Alaska State Parks

Trail Management Handbook

May 2015

Section 4: Sustainable Trail Design Framework

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A “Sustainable Trail Design Framework” is necessary to create a trail system that has minimum impact on natural systems and reduced maintenance costs. A “***sustainable trail***” is defined as a trail that conforms to its terrain and environment, is capable of handling its intended use without serious resource degradation, requires minimal maintenance, and focuses on maximizing the user experience. This involves the use of integrated water control, curvilinear layout, grade control and full bench construction. While initial construction costs may be more, reduced future maintenance costs will compensate for this investment.

The guidelines on the following pages will be considered and integrated when building or improving trails within Alaska State Parks. At times, certain circumstances may make the use of some of these guidelines difficult or impossible to fully implement. In these cases reasonable measures should be taken while maintaining the spirit of the guidelines. Many segments of existing State Park trails do not yet meet sustainable standards. Where this is the case, a higher level of maintenance is required to keep the trail tread in reasonably good condition while minimizing impacts on park resources. The ultimate result of sustainable trails are park resources that provide improved transportation alternatives, recreational opportunities, environmental aesthetics, open space preservation, and increased adjacent property values.

By constructing ***rolling contour trails***, sustainability can be achieved. Rolling Contour Trails encourage water to flow off of trail tread by gently traversing a hillside and incorporating ***Grade reversals*** and ***outslope*** into their design. The list below includes the basics of *sustainable trail* characteristics. See Appendix A for diagrams of standard trail structures.

All drawings in Section 4 are original artwork by Ted Kincaid unless otherwise noted.

4.1 The Six Essential Elements of Sustainable Trails

(Adapted from Alaska Trails *Sustainable Trails 101* curriculum.)

1. **The Half Rule:** Trail grade should not exceed ½ the sideslope that the trail traverses; if so, it becomes a *fall-line* trail (***fall-line*** – the steepest route of descent down a slope. Water flowing down a hillside will travel along the *fall-line*).

2. **The 10% Average Guideline:** The average trail grade, or overall trail grade should not exceed 10% along the alignment of the trail. In most cases, keeping trail grades at or below 10% will assure long term sustainability, and this should be an objective for all trail projects, unless specifically designed at greater grades.

3. **Maximum Sustainable Grade:** This is the defined maximum tread grade that can be constructed along the trail. This is typically restricted to runs of less than 50 feet, and no more than 5% of total length of the trail. Determining the *maximum sustainable grade* for a trail involves many variables that are specific to a region or trail section. For example, soils that have a very high organic content will be less stable than those that are composed of weathered granite. Variables influencing the *maximum sustainable grade* include:

    A. Soil type

B. Presence of surface rock or bedrock
C. Annual rainfall / intensity
D. Type and spacing of integrated water control features
E. Types of users
F. Numbers of users
G. Desired level of difficulty

4. **Grade Reversals:** These are areas at which a climbing trail levels out and then changes direction, dropping subtly a short distance (20-50 feet) before rising again. Ideally, grade reversals are incorporated into a trail's initial design as part of its *curvilinear layout* (see below). Water control features such as ***rolling grade dips*** and ***knicks*** can be integrated into an existing trail as a maintenance item. ***Waterbars*** are not recommended due to their higher maintenance requirements.

5. **Outslope:** As the trail contours across a hillside, the downhill or outer edge of the tread should tilt slightly downhill and away from the uphill trail edge. Under typical circumstances, this *outslope* should be less than 5%, although individual conditions may warrant otherwise. Anything greater will usually lead to tread creep and user discomfort. Outslope is influenced by the forces of compaction, displacement, and erosion, which collectively reduce the effectiveness of the design element. Even on trails that are constructed with proper outslope, it will often deform through time and routine maintenance is needed to restore a trail tread to its designed outslope with these forces in mind. The integration of *grade reversals* and *rolling grade dips* insure that water is managed along the trail if outslope is compromised.

6. **Durable Tread Surface:** The Tread Surface of a trail should be compacted and durable enough to support the managed use and shed water. Surfacing should take into consideration special characteristics of the soils such as the presence of permafrost, organic/muskeg soils, volcanic ash, saturated soils and other environmental conditions. Many trails in Alaska are not sustainable due to flat terrain or the soil characteristics noted above. Often, trails suitable for winter travel do not support summer use. In these cases tread surfaces require trail hardening to ensure sustainability. Trail hardening includes techniques such as gravel capping, boardwalk and planking decking, the use of geotextile surfaces, and other means to provide a sustainable tread.

4.2 Trail Layout and Design

(Adapted from International Mountain Biking Association's *Trail Solutions.*)

Control points need to be identified in the design process, because these are places that determine where the trail is constructed. A control point could be the trailhead or a public use cabin. ***Positive control points*** are interesting places that you want users to visit while on the trail. A scenic overlook (a *positive control point*) could discourage switchback cutting by making people want to stay on the established trail. Connect the trail to these *positive control points*, especially if they are near the trail, or people may end up making new ***social trails*** to get there. Make sure to route the trail far away from ***negative control points***, so visitors aren't encouraged to investigate; these places you want users to avoid can include sensitive habitats, private property, an archaeological site, etc. It is helpful to make waypoints for control points with a GPS. By plotting these points on a topographic map, a rough sketch of the trail can be drawn using contour lines as a guide to keep the route sustainable.

4.2.1 Trail Layout Marking (Adapted from Alaska Trails *Sustainable Trails 101* curriculum.)

Once the basic route has been decided upon, a crew experienced in trail design can put in the initial flagline or staking; stakes will have distances denoted on them (0+00, 1+00, 2+00, etc.). Pin flags can then be placed between stakes that are generally 5-10 feet apart for the ***trail layout marking***. Some commonly used methods for Trail Layout Marking are described below.

Center Line Method: Pin flags are placed in the center of the trail tread. A defining line is cut through the organic layer half the tread width on the uphill side to aid in trail construction.

Uphill Edge Method: Flags mark the uphill edge of the tread. A line is cut through the organic layer on the lower boundary of the tread.

Downhill (Critical) Edge Method: The *downhill edge* is marked with pin flags. A line is cut through the organic layer on the upper boundary of the tread.

4.2.2 Trail Clearing (Adapted from Alaska Trails *Sustainable Trails 101* curriculum.)

Bright survey tape can be used to mark the boundary of the ***trail corridor*** for clearing (width and height) based on management objectives. As the corridor is cleared don't remove any more vegetation than necessary to retain the look of a trail rather than a road. (see Appendix A, Sheet 1). When pruning trees to clear the corridor, the ***"three-cuts" method*** is encouraged to keep bark from peeling off of a tree when its branch is removed. First cut from the bottom several inches from the bark collar to remove the bulk of the branch. Next, cut from the bottom just outside of the branch's bark collar. Finish cutting through the branch from the top.

When clearing trees from the tread, they must be completely removed from the tread rather than be cut at their base; as the ground is compacted the stump will protrude otherwise. By cutting to waist level initially, you can gain leverage to pull them out. If more than half of a tree or shrub needs to be pruned, it should be completely removed.

4.3 Design Concepts

(Sections 4.3- 4.3.6 adapted from International Mountain Biking Association's *Trail Solutions*.)

The goal of creating a *sustainable trail* is ultimately to define and minimize its short and long term maintenance needs. If a potential trail or system is planned and built with anticipation of impact-causing conditions (such as the *maximum sustainable grade* variables listed above), there will be less troubleshooting and reconstructing – or at least, a routine maintenance plan for the expected degradations. Planning a sustainable trail requires integration of the essential elements listed above, and also consideration of the following layout and design concepts.

4.3.1 Bench Cut Trails (See Appendix A: Figures A.2-A.4.)

Full bench construction is the preferred method when building *bench cut trails*. ***Full bench trails*** cut the tread entirely from the hillside from compacted soils, resulting in a more stable tread than the alternative, the ***partial bench trail***. In *partial bench construction*, only part of the tread is created by digging into the hillside; the rest of the tread surface is created from the excavated soil. This method is not recommended because the outer tread is not as durable as the inner tread. If it is not possible to use *full bench construction*, possibly due to an immovable obstacle, a retaining wall should be used to reinforce the tread. Five steps describe the *full bench construction* process, once the Trail Corridor is cleared.

1. **Dig the Tread.** Begin by raking the loose organics (branches, leaves, etc.) uphill for use later. Mark the upper and lower extent of the tread based on pin flag locations and prescribed trail width. Begin grubbing (using a *Pulaski*) the tread through the organic soil into mineral soil. Broadcast the debris downhill and far off the trail (using a *McLeod*).

2. **Cut the Backslope.** The *backslope* of the trail is the excavated slope above the trail *tread* and below the natural hillside. The *backslope* must be shaped to transition into the hillside to prevent erosion on to the trail. Use a *Pulaski* to sculpt the *backslope* and broadcast excess soil. Be sure to adequately pack the *backslope* with a *McLeod*.

3. **Outslope the Trail Tread.** *Outslope* is very important so water sheds across it and doesn't follow it. Use a *McLeod* to create a slope of 3-5%.
4. **Compact the Tread.** Tamp down the trail *tread* with a tamper, tamping bar, or plate compactor (dry soils can make this tricky). If not done properly trail users could pack the center of the tread leaving a concave surface for water to run down.

5. **Tread Finishing.** Remove trail markings (stakes, pin flags, survey tape). Cover the *backslope* and broadcasted soil with the loose organics that were piled up from step 1.

4.3.2 Climbing Turns (See Appendix A: Figure A.6.)

If your trail cannot climb fast enough with a sustainable grade to reach control points a ***climbing turn*** may be the solution. *Climbing turns* help a trail gain elevation without the extra work required to build a ***switchback***. Climbing turns should have a wide radius and provide a free flowing trail (as opposed to a Switchback). Climbing turns shouldn't be built on slopes steeper than a 7% grade because a short section will become fall line; to mediate this ***grade reversals*** should be constructed immediately above and below the turn.

4.3.3 Switchbacks (See Appendix A: Figure A.5.)

If the slope you are trying to climb is greater than 7% grade it may require a true ***switchback***. Switchbacks avoid the fall line by constructing a ***turning platform*** with a 2% maximum grade. This avoids having fall line sections (like the *climbing turn*), and allows climbing steeper slopes. *Retaining walls* may be needed to support the *turning platform* and trail below. The trail just above and below the *turning platform* should have a grade no greater than 5%. Above the *turning platform* the trail is *outsloped* for a short ways to drain water into an uphill drain ditch. An ideal location for a switchback will be on the least steep terrain. A viewpoint to the outside on the *switchback* can encourage users to stay on the trail; obstacles (trees, boulders, etc.) inside the trail at switchbacks can keep people on the trail as well.

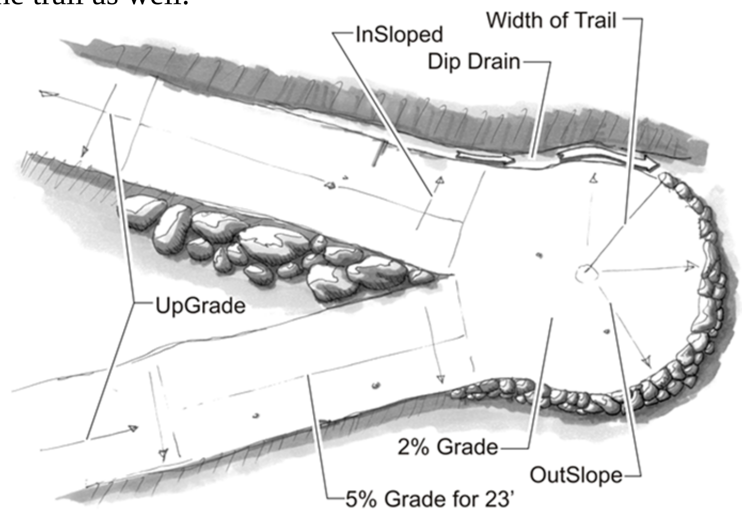

Figure 4.1 - Switchback Design

4.3.4 Retaining Walls (see Appendix A: Figure A.17.)

Retaining walls may be needed for switchbacks or partial bench construction. Rock is preferred over wood for its durability. The source rock should be heavy, blocky, and be found locally. Make the footing *insloped* when excavating the footing for the *retaining wall*. Large rocks should be embedded below the soil surface for the base. The next layer(s) of rocks should be offset so the joints don't overlap. As each rock layer is added the fill should be compacted. Walls should also be tilted inward (this is referred to as ***batter***) towards the trail and back filled with gravel and/or mineral soil. Large flat capstones should keep everything together.

Crib walls are retaining walls constructed with logs or treated timbers. The logs are stacked and notched so they are able to hold back the fill material. As with rock *retaining walls*, each log layer is added the fill should be packed. The walls should also have *batter* for stability.

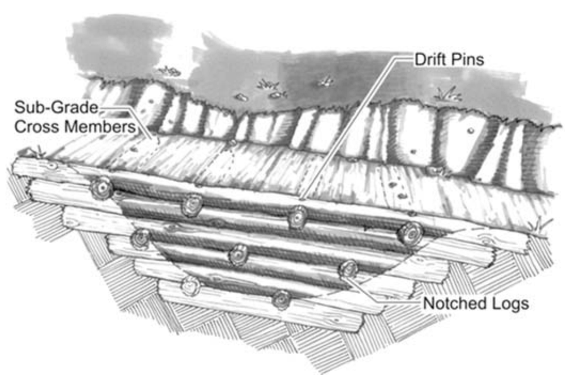

Figure 4.2 - Crib Wall Design

Trail armoring is used to make a trail more durable using rock, and may be necessary in certain situations. Heavily traveled trails, overly steep trails, or trails that traverse damp soils may need some reinforcement. Below a few common armoring techniques.

Flagstone paving is the simplest method, and involved placing large flat stones on mineral soil (organics removed from surface), or a mix of aggregate. ***Stone pitching*** is the process of skillfully placing stones on end into the ground, carefully aligning rock joints. ***Raised tread construction*** can be used to lift tread above wet ground. Large rocks are placed into mineral soil, a layer of smaller rocks is placed above, and capped with aggregate.

A few of the following tips may be useful in a trail Armoring Project.

1. Angular square-shaped rocks work far better than rounded for trail armoring.

2. Gravity makes working from the bottom to the top much easier.

3. Trail compaction is just as important with rock construction as it is with soil, so take the time.

4. It may be advantageous to add natural barriers to the edge of the trail, especially in wet areas, to keep people on the trail.

5. Be sure to fill any gaps between armoring rock.

6. ***Keystones*** that are trail width and very heavy should be placed every 4 to 6 feet to keep the armoring in place.

7. Avoid aligning joints when assembling stones, as this can weaken the structure.

8. Continue to use sustainable trail techniques; keeping water from running down the trail will help the armored trail last much longer.

9. Rolling rocks is not preferred. This can be dangerous, and the rocks probably won't stop in their desired location.

10. Have at least 3 *pry bars* on hand for moving rock.

11. *Rock hammers* with *chisels* can shape rock, while *sledgehammers* can help wedge stones or break them. *Pulaskis* are a good choice for digging and rock positioning.

12. It's easiest to use local rock, but quarry from an area out of sight from the trail, and uphill if available. Restore quarry area after work is complete.

4.3.6 Geosynthetics

Geosynthetics are man-made materials that help stabilize soils or prevent their mixing. ***Geotextiles*** (***Geotex***) keep layers from mixing, while allowing water to drain through. These are used in boggy areas to separate the wet soils from the overlying material that will be placed on top to create the tread surface. A honeycombed plastic panel called geogrid ***Geocell*** can be used to hold soils in place when the soils are wet. Use only when appropriate, because it is fairly expensive.

4.3.7 Water Crossings

(Sections 4.3.7- 4.3.8 adapted from International Mountain Biking Association's *Trail Solutions*, and USFS Wetland Trail Design and Construction)

Water crossings can be the most complex part of trail construction, and should be avoided if possible. It is important to know if your stream crossings will affect wetlands or anadromous streams for permitting reasons and habitat protection. It is best to avoid water crossings unless absolutely necessary, but it is usually impossible to route a trail without crossing one. Before deciding on a water crossing method it is best to consult historical stream flows and assess the riparian habitat. The goal is to create a sustainable corridor while minimizing impacts to the waterway.

A trail should always descend to a water crossing and climb out of it so water never has the opportunity to follow the trail downhill. *Grade reversals* should also be present near the stream so water doesn't erode the trail surface into the stream. There are three main types of water crossings: a ***stream ford***, a ***culvert***, or a ***bridge***. When constructing a *stream ford* or a *bridge* the most suitable section of a stream will be in a riffle area (not a meander); although stream channels will migrate over time, this is will be the most stable area.

A ***stream ford*** is an armored crossing that used large stones to increase the durability of a stream crossing and both entrances to it. The trail on each side of the crossing should be armored for several feet to guard against sediment or the trail washing out during high flows. This technique is only suitable for streams up to three feet deep, and beyond that a bridge may be necessary. The most durable method of stream armoring is *stone pitching*.

A ***culvert*** (see Appendix A: Figure A.12) is a conduit to deliver a small volume water beneath a trail; this can be accomplished with plastic or metal piping or rock structures. Wood is not durable and isn't recommended. It is important to get some information from locals about the maximum flows, look at evidence in the stream bed. Although *culverts* are often the cheapest solution to a water crossing, they require maintenance, and need to be installed correctly to avoid habitat disruption and drainage problems. A *culvert* should be at least as wide as the stream bed and ideally as wide as the largest flows expected. If the *culvert* isn't wide enough, it may clog quickly. *Culverts* may not be the best solution in an anadromous stream, although a better option may be to cut a *culvert* lengthwise and install it as an arch. There should be at least one foot of soil above the culvert.

Bridges are appropriate for stream large stream crossings that may otherwise be dangerous to ford, or have high peak flows. They can be a complex engineering project or as simple as a log with a hand rail. *Bridges* can be quite expensive and often require permits, so plan accordingly. Large *bridges* will likely be constructed by engineers, but below are some helpful hints on building smaller scale wooden bridges.

1. Strip bark off of local logs to postpone rot and prevent insect damage.

2. Unfinished wood harvested near the bridge site will not have the longevity of treated wood and may need to be replaced often.

3. Due to rot potential, wooden ***stringers*** (structural supports for a bridge that span the width of the stream) should not rest on the ground.

4. Screws and bolds will hold bridges together better than nails.

5. There should be a clear line of sight for people on either side of the bridge for motorized and bicycle trails.

4.3.8 Wetland Trail Structures

Trails should be routed away from wetlands whenever possible, but sometimes this is unavoidable. Keep in mind there may be extra permitting or environmental studies involved. *Trail armoring* and *geosynthetics* are possible solutions for trail construction in damp soils, and are mentioned above. ***Turnpike***, ***causeway, puncheon***, and ***bog bridge*** are other options to cross wetland soils.

Turnpikes (see Appendix A: Figure A.14) are typically an effective option for crossing wet soils. They are suitable when the water table is high, there is no more than a 20% *sideslope*, and soils are at least moderately drained. It is appropriate for consistently wet soils that don't experience flooding. *Turnpike* is built by first excavating ditches on each side of the trail location. A shallow trench can then be dug between ditches and be filled with rock/aggregate; above that should be *geotextile* fabric topped with compacted gravel. The tread surface should be crowned. Rock or log ***retainers*** should be used to hold the tread together, although rock is preferred for durability. Pins should be placed on the outside of retainers to keep them in place. To encourage drainage away from the trail, ***culverts/drains*** and ***leadoff ditches*** are periodically needed. On steeper terrain ***stepped turnpike*** (see Appendix A: Figure A.15) can be used.

A ***causeway*** is a *turnpike* without side ditches. These take less time to construct, and may be suitable for seasonally wet areas. Keep in mind there is less drainage involved in this trail structure.

Puncheon uses ***mud sills*** and ***stringers*** to elevate decking above wet soils. *Mud sills* rest in excavated soils. *Stringers* rest in notches on top of the *mud sills*; they should be connected by ***lag screws***. *Stringers* have a flat surface on top to lay decking on. The decking should be treated lumber, and securely nailed into the *stringers*. A ***kickrail*** can also be added above the decking to guide walkers' feet. This is often installed on *puncheon* that is more than a couple feet above ground; this should be nailed to the decking. Keep the decking level to prevent hikers from slipping.

A ***bog bridge*** is a simple trail structure that consists of treated timber planks resting on sleepers. The tread is usually one or two 12 inch planks from 6 to 9 feet long. Sleepers rest approximately every four feet, dependent on plank thickness, in excavated soil, and planks are nailed to notched sleepers. *Bog bridges* are commonly used in backcountry areas because they require less material than *puncheon*. For areas that gain elevation the *step and run technique* can be used; use spacers to elevate the planking on steeper terrain. Keep decking level to prevent a slipping hazard.

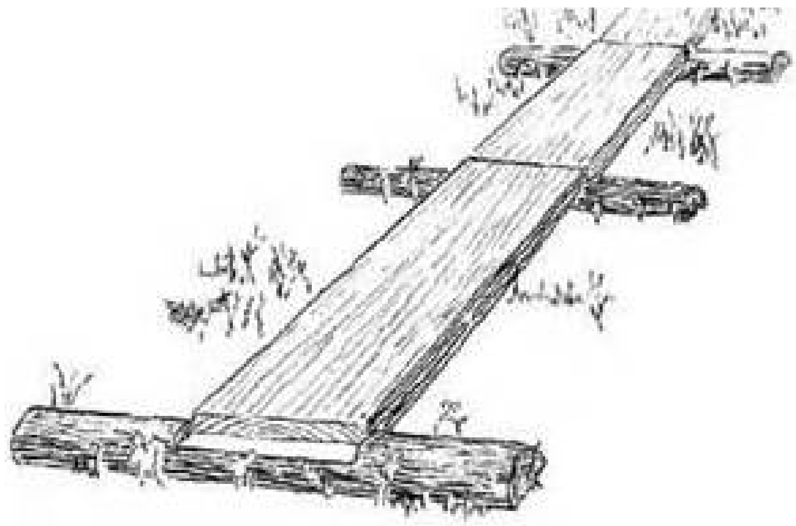

Figure 4.3 - Bog Bridge (USFS *Wetland Trail Design and Construction*)

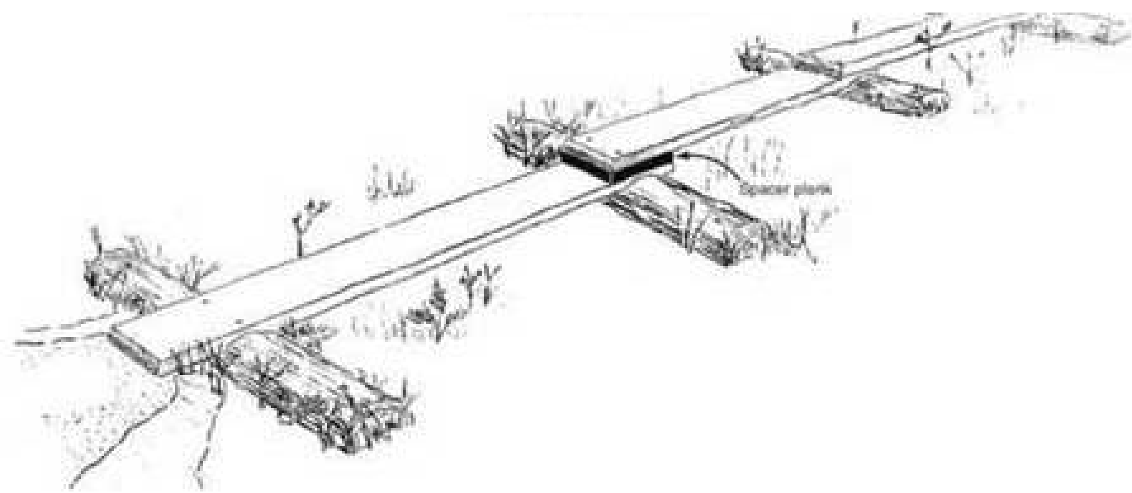

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Figure 4.4 - Bog Bridge: Step and Run Technique (USFS *Wetland Trail Design and Construction*)

4.3.9 Trail Maintenance

(Sections 4.3.9- 4.3.10 adapted from International Mountain Biking Association's *Trail Solutions*.)

Trails need to be maintained periodically to prevent resource degradation and give users a quality experience. Vegetation needs to be cleared from the trail corridor based on Trail Management Objectives. Spring is a good time to clear logs, and Fall is a good time to trim overgrown grasses.

When clearing woody brush, make sure to cut to near the bark collar or to the ground to avoid "***punji sticks***" that trail users can potentially trip or impale themselves on. When clearing, give emphasis to downed trees that users are detouring around or trapping water; both can lead to trail degradation. Roots should be removed if they present an excessive tripping hazard or run parallel with the trail. Raised roots may be evidence of an erosion problem.

Drainage specific problems may develop over time without maintenance. This may be especially true with trails that weren't designed sustainably. If water is flowing down the trail, the outslope may need to be restored or the tread may need to be ***de-bermed*** (removing the berm on the downhill side of the tread). Other options are to add trail structures such as a ***knick*** or ***rolling grade dip*** as problems arise.

Knicks are five to ten foot semi-circular sections of trail that are shaved down to a 15% outslope; they are added to divert water from a ponded area on a trail. A *rolling grade dip* uses the soil from a *knick* to build a ramp on the downhill side of the *knick*. The ramp should be at least ten feet long and gradually blend into the trail. Occasionally *knicks* and *rolling grade dips* need clearing of silt, leaves, and twigs. Avoid using ***waterbars***; they require maintenance, people often walk around them, and they easily fill with sediment. If your trail is steep, has running water down it, and a reroute isn't possible, the techniques above along with armoring may be the only solution.

It is also important to keep trail structures in working safe order, these structures will periodically need new decking and planks. A board with a nail in it can certainly be a hazard. At some point trail structures will reach the end of their useful life and will need to be completely replaced.

4.3.10 Trail Reclamation

In certain situations it may be necessary to reroute a trail or section of trail. Significant maintenance may be needed to maintain a trail designed without sustainability in mind. If a trail suffers from one or more of the following problems it may be prudent to look at possible reroutes: tread erosion, excessive grades, marshy terrain, trail-braiding (users avoiding a muddy or rutted section).

Before rerouting a trail make sure the public knows the purpose, because some people probably enjoy using the trail no matter what state it is in. Community meetings and signs may help communicate goals to be accomplished by a trail reroute.

An especially important part of creating a reroute will be to reclaim the original trail. If a degraded trail isn't reclaimed it can decrease water quality, become an eyesore, and confuse trail users. Begin by ***scarifying*** the old trail. This will prepare its surface for new vegetation to grow; use native seeds. If above tree-line or in an open meadow, you may be able to transplant the vegetation mat from the new trail to reclaim the old trail. Logs, leaves, and other organics can be spread to further disguise the area. If the erosive forces are too much, ***check dams*** may need to be installed to trap sediment on the trail. Rocks, logs, or burlaps sacks filled with soil may be used.

4.3.11 Special Implications for Alaska

Alaska has some unique challenges when it comes to trail building. In some regions, the geography and geology may make construction very difficult or expensive. Here are a few things to be aware of.

There are countless winter trails in Alaska that often follow the easiest way from A to B across snow and frozen rivers, and swamps. As ice and snow melts many of these winter trails continue to be used during the summer. As trail becomes muddy, users will hike/drive around the muddy areas. This trail can turn from multiple braids to an impassable mud bog. A wetland suitable trail structure may be advisable if there is no other option to connect trails on better soils. If most of the trail is across wetland soils a complete reroute or seasonal closure may be necessary.