition 10-25% similar to unaffected.
- 6 Veg percent cover 75-50% of unaffected veg; species composition < 10% of unaffected.
- 7 Veg percent cover 50-25% of unaffected veg; species composition < 10% of unaffected.
- 8 Veg percent cover < 25% of unaffected veg; species composition < 10% of unaffected.

Soil

(Same as Active Trail Code)

Microrelief

Depression

- 1 No depression.
- 2 Tracks depression < 2.5 cm in < 1/2 of inactive trail.
- 3 Depression < 2.5 cm.
- 4 Depression 2.5-5 cm.
- 5 Depression 5-10 cm.
- 6 Depression 10-15 cm.
- 7 Depression 15-20 cm.
- 8 Depression > 20 cm.

Tussocks

- 1 No tussock destruction.
- 2 Tussock # and height approx. equal to unaffected area.
- 3 Tussock height and veg cover 90% of unaffected area.
- 4 Tussock height and veg cover 60-90% of unaffected area.
- 5 Tussock height and veg cover 25-60% of unaffected area.
- 6 Tussock height and veg cover 10-25% of unaffected area.
- 7 Tussock height and veg cover 0-10% of unaffected area.
- 8 No tussocks left.

Appendix C. Mitigation Site Layout.

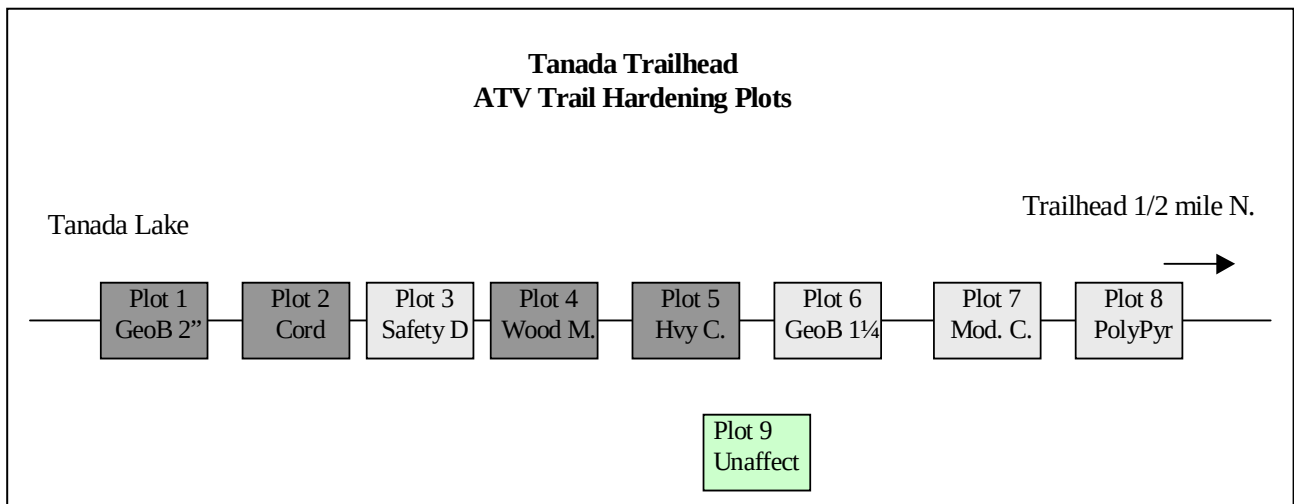


Figure C1. Tanada Trailhead Mitigation Site Layout. Dark gray boxes represent plots that were established in heavily impacted trail sites and light gray boxes are plots that were established in moderately impacted trail sites.

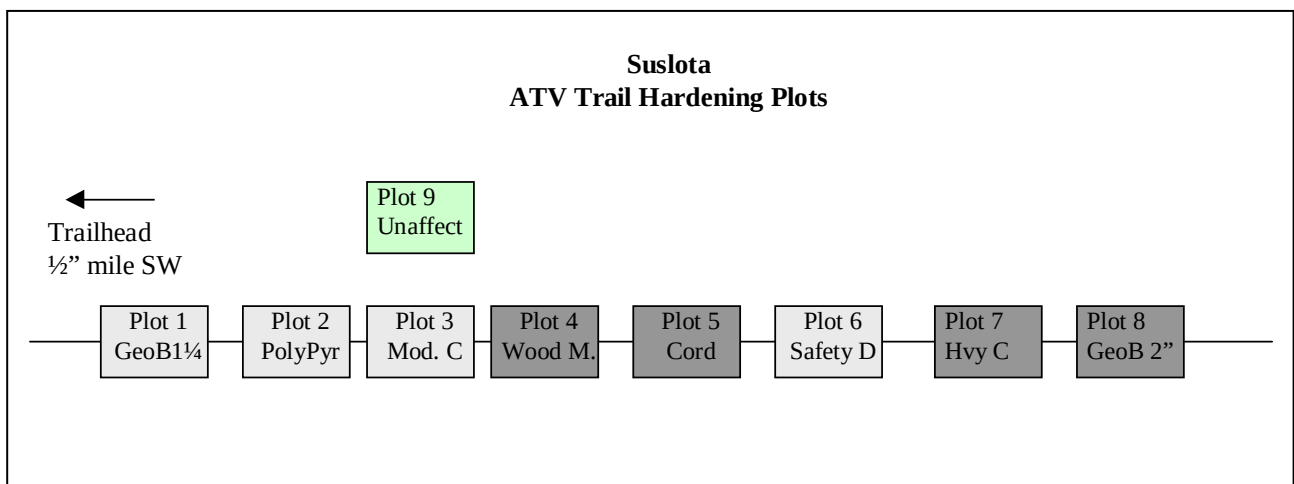


Figure C2. Suslota Trailhead Mitigation Site Layout. Dark gray boxes represent plots that were established in heavily impacted trail sites and light gray boxes are plots that were established in moderately impacted trail sites.

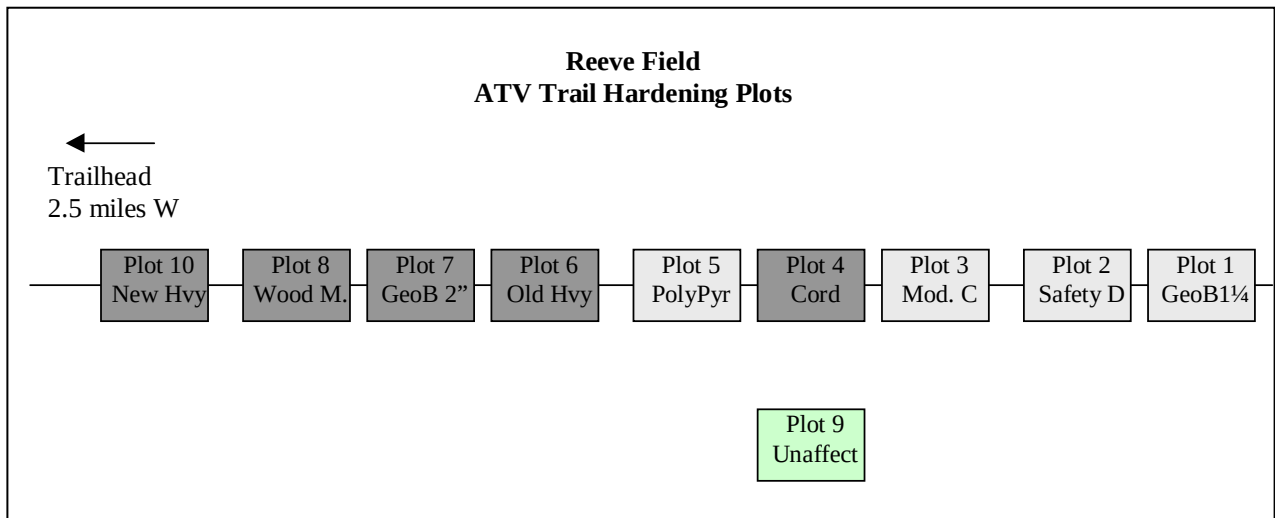


Figure C3. Reeve Field Mitigation Site Layout. Dark gray boxes represent plots that were established in heavily impacted trail sites and light gray boxes are plots that were established in moderately impacted trail sites.

Table C1. ATV hardening study site information, GPS latitudes and longitudes are given for general site locations. Aerial photograph numbers for 1:6000 CIR aerial photography from ATV Study.

Trail Name	Study Site	Segment	Polygon Number	Photo Number	Latitude	Longitude
Tanada Lake Trail	Tanada Trailhead	1	5	1-33-8438	62°32'37.8	143°21'55.7
Suslota Lake Trail	Suslota	1	1	1-21-8460	62°37'48.9	143°42'37.7
Reeve Field Trail	Reeves Field	1	16 & 18	2-49-8678	62°23'59.7	142°55'32.6
Tanada Lake Trail	Tanada Lake	3	20	1-32-8391	62°27'45.4	143°22'14.0

Appendix D. Treatment Material Specifications and Purchasing Information.

Corduroy

A total of approximately 726 straight tree poles were purchased locally from Jesse Leboeuf, POB 705, Glennallen, Alaska 99588, (907) 822-8123, for use in the Corduroy treatment. Specifications were as follows:

- ⇒ Straight Tree poles
- ⇒ 2" top diameter, 4" bottom diameter, 6' length
- ⇒ No more than a 1 ½" bow over the 6' length
- ⇒ Tree species native to the Copper River Valley area of Alaska
- ⇒ Bark did not need to be removed
- ⇒ Limbs trimmed flush with the body of the pole
- ⇒ Poles were securely bundled in 3 places with a 3/8" nylon rope or plastic banding. Total number of bundles must be divisible by 4 and each bundle must weight less than 100 lbs.

Geoblock® 2"

A total of 336 block of Geoblock® SS362 Porous Pavement System measuring 2"depth x 3' x 1' were purchased from Soil Stabilization Products Co., P.O. Box 2779, Merced CA 95344; local distributor at time.

Local Alaska distributor:

GeoChem Inc.
3464 Newcomb Dr.
Anchorage, AK 99508-4869
(907) 562 -5755

Manufacturing company:

Presto Products Company
PO Box 2399
Appleton, WI 54912
(800) 548-3424
Web page: www.prestogeo.com (click on porous pavement systems)

Current material Geoblock® 2" (GBM-5150) specifications are as follows:

- ⇒ Unit dimensions: (width x length) 0.5 m x 1.0 m (20" x 40") or 5.38 square feet
- ⇒ Current Cost per unit: \$11.00 - \$14.00/unit depending on size of order, plus shipping
- ⇒ 50% Recycled Polyethylene Plastic
- ⇒ Color: Charcoal black
- ⇒ Ultra-violet light stabilization
- ⇒ Top open area per unit: 87% Bottom open area per unit: 40%
- ⇒ Interlocking offset shear transfer tabs (1 per cell or every 2"), can be screwed together with # 8 ¾" stainless steel phillips wood screws (not included)
- ⇒ Units per pallet: 44
- ⇒ Material weight: 10 lbs./unit or 475 lbs./pallet

Geoblock® 1 ¼”

This material is no longer available. A total of 336 block of Geoblock® SS361 Porous Pavement System measuring 1 ¼”depth x 3’ x 1’ were purchased from Soil Stabilization Products Co., P.O. Box 2779, Merced CA 95344, 1-800-523-9992.

Polynet PN-3000 / Pyramat™

A total of 960sf of Polynet PN-3000 was purchased from Northwest Lining & Geotextile Products, Inc., 21000 77th Avenue South, Kent, WA 98032, 800-729-6954, for the Polynet PN-3000 / Pyramat™ treatment. Additionally, a total of 1,920sf Polynet PN-3000 was purchased to be used as underlayment for the Corduroy, Wood Matrix, Geoblock® 2” and Geoblock® 1 ¼” . As an underlayment, Polynet PN-3000 covered ½ the length of the above treatments with Landlok® ECRM 450 covering the remaining ½ of the length. Polynet PN-3000 specification are as follows:

- ⇒ A geonet manufactured by extruding two sets of polyethylene strands to form a diamond shape.
- ⇒ Provides superior planar water flow
- ⇒ Inert to biological and naturally encountered chemicals, alkalies, and acid
- ⇒ Resistant to UV light exposure
- ⇒ Thickness 0.2 to 0.25 in.
- ⇒ Tensile strength 50+-10 ppi
- ⇒ Transmissivity (M(sq)/sec) 1X0.001
- ⇒ Non-toxic to plants and animals
- ⇒ Roll width 7.54’ X 300’

A total of 1080sf of Pyramat™ was purchased from Northwest Lining & Geotextile Products, Inc., 21000 77th Avenue South, Kent, WA 98032, 800-729-6954, for the Polynet PN-3000 / Pyramat™ treatment. Specifications are as follows:

- ⇒ Three dimensional, lofty woven polypropylene geotextile with a matrix composed of polypropylene mono-filament yarns woven into a uniform, dimensionally stable configuration of resilient pyramid-like projections.
- ⇒ The material shall exhibit very high interlock and reinforcement capacity with both soil and root systems and demonstrate high tensile modulus.
- ⇒ Tensile Strength 3,000 X 2,200 lbs/ft
- ⇒ Tensile Elongation 45-50% (max)
- ⇒ Tensile Strength at 10% Elongation 1,850 X 1,600 lbs/ft (typ)
- ⇒ Thickness 0.5 in.
- ⇒ Resiliency 80%
- ⇒ UV Resistance @1000 hrs 80%
- ⇒ Velocity (unvegetated) - Short Term 20 ft/sec, Long Term 10 ft/sec
- ⇒ Shear Stress (unvegetated) - Short Term 8 lbs/sf, Long Term 3 lbs/sf
- ⇒ Inert to all biological and naturally occurring chemicals
- ⇒ Roll size 6/X90’ (540sf)

Safety Deck®

This material is no longer available. A total of 400 tiles of Safety Deck® II were purchased from the Mat Factory Inc., 760 W. 16th St. Suite E, Costa Mesa, CA 92627, 1-800-628-7626. Specifications are as follows:

- ⇒ Recycled PVC hollow open interlocking mat tiles
- ⇒ Physical Dimensions - 19 ¾" X 19 ¾" size tiles, area of square openings is .85 to .95 inches, area of round openings is .40 to .50 inches.
- ⇒ Tensile strength - 1400 to 1420 PSI
- ⇒ Elongation @ break 130 to 140 percent.
- ⇒ Compressive strength > 1910 PSI
- ⇒ Color: green
- ⇒ Inert to biological and naturally occurring chemicals
- ⇒ Non - toxic to plants and animals

A total of 1084sf of SCRIM Mesh was also purchased from the Mat Factory Inc. to be used as an underlayment for the Safety Deck®. Specifications are as follows:

- * Geonet manufactured by extruding two sets of polypropylene strands to form a diamond shape
- * Inert to biological and naturally occurring chemicals
- * Non-toxic to plants and animals
- * To be used in four 6.6'X41.2' study plots

Wood Matrix

A total of 126 pieces of 2" x 4"x 10' and a total of 108 pieces of 2"x 4"x 12' rough cut untreated spruce lumber was purchased locally from Regal Enterprises (Terry), Mi 13 Edgerton Hwy., Copper Center, AK (907) 822-5844. Specifications were as follows:

- ⇒ Rough Cut, untreated spruce lumber
- ⇒ 2" x 4" x 10' dimensional lumber
- ⇒ See photo below and contact Wrangell-St. Elias NP/P for construction information.

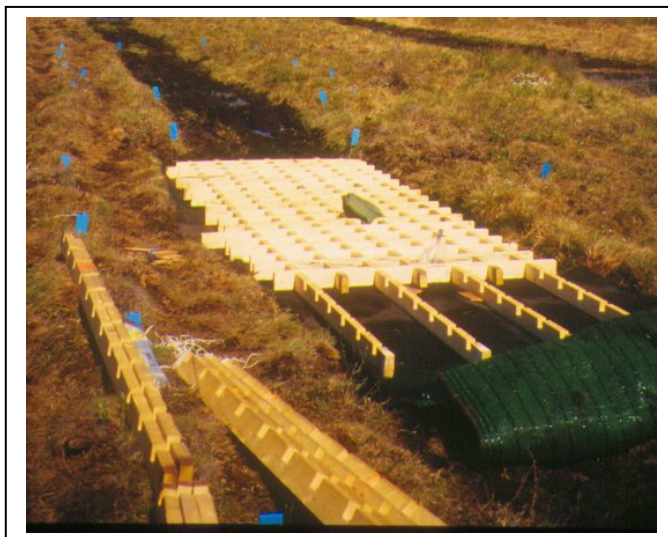


Figure D1. Construction of Wood Matrix on site in Wrangell-St. Elias NP/P.

Underlayments of Polynet PN-3000 and Landlok® ECRM 450

A total of 5,826sf of Polynet PN-3000 was purchased from Northwest Lining & Geotextile Products, Inc., 21000 77th Avenue South, Kent, WA 98032, 800-729-6954. As an underlayment, Polynet PN-3000 covered ½ the length of the Corduroy, Wood Matrix, Geoblock® 2” and Geoblock® 1 ¼” treatments with Landlok® ECRM 450 covering the remaining ½ of the length. A total of 1,920sf was used as an underlayment with an additional 3,906 applied on troublespots between treatments or left for future use. Specifications are outlined above in the Polynet PN-3000 / Pyramat™.

A total of 2700sf of Landlok® ECRM 450 was purchased from Northwest Lining & Geotextile Products, Inc., 21000 77th Avenue South, Kent, WA 98032, 800-729-6954. As an underlayment, Landlok® ECRM 450 covered the 2nd half of the length of the Corduroy, Wood Matrix, Geoblock® 2” and Geoblock® 1 ¼” treatments. A total of 1,920sf was used as an underlayment with an additional 780sf applied on troublespots between treatments or left for future use. Specifications are as follows:

- ⇒ Dense three dimensional web of polyolefin fibers positioned between two biaxially oriented nets and mechanically bound together by parallel stitching with polyolefin thread. Standard width roll contain a minimum of 30 continuous parallel threads running throughout the length of matting to firmly anchor fibers and edges in place.
- ⇒ Thickness .50in. (+or -0.05)
- ⇒ Tensile strength 170X125 (lb./ft)
- ⇒ Inert to all biological and naturally occurring chemicals
- ⇒ Non-toxic to plants and animals
- ⇒ Roll size of 6.5’ X 138.5’ (900.25 sf)

Anchoring materials

A total of 1000 pieces of #3 rebar were purchased from Weld Air, Wasilla, AK (907) 373-2000. #3 rebar was bent on one end to a 180° hook and were used for anchoring materials. Of the 1000 pieces of #3 rebar, a total of 304 pieces were used to anchor materials (see anchoring diagrams in Appendix E.) with additional rebar used to permanently mark vegetation, thaw depth and subsidence transects or left over for future use. Specifications are as follows:

- ⇒ 3/8” diameter
- ⇒ Cut to 36” lengths

A total of 200 pieces of bulk steel rod was additionally purchased from Weld Air and used in making pilot holes for the #3 rebar. Specifications are as follows:

- * Cold rolled
- * ¼” diameter
- * Cut to 30” lengths

A total of 192 Duckbill® Earth Anchors (Model 68-DB-1) were purchased from Forestry Suppliers Inc., 205 West Rankin Street, P.O. Box 8397, Jackson, Mississippi 39284-8397, (601) 354-3565. A total of 144 Duckbills® were used to anchor treatments. Duckbill® specifications are as follows:

- * 5” long
- * 1” diameter
- * Holding capacity to 1,100 lbs. In normal soil
- * 1/8” 30” Cable

Appendix E. Treatment Material Preparation, Installation, and Sling Load Operation.

Corduroy

Preparation

Corduroy was bundled into amounts two people would be capable of handling. The approximate weight was 100 lbs./bundle with ten pieces 3" X 72" per bundle. Four bundles would be used per site. These bundles were tied together with 1/4" manila rope and 1/4" poly rope. Bundles were then banded with metal 1" banding and clips. This was done for safe transport via truck to the staging areas and then via helicopter to individual work sites with sling gear.

Installation

The Corduroy was transported to the individual work sites via helicopter in a sling operation. Tyvec marker placement in close proximity to the treatment sites allowed sling load material drop off close to treatment plots and precluded extensive ground transport of the material. Once the material was on site, it was untied and the metal bands were removed. Next, the underlayment materials, Polynet PN-3000 and Landlok® ECRM 450 were tie-wrapped together in the middle with 6-7" long tie wraps. These underlayment materials were then spread out in the surveyed treatment plot which covered a 6' X 40' area. The ground at the Suslota study site, corduroy treatment area required the most leveling with hand tools (pulaski). Several large tussocks had to be cut down. The Corduroy treatment areas at the Tanada Lake, Tanada Trailhead and Reeve Field study sites required little or no excavation or leveling.

Once the treatment plot was leveled and the underlayment materials in place, installation of the Corduroy began. 1/4" braided nylon rope was used to weaving over and under each piece of Corduroy. This was done with 3 separate pieces of nylon rope. The rope was square knotted after weaving 8 pieces of corduroy together. It required splicing of rope every 10 feet. This method created a strong, flexible secure attachment. It required 4 people for efficient installation, three people weaving the nylon ropes while one person handed individual pieces of Corduroy to the group. The whole process of weaving took approximately 2 hours to complete a 6' X 40' treatment. Secured in this manner, Corduroy becomes moveable and is able to conform to curves and irregular terrain.

Overall, the maintenance crew installing the treatment material were of the opinion that Corduroy was the best material because of ease of installation, cost, labor time, flexibility, availability of material. The purchase of pre-cut, measured and limbed poles greatly reduced the labor time normally involved in laying Corduroy with on-site materials. It was recommended that Aqualine replace 1/4" braided nylon rope for weaving because of added strength and ease of usage when cut.

Wood Matrix

Preparation

Preparation of the wood matrix required the construction of several wooden sawhorses to facilitate the measurement & cutting of the 2" X 4" material. The purchase of measurement & cutting tools was accomplished for construction of sawhorses and the wooden matrix material. These tools: 25' tape measure; framing square; 7.25" circular saw blades; 8D nails; Knee pads; Backbraces; 24" adjustable clamps; tool pouches; pony clamps, 1/2" pipe clamps; Claw hammers; Wood chisels; Sawhorse brackets; Leather gloves; Safety Goggles; Carpenter pencils along with the use of a 011 Stihl chainsaw in the field where used.

The untreated Spruce 2" X 4" X 10' & 2" X 4" X 12' material was cut & notched. This was accomplished with the use of jigs & patterns to facilitate construction labor time. Therefore many boards were cut simultaneously for efficiency. After all the 2" X 4"s were cut, they were laid out on the ground and fitted together. This saved time putting the matrix together in the field. The next step was to color code the proper boards for assembly in the field. We used a separate spray paint for each section of the wood lattice that went together. This process proved very useful. Following this step

we bundled and metal banded like color coded 2" X 4" 's together for staging and transport via helicopter to the various job sites.

Using 24" adjustable metal clamps and 6' adjustable pipe clamps & sawhorses many 2"X4"s were clamped together. They were then measured and marked for the cutting of 2" notches. This jig & pattern hastened construction of the wood matrix. It allowed for multiple creation of 2"X4" notches. This method of construction created an average time of construction of 16 hours per wood matrix per site for a total of 64 hours to construct all 4 wood matrix sites which was a great savings in time & labor costs on this phase of the preparation.

Installation

The Wood Matrix 2" X 4" pieces were transported to the individual treatment sites via helicopter in a sling operation. The 2" X 4" pieces were the most difficult to sling to the treatment sites.

The Suslota, Reeves Field, Tanada Trailhead study sites all required leveling with a pulaski. This required the cutting of tussocks and redistribution of material in low areas within the treatment site. Once leveling of the treatment site was accomplished, the underlayment materials which included a 6' X 20' piece of Polynet PN-3000 and a 6' X 20' piece of Landlok® ECRM 450 were attached together with 6-7" long plastic tie wraps to form a 6'X40' piece. The attached underlayment materials were placed squarely in the surveyed treatment site.

The color coded 2" X 4" pieces were laid out and assembled from one end working to the other. Extra effort was required for fitting the pieces together due to the untreated green Spruce wood warping & twisting because the green wood dried over time. A chainsaw was required to widen the notches for proper fitting. Assemble was initially accomplished with 8D nails. After inspection of attachment it was decided to use 16D nails for better holding power. All the joints in the wood matrix were gusseted with 1/4" 6" X 6" plywood gussets on both sides of the joints. These were attached by using 8D nails. Two and/or three people can efficiently assemble this wood matrix. The wood matrix pattern and specifications can be viewed in diagram #2.

Overall the maintenance crew felt that this treatment was successful, but not the best in terms of ease of installation. It required skilled workers with carpentry experience. This material did not readily conform to varied terrain or ease of use in curved paths because of its rigidity. It was essential that the treatment site be level, therefore it required more labor and was not as flexible a material. Green wood was not recommended for construction of a wood matrix but rather kiln dried 2" X 4" 's. This would make the material more costly and availability of material more limited for field use.

Geoblock® 1 1/4"

Preparation

The Geoblock® 1 1/4" was measured and cut in half with a 7 1/4" skilsaw. One-half of all the blocks were cut in half in order to alternate the pattern of the material for greater strength. The current dimensions of the Geoblocks do not require cutting.

Installation

The Geoblock® 1 1/4" material was transported to the individually marked treatment sites via helicopter in a sling operation. Excavation and leveling was required at the Suslota and Tanada Trailhead treatment sites, but little or none at the Tanada Lake & Reeves Field treatment sites. The Geo Block material conformed to the varied ground better than the wood matrix, but not as well as Safety Deck, Polynet/Pyramat or the Corduroy treatments.

The underlayment materials of 6' X 20' piece of Polynet material and 6' X 20' piece of landlok material were attached together with 6-7" plastic tie wraps. These underlayment materials were squarely placed in the surveyed treatment site.

The Geoblock® 1 ¼" material was laid out in a alternating pattern of 2 whole 3' squares tied together 6' wide and then two 1 1/2' squares on either side of a whole 3' square tied together on top of the underlayment. These two alternating patterns were attached for the full length of the treatment. The Geoblock® 1 ¼" material was double wrapped and tied with nylon twine and seine twine. This attachment was used for strength and security of attachment.

Maintenance crew felt this material was successful but not the best. It required leveling and excavation. It was considered the best in terms of long term survival and durability. The material worked well for curves, but was not the best for uneven terrain although it was better than the wood matrix in this regard. It allowed for good vegetation growth. The labor cost and initial purchase are high. The availability of the material was questionable (and it is no longer available).

Geoblock® 2"

Preparation

The Geoblock® 2" was measured and cut in half with a 7 1/4" skilsaw. One-half of all the blocks were cut in half because this enabled us to mix the blocks into an alternating pattern for greatest strength. The current dimensions of the Geoblocks do not require cutting.

Installation

The Geoblock® 2" materials were transported to the individually marked treatment sites via helicopter in a sling operation. All geo tech materials were easy to cargo net and sling to the treatment sites. As with all other treatment materials this improved efficiency and proved for close proximity of work materials to work sites.

Excavation and leveling was required at the Tanada Lake, Suslota, Tanada Trailhead sites and especially at the Reeve Field site. The Geoblock® 2" material conformed to uneven terrain better than the wood matrix but not as well as the Corduroy, Safety Deck, and Polynet material.

The underlayment materials of 6' X 20' piece of Polynet material and 6' X 20' piece of landlok material were attached together with 6-7" plastic tie wraps. These underlayment materials were squarely placed in the surveyed treatment site. The Geoblock® 2" was then installed on top of the underlayment material.

The Geoblock® 2" material was laid out in a alternating pattern of 2 whole squares tied together 6' wide and then 2 - 3' squares and 1 whole square tied together. These two patterns alternatively attached together for the full length of the 40' treatment. These materials were double wrapped and tied with nylon twine and seine twine. This attachment was used for strength and security of attachment. (Geoblock® 2" material now has clips that connect the blocks together.)

Maintenance crew felt this material was successful. Although, it did require leveling and excavation. It was considered the best in terms of long term survival and durability. The material worked well for curves, but was not the best for uneven terrain although it was better than the wood matrix in this regard. It allowed for good vegetation growth. The initial labor and purchase costs were high, but the durability and low maintenance needs should be considered.

Safety Deck®

Preparation

The Safety Deck® was tied in bundles of 2 boxes each for ease of handling in staging and transport via helicopter in the sling operation.

Installation

The Safety Deck® & Scrim Mesh material was transported to the individually marked treatment sites via helicopter from staging areas in a sling operation. The Safety Deck® & Scrim Mesh were easy to sling in cargo nets to the work sites.

Excavation and leveling was required at Suslota but not at the other treatment sites. Safety Deck® material conformed fairly well to uneven terrain. Once excavation was completed, the installation procedures continued. The underlayment material was a 6' X 40' piece of Scrim Mesh laid squarely in the surveyed treatment site.

The Safety Deck® material was snapped together with 4 pieces wide and 25 pieces long to give a 6' X 40' treatment coverage. The Safety Deck® tiles were woven together both lengthwise and crosswise with nylon parachute cord. Each square was woven and then square knotted to itself the full length & width of the treatment. This was a labor-intensive task. But have proven to be a very secure attachment.

The maintenance crew felt the material was successful, but due to the cost of the material and labor it might be cost prohibitive. It was the most costly to initially purchase. It required extensive labor costs to attach to itself securely. It is very flexible during warm temperatures but more rigid in the cold. It conformed to uneven terrain better than all other materials except the Polynet/Pyramat treatment. It can be used in curved paths & trails. It allowed for vegetation regrowth. The availability was questionable (and it is no longer available) but the long term survival and durability of the material appeared good.

Polynet PN-3000 / Pyramat™

Preparation

The Polynet PN-3000 was measured and cut with a scissors or a metal snipper. It was cut into four 6' X 40' blocks for the Polynet PN-3000 / Pyramat™ treatment. These blocks of material were rolled up and tied with parachute cord for ease of staging and transport via helicopter in the sling operation.

The Pyramat™ was cut in four 6' wide X 40' long blocks with a scissors or metal snipper for use with the Polynet PN-3000. It was then rolled up in a tight roll for staging and transport via helicopter in the sling operation.

Installation

The Polynet PN-3000 / Pyramat™ materials were transported to the individually marked treatment sites via helicopter from staging areas in a sling operation. The Polynet PN-3000 / Pyramat™ was easy to sling in cargo nets to the work sites.

Excavation was necessary at all sites for the anchoring system. However, the sites required little or no leveling. Polynet PN-3000 / Pyramat™ material conformed to the uneven terrain the best of all the treatments due to its flexibility.

The material was laid out with a 6' x 40' piece of Pyramat material on the bottom and then a 6' x 40' piece of Polynet material on the top. The two materials were attached together with 7" plastic tie wraps every 2' around the perimeter of the 6' x 40' area. These materials were anchored with hooked rebar and log anchors as needed. Six duckbill anchors, eight hooked rebar and wood log anchors were used to anchor the 12 meter section of material. The edges of the material were buried under ground (excavation) and two foot sections of 4" diameter logs were anchored along the edge of the material with duckbills. See photo in Figure D-5.

The maintenance crew felt this treatment material was easy to use because it conformed to the uneven terrain well, labor costs were low and it could be used on curves in the trails. However, they felt the Pyramat was likely to unravel without a border around the edges.

Underlayments of Polynet PN-3000 and Landlok® ECRM 450

Preparation and Installation

The Polynet PN-3000 was measured and cut with a scissors or a metal snipper. It was cut into sixteen 6' wide X 20' long blocks to be used as the underlayment for half the length of the Corduroy, Wood Matrix, Geoblock® 2", Geoblock® 1 ¼" treatments. These blocks of material were rolled up and tied with parachute cord for ease of staging and transport via helicopter in the sling operation.

Landlok® ECRM 450 was measured and cut into sixteen 6' X 20' blocks to be used as the underlayment for half the length of the Corduroy, Wood Matrix, Geoblock® 2", Geoblock® 1 ¼" treatments. These blocks of material were tightly rolled & tied with parachute cord for staging and transport via helicopter in the sling operation. The maintenance crew thought this material was fragile. It had a tendency to unravel and catch on branches due to the fact it had no edging support. It appeared in 1996 to reduce vegetation growth and did not conform well to varied terrain.

Anchoring materials

Preparation

A bending jig was manufactured at the maintenance shop in Glennallen. This allowed for fast bending of the material which was found to be very rigid. A 180° degree hook was made on one end of the #3 rebar. This allowed the #3 rebar to be used as anchors for all treatments.

Appendix F. Detail Costs of Transportation, Labor and Material

Table F1. Total Project Mitigation Treatment Costs by Treatment Type, Wrangell-St. Elias National Park and Preserve. Includes costs for all four sites.

Mitigation Treatment	Transportation	Labor	Material	Total
Corduroy	\$1095	\$1750	\$1455	\$4300
Wood Matrix	\$1545	\$3055	\$1315	\$5915
Geoblock® 2"	\$645	\$2080	\$4870	\$7595
Geoblock® 1 ¼"	\$645	\$2145	\$3545	\$6335
Safety Deck®	\$1095	\$2285	\$7415	\$10795
Polynet PN-3000/ Pyramat™	\$645	\$1760	\$1495	\$3900

Table F2. Mitigation Treatment Transportation, Costs and Sling Load Details by Treatment Type, Wrangell-St. Elias National Park and Preserve. (Wooden box and ferry time costs should be divided by 6 (no. of treatments) and added to cost by materials for true cost).

Material	Hours	Cost	No. of sling loads	Sling load weight (lbs)
Geoblock® 2" Sling Load (+ underlayment materials)	1	\$450.5	4	400
Wood Matrix Sling Load	3	\$1351.5	12	200
Corduroy Sling Load (+ underlayment materials)	2	\$901	8	400
Geoblock® 1 1/4" Sling Load (+ underlayment materials)	1	\$450.5	4	400
Safety Deck® Sling Load (+ Scrim Mesh)	2	\$901	8	400
Polynet PN-3000/Pyramat™ Sling Load	1	\$450.5	4	200
Wooden box with rebar, nails, tarps etc.	1	\$450.5	4	500
Ferry time (To & from Anch. & sites)	1.6	\$720.8	-	-

Table F3. Mitigation Treatment Materials, Size and Cost by Treatment Type in 1996, Wrangell-St. Elias National Park and Preserve.

Treatment Material	Unit Cost per Square Feet (sf) or piece	Cost per Treatment	No. of sf or pieces per Treatment	No. of sf or pieces per plot	No. of sf of left-over material
Geoblock® 2" Material costs (not incl. shipping or extra mat.)	\$3.99/sf	\$3830.4	960sf	240sf	48sf
Geoblock® 2" Shipping		\$505.52			
Geoblock® 2"/Polynet PN-3000 (incl. shipping)	\$0.35/sf	\$168	480sf	120sf	
Geoblock® 2"/ Landlok (incl. shipping)	\$0.45/sf	\$216	480sf	120sf	
Geoblock® 2"/ Rebar (36")	\$0.81ea	\$38.88	48pc	12pc	
Geoblock® 2"/ Duck Bill	\$3.95ea	\$94.8	24pc	6pc	
Geoblock® 2"/ Duck Bill shipping	\$0.63ea	\$15.12	24pc	6pc	
Wood Matrix Material costs (2"x4"s, 126 -10' pieces & 108 - 12' pieces)		\$766.8	960sf	240sf	
Wood Matrix/ Polynet PN-3000 (incl. shipping)	\$0.35/sf	\$168	480sf	120sf	
Wood Matrix/ Landlok (incl. shipping)	\$0.45/sf	\$216	480sf	120sf	
Wood Matrix/ Rebar (36")	\$0.81ea	\$51.84	64pc	16pc	
Wood Matrix/ Duck Bill	\$3.95ea	\$94.8	24pc	6pc	
Wood Matrix/ Duck Bill shipping	\$0.63ea	\$15.12	24pc	6pc	
Corduroy (655 poles, 1.25 ea)	\$1.25ea	\$871.25	160pc	40 pc	lost 50 poles?
Corduroy (shipping -gas money)		\$50			
Corduroy/ Polynet PN-3000(incl. shipping)	\$0.35/sf	\$168	480sf	120sf	
Corduroy/ Landlok (incl. shipping)	\$0.45/sf	\$216	480sf	120sf	
Corduroy/ Rebar (36")	\$0.81ea	\$38.88	48pc	12pc	
Corduroy/ Duck Bill	\$3.95ea	\$94.8	24pc	6pc	
Corduroy/ Duck Bill shipping	\$0.63ea	\$15.12	24pc	6pc	
Geoblock® 1 1/4" Material costs (not incl. ship or extra material)	\$2.83/sf	\$2716.8	960sf	240sf	
Geoblock® 1 1/4" Shipping (193.6('96) + 100('95))		\$293.6			

Treatment Material	Unit Cost per Square Feet (sf) or piece	Cost per Treatment	No. of sf or pieces per Treatment	No. of sf or pieces per plot	No. of sf of left-over material
Geoblock® 1 1/4"/ Polynet PN-3000 (incl. shipping)	\$0.35/sf	\$168	480sf	120sf	
Geoblock® 1 1/4"/ Landlok (incl. shipping)	\$0.45/sf	\$216	480sf	120sf	
Geoblock® 1 1/4"/ Rebar (36")	\$0.81ea	\$38.88	48pc	12pc	
Geoblock® 1 1/4"/ Duck Bill	\$3.95ea	\$94.8	24pc	6pc	
Geoblock® 1 1/4"/ Duck Bill shipping	\$0.63ea	\$15.12	24pc	6pc	
Safety Deck®	\$5.17/sf	\$5604.28	1084sf	271sf	
Safety Deck® shipping		\$1391.72			
Safety Deck®/Scrim Mesh	\$0.25/sf	\$271	1100sf	275sf	
Safety Deck®/ Rebar (36")	\$0.81ea	\$38.88	48pc	12pc	
Safety Deck®/ Duck Bill	\$3.95ea	\$94.8	24pc	6pc	
Safety Deck®/ Duck Bill shipping	\$0.63ea	\$15.12	24pc	6pc	
Polynet PN-3000/ Pyramat™ - Polynet PN-3000 (incl. shipping)	\$0.35/sf	\$336	960sf	240sf	
Polynet PN-3000/ Pyramat™ - Pyramat™ (incl. shipping)	\$1.05/sf	\$1008	960sf	240sf	
Polynet PN-3000/ Pyramat™ / Rebar (36")	\$0.81ea	\$38.88	48pc	12pc	
Polynet PN-3000/ Pyramat™ / Duck Bill	\$3.95ea	\$94.8	24pc	6pc	
Polynet PN-3000/ Pyramat™ /Duck Bill shipping	\$0.63ea	\$15.12	24pc	6pc	

Table F4. Mitigation Treatment Labor, Hours and Costs by Preparation and Installation Categories Shared by All Treatment Types, Wrangell-St. Elias National Park and Preserve.

Preparation and Installation Categories Shared by all Treatment Types	Labor Hours	Actual 1996 Cost *	Average Cost **
LABOR COSTS for staging materials			
Staging materials – Sling load (6A)	5.5	\$138.19	\$99
Staging – moving material for staging (5H)	14	\$282.3	\$252
General Material Staging (4A,6A)	113	\$2371.12	\$2034
General Material Staging(4A,5H)	46	\$894.26	\$828
TOTAL	178.5	\$3685.87	\$3213
LABOR COSTS for site preparation			
Site Prep (6E)	20	\$515.52	\$360
Site Prep w/ General Materials (4A, 6E)	25	\$471.68	\$468
TOTAL	45	\$987.2	\$828
LABOR COSTS for general material handling			
Handling/measurements(5A&C)	34	\$658.39	\$612
General Material handling before field (4A,5A)	37.5	\$649.08	\$675
General Materials (4A)	14	\$238.98	\$252
Gen. Material Installation (4A,6I)	31	\$529.17	\$558
TOTAL	116.5	\$2075.62	\$2097
LABOR COSTS for general project support			
General Project Support (5I)	59	\$1115.89	\$1062
TOTAL	59	\$1115.89	\$1062
LABOR COSTS for underlayment materials			
General Landlok Staging(4G, 5H)	2		\$34.14
General Landlok Staging(4G, 5H)	2	\$36	
General Polynet PN-3000 Handling (4K,5A)	1		\$19.06
General Polynet PN-3000 Handling (4K,5A)	1	\$18	
TOTAL	3	\$54	\$53.2

* Actual 1996 Costs were calculated using actual cost and hours of actual laborer completing task. Laborers included 1-WG-7 and 2-WG-5 maintenance workers.

** Average Costs are based on a average of the 1-WG-7 and 2-WG-5 maintenance workers (\$18.00/hr) regardless of the actual laborer completing the task.

Table F5. Mitigation Treatment Labor, Hours and Costs by Treatment Types, Wrangell-St. Elias National Park and Preserve.

Treatment Materials	Labor Hours	Actual 1996 Cost *	Average Cost **
CORDUROY			
Corduroy Material Installation (4J, 6I)	36	\$630.44	\$648
Corduroy Site Prep (4J, 6E)	3.5	\$95.3	\$63
TOTAL	39.5	\$725.74	\$711
GRAND TOTAL (includes general preparation and installation categories shared by all treatments as well as polynet PN-3000/Landlok® costs; excludes general project support)	97.25		\$1747.5
WOOD MATRIX			
Wood Matrix Material Installation (4B, 6I)	43	\$741.97	\$774
Wood Matrix Handling before field(4B,5A)	60	\$1024.2	\$1080
Wood Matrix Staging(4B,5H)	2	\$34.14	\$36
Wood Matrix Site Preparation (4B, 6E)	7	\$119.49	\$126
TOTAL	112	\$1919.8	\$2016
GRAND TOTAL (includes general preparation and installation categories shared by all treatments as well as Polynet PN-3000/Landlok® costs; excludes general project support)	169.75		\$3052.5
GEOBLOCK®2"			
Geoblock® 2" Material Installation(4C,6I)	56.5	\$986.51	\$1017
Geoblock® 2" Staging(4C,5H)	2	\$34.14	\$36
Geoblock® 2" Handling before Field (4C, 5A)	6	\$102.42	\$108
Geoblock® 2" Site Preparation (4C,6E)	3	\$51.21	\$54
TOTAL	67.5	\$1174.28	\$1215
GRAND TOTAL (includes general preparation and installation categories shared by all treatments as well as Polynet PN-3000/landlok® costs; excludes general project support)	125.0		\$2250
GEOBLOCK® 1 ¼ "			
Geoblock® 1 1/4" Material Installation (4D,6I)	50	\$878.54	\$900
Geoblock® 1 1/4" Site Preparation (4D,6E)	3	\$51.21	\$54
Geoblock® 1 1/4" Staging(4D,5H)	2	\$34.14	\$36
Geoblock® 1 1/4" Handling before Field (4D, 5A)	6	\$102.42	\$108
TOTAL	61	\$1066.31	\$1098
GRAND TOTAL (includes general preparation and installation categories shared by all treatments as well as Polynet PN-3000/Landlok® costs; excludes general project support)	118.5		\$2133
SAFETY DECK®			

Treatment Materials	Labor Hours	Actual 1996 Cost *	Average Cost **
Safety Deck® Material Installation(4E, 6I)	68.5	\$1328.06	\$1233
Safety Deck® Site Preparation(4E, 6E)	1.5	\$26.61	\$27
TOTAL	70	\$1354.67	\$1260
GRAND TOTAL (includes general preparation and installation categories shared by all treatments; excludes general project support)	127		\$2283
POLYNET PN-3000/PYRAMAT™			
Polynet PN-3000/Pyramat™ Material Installation (4F,6I)	34	\$613.96	\$612
Polynet PN-3000/Pyramat™ Handling (4F,5A)	7	\$121.48	\$126
TOTAL	41	\$735.44	\$738
GRAND TOTAL (includes general preparation and installation categories shared by all treatments; excludes general project support)	98		\$1761