Sustainability of National Park Service Backcountry Trails
Minimizing Resource Impacts
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Summary

In order to provide the basis for the most sustainable backcountry trail for all trail types with the least impact to natural, historic, cultural and aesthetic resources, the National Park Service (NPS) recommends establishing guidelines for each trail for average trail profile grade of 10% to 12% (where necessary to climb or descend, and lower where appropriate), for maximum trail profile grade at 12% to 15%, and the relationship between the trail profile gradient and prevailing cross slope grade in the immediate vicinity along the trail centerline at less than one quarter ("high slope alignment angle" (Marion, Jeffrey L., 2006)). Design techniques such as grade reversals and rolling contour trails increase sustainability by assuring prompt drainage of rainfall and snowmelt off the trail while also improving the visitor experience. Construction techniques such as retaining walls, switchbacks, stone paving, bridges, etc., improve trail surfaces, reduce impacts and increase sustainability. And customizing trail project guidelines per state-of-the-art scientific research and landscape architectural criteria will increase sustainability.

Discussion

NPS 2006 Management Policies defines backcountry:

> *"The [National] Park Service uses the term backcountry to refer to primitive, undeveloped portions of parks. This is not a specific management zone, but rather refers to a general condition of land that may occur anywhere within a park."*

Natural Resource Management Reference Manual #77 (RM #77) (2006) offers comprehensive guidance to National Park Service employees responsible for managing, conserving, and protecting the natural resources found in National Park System units. RM #77 defines backcountry trail sustainability as the following:

> *"Sustainability of backcountry trail corridors is defined as the ability of the travel surface to support current and anticipated appropriate uses with minimal impact to the adjoining natural systems and cultural resources. Sustainable trails have negligible soil loss or movement and allow the naturally occurring plant systems to inhabit the area, while allowing for the occasional pruning and removal of plants necessary to build and maintain the trail. If well-designed, built, and maintained, a sustainable trail minimizes braiding, seasonal muddiness and erosion. It should not normally affect natural fauna adversely nor require re-routing and major maintenance over long periods of time."*

Minimizing impact to natural, historic, cultural and aesthetic resources is a foundational premise of NPS management decisions and a management responsibility. Preservation of park resources for future generations and preclusion of impairment of park resources are both mandated by the NPS Organic Act.

Trampling of vegetation, compaction of trail tread materials, erosion of trail tread materials and trail muddiness are impacts associated with trail corridors. These impacts are a concern to NPS managers. Trail erosion causes unsightly gullies and can cause impacts immediately adjacent to the trail corridor by exposing roots of trees. Erosion of trail materials also dries out the soil substrate adjacent to trails which is critical to ground cover, grasses and understory plant health and success, causing further impacts and trail widening. Eroded materials can also be deposited downhill from trails and enter aquatic systems causing changes to water quality and related impacts.

The NPS is required to consider cost of initial construction as well as on-going maintenance requirements in its management decisions. Therefore, trailside decisions which influence sustainability, minimize impacts to natural, historic, cultural and aesthetic resources, and have cost variables must be carefully analyzed in the NEPA / Section 106 (of the National Historic Preservation Act) compliance processes.

Utilizing the expertise of an interdisciplinary team of professionals with experience in backcountry trails in compliance processes is foundational to backcountry trail sustainability. Interdisciplinary teams are best qualified to provide trail sustainability expertise for trail projects as has been expressed in trails literature since the Civilian Conservation Corps era of the NPS. Landscape architects, civil engineers, soil scientists, natural resource specialists, cultural resource specialists, botanists, biologists, interpreters, outdoor recreation planners, restoration ecologists and others are important members of interdisciplinary backcountry trail teams.

Bases of Backcountry Trail Sustainability

Sustainability of backcountry trails is based upon the physical capacity of the land to support the intended visitor use. Suitable topographic and soil substrates are foundational to trail sustainability; therefore care must be exercised in their selection. Solar aspect (compass orientation of the topographic landform) influences sustainability, therefore the implications of trails on different solar aspects must be considered. For example, north facing slopes are typically colder and wetter than south facing slopes. Types of use as well as volumes and seasons of use also influence sustainability; therefore characteristics of proposed use(s) must be carefully analyzed.

Sustainability of backcountry trails is much an art as it is a science. From the NPS' *Sketchbook*:

> *"Sustainability of backcountry trails can be summarized as the art and science of the optimum investment of time and materials into a trail over the project's life cycle."*

And sustainability of backcountry trails is similar in concept to a wilderness ethic. From the NPS' *Sketchbook:*

[Sustainability of backcountry trails] *"... is based upon the wilderness ethic of minimum alteration of natural systems and minimum evidence of human presence established through the historic tradition of federal land management agencies."*

Definitions & Comments

Fall Line. Fall line is defined as the course of water down a hillside as influenced by gravity, or the route a skier would take straight downhill.

Fall Line Trail. A fall line trail would be measured as approximately 0 degrees as it does not vary from the straight downhill line (Marion, 2006).

Contour Trail. A contour trail is defined as a trail that is level and parallel to the contour. A contour trail would be measured at approximately 90 degrees.

Rolling Contour Trail. A rolling contour trail is a trail that gently rises or falls from the contour.

Side-hill Trail. A side-hill trail is a trail that finds the *"happy medium between the trail's function to gain elevation and the tendency of water and foot traffic to rapidly erode trails on steep grades."* – Appalachian Mountain Club, 1981.

Topographic Prevailing Cross Slope. Topographic prevailing cross slope is defined as the percentage of slope grade perpendicular to the contour. This term refers to the "lay of the land." In general terms gentle prevailing cross slopes (< 30%) would be characteristic of hills and steep prevailing cross slopes (up to 100% or even higher) would be characteristic of mountain topography. Note that a prevailing cross slope of 100% is only at a 45 degree angle, and many mountainous areas greatly exceed 100% prevailing cross slope grades. Prevailing cross slopes are usually expressed in ranges, for example 20% to 30%, or over 50%. Prevailing cross slope ranges help planners analyze the topography's ability to support sustainable trail use. Utilizing prevailing cross slopes grades between 20% and 70% for backcountry trails offer the best opportunity to achieve sustainability. Prevailing cross slopes less than 20% typically need imported surfacing and significant maintenance to remain sustainable because water does not typically drain freely on these cross slopes. Prevailing cross slopes over 70% are typically impractical to build on or require substantial costs to implement properly. Experienced interdisciplinary teams commonly utilize prevailing cross slopes of less than 50%.

Trail Profile. Trail profile is defined as the centerline of the trail as it traverses topography.

Trail Centerline. See Trail Profile.

Trail Profile Gradient. Trail profile gradient is defined as the rise or fall of a trail along the trail profile and is expressed in percent. For example, a trail with a 5% profile gradient rises (or falls) 5 feet vertical in 100 feet horizontal feet. Trail profile gradient is independent of prevailing cross slope grades. Trail profile gradients can be measured accurately, and are usually expressed to within 1 percent and can be positive (rising) or negative (falling) depending upon direction of travel. Trails with profile gradients of + 5% (or - 5%) can cross topography with prevailing cross slopes of any range, for example 20% to 30%, 30% to 40%, or over 40%. Likewise, trails with profile gradients of + 7% (or - 7%) can cross topography with prevailing cross slopes of any range, for example 20% to 30%, 30% to 40%, or over 40%.

Coarse (or mineral) Soils. Coarse soils are defined as free draining soils with large particle sizes and low percentages of organics. Coarse soils offer the best opportunity for trail sustainability because they drain freely. Soils which are predominantly made up of silts and clays are inherently unsustainable because they hold moisture and do not form a firm substrate for trail traffic, causing muddiness. These soils also usually coincide with prevailing cross slopes less than 20%.

Trail Slope Alignment Angle. The trail slope alignment angle (Marion, 2006) is defined as the angle from the fall line to the trail alignment. *"Trails that more closely follow the contour have a high slope alignment angle: they are more perpendicular to the [prevailing cross] slope. Known as "side-hill" trails, their steeper side-slopes confine use to the constructed tread and facilitate tread drainage."* Marion goes on further to state: *"The easy removal of water from side-hill trails and the ease of angling them to avoid steep trail gradients makes high slope alignment angle trails far more sustainable and less expensive to maintain over time."* Marion suggests that high slope angle trails, that are above 67 degrees, display minimum erosion and have fewer natural, historic, cultural and aesthetic resources impacts.

NPS Guidelines and Comparison to Marion, 2006

The NPS had previously defined (1991), and reiterated in 2007, that the optimum trail alignment ratio as ¼ of the prevailing cross slope and recommended this as a guideline ("¼ ratio guideline"). The expression of a ratio for trail alignment from the contour versus an angle from the fall line facilitates application on the ground by trail planners and designers. The high slope alignment angles expressed by Marion (67 degrees < X < 90 degrees) correspond to the NPS ¼ ratio guideline as follows: 90 degrees minus 67 degrees = 23 degrees; 23 degrees / 90 degrees approximately ¼. The best opportunity for backcountry trail sustainability would therefore be for trails with slope alignment angles from approximately 67 degrees through 90 degrees.

Field investigation indicates that few trails that are low slope alignment angle trails, 0 degrees through 67 degrees (or exceed the ¼ ratio guideline), are stable without causing erosion and impacts to natural, historic, cultural and aesthetic resources. Therefore the NPS recommends establishing a trail profile gradient guideline at less than ¼ the prevailing cross slope grade in the immediate vicinity along the trail centerline (this corresponds to high slope alignment angles (Marion, 2006)) to afford the best opportunity to minimize erosion and corresponding resource impacts and for long-term sustainability.

Popular trail documents refer to this concept alternately as "contour curvilinear alignment," "rolling contour trail," or "trail contouring." Note that a "contour trail" would have a slope alignment angle of 90 degrees. Trails that cross slopes at steeper gradient ratios (or with low slope alignment angles) will likely result in unnecessary erosion and corresponding resource impacts, be harder to maintain, be more costly over the life cycle and may have to be re-routed (with corresponding ecological restoration of unsustainable corridors).

Planners who propose trails on the higher slope alignment angle (and less than the ¼ ratio guideline) will ensure that trails minimally impact natural, historic, cultural and aesthetic resources.

There may be instances that require interdisciplinary teams to exceed the ¼ ratio guideline. Interdisciplinary teams must balance research findings, sound judgment, trail standards, construction impacts, construction costs and maintenance costs when exceeding any guideline to develop the best solutions for the situation at hand.

As with all planning and design projects, customizing trail project standards per scientific research and landscape architectural criteria will do much to improve and attain backcountry trail sustainability. From the NPS' *Sketchbook*:

> *"Key to project success is customizing scientific and landscape architectural sustainability criteria to the project at hand across the trail project cycle as well as being patient during implementation."*

Average Profile Gradient

Establishing an average profile gradient based upon topographic analysis and trail system components also assists in minimizing erosion and assuring long-term sustainability and is subordinate to the high slope alignment angle. Average trail profile gradients are commonly established at 10% or 12%, with lesser profile gradients preferable where topography and distance allows.

Maximum Profile Gradient

Establishing a maximum trail profile gradient, based upon topography and soils, is subordinate to establishing an average profile gradient and also helps minimize erosion while encouraging long-term sustainability. Maximum trail profile gradients are commonly established at 12% or 15%, and can be combined independently with the average profile gradient, for example: 10% average profile gradient with a maximum 15% profile gradient. Maximum profile gradients are typically used only for short distances, for example just 25 feet or 50 feet.

Few trails in any topographic or soil condition are sustainable at profile gradients over 10%. Stressing the over-riding importance of the slope alignment angle to long-term sustainability of trails, from Marion, 2006 (page 8) explains, *"The importance of slope alignment angle increases in significance as trail [profile] slope increases."* As the tendency and need in mountain trail projects is to climb at steep trail profile gradients (for example at 12% or possibly 15%), even quickly, trail planners and designers would still be prudent to observe the high trail slope alignment angle guideline.

Optimum Trail Corridors

Optimum trail corridors will connect trailheads with destinations and consider linkages within the trail system. Once corridors are established, incremental improvements can be made over time to achieve trail sustainability. Multiple corridors can be studied together, adjustments made, and assembled into an area-wide plan. The most sustainable corridor is the corridor implemented to sustainable criteria, incrementally improved (see **Construction Techniques** below) and with minimal or no re-routing.

Assessment of Established Trail Corridors

For established trail corridors, the existing trail plan and profile alignment can be assessed according to sustainability criteria, and compared to what would be an optimal designed-for-sustainability alignment. The resulting analysis can be utilized in the NEPA / Section 106 process and form the basis of management decisions on how to bring the existing corridor up to sustainable status. For example, maybe just particular segments of trails need to be replaced with new alignments and redundant corridors restored to natural conditions to have a continuous sustainable trail corridor.

New Uses on Existing Trails

In order for the NPS to make a determination of allowing new uses on existing trails, a NEPA / Section 106 analysis (existing trail uses and current environmental conditions compared to the proposed uses and corresponding anticipated environmental conditions) must be conducted. Mountain bicycles, horses and hikers all have different physiology when using trails. Periodic field reviews may be required to determine continued allowable new uses on existing trails.

Construction Techniques

Construction techniques can be utilized to improve sustainability of trail corridors and minimize natural, historic, cultural and aesthetic resource impacts. Full bench construction (cutting the entire trail tread into a hillside rather than cutting ½ of the trail tread into a hillside and using the cut material to fill the other half) is the most important construction technique to ensure sustainability. "½ bench" trails are typically unsustainable. Drainage considerations, continuously integrated into the trail's construction, are also required to ensure sustainability.

Other design / construction techniques such as trail profile gradient reversals and rolling dips are available to ensure sustainability. These techniques must be accounted for when planning and designing trails. For example, if grade reversals are planned to allow for drainage, the distance of cumulative height of vertical falls must be added to the ensuing remaining climb. Hence estimations of trail lengths at various average profile gradients must include consideration of profile gradient reversals.

Miscellaneous hardening (a.k.a. "armoring") solutions are often required when implementing trails. These include retaining walls, switchbacks, climbing turns, stone paving, paved dips, waterbars, turnpikes, puncheon, trench drains, bridges and other solutions. Sometimes imported gravels, geotextile fabrics and pipes (steel or plastic) are required to improve trail surfaces and increase sustainability. The preference for sustainable trails is for the majority of the corridor to consist of natural surfaces. Adequate planning for sustainability typically reduces the amount of trail hardening required with the acknowledgement that extensive hardening may be required for some corridors. It is also acknowledged that some trails can only be implemented with extensive hardening improvements.

Maintenance Requirements

Trails implemented to sustainability criteria will always have the lowest maintenance requirements.

Conducting maintenance activities on a regular basis up to four times per year combined with maintenance activities on an as needed basis will increase sustainability of backcountry trails.

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