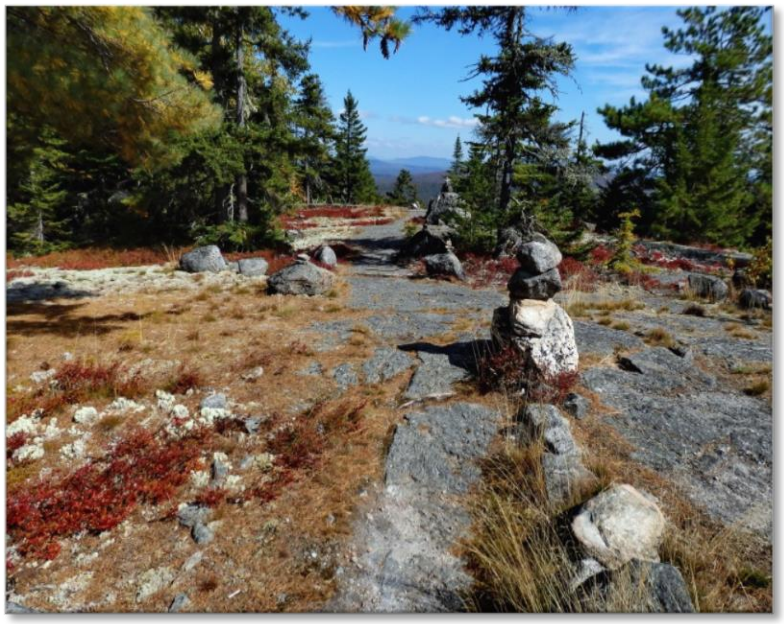
U.S. Geological Survey, Virginia Tech Field Unit
RESEARCH REPORT

Sustainable Camping "Best Management Practices"



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ABSTRACT

This sustainable camping "Best Management Practices" (BMPs) document was compiled to provide comprehensive guidance on the best available management strategies and actions found by researchers and managers to be effective in minimizing camping resource and social impacts. While developed as part of a comprehensive study of camping impacts along the Appalachian National Scenic and Recreational Trail, this document was also designed to be applicable to a wide array of backcountry and wilderness settings. It is intended to serve as a reference document and "toolbox" describing a wide array of site management, educational, and regulatory "tools" and practices to aid managers and volunteers in avoiding and minimizing camping impacts. Recreation ecology and social science research provided the foundational knowledge from which these science-based BMPs were derived, augmented by case examples of management experimentation, refinement, and success in seeking to accommodate increasing visitation while reducing associated negative impacts. A "sustainable campsite" is one that can accommodate the intended type and amount of use over time without unacceptable levels of expansion, degradation, maintenance, and social crowding or conflict. Sustainability is inclusive of resource, social, and managerial dimensions.

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INTRODUCTION

Increasing visitation to protected natural areas, including long trails like the AT, will continually challenge the community of land managers, non-profit staff, and volunteers to sustain high quality resource conditions and visitor experiences. Visitors participating in a diverse array of recreation activities, including hiking, backpacking, and camping, contribute to an equally diverse array of direct and indirect impacts on park resources, including vegetation, soils, water, and wildlife. The term *impact* is commonly used to denote any undesirable visitor-related change in the quality of resources or visitor experiences. The field of study devoted to investigating visitation-related resource impacts and the development of "Best Management Practices" to avoid or minimize them is known as Recreation Ecology.

Scientific research plays an important role by documenting the type and severity of resource impacts that occur, and their relationships with a diverse array of influential factors (Table 1). For example, relational analyses such as regression modeling can identify the most significant factors that minimize soil loss or muddiness on trails or the proliferation and expansion of campsites. These factors can be targeted for manipulation by management actions to improve the sustainability of the recreational infrastructure, defined as trails and recreation sites, including overnight campsites and shelters.

Table 1. Descriptions of use-related, environmental, and managerial factors that can affect the nature and severity of visitor impacts to natural resource conditions and visitor experiences.

FACTORS	DESCRIPTION
Use-Related	
Amount of Use	Number of visitors who hike a trail or use a campsite per month or year.
Type of Use	Activity by duration (day, multi-day, weeks/months) and mode (day-hiking, backpacking, horse, mountain bike).
Density of Use	Dispersed or concentrated use, including People At One Time (PAOT) at camping areas.
User Behavior	Visitor knowledge and use of low- vs. high-impact outdoor practices.
Timing of Use	Season of use and peak/high use vs. moderate/low use periods.
Environmental	
Vegetation Type	Variation in vegetation trampling resistance and resilience (recoverability).
Substrate Type	Variation in substrate trampling resistance (organic litter, soil, gravel/rock, bedrock, snow)
Topography	Variation in terrain slopes that influence visitor behaviors, erosion rates, and others.
Climate/weather	Amount/season of rain and snow, length of growing season, and temperature range.
Wildlife Tolerance	Wildlife characteristics and tolerance to visitor disturbance and habitat changes.
Managerial	
Infrastructure	Provision of trails and recreation sites and their sustainability (e.g., location, durability, spatial distribution).
Maintenance	Maintaining trails and sites to preserve their condition and concentrate use and impact.
Regulation	Rules governing amount, type, and location of visitation and visitor behavior.
Education	Communication of low impact practices to minimize resource and experiential impacts.

Marion et al. (2018a) define a sustainable campsite or trail as: *"…one that can accommodate the intended type and amount of use over time without unacceptable levels of expansion, degradation, maintenance, and social crowding or conflict*." Sustainability is inclusive of resource, social, and managerial dimensions. Resource sustainability refers to the ability of campsites to sustain intensive use over time without expanding or developing unacceptable levels of resource degradation. Social sustainability refers to the ability for a camping system to meet visitor needs and desires: visitors may expand existing sites or create their own if the number, locations, type, and attributes of campsites are not desirable. This suggests that campsite sustainability is also dependent on campsite attributes like proximity to water, campsites, and trails or number and quality of tenting spots. Similarly, sustainable camping management cannot be achieved if managers and partnering organizations lack the capability to identify sustainable campsites, move visitors to them, monitor and maintain site conditions, and close/rehabilitate unnecessary or unsustainable campsites. Sustainable camping management requires the successful consideration and integration of all three dimensions

This sustainable camping "Best Management Practices" (BMPs) document was compiled to provide comprehensive guidance on the best available visitor use management strategies and actions found by researchers and managers to be effective in sustaining visitation to protected natural areas. Recreation ecology and social science research has provided the foundational knowledge from which these science-based BMPs were derived, augmented by case examples of management experimentation, refinement, and success in their application to accommodate increasing visitation while reducing the associated negative impacts (Hammitt et al. 2015, Marion 2016, Manning 2010, Manning et al. 2017).

BMPs can be proactive or reactive in avoiding, minimizing, or resolving troublesome recreation-related resource and social impacts. Proactive management anticipates a problem and seeks to avoid or minimize the likelihood of it occurring before its emergence. Reactive management responds to problems after they occur, often when unacceptable resource or social conditions have developed that are more difficult or expensive to rectify. Professional management is enhanced when managers adopt a comprehensive planning and decision-making framework that proactively prescribes desired resource and social conditions which are evaluated through the selection and monitoring of indicator thresholds (standards) that measure management's success in maintaining desired conditions. Such frameworks provide a defensible process for selecting, enacting, and evaluating the efficacy of corrective BMPs to sustain or restore desired conditions (Manning 2010).

These management frameworks are often employed as a component of legally-mandated carrying capacity planning requirements. Laws dating from the 1970's simplistically linked the maintenance of resource and social conditions to visitor numbers, though later research and management experience have revealed greater complexity in the factors that influence conditions and the diverse array of corrective tools available to managers. Most recently, staff from six U.S. federal agencies formed an Interagency Visitor Use Management Council (IVUMC) to "increase awareness of and commitment to proactive, professional, and science-based visitor use management on federally-managed lands and waters" (http://visitorusemanagement.nps.gov/). They define "Visitor Use Management" (VUM) as the "proactive and adaptive process for managing characteristics of visitor use and the natural and managerial setting using a variety of strategies and tools to achieve and maintain desired resource conditions and visitor experiences." They emphasize that managing visitor access and use for recreational benefits and resource protection is inherently complex, requiring consideration of natural and social science studies, management experience, and professional judgment. The VUM process and its implementation steps are described in Figure 1.

In summary, carrying capacity and VUM decision-making have shifted from a narrow focus on numeric carrying capacity to a broader process that incorporates a more comprehensive array of management strategies and actions (Graefe et al. 2011). VUM incorporates a sliding scale of analysis that preserves flexibility in responding to problems with varying spatial scales, complexity, and risk. These strategies and actions are considered here as comprising a "management toolbox" of alternative options for managers to consider and select from during decision-making focused on preserving high quality resource and social conditions (Marion 2016). This sustainable camping Best Management Practices document is intended as an aid to protected natural areas managers seeking

to improve both resource and social (experiential) conditions associated with camping, though it is also applicable to addressing the management of day-use recreation sites. Within the VUM process it can be used as a management resource or reference document for staff seeking to "Identify management Strategies" (steps 8-11) or "Implement, Monitor, Evaluate, and Adjust" (steps 12-14). It can also be used outside of a VUM or similar process by managers seeking to improve the resource or social conditions of campsites or recreation sites in frontcountry, backcountry, or wilderness settings.

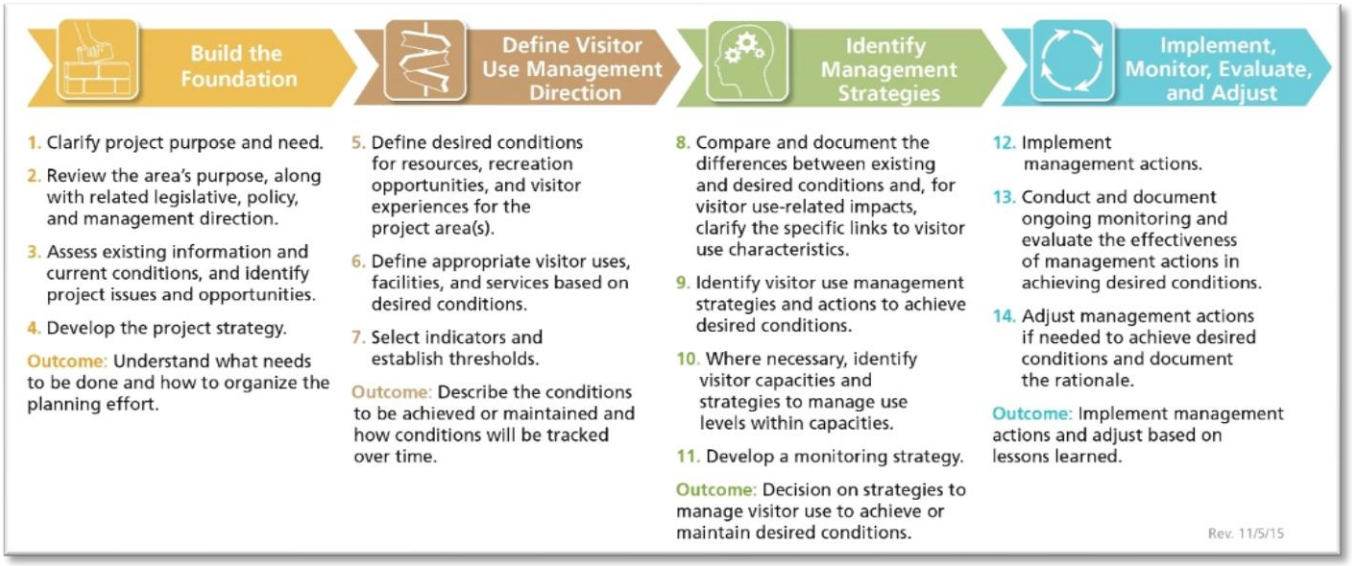

Figure 1. The Interagency Visitor Use Management Council has developed a new Visitor Use Management framework for federal land management agencies that includes 4 core elements and 14 steps.

A PROBLEM ANALYSIS PROCESS FOR EVALUATING AND MANAGING RECREATION IMPACTS

Before introducing and describing the management toolbox and specific BMPs, it's important to outline a process for evaluating resource and social impact problems, the factors that caused them or influence their severity, and steps for identifying and selecting the most effective impact reduction strategies and actions. This problem assessment process was developed as part of an AT research study in 2002 designed to assess and resolve camping impact management problems (Marion 2003).

The problem analysis process begins with the assembly of a team of individuals who have historical knowledge and experience with the problem area and its management history and relevant expertise and experience in topics required for its resolution (e.g., recreation resources management, trail or camping management, social science). Individuals with differing educational backgrounds, management experience, and perspectives are beneficial, including representatives from land management agencies, non-profits, volunteers, and recreationists. The following process, outlined in Table 2, is optimally applied with a few meetings and a site visit but could be applied through online or phone conferencing with photos to illustrate site conditions.

Table 2. Outline of a two-step Problem Analysis process for evaluating recreation resource and social impact problems and selecting effective management strategies and actions (adapted from Marion 2003).

I. IDENTIFY AND EVALUATE THE PROBLEM
➢ ***Describe area and use(s)*** - provide background information about the area, facilities, and visitor use. ➢ ***Describe problem(s)*** - briefly describe the facility, resource and social impact problems that are occurring. ➢ ***Problem significance*** - consider if and why the impacts are significant or unacceptable to land managers and protected area visitors ➢ ***Previous management actions*** - describe the history of the problems and previous actions; discuss the effectiveness of these actions and why they did or didn't work. ➢ ***Causes and influential factors*** - discuss the underlying causes for the impacts and the role of non-causal but influential factors that may intensify impacts. Consider use-related factors (type and amount of visitor use, visitor behavior, use density), environmental factors (soil and vegetation type, environmental sensitivity, topography), and managerial factors (siting, design, construction, and maintenance of facilities, visitor management).
II. LIST, EVALUATE, AND SELECT STRATEGIES AND ACTIONS
➢ ***List potential strategies and actions*** - create a comprehensive list of appropriate and potentially effective management strategies and tactics. Strategies are broad approaches (e.g., modify visitor behavior, manage sites and facilities) and actions are the specific means used to implement a strategy (e.g., educate visitors, relocate trails or campsites). ➢ ***Evaluate strategies and tactics*** - discuss and evaluate the following attributes for each strategy and tactic: potential effectiveness, management feasibility (cost, staffing, long-term maintenance), advantages/disadvantages (e.g., costs to visitor freedom), expected visitor compliance, etc. ➢ ***Formulate recommendations*** - through group discussion, develop and write recommendations for those strategies and actions that reflect the group's consensus views. Describe the selected action or group of actions to implement first and what might be tried next if these are ineffective.

Identify and Evaluate the Problem

The problem analysis begins by developing the group's collective knowledge of the area, including the amounts and types of recreational uses, and the resource and/or social problems to be addressed. One or more meetings with team members are useful, with members sharing their knowledge of the area, recreation use history, nature and severity of the impact problems, and differing perspectives. The significance of the problems and degree to which current conditions are unacceptable are considered when deciding whether management actions are needed. Next, participants with the longest experience in the area are asked to relate the history of the problems or impacts. Previous management actions are described, and their effectiveness discussed and evaluated, including why implemented actions were or were not effective.

The core of a good problem analysis is a thorough evaluation of an impact's underlying causes and identification of factors that influence impact severity. For example, heavy camping use may be the cause for excessive vegetation loss, but fragile ground vegetation and ill-defined campsites may significantly contribute to the

creation of unacceptably large campsites. Similarly, too many campers may be the cause for excessive campsite proliferation and crowding/conflict in a popular area but the flat terrain, lack of separation between campsites, and/or periods of extreme peak use may also significantly contribute to the development of unacceptable conditions. The relative influence of three groupings of factors: use-related, environmental, and managerial, should be examined and discussed (Table 1). An improved understanding of these causal and influential factors is essential before evaluating alternative strategies and actions to select the most effective course of action.

List, Evaluate, and Select Strategies and Actions

Step two involves brainstorming by team members to list and then evaluate a diverse array of management strategies and actions. Table 3 contains a listing of potential strategies and actions for managing recreation-related resource and social impacts. A review of this list will help to ensure that no potentially effective actions are overlooked. Following list development, study team discussions should focus on careful evaluations of the advantages and disadvantages of each action. Several important attributes should be considered, including potential effectiveness, management feasibility, costs to visitor freedom and satisfaction, expected visitor compliance, and others as appropriate.

Table 3. Core management strategies and actions for avoiding or minimizing resource and social impacts in wildland settings (adapted from Cole et al., 1987 and Marion 2003).

STRATEGIES	ACTIONS
VISITOR MANAGEMENT	
Modify Amount, Density, and Type Use	Redistribute, discourage, or limit use. Redistribute or reduce peak use. Modify type of use.
Modify Location of Use	Disperse use to levels that prevent lasting impact. Concentrate use on sustainable trails and campsites to limit the area of impact. Encourage/require visitors to camp away from water, trails, and/or campsites.
Modify Visitor Behavior	Persuasive communication, interpretation, or education. Regulation and enforcement - prohibit or require certain practices and equipment.
SITE MANAGEMENT	
Increase Sustainability	Design, construct, relocate, or maintain sustainable trails and campsites.
Close/Rehabilitate Trails or Sites	Close and rehabilitate unnecessary or less sustainable trails and campsites.

The final step is selecting one or more preferred actions recommended for implementation. Careful consideration of the history of impacts and their management, the desired resource and social conditions for the area, and factors which either cause or influence camping impacts can help guide more objective and effective decision-making. The history of camping impacts illustrates use and impact trends and the relative effectiveness of prior management interventions. Desired condition statements will suggest the appropriateness of alternative actions relative to the natural, social, and managerial settings of the zone the area is situated within. More latitude in the use and construction of facilities is generally accepted in frontcountry settings in contrast to wilderness, where an unmodified and undisturbed natural environment assumes a greater prominence. Even actions that are appropriate in backcountry settings may not be appropriate in designated wilderness. The Wilderness Act (P.L.

88-577) defines wilderness as "undeveloped" lands "without permanent improvements" which "have outstanding opportunities for solitude or a primitive and unconfined type of recreation," and where "the imprint of man's work is substantially unnoticeable."

An examination of the Wilderness Act (Landres et al. 2015) reveals five core qualities of wilderness character, including natural conditions, solitude or a primitive and unconfined type of recreation, undeveloped, untrammeled, and other features of value. For example, managing a developed infrastructure of sustainable trails and campsites detracts from the undeveloped character of wilderness, but their presence protects natural and social conditions by reducing the aggregate area of trampling impact associated with much higher numbers and densities of visitor-created trails and campsites. Wilderness managers generally seek to apply the minimum tools, equipment, regulations, or infrastructure development practice that will accomplish their desired results.

Generally, initial actions are those which are feasible, have a low cost to visitors, and are judged to have a good chance at effecting the desired change in conditions. Early guidance suggested that managers consider indirect actions such as education or site maintenance, before regulatory or site development actions, because they are less obtrusive and do not compromise visitor freedom. More restrictive, expensive, and/or obtrusive actions (e.g., rationing use or developing facilities) may be deferred until justified by the failure of one or more preceding actions. However, severe or unacceptable impacts may warrant bypassing such light-handed efforts in favor of actions necessary to achieve more effective or immediate results. Cole (1995d) states that preserving visitor freedoms at the expense of severe environmental degradation would be inappropriate, while McAvoy and Dustin (1983) argue that coercion can be effective and necessary to halt the types of degradation that occur quickly yet require decades to recover from.

Decisions about the use of site hardening and facility development actions in wilderness are particularly difficult. A constructed and maintained trail is a permanent wilderness facility designed to both facilitate wilderness travel and protect resources. Such facilities can involve vegetation disturbance, soil excavation and deposition, and the potential disruption of surface water movement. However, a properly managed trail system limits the areal extent and severity of recreation impacts by concentrating traffic on durable tread surfaces. The absence of formal trails in popular locations would lead to a proliferation of poorly located and heavily impacted visitor-created trails. Similarly, although less common in wilderness, designated campsites can be located, constructed and maintained to substantially reduce the areal extent and severity of camping impacts. The Wilderness Act clearly permits managers to employ such facilities, although their use must be justified as the minimum means for managing sustainable visitation.

For each action, identify likely individuals or organizations responsible for implementing the action and describe the necessary resources they will require. An implementation schedule should also be developed and efforts to obtain funding and staff initiated. At this time, it is also useful to consider how a planned action should be monitored for evaluating effectiveness. For example, measurements or a photographic record of existing site sizes and conditions provide a baseline for future comparison and should ideally be conducted prior to implementing corrective actions.

Adaptive Management and Monitoring

Adaptive management can be defined as "… flexible decision making that can be adjusted in the face of uncertainties as outcomes from management actions and other events become better understood. Careful monitoring of these outcomes both advances scientific understanding and helps adjust policies or operations as part of an iterative learning process." (National Research Council 2004). The previously described VUM carrying capacity process (Figure 1) incorporates adaptive management in the final implementation stage through steps 13 and 14 and additional guidance is provided by Williams and Brown (2012). Managers can collect observational or empirical data before-and-after new management actions are applied to evaluate the degree to which unacceptable problems were resolved or desired conditions were achieved. Ongoing monitoring programs can also provide data to discern and document the status of resource or social conditions in relation to management

thresholds (standards) of quality. Such data collection can provide more objective and compelling evidence needed to support new actions that may be more regulatory, publicly salient, or costly. Analyses of such data may also provide additional understanding and insights into the selection of more effective actions and supporting measures.

Scientists and statisticians can assist the development of valid visitor impact monitoring or efficacy assessments that employ reliable designs, protocols, and quality assurance procedures. Monitoring protocols are often developed by scientists for use by managers to provide accurate and precise data on physical attributes (e.g., trail width or campsite size), vegetation cover, tree damage, and soil exposure, muddiness, and erosion (Marion 1991, Cole 2006). More thorough reviews of the visitor impact monitoring literature, assessment methods and manuals, and examples of monitoring data indicators can be found in publications for formal trails (Dixon et al. 2004, Hawes et al. 2006, Hill and Pickering 2009, Marion and Carr 2009, Marion and Leung 2011, Marion et al. 2006, 2011a), informal (visitor-created) trails (Leung and Louie 2008, Leung et al. 2011, Marion and Wimpey 2011, Marion et al. 2011b), and recreation sites and campsites (Marion and Carr 2007, 2009, Cole 2013a, Cole and Parsons 2013, Newsome et al. 2013).

CAMPING MANAGEMENT STRATEGIES AND ACTIONS

Protected area managers have a diverse array of strategies and actions to achieve resource protection and visitor management objectives (Cole et al. 1987, 1997; Leung and Marion 1999, 2004; Marion 2016). Related to camping, managers commonly seek to achieve the following core objectives: *1) limit campsite numbers and the aggregate areal extent and severity of resource impact, 2) promote high-quality social conditions, and 3) preserve visitor freedom to camp in desirable locations.*

A diverse array of visitor use management strategies and actions have been proposed to address resource or social visitor impact management problems (Anderson et al. 1998, Hendee and Dawson 2002, Hammitt et al. 2015). Problems may be addressed through an array of management strategies and actions (tactics) which collectively comprise the "visitor impact management toolbox." Strategies are broad approaches that address underlying causes of problems. Actions are the means used to implement a strategy, often involving one or more specific management actions. To illustrate, consider the problem of excessive campfire-related impacts. Following a careful problem analysis, an educational strategy is identified as the most appropriate first course of action. Specific actions might include the distribution of an educational brochure promoting Leave No Trace campfire and firewood collection practices and dissemination of this information via personally delivered messages through agency and volunteer staff at visitor centers and in the field. If monitoring after a couple years revealed this course of action to be ineffective, managers might then justify a regulatory strategy involving the prohibition of woods tools (axes, hatchets, saws) or campfires.

Cole et al. (1987) proposed eight categories of strategies and actions with management guidance to address common wilderness management problems, reorganized into five core strategies in our Table 3. Management interventions seek to avoid or minimize impacts by manipulating either use-related factors (e.g., amount or type of use and user behaviors) or environmental factors (e.g., environmental resistance and resilience related to vegetation or soil attributes, topography, and others) (Hammitt et al. 2015, Pickering 2010). The most common management strategies and action, which are presented in this section, are also described in Anderson et al. (1998), Brown et al. (1987), Cole (1989), Cole et al. (1987), Hammitt and Cole (1987), Hendee and Dawson (2002). Readers are encouraged to access these references for additional guidance.

The remainder of this section reviews the most relevant and recent recreation ecology literature that informs the selection of effective visitor impact management strategies and actions presented under the five core strategies outlined in Table 3. While our focus is on resolving resource impacts, we also highlight instances where potential social problems, including crowding and conflict, can be simultaneously addressed. These management responses (Table 3) can be broadly grouped into two categories: *Visitor Management Strategies* that reduce or manipulate use, concentrate or disperse recreation activity on durable substrates, or modify visitor behavior to minimize

resource impact, and *Site Management Strategies* that develop sustainable impact-resistant trails and recreation sites or close and hasten recovery on unnecessary or less sustainable trails and sites.

Visitor Management: Modify the Amount, Density, and Type of Use

Managers can control or influence amount of use, density of use, type of use, and user behavior. The type of visitor action contributing to the management problem is often an important consideration (Cole 1990a). For example, careless, unskilled or uninformed actions are often most appropriately addressed through visitor contacts and educational responses (Lucas 1982). Unavoidable impacts are commonly reduced by shifting visitation to durable surfaces and impacts from visitors knowingly engaging in illegal actions are most appropriately addressed by law enforcement actions.

Amount of Use

Amount of use is perhaps the most studied use-related factor. Studies have consistently found a nonlinear asymptotic relationship between amount of use and amount of impact (Cole 1992, Hammitt et al. 2015, Marion 2016, Marion et al. 2016). Most forms of camping impact occur rapidly with initial and low levels of use (<10-15 nights/year), then begin to level off as near-maximum impact levels are reached at moderate to high use levels (Figure 2). For example, most broad-leafed herbs growing under forest canopies lack trampling resistance and resilience (ability to recover) and are soon lost on low to moderate use campsites (Marion et al. 2016). Organic litter is also easily pulverized and lost, though exposing the underlying mineral soil is a slower process that continues to expand as use continues to increase from moderate to high levels (Marion et al 2016). This asymptotic use-impact relationship has been corroborated by recent experimental trampling studies conducted in diverse geographic and ecological settings for most impact indicators, except exposed soil, which has a more linear relationship (Cole 1995c, Cole 1993b, Kuss and Hall 1991). These empirical findings are supported and explained by Cole's (1992) hypothetical campsite impact modeling, where campsite sizes do not expand with increasing use due to the natural tendency for activity concentration to increase as campsites become more heavily used and impacted.

The management implications of an asymptotic use-impact relationship for camping impacts are illustrated in Figure 2. When camping is unconfined (unregulated) visitors frequently create large numbers of campsites that receive only moderate use (Cole 1993a, 2013). Managers often seek to close and recover unnecessary campsites, often those which are least sustainable or too close to water, trails, or other sites. In Figure 2, managers could close two campsites and shift use to a third, preferably a site with durable substrates and limited expansion potential. Because of the curvilinear use-impact relationship, impact on this third site would increase only marginally, from "a" to "b," and *aggregate impact would decline substantially*, from three sites with an

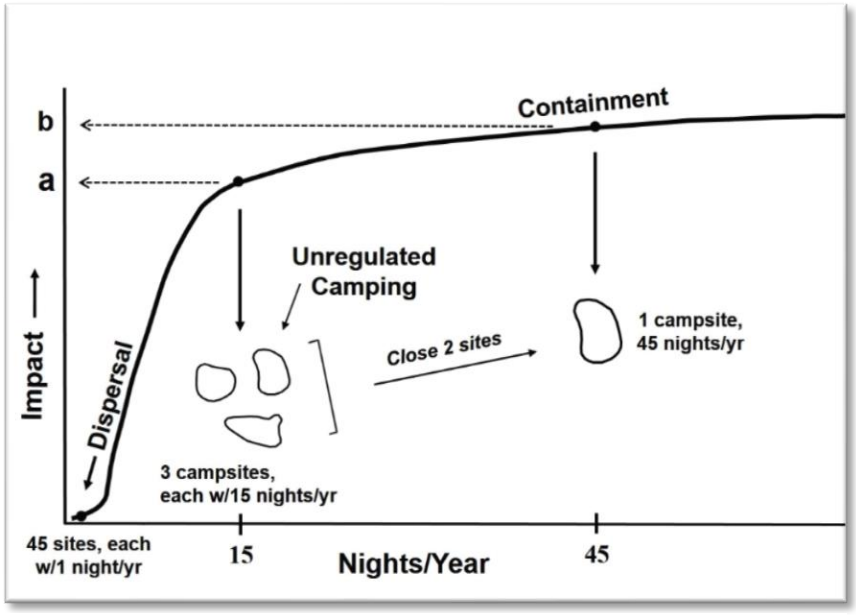

Figure 2. A generalized model of the use-impact relationship for trampling on vegetation and soil illustrating when use-reduction is and is not effective and the empirical basis for effective dispersal and containment strategies.

"a" level of impact to one site with a "b" level of impact (Figure 2). Effective application of this strategy requires education and/or regulations directing visitors to camp only on a limited subset of designated or well-established campsites. Problems with crowding and conflict can also be resolved by physically separating the selected campsites from each other and from trails (Manning et al. 2017).

The asymptotic relationship also applies to trampling along trails, where low and initial levels of trail use remove vegetation and organic litter and soils, or they are purposefully removed during trail construction (Birchard and Proudman 2000, Marion et al. 2016, Marion and Wimpey 2017). Following construction and/or moderate levels of trail use, trail treads are comprised largely of compacted exposed mineral soil or rock and are highly resistant to further use-related change. However, studies have found one form of trail impact, widening, to be significantly influenced by amount of use (Farrell and Marion 2002, Olive and Marion 2009, Wimpey and Marion 2010).

The asymptotic use-impact relationship reduces the potential effectiveness of use limitation for addressing recreation impacts. Substantial use reductions would be necessary to achieve even modest improvements in most resource condition indicators on heavily impacted campsites and trails (Figure 2). Use reductions can lead to pronounced improvements at lower use levels, where use and impact are more strongly related, although slow recovery rates prevent rapid improvements (Marion 2016). Two use-related attributes, the number of groups camped at one time and place, and group size, represent important exceptions and are discussed in following sections.

Density of Use

Campsite proliferation problems are common when managers permit largely unconfined or unregulated "dispersed" camping that allows visitors the freedom to find and select a campsite of their choice, with minimal regulatory interference. Recreation ecologists who study the impacts of visitor use in protected areas have consistently documented some substantial avoidable and unacceptable natural resource and experiential impacts associated with unconfined camping policies (Cole 1982a, 1982b, 2013; Leung and Marion 2000, 2004). Three common/chronic problems include (1) visitors frequently create unsustainable campsites in flat terrain close to popular attraction features or destination locations, water, and formal trails; (2) visitors create high-density clusters of large campsites with unacceptable levels of resource and social impact in the most popular areas; and (3) site proliferation over time leads to exceptionally large numbers of unnecessary campsites. A more comprehensive review and summary of research findings regarding unconfined/unregulated camping policies is provided by Marion et al. (2018a).

All these problems relate to the density of use. Unconfined camping can work at low to moderate use levels and use densities, but it breaks down under conditions of high use, particularly at popular camping destinations. Managers frequently observe that many campsites are expanded or created during peak use weekends or seasons. Peak use is often dramatically higher than typical use, often creating a "musical chairs dilemma" of too many groups and too few campsites. Large numbers of groups camping, such as created by the substantial "bubble" by AT thru-hikers each year, disproportionately contribute to campsite proliferation and expansion problems as they move northward. This extended mobile "peak use" event causes dense clusters of campsites to form around shelters and water sources, with core campsites often expanding and merging with others into extremely large mega-sites. As the bubble of thru-hiker use moves northward, hikers drop out or disperse and these problems lessen over time. Unfortunately, large events such as organized "trail magic" hiker feeds, celebrations such as the Damascus "Trail Days," and weather events act to concentrate thru-hikers again in time and space.

Use limits and rationing are a beneficial and perhaps essential option for managing resource and social impacts in high use areas, particularly with respect to constraining the damaging long-term effects of peak use, such as the large annual bubble of AT thru-hikers. Considerable campsite expansion and proliferation occurs at times of high or peak use, with their recovery effectively prevented by occasional subsequent use throughout the rest of the year. Possible solutions include setting a daily cap on all backpackers departing from Springer Mountain or requiring all springtime campers in the southern AT corridor to have a camping permit, with zone-based limits on permit numbers that match campsite supply. Equitability could be addressed by favoring thru-hikers within quotas

over other hikers who could choose to visit the southern AT during other seasons of the year. Use rationing can also be an important management element in areas like the White Mountains that consistently see extended periods of very high use, unless the higher demand for camping can be met by developing sufficient numbers of sustainably designed and managed campsites.

Type of Use

Types of uses that result in greater or disproportionate impacts are often subject to special regulations or educational programs (Marion and Reid 2007). Use along the AT is relatively homogenous due to prohibitions on motorized, horse, and mechanical (mountain bike) uses. While there may be some differences in impacts between day and overnight users or between weekend, section, and long-distance backpackers the differential management of these groups related to reducing hiking or camping impacts is a largely unexplored topic. Targeting day use and novice campers with introductory Leave No Trace information and practices focused on the predominant local impacts or problems will often be the most effective action. Targeting youth and novice visitors best addresses careless, unskilled, and uninformed high impact behaviors as these are more highly related to visitor knowledge and skill level (Hendee and Dawson 2002). Long distance hikers can be targeted with more comprehensive or "advanced" low impact information - these individuals are important because of their substantially greater number of camping nights and because they serve as role models during their numerous interactions with short-term AT hikers.

Large groups are perhaps the most important type of use that require special management attention. Large organized groups can be from commercial companies or from youth-serving organizations like camps, colleges, scouting, and churches. Loosely affiliated large "groups" of thru-hikers are also quite common along the AT, with observations that they often hike separately but camp together most nights. Large groups can uniquely contribute to the problems of campsite expansion and proliferation because they may be unwilling or unable to split and camp separately on existing standard-sized campsites.

Land managers have commonly addressed this problem by establishing group size limits, particularly for wilderness, to address resource and social impact issues (Cole et al. 1987, Monz et al. 2000). However, few studies have examined the relationship between group sizes and resource or social impacts, nor is it expected that they could provide specific defensible guidance for selecting a meaningful size limit (Monz et al. 2000). Decisions about group size limits require subjective judgments and a limit of 10 is unlikely to be any more "correct" than 6 or 15 as resource and social impacts are primarily a function of visitor behavior rather than group size (Marion 2014, Monz et al. 2000). There is no magic "best" number; key management challenges are for groups to match their size with campsite sizes by finding a large site or splitting up to avoid campsite expansion or creation.

As noted in the ATC's Policy on Organized Group Use: "Organized group use, whether for profit or not-for-profit, can have many benefits including promoting safe, responsible use of the Trail and advancing "Leave No Trace" practices, offering enriched appreciation of the outdoors through interpretation of the area's natural and cultural history, educating youth, promoting development of a conservation ethic through direct contact with wild-land settings, and helping people connect with nature and develop a sense of their own roles and responsibilities within the larger community of life." Thus, organized groups present AT managers with some unique opportunities. Most outdoor enthusiasts are introduced to the out-of-doors by some type of group-related outdoor program. The organizations that operate these largely novice and youth-oriented programs can be efficiently targeted, allowing cost-effective education of large numbers of public land visitors by their group leaders. Inexperienced youth tend to be more receptive to adopting Leave No Trace practices, providing an opportunity for instilling life-long LNT skills and ethics. An LNT pamphlet that specifically targets LNT practices for large groups has been developed (http://www.LNT.org), including an AT-specific version.

An educational focus recognizes and avoids or reduces the significant visitor-related costs associated with group size regulations. Volunteer, non-profit and commercial organizations are significantly disadvantaged by group size limits, which necessitate additional leadership. Smaller staff/participant ratios translate into higher costs for participants which reduces the economic viability of outdoor education programs or displaces them from public

lands. AT-specific education efforts targeting organized groups have already been pioneered and implemented in the White Mountains and other areas along the AT. The ATC has also developed an Organized Group Management Manual to guide group use management and educational efforts (ATC 2015). It describes proactive group management options including a voluntary group overnight use reservation system, group use management case studies, and numerous educational materials.

ATC policies also generally prohibit (with some exceptions) large group competitive races and fundraising events and other special event activities due to their greater potential to "cause significant adverse effects to natural, cultural, and experiential resources." Marion et al. (2016) provide a comprehensive review of the literature on the environmental and social impacts of large special events and results from research of several large group events, finding that impacts can be avoided or minimized when professionally managed. They also provide guidance on adaptive management and Best Management Practices for evaluating and managing large special events.

Site management actions offer a final option to address large-group impacts. Group-use campsites have been designated in some areas and could be developed in others (Figure 3). Accommodating groups on carefully selected sites would likely involve less resource impact than splitting them up to camp on separate sites. Informal or formal reservation systems may be needed to facilitate site use by organized groups. The ATC's Organized Group Management Manual provides additional guidance and includes procedures for conducting inventories of existing or new locations for group use campsites and best practices for developing sustainable campsite designs.

Figure 3. Substantial group use in New Hampshire's White Mountains is often accommodated on specially-developed group use campsites like this one, which separate and spatially restrict camping to minimize both resource and social impacts.

Visitor Management: Modify the Location of Use

Although land managers have commonly adopted a proactive approach to trail management that emphasizes sustainably designed, constructed, and managed formal trail systems, studies find that a similar strategy has rarely been applied to camping management (Cole 1982a, 1982b, 2013; Leung and Marion 2000, 2004). As previously reviewed, the consequences of unconfined "dispersed" camping often include the creation of excessive numbers of unsustainable campsites, often close to water, other campsites, and in flat terrain where site expansion and proliferation will be a persistent problem, along with visitor crowding or conflict. We present and describe a simple classification system of camping management strategies and options and urge managers to consider adopting a more proactive and sustainable camping "containment" strategy that emphasizes voluntary or required use of a reduced subset of *management-selected or -created campsites* based on evaluations of their resource and social sustainability, including visitor campsite preferences.

Recreation ecology research has revealed the greater merits of two core camping impact management strategies, dispersal and containment, derived from an improved understanding of the relationship between amount of use and resource impact (Marion 2016). The asymptotic relationship between camping use and resource impact has significant implications for devising effective camping impact management strategies (Figure 2). A clear implication is that managers can employ a **Dispersal Strategy** to avoid resource impacts by reducing use to very

low levels that prevent impacts lasting more than a year (Table 4). Alternatively, managers can employ a **Containment Strategy** to minimize aggregate camping impact by concentrating use on a limited subset of more heavily used sites (Leung and Marion 1999, Marion 2016). This is consistent with the national Leave No Trace program's guidance to disperse use in remote or low-use areas and concentrate use on trails and campsites in popular areas (www.LNT.org, Marion 2014).

Table 4. Camping management strategies, options, and guidance (from Marion et al 2018a).

Camping Strategy	Use Level	Description and Guidance
UNCONFINED **(Dispersed Camping)**	All	Visitors have the freedom to select or create a campsite in the location of their choice, sometimes modified by guidance to avoid locations close to water or formal trails or to use an existing site. Campsite proliferation, excessive aggregate resource impact, and high-density camping are frequently significant problems in popular areas.
DISPERSAL STRATEGY **Pristine Site Camping**	Low-Mod	Visitors are asked to camp on durable *previously undisturbed* surfaces at low use levels that avoid lasting impact. Difficult to achieve in high use areas and requires visitors to learn and consistently apply low impact pristine site camping practices.
CONTAINMENT STRATEGY **Established Site Camping**	All	Visitors are *encouraged to camp* on a subset of well-established sustainable campsites selected by managers to promote resource protection and desired social qualities. Supporting actions include campsite maps to aid visitors in finding the selected campsites and a program to close and restore non-selected campsites.
Designated Site Camping	Mod - High	Visitors are *required to camp only* on a subset of sustainable designated campsites selected by managers to promote resource protection and desired social qualities. Managers generally mark designated campsites on maps, have signs and/or some facilities, and remove hazardous trees. Designated sites are managed as "first-come first-served" or, more rarely through a reservation system.

Containment is effective above moderate use levels because per capita impacts diminish substantially and campsite conditions stabilize, achieving a relatively constant equilibrium over time (Cole 2013, Marion and Cole 1996). Even doubling use on a well-established campsite only marginally increases measurable resource impacts, particularly for sustainably selected campsites that resist site expansion (Figure 2). Recall also that Cole (1992) attributes some of these counterintuitive findings to the natural tendency for activity concentration to increase as campsites become more heavily used and impacted.

Dispersal Strategy

A true or "pure" dispersal strategy is **Pristine Site Camping** (Table 4, Figure 4), where visitors are asked to:

1) locate an area out of sight or distant from trails, water, and campsites with no evidence of trampling disturbance *which also* allows camping on resistant surfaces that show little evidence of camping impact;
2) camp one to several nights, concentrating activities on the most resistant surfaces available, and departing before any lasting impact is created; and
3) restore and naturalize the site to mask visible impacts and deter future campers from finding and reusing it.

Trampling-resistant surfaces include rock, mostly non-vegetated areas, or grassy areas (Marion 2014). Cole and Benedict (1983) and Marion (2014) describe this form of camping, cautioning that visitors must apply these low impact practices to avoid the creation of new campsites. Though this form of camping is permitted in many

protected areas, few managers have encouraged this practice, perhaps because when ineffectively applied it can lead to campsite proliferation (Marion 2016). Achieving the level of camping dispersal necessary to prevent lasting impact can be challenging (Cole 1995a). Mountainous topography, dense vegetation, availability of trampling-resistant surfaces, ability to camp out of sight from trails, and limited water frequently constrain the number of potential camping locations. Furthermore, many visitors prefer camping on established sites close to trails, water and popular features (Marion et al. 2018a,b, White et al. 2001). If done in the manner suggested, it can be successful in a diverse array of settings, but from a pragmatic perspective it has the best probability for success in more remote, low use settings with more experienced backpackers/campers, including long-distance hikers. The following sources provide additional reviews of dispersed pristine site camping practices: Cole 1989, 1995a, Hampton and Cole 2003, http://www.LNT.org, Marion 2014.

Figure 4. Dispersed pristine site camping: A) Tent camping on organic litter, B) Hammock camping on organic litter, C) Tent camping on the Pacific Crest Trail, and D) Same site after removing tent and restoring the site.

Containment Strategy

Recreation ecology studies support a containment strategy as the most effective option, particularly in moderate to high-use settings, with visitors *encouraged* to use a limited number of carefully selected **Established sites** that meet agency guidance, or with visitors *required* to use only **Designated sites** (Table 4, Figure 5)(Cole 2013, Marion 2016, Reid and Marion 2004). The core objective of a concentration strategy is to contain camping impact to the smallest number of sites needed and to spatially concentrate camping activity on each site to minimize the total or aggregate area of camping disturbance (Cole 1992, Leung and Marion 1999, 2004, Hammitt et al. 2015). Since use is concentrated on highly-visited campsites a key component of success is the careful selection of *sustainable* campsites that protect resource *and* social conditions. This includes the selection of small campsites that are unlikely to expand under intensive long-term use and that visitors will prefer using due to their utility, scenery, and social attributes like privacy and noise. A containment strategy, as evidenced by the development, construction, and maintenance of formal trail systems, has a long tradition of use in wilderness. However, its application to camping management is less common, though a variety of options have been successfully applied and are in use (Marion 2016, Marion et al. 1993).

Figure 5. Containment strategy with: A) Established site camping, and B) Designated site camping. Both campsites are in Maine.

Established campsites can be marked or unmarked on the ground and maps and they typically have few or no facilities. They are generally more numerous and offer greater visitor choice than designated campsites, which are marked and may have greater infrastructure development, such as anchored steel fire rings, primitive toilets, or food storage facilities. Since visitors are required to use designated campsites agency staff generally assume greater responsibility for removing hazardous trees. However, the smaller number and sizes of sustainable designated sites make it easier for agency staff to manage hazard trees, and agency control over campsite locations allows for shifting them to more open settings with fewer or smaller trees.

Regardless of whether campsites are designated or established, campsite preferences must also be considered to ensure that visitors will want to use them and that they will have high quality experiences. Many studies have investigated campsite preferences and Brunson and Shelby (1990) developed a campsite choice model describing a hierarchy of campsite attributes that provide a basis for campsite selection:

Necessity attributes: Sufficient level ground available for tenting and proximity to water.

Experience attributes: Site privacy (distance to trail and occupied sites), scenic beauty, well-drained tent sites, screened from other sites, lack of human noise.

Amenity attributes: Shade, lack of litter, campfire ring/seating, availability of firewood, bug-free.

Additional campsite preference information can be found in Brunson and Shelby 1990, Cole and Hall 2009, Heberlein and Dunwiddie 1979, Shindler and Shelby 1992, and White et al. 2001.

Finally, the selection of a camping management strategy must also consider management capabilities to effectively implement a specific camping policy. Does sufficient information exist, and can it be applied to identify campsites that are ecologically, socially, and managerially sustainable? Can managers or volunteers effectively move visitors to these campsites while closing/restoring unnecessary and unsustainable campsites? Can supporting low impact camping practices be effectively communicated to visitors?

Under a containment strategy, managers must "trade-off" resource protection "benefits" with visitor regulation and freedom "costs." The previously described camping impact management problems that develop under Unconfined camping in moderate to high use areas demonstrate to managers that a Containment strategy may be necessary, but implementation requires a selection between Designated and Established site camping options. Since campsites are limited in number, managers need to match the number and distribution of these sites to the desired amount and distribution of overnight visitor use by management zone.

Designated Site Camping. The greatest resource and social protection is provided with designated campsites *and* a fixed itinerary reservation system that ensures very high site occupancy rates by matching specific sites and groups. Visitors obtain a permit listing each night and campsite and are unable to deviate as most other campsites will be occupied. This option is generally applied only in the most popular areas where intensive use requires and justifies intensive management to protect resource and social conditions. While fixed itineraries best minimize site numbers and aggregate area of camping disturbance, they are highly regimented for visitors, allowing little to no flexibility when bad weather, blisters, or other obstacles slow their travel (Stewart 1989). Furthermore, while managing "off-itinerary" groups is often a chronic problem, many visitors appreciate knowing they have a "reserved" site at the end of the day when in high-use areas.

A less restrictive option is to require camping on designated sites but use zone-based trailhead rationing to restrict visitation. Visitor surveys, observations, and management goals provide guidance for determining the number and distribution of campsites and entry point quotas (Freimund and Cole 2001). To avoid excessively large inventories of campsites, use surveys can be conducted during average high use periods (e.g., not peak use). However, without a fixed itinerary of reserved sites, somewhat larger numbers of campsites are necessary to avoid the "musical chairs" dilemma of too many visitor groups and too few campsites. For example, during high use periods a system with fixed itineraries could achieve very high occupancy rates, while a system with unfixed itineraries would likely require lower occupancy rates to improve the ease of visitors finding an open site without excessive travel and searching.

Established Site Camping. An increasingly common option is to ask, not require, visitors to use only Established campsites (Marion et al. 2018a). Managers must also: 1) apply resource and social selection criteria to identify a sustainable sub-set of "preferred" Established sites to leave open, and 2) develop and sustain the capability to close all other campsites, including any new campsites that visitors may create. This non-regulatory educational option allows visitors greater latitude in seeking out campsites that meet their needs. Once again, to avoid the musical chairs dilemma, larger numbers of Established campsites are necessary, but when successfully applied this option provides substantially greater protection of resource and social conditions than unconfined camping.

For Designated and Established site camping options a system for limiting/rationing use is needed in places or times where current use exceeds desired use. Management experience reveals that such rationing systems generally restrict and redistribute use only during peak use weekends or popular seasons that generally represent a small portion of the entire year. However, it's important to recognize that peak use is sometimes "substantially" in excess of typical use, presenting a significant dilemma to managers. Consider these four management scenarios for responding to the challenges of peak use:

1) *Ignore peak use* – Under this scenario peak users will either expand existing campsites or create new campsites. Even limited use throughout the year is likely to prevent these expanded camping areas from

recovering. *Outcomes:* the areal extent of resource impacts will be substantial, along with social impacts from crowding, conflict, and noise when visitation is high.

2) *Accommodate peak use* – Campsite numbers or sizes expand to accommodate peak use, creating an exceptionally large infrastructure of camping capacity, much of which is little-used throughout much of the year. This excessive infrastructure and resource impact is generally considered to be "avoidable" impact. A more optimal option is to actively shift peak use to "overflow" camping areas, such as dry grassy meadows. We discuss the greater trampling resistance and resilience of grasses in a following section. *Outcomes:* the areal extent of resource impacts can be substantial unless peak use is directed to resistant overflow areas. Social impacts are avoided if the camping infrastructure is carefully designed but can be substantial if visitors select/create the campsites.
3) *Ration use* – A permitting process matches camping demand with supply, shifting unmet demand in time and space to minimize aggregate camping impact while maximizing opportunities for high quality camping experiences. However, a burden or "cost" is placed on managers to administer the system and on visitors to comply with it, including their ability to visit a desired location at a preferred time. *Outcomes:* resource and social impacts are effectively minimized, but managers and visitors must accept the "cost" of rationing use.
4) *Shift use* – The active marketing of alternative thru-hike itineraries, including southbound and "flip flop" options, has gained increasing traction and success, suggesting to backpackers that they will conserve the trail and benefit from milder weather, less crowding, and greater campsite availability. This scenario "flattens" the thru-hiker bubble of peak use. This can also be applied to resolve high use at popular attraction features like McAfee Knob, to reduce and shift use to alternative locations. *Outcomes:* resource and social impacts are effectively minimized, this is the best possible option.

Preferred established or designated campsites can be identified through a careful selection process that emphasizes the selection of the most sustainable existing campsites and, over time, the creation and use of new, highly sustainable locations identified by managerial actions. Campsites that are less sustainable, are unnecessary, or are too close to water, cultural/historic sites or threaten wildlife, rare species, or sensitive habitats can be closed and restored (Marion et al. 2018b). It is also critical to include visitor campsite preference criteria, such as the presence and conditions of desirable campsite features, scenic beauty, solitude, and proximity to water, trails, or favored locations, to ensure that selected campsites will be used by visitors and provide high-quality social conditions and visitor satisfaction (Brunson and Shelby 1990, Daniels and Marion 2006, White et al. 2001).

A combination of camping management strategies may provide the most effective or optimal policy (Leung and Marion 1999). For example, at Shenandoah NP most of the backcountry and wilderness is managed for Established site camping. Visitors are required to use marked Designated campsites (first-come, first-served basis) if they stay near a shelter and Dispersed pristine site camping is permitted, particularly when designated or established campsites are full at peak use times. A few areas containing sensitive cultural and natural resources or that accommodate high day use are closed to camping. While more complex, such combined strategies offer substantial flexibility in balancing resource protection and recreation provision objectives.

Efficacy of the Containment Strategy. We briefly review two studies that evaluate and demonstrate the efficacy of Designated and Established site camping in reducing the aggregate extent of camping impact. In 1988, NPS managers at Delaware Water Gap National Recreation Area sought to improve the efficacy of their Designated site camping policy along the Delaware River by designating specific campsites rather than camping areas (Marion 1995). To address problems with campsite expansion and proliferation within the designated camping areas, managers installed anchored steel fire rings to identify each legal campsite and these were selected to maximize inter-site distances to reduce visitor crowding and conflict. Campsites not selected were closed and left to recover naturally, with "No Camping" signs placed on sites receiving repeated use. Enhanced education along with limited ranger patrol and enforcement efforts improved designated site camping compliance.

Evaluations of subsequent monitoring data from 1986 to 1991 revealed a reduction from 179 campsites (116 designated and 63 illegal) to 110 campsites (87 designated and 23 illegal) (Marion 1995). "Recovered sites" were those where campsite boundaries had disappeared (i.e., ground vegetation and leaf litter were undisturbed and

natural in appearance, though compositional changes remained evident and shrubs and saplings were still missing). Use levels for designated campsites increased 28%, from 268 to 344 campers/site/year, but the aggregate area of camping impact for all sites decreased 50%, from 302,896 ft^2 to 150,910 ft^2. Rangers reported that campsite demand exceeded supply typically on two peak use weekends each year, during which enforcements efforts were suspended.

A study by Williams and Marion (1995) evaluated actions at Shenandoah NP to resolve problems with their Unconfined dispersed camping strategy, which starting in 1974, directed visitors to choose campsites more than 25 ft from water and out-of-sight from trails and other campers. A census survey in 1992–1993 found that 68% of all sites (n=725) were in violation of these polices, including 25% located fewer than 25 feet from water and 56% within sight of formal trails (58% were <150 ft. from trails) (Williams and Marion 1995). Scientists and managers who examined the survey findings and permit data concluded that there were large numbers of campsites receiving low levels of use that, if eliminated, would substantially reduce aggregate camping impact.

In a second study by Reid and Marion (2004) park staff conducted campsite use surveys in in 1999 within sampled zones on six high (not peak) use weekends, establishing a mean campsite occupancy rate of only 16%, revealing the presence of substantial numbers of unnecessary campsites and "avoidable" impact. An Established site camping policy was implemented in 2000 by asking visitors to use only "well-established" campsites in most of the park. They also sought to close unnecessary and less sustainable campsites, assessed as sites with a higher potential for expansion based on topography, rockiness, and dense woody vegetation. Through their selection of Established sites managers also sought to increase site spacing from water, trails, and other selected sites to protect resource and social conditions. Park staff performed limited restoration work once a year on all "closed" campsites, consisting of fire ring removal and placement of leaves, brush, and/or logs on barren areas to enhance restoration and deter camping.

Over three years (1999 to 2002), campsite numbers were reduced by 49% within the sampled zones, aggregate campsite area by 51%, and area of vegetation loss by 44% (Reid and Marion 2004). Campsite occupancy rates increased 53% from approximately 19 to 29 nights/year on the Established campsites, but their mean size increased only 3%. The mean number of campsites visible was reduced from 1 to 0.4, and mean distance to the nearest other campsite increased from 49 to 59 ft. One interesting finding was that visitors frequently failed to find and use most Established campsites located out of sight from trails. This suggests that visitors may require maps, GPS coordinates, or navigational phone apps that identify campsite locations.

Established site camping has also been implemented successfully in other wilderness areas when managers have implemented programs targeting the closure and restoration of unnecessary, illegal, or unsustainable campsites. See Cole and Ferguson (2009) and Cole and Parsons (2013) for further examples of management actions and evaluations of their efficacy.

Durable Surfaces and Vegetation Responses

Visitors camp and hike on vegetation so it's important to consider the response of trampling to vegetation when selecting camping locations or considering a dispersal strategy and guidance. Collaborations with land managers also reveal some misinformation regarding the resistance of vegetation, particularly meadows, to trampling. This section begins by describing the most trampling-resistant surfaces that managers and visitors should seek for travel and camping. Next, a branch of recreation ecology research that has focused on experimental trampling studies of vegetation is described, including defining some relevant terms. This is followed by a review of core findings and management implications.

Visitor impacts can be effectively minimized by spatially concentrating recreational activities on trampling-resistant surfaces, including (ranked in decreasing order) durable rock, gravel, or snow; to areas with little to no vegetation such as well-established trails and recreation sites and dense shady forests that support little ground vegetation cover; to dry open meadows with low grasses or sedges (Cole 1995a,b, Cole and Monz 2003, Marion 2014).

Empirical studies of campsites and trails to investigate vegetation impacts are always confounded by an array of use-related factors that fall outside the control of investigators, including the amount, type, behavior, group size, and season of use. Experimentally-designed trampling studies have been developed and efficiently applied to address these important deficiencies (Cole, 1993b, 1995a, Cole and Bayfield 1993). These studies define parallel transects that various numbers of trampling passes (e.g., 0, 25, 75, 200, 500) are randomly applied to, including a control that receives no trampling. Before and after measures of plant cover by species are taken within quadrats placed along the transects and trampling can be continued for more than a year to simulate longer term recreational activity.

Plant responses to foot traffic is assessed using the following measures:

Plant resistance – ability of plants to resist trampling damage, measured as its mean relative cover after a specified range of trampling passes are applied. Formula: (surviving cover/initial cover) x (initial cover on control/surviving cover on control) x 100% (see Cole 1995a for further detail).

Plant Resilience – ability of plants to recover rapidly, measured by subtracting mean relative cover after trampling from mean relative cover after one year of recovery.

Tolerance – ability of plants to both resist and recover from trampling damage, their durability, measured by dividing the resilience measure by 100% minus relative cover after trampling (the amount of recovery that could possibly have occurred). Plants with higher tolerance measures can be highly resistant to trampling, highly resilient, or a combination of both.

Growth forms – plant life-forms confer trampling resistance and resilience, including three relevant types: *Chamaephytes* are plants that bear their growing tips (perennating buds) up to 20 inches above the ground surface. *Hemicryptophytes* have their buds close to the ground surface. *Cryptophytes* have their buds well below the ground surface.

While there are numerous recreation ecology publications from experimental trampling studies (Barros and Pickering 2014, Cole 1985, 1987, 1995b,c, Cole and Spildie 1998, Marion and Cole 1996, Pickering and Growcock 2009, Roovers et al. 2004) we will focus on a definitive U.S. study by Cole (1993b) of 16 different vegetation types in the mountainous regions of four states (WA, CO, NH, NC), and a meta-analysis of trampling studies conducted by Pescott and Stewart (2014).

Regardless of continent, region, or elevation, experimental trampling studies have consistently found that graminoids (grasses and sedges) growing in tufts or turfs are the most resistant to trampling, and that tall broad-leafed forbs (herbs) and ferns are the most fragile (Figure 6) (Cole 1993b, Pescott and Stewart 2014). Cole notes that the most resistant vegetation types can tolerate 25 to 30 times as much as the least resistant type – a compelling explanation for why we grow grass on football fields and not herbs or ferns. For example, the most resistant plant investigated was a sedge (*Carex nigricans*) that required 600 trampling passes to reduce plant cover by 50%, a level of loss achieved with only 20 passes in patches of ferns (*Dryopteris*). This finding was borne out in meta-analyses by Pescott and Steward (2014), who add that these functional traits of plants are likely more important than differences in the intensity of use when considering the effects of recreational activities.

A somewhat surprising finding is that alpine plants were more resistant and resilient to trampling than many subalpine and lower elevation vegetation types (Cole 1993b). Since alpine plants grow in harsh conditions their leaves are tough and short and most of their biomass is protected below ground. Alpine plants are primarily Cryptophytes or Hemicryptophytes and dominated by turf-forming graminoids. Cole notes that results would likely be different if high-intensity and/or long-duration trampling had been applied. The subalpine zone had greater variability in plant resistance depending on vegetation type, including some with low shrubs, ferns, and herbs that were less resistant and/or resilient.

Resilience was found to be primarily related to plant life-form, with chamaephytes, particularly shrubs, substantially less resilient than hemicryptophytes and cryptophytes (Cole 1993b, Pescott and Stewart 2014). While some woody stems are initially resistant, high levels of trampling will break them, requiring long recovery

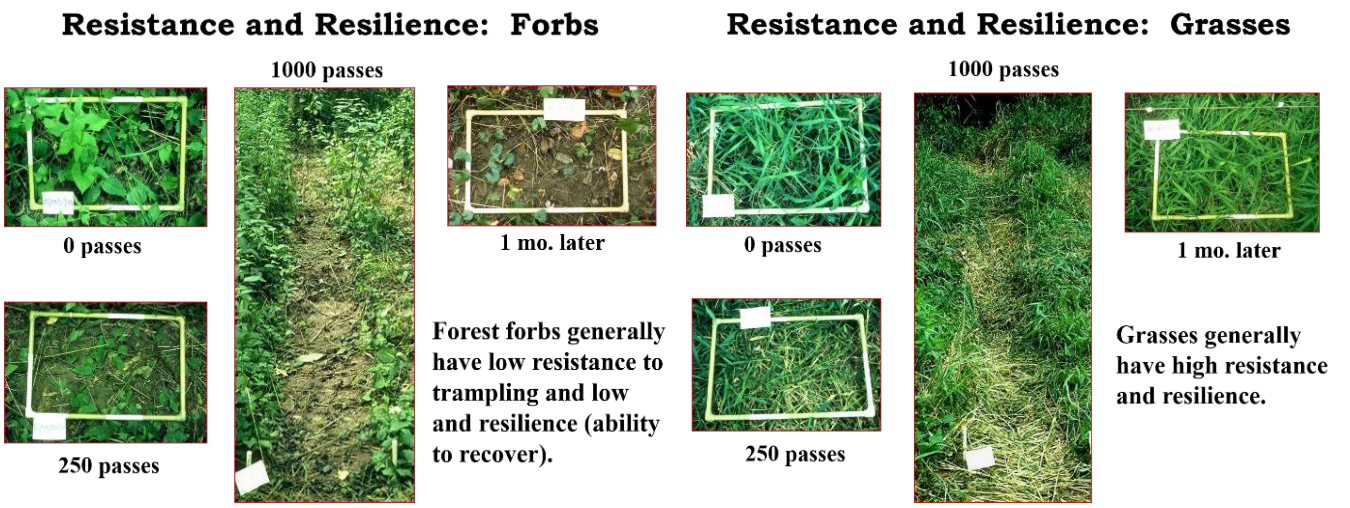

Figure 6. Photos of quadrats and lanes subjected to 0, 250, and 1000 trampling passes, followed by 1 month of recovery (Cole and Marion, 1996).

times. Repeated long-term trampling removes woody shrubs and tree seedlings. While tall forbs have low trampling resistance their resilience can be high after single trampling events, but low under repeated or prolonged trampling (Figure 6). Finally, tolerance (plant durability) was found to be more greatly influenced by resilience than resistance, and the most tolerant plants tended to be graminoids with tuft or turf growth forms (Cole 1993b). Low-growing forbs, like clover, dandelions and plantain in sunny locations, can have moderate to high tolerance. Finally, Eastern vegetation types had the most fragile vegetation types due to the prevalence of closed forest canopies that favor shade-tolerant tall broad-leafed forbs (Cole 1993b).

The practical management implications of these findings are as follows:

- Camping impacts can be minimized by selecting or encouraging visitors to use non-vegetated sites such as substantially barren rock, gravel, and soil, including sustainable well-established campsites (Figure 7a). Particularly dense forests that support little vegetation cover minimize vegetation impacts and have a less impacted appearance (Figure 7b).
- When camping on vegetation is necessary, impacts are best minimized by avoiding locations with tall forbs and favoring dry meadows, shrub-lands, or open forests with grasses and sedges that both resist trampling damage and recover more rapidly from damage (Figure 7c). For this reason grassy meadows can be ideal locations for temporary "overflow" camping during peak use periods.
- When camping under forest canopies is necessary, recognize that trees will eventually be lost without replacement, creating open overstories that will allow grasses and sedges to replace forbs over several decades. While this successional process results in more sustainable ground vegetation, it will be compositionally and visually dissimilar from adjacent off-site vegetation (Figure 7d).

Graminoid-dominated plant communities tend to be sun-loving and shade-intolerant so the presence and density of forest cover can be an easily applied gauge of plant resistance. Several campsite studies have found a significant correlation between decreasing canopy cover and increasing graminoid vegetation cover (Eagleston and Marion 2017, Marion and Cole 1996, Marion et al. 2018a).

Figure 7. A) The barren substrates on a well-established campsite are a durable surface on which to concentrate traffic, though this forested campsite reveals a nearly 100% loss of the original forbs, B) Vegetation loss can be minimized by selecting campsites in dense forests that support very little vegetative ground cover, though campsite boundaries are less apparent. C) In meadows and shrublands grasses and sedges are highly resistant and resilient to trampling damage, limiting exposed soil to the most intensively trafficked core areas. D) In forested settings campsites will lose trees without replacement over time, but increased sunlight allows the establishment of shade-intolerant but resistant grass and sedge cover that increases campsite sustainability.

Visitor Management: Modify Visitor Behavior

Education or Regulation

Many impacts are avoidable or easily minimized, often caused by uninformed, unskilled, or careless behavior (Lucas 1982). Education and regulations developed to modify visitor behaviors are effective methods for avoiding or minimizing resource and social impacts associated with overnight visitation. Common avoidable camping-related resource impacts include littering, enlarging campsites, creating new campsites, moving or building new fire sites, improper disposal of human and food waste, cutting or damaging trees and shrubs, and feeding wildlife. Management efforts can also effectively minimize unavoidable impacts, such as vegetation disturbance caused by foot traffic and tents.

Generally, visitor education should be given an opportunity to resolve problems before regulations are imposed, unless impacts are likely to occur very quickly, are severe, or long-lasting. An incremental adaptive management approach ensures that actions are effective and visitor freedoms are not unnecessarily restricted. Leave No Trace camping practices have been developed to address every common camping management problem (Cole 1989, Hampton and Cole 2003, Marion 2014), along with an array of education techniques for conveying such practices to visitors (Doucette and Cole 1993). The list includes selection of resistant campsites away from streams, trails, shelters, and other occupied campsites, confining activities within core use areas to avoid enlarging sites, using stoves and low impact campfire practices, proper food storage and cleanup, proper human waste disposal, and practices to avoid impacts to wildlife and the recreational experiences for other visitors. These practices are taught in LNT training courses offered by a variety of organizations, including the ATC.

As an illustration, consider campsite expansion and proliferation and what an educational program might do to address this common management challenge. Peak use in popular areas can be reduced by asking visitors to shift their use to alternative locations or less busy times. Describing the long-term impacts associated with campsite expansion and proliferation provides a compelling rationale to visitors to encourage them to consider the following additional camping practices: 1) planning trips and hiking schedules so that existing campsites can always be used, 2) matching their group size to campsite sizes so that small groups use small sites and large groups using large sites or splitting up to camp on two or more sites, 3) restricting all camping activity to the most durable and barren campsite areas, 4) improved searching for existing sites that may be hidden from view, sharing available space on campsites used by others, or increased use of "dry" campsites, and 5) effective application of dispersed pristine site camping practices when weather or other circumstances require camping in an are with no available existing campsites.

Visitor education is favored by both managers and visitors as an indirect or light-handed voluntary approach that fosters a deeper appreciation for protecting natural areas and encouraging low impact behaviors and ethics (Marion and Reid 2007). Most impacts are not from malicious acts but result from a lack of awareness regarding the consequences of outdoor activities and lack of knowledge regarding appropriate low impact practices (Manning 2003). A comprehensive review of studies that investigated the efficacy of educational interventions by Marion and Reid (2007) found that most were effective in increasing visitor knowledge and altering visitor behaviors. However, sometimes the stated problems were not entirely or sufficiently resolved, requiring additional interventions such as site management actions or regulations.

Although more restrictive to visitor freedom and experiences, regulations offer another option for altering visitor behavior to reduce impacts (Cole et al. 1987, Lucas 1982, Manning et al. 2017). Examples include requirements on the location of camping, such as restricting camping to designated sites or prohibiting camping in certain areas or within a set distance from trails or waterbodies (Cole et al. 1987, Marion et al. 2018b). Axes, saws, or campfires may be prohibited, or campfires may be restricted to designated fire rings. Proper food storage may be required and feeding wildlife may be prohibited. Finally, managers must consider their ability to enforce regulations. The remote nature of the trail environment and declining agency budgets make it difficult to enforce regulations along the AT. While ridgerunners and volunteers can remind visitors of regulations, they cannot enforce them.

In the following section an in-depth examination of tree damage and felling on campsites is provided using research data to illustrate the challenges of both educational and regulatory actions (Figure 8).

A Case Study in Deterring Tree Damage

In 1993, field crews surveyed all backcountry campsites (N=327) in Great Smoky Mountains NP to establish baseline conditions (Marion and Leung 1997). For campsites with trees, findings revealed that 63% of onsite trees had visitor-caused damage rated as moderate to severe. A total of 1,128 trees were tallied as damaged within campsite boundaries with an additional 1,249 damaged trees in adjacent offsite areas. Tree stumps were found on 60% of campsites, with a total of 724 stumps within campsite boundaries and 2,642 found in adjacent offsite areas. So many trees had been removed from once forested campsites that 25% of campsites no longer had *any* trees within their boundaries.

Similar findings were reported from a 32-year study of 81 designated campsites in the Boundary Waters Canoe Area Wilderness (BWCAW) (Eagleston and Marion 2017). A 2014 survey found 384 tree stumps within campsite boundaries and 1050 stumps in adjacent offsite areas, this equates to an estimated 35,600 tree stumps when extrapolated to all 2000 BWCAW designated campsites. A substantial majority of stumps were less than 6 inches in diameter, suggesting they were cut by visitors for firewood, as opposed to agency removal as hazardous trees. While only 4 campsites had no trees in 1982, an additional 21 campsites became treeless by 2014, nearly a third of all study sites. These impacts have occurred despite low-impact educational messaging that has been in the BWCAW permitting process since the 1970's, including statements about collecting dead and downed wood and a regulation prohibiting the cutting of live vegetation. These actions have been ineffective in deterring the continued damage and cutting of trees, promoting the authors to suggest a prohibition on woods tools.

LNT messaging directly related to such findings include the following:

- Land managers are increasingly prohibiting campfires due to their many associated impacts. However, most of these impacts are *entirely avoidable*. Do your part by adopting safe and low impact campfire practices or consider not having a campfire. Build a campfire only if there is a plentiful wood supply and gather only dead and downed wood that you can break by hand.
- Leave axes, hatchets, and saws at home – woods tools can be dangerous and are unnecessary. Small-diameter wood is more easily burned to ash and extinguished, avoiding the build-up of unburned wood and charcoal in fire pits and the dangers of igniting a wildfire at night or after you leave.

The ATC has already developed a full suite of LNT AT-specific educational information and recommended practices. Educational messages are conveyed on the ATC website, at visitor centers and agency offices where visitors obtain information, through educational talks and pamphlets, on posters and signs at trailheads and shelters, through personal contacts by agency staff, trail club members, and AT ridgerunners or site caretakers. The ATC also teaches the LNT Master Educator and Trainer courses annually, and has developed LNT videos and thru-hiker courses and workshops. If targeted problems are not successfully resolved by educational efforts such work can be intensified, focused on specific problems, or specifically target organizations or groups identified as being associated with the impacts in question.

Regulations provide an alternative means for influencing visitor behaviors. In a survey of managers at NPS parks with backcountry and wilderness camping, 44% of respondents reported that their park had prohibited campfires, partially in response to tree damage and felling (Marion et al. 1993). However, Reid and Marion, (2005) evaluated campfire-related impacts and polices in seven protected areas, finding that fire bans *did not* substantially reduce tree damage and cutting due to continued illegal campfire activity. Prohibitions on axes, hatchets, and saws were identified as a potentially more effective response.

Site Management: Increase Resource Resistance

Flat, dry ground near water and the trail have been the traditional requirements for a good backcountry campsite. However, research and management experience have shown that these are often poor locations for low-impact campsites (Marion et al. 2016). Large flat shorelines, floodplains, and ridgetops offer many potential camping locations, but they also offer no resistance to campsite expansion and proliferation, which also contribute to a high density of campsites that reduce experiential qualities (Eagleston and Marion 2017, Marion et al. 2018a). To increase the sustainability of camping management it is best to avoid flat terrain by moving trails entirely away from these flat locations, which are also less sustainable for the trails (Marion 2016, Marion and Wimpey 2017).

Managers can also influence or control the locations where visitors camp and manage the sites they use. Both the areal extent and severity of camping impacts can be reduced through careful site selection, design, construction, facilities, and maintenance. The location and spatial arrangement of campsites also determine the social conditions for visitors who use them.

Figure 8. Tree damage from woods tools (axes, hatchets, and saws) is an entirely "avoidable" camping impact that over time removes campsite trees. Low impact campfires should be built using small-diameter dead and downed wood that is broken by hand; woods tools such as axes, hatchets, and saws are unnecessary.

Recreation ecology studies frequently reveal that an array of use-related, environmental, and managerial factors significantly influence natural resource impacts, and that managers can manipulate these factors to minimize impacts while sustaining large and increasing numbers of visitors (Eagleston and Marion 2017, Marion 2016, Marion and Farrell 2002). While the practice of closing undesirable or unsustainable campsites has been adopted in some backcountry and wilderness areas (Cole and Parsons 2013, Marion et al. 2018a), the practice of actively selecting, designating, or constructing highly sustainable campsites remains rare (Daniels and Marion 2006, Marion et al. 2018b). This section provides both empirical data and guidance demonstrating that replacing unconfined dispersed camping management policies with a containment strategy in moderate to high use areas and a true dispersed pristine site camping policy in low use areas can yield significant reductions in aggregate areal measures of camping impacts.

Cole's (1992) hypothetical models of camping impact suggest that increasing use can have a substantial effect on areal measures of impact, with peripheral and off-site vegetation disappearing as campsite boundaries expand. However, if use increases and camping activities are spatially concentrated, the impacted area remains constant, as trampling impacts are contained within campsite boundaries and percent vegetation loss increases to near maximum levels. A key management objective related to campsite sustainability at a site scale is discovering and implementing actions that limit campsite expansion by promoting the spatial concentration of camping activities (Cole 1989). Similarly, implications for a landscape scale, where managers seek to minimize aggregate camping impacts at a unit level suggest a strong focus on actions that limit campsite proliferation (Cole and Parson 2013, Leung and Marion 2004). These findings and results from the current AT study all emphasize the need to shift camping in moderate to high use settings from flat to sloping terrain, where topography will act to effectively concentrate activities and impacts to small "footprint" campsites more effectively than reliance on education or regulation. When camping cannot be shifted from flat terrain then the next most effective action is to confine camping to either camping shelters and huts or to constructed tent pads. As will be described in this section, both actions can be effective in constraining both campsite expansion and proliferation, accommodating ever-increasing visitation while halting and even reversing aggregate areal measures of camping impact.

Using Topography to Limit Impact

A small but growing number of studies have investigated the influence of topography (e.g. Cole 2009, Cole 2013a, Daniels and Marion 2006, Eagleston and Marion 2017, Leung and Marion 1999, Marion and Farrell 2002). At Isle Royale National Park, Marion and Farrell (2002) attributed small campsite sizes and aggregate impact to the intentional placement of campsites in sloping terrain, where small "side-hill" campsites were constructed through excavation and fill to create small clusters of tent sites. Success in limiting the areal extent of impact was partially attributed to managers actively creating and maintaining smooth, well-drained tent pads and providing visually obvious site boundary cues that encourage visitors to stay on-site (Farrell and Marion 2002).

Statistical modeling of campsite data from this study of AT campsites revealed that the single best predictor of campsite size was the percent of a 33-ft wide buffer or "doughnut" configured around a campsite with slopes in excess of 15%. The implication of this finding is that spatial concentration of camping activities is highest when a campsite is surrounded by steep terrain. High off-site rugosity (mostly rockiness) and side-hill site construction were other significant predictors of small campsite sizes. The influence of side-hill campsites is conferred by the steep surrounding topography and off-site rugosity is essentially the influence of micro-topography. A 32-year study by Eagleston and Marion (2017) discovered that selecting campsites in dense woody vegetation is only temporarily effective in deterring site expansion, as woody vegetation is removed over time by insects, disease, fires, or felled by visitors for firewood.

Natural Side-hill Campsites. While visitors generally seek out large flat areas for camping, managers and volunteers can instead conduct ground-based searches for clusters of small flat spots surrounded by sloping topography or excessive rugosity and create campsites by preparing smooth well-drained tent pads with short access trails (Figure 9). Ideally these "naturally-occurring" side-hill campsites would be located near water sources and perhaps between 100 and 200 ft from the AT, with inter-site spacing of more than 100-200 ft to enhance

privacy/solitude. The authors' current research is developing new computer-based GIS analyses to locate these campsites in areas with LiDAR-derived topography data. We suggest that the AT community could sustainably create additional camping capacity by creating clusters of these naturally-occurring side-hill campsites and communicating their locations with a distinctive paint blaze on their access trails and incorporating them into AT guidebooks and phone apps that are increasingly being used by visitors for navigation.

Figure 9. Careful searches can reveal naturally-occurring flat spots surrounded by sloping terrain and rockiness that inhibit campsite expansion and proliferation.

Constructed Side-hill Campsites. While the efficacy of these proposed naturally-occurring side-hill campsites has not been investigated, they are similar to and more easily created than constructed side-hill campsites, which have been investigated. Annapolis Rocks, MD was identified by a survey of the Appalachian Trail's volunteer clubs in 2000 as the most impacted camping area (Figure 10) (Marion 2003). Daniels and Marion (2006) describe the many unacceptable resource and experiential impacts associated with a large cluster of visitor-created campsites in flat terrain. In 2003 the campsites were closed, and camping was shifted to constructed side-hill campsites in

Figure 10. A) One of three "mega-sites" within a cluster of 19 campsites at Annapolis Rocks, MD. This location illustrates the chronic problems that an unconfined camping policy allows: unacceptable resource and social conditions due to excessive site proliferation and campsite expansion in large flat areas. B) Camping was shifted to constructed side-hill campsites in nearby sloping terrain where topography constrains site expansion.

adjacent sloping terrain, reducing aggregate areal impact from 43,099 ft^2 to 6,243 ft^2). The new campsites were spaced apart above and below a side-hill access trail at locations to enhance the potential for solitude.

A questionnaire examined visitor satisfaction with camping on the side-hill campsites using a scale of 1 (highly dissatisfied) to 5 (highly satisfied) to evaluate 22 utility, environmental, and social indicators. The indicator that scored lowest for the clustered visitor-created campsites, "privacy of my campsite" (3.26), became the highest score for visitors camping on the new side-hill campsites (4.30). The next four highest indicators were "number of people camped near me" (4.23), "security of my belongings" (4.23), "noise from other groups" (4.21), and "naturalness of the area near my campsite" (4.18) (Daniels and Marion 2006). An identical process was applied in 2003 at the second most impacted AT camping area at Slaughter Gap near Blood Mountain, GA, with similar success, as illustrated with photos (Figure 11).

Figure 11. Substantial resource and social camping impacts in 2003 at Slaughter Gap in Georgia were addressed by replacing its camping capacity with new constructed side-hill campsites. The AT and another trail were relocated to "hide" this long-used popular camping location and the area has since recovered (photos provided by the Georgia Appalachian Trail Club volunteers).

In Georgia the number of thru-hikers has increased from around 1,000 in 2006 to 3,000 in 2015, and this large annual "bubble" of use continues to grow, causing the Appalachian Trail Conservancy to create a voluntary registration system for north-bound hikers to self-limit hiker numbers to less than 50 hikers/day. This recurring annual springtime bubble of exceptionally high camping demand is causing excessive camping impacts, such as at the Hawk Mountain Shelter, often the first or second overnight destination for northbound AT thru-hikers. Over many years a large cluster of campsites been created by hikers around the near the shelter, which is situated in flat terrain, and sometimes accommodates 50-100 campers/night (Figure 12A). The area was captured by the sampling for this AT study, documenting a common pattern of core campsites expanding into numerous "mega-sites" with active campsite proliferation occurring to produce 42,533 ft^2 of aggregate area of impact, vegetation loss occurring over 24,197 ft^2, 25,940 ft^2 of exposed soil, and including 92 damaged trees, 163 tree stumps, and 89 trees with exposed roots. These common resource impacts are accompanied by equally problematic social and experiential impacts, including crowding, conflict, loss of opportunities for solitude, and noise. This high-density camping area typifies visitor impact management problems found across the state of Georgia and into North Carolina and Tennessee.

In 2015/16 a collaborative effort between the Appalachian Trail Conservancy (ATC), the U.S. Forest Service, scientists, and the Georgia Appalachian Trail Club (GATC) led to the development and implementation of the Hawk Mountain Camping Improvement Project, which can shift up to 32 tents from the flat areas surrounding the shelter to earthen "side-hill" tent pads constructed in sloping topography less than a mile away along the AT (Figure 12A & B). Since side-hill campsites require terrain slopes in excess of 15% for efficacy, Dr. Wimpey provided a slope classification map used by a USFS contractor to locate and identify potential locations for side-hill campsite

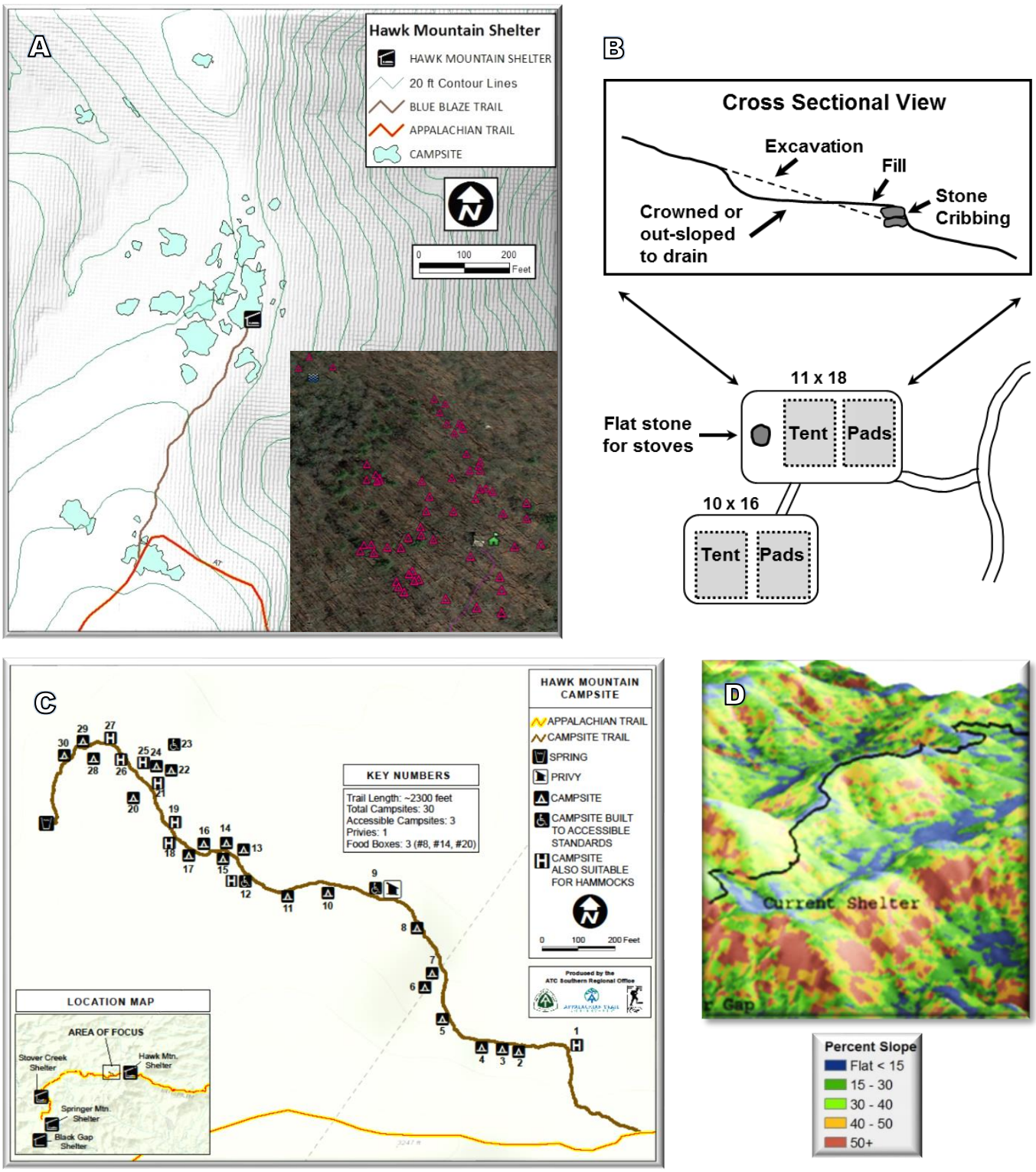

Figure 12. A) A GIS map showing the Hawk Mountain Shelter and numerous associated campsites. To mitigate the unacceptable resource and social impacts that had developed, most camping is being shifted to 30 side-hill campsites constructed as illustrated in (B) and (C). A GIS-generated slope map (D) reveals the flat terrain in the existing shelter area and was used by U.S. Forest Service Staff to narrow the search for locating side-hill campsites in terrain with 15-30% slopes.

construction (Figure 12D). GATC volunteers initiated the side-hill campsite construction work but the work was finished by a contractor with an excavator to complete the work in time for the next year of thru-hikers. Club staff did finishing work on the campsites and trails, installed an above-ground moldering privy, steel food storage boxes, rock armoring at the water source, and a sign with a map showing the campsite layout and best accessible and hammock sites (Figure 12C). The aggregate size of the 30 side-hill campsites is 6,934 ft^2, 16% of the former aggregate area of disturbance.

Naturally-occurring and constructed side-hill campsites can clearly concentrate camping activities on small campsites, resolving the traditional problems of site expansion and proliferation due to the natural influence of sloping terrain or rugosity, in the form of rockiness or uneven surfaces. Visitors and some AT volunteers have experimented with placing side-hill campsites along old forest roads, but this study revealed this practice as somewhat ineffective in constraining expansion along the road corridor. Experimentation with the placement of small boulders, felled trees, ice-berged rocks, or even brief removal of the roadbed to constrain site expansion is needed to make this a viable practice.

These types of "small-footprint" campsites also effectively limit other forms of camping impact, such as number of fire sites, damaged or felled trees, soil exposure, and area of vegetation loss. Due to their smaller size, side-hill sites have considerably fewer onsite or adjacent trees that managers may need to survey and remove as hazardous trees. As previously noted, to enhance experiential qualities, reducing crowding, conflicts, and noise, managers can and should always separate side-hill sites by more than 100-200 ft (Daniels and Marion 2006). Additionally, careful attention to selecting campsites that include or rank high for important necessity, experience, and amenity attributes will ensure sites that will be valued and used by visitors. As one example, continuing long-term research and measurements on the Annapolis Rocks side-hill campsites reveal that soils settled and compacted following construction on most sites to create uneven surfaces and water drainage is often problematic. Side-hill campsites are an important infrastructure facility that must receive ongoing maintenance, just as trails do, to perform their important function of attracting and spatially concentrating camping activity.

Finally, an advantage of relying on topography or rugosity to spatially concentrate camping activity is that campers are simply interacting with the natural environment, which effectively compels their innate behaviors. It's simply uncomfortable to erect a tent or cook a meal in sloped, rocky, or uneven terrain. This is viewed as more natural and effective than compelling similar behaviors through regulations (e.g., visitors must camp within 20 ft of a fixed camping post or fire ring). Similarly, reliance on education and low impact practices (e.g., please camp in the already barren central core campsite areas) is only effective when visitors are fully aware of and compliant with such voluntary practices (Marion 2014, Marion and Reid 2007).

Using Facilities to Limit Impact

When camping cannot be shifted to terrain where topography or rugosity acts to spatially concentrate camping activity research suggests the next best option is construction of camping facilities such as shelters, various types of visually-obvious tent pads, and other features like anchored fire rings. This section first examines research results on camping shelters like those on the AT, followed by a review of constructed tent pads. *Note:* A section on legal liability associated with the use of structures, the selection and use of sustainable established or designated campsites, and related campsite facilities is also included in a following section.

Shelters. The provision of shelters is a long tradition for the AT that predates its designation and the Wilderness Act of 1964. Studies have shown that these structures concentrate visitor activities to the extent that areal measures of disturbance are substantially lower than for a similar number of visitors camping in tents. However, some managers question their necessity or appropriateness in backcountry and particularly in wilderness. They are artificial permanent structures and many now use dimensional lumber and are not rustic in appearance, a few are exceptionally large and elaborate, with second and third stories and covered porches.

In a study of backcountry and wilderness campsites at Isle Royale National Park, Marion and Farrell (2002) found the mean size of three-sided shelter sites (420 ft^2, including the shelters and adjacent trampled areas) to be 35% smaller than campsites (646 ft^2). Shelter sites also had about half the exposed soil and area of vegetation loss as campsites. These findings are even more consequential given that: 1) many Isle Royale campsites were side-hill constructed, while those in flat terrain had embedded logs or rocks to define tent pads, and 2) shelter sites are popular and receive substantially greater use. The authors noted that: "Shelters serve to spatially concentrate camping activities to wooden shelter floor and to the area immediately in front of the shelter." This park has only 3.77 ft^2 of disturbed area per overnight stay, the lowest of seven other protected areas for which this measure could be computed (Marion and Farrell 2002). This achievement was attributed to the following actions: 1) restriction of camping to a limited number of designated campsites with high occupancy rates, 2) substantial use of side-hill campsites and camping shelters that spatially concentrate camping activities, 3) restrictions on group sizes to six for most campsites and shelters and to 10 for group use campsites, 4) communication of LNT messages to "confine your activities to these durable locations to preserve the natural conditions in surrounding areas," 5) an active park maintenance program that keeps the tent pads smooth and well-drained to attract and contain use, and 6) loss of campsite trees has enabled grasses to colonize around them and in low use areas.

Another interesting finding was that campsites with anchored picnic tables were an average of 129-172 ft^2 smaller and had even larger reductions in area of vegetation loss and exposed soil than sites without picnic tables. While many would consider a picnic table to be a *visitor convenience* facility and thus inappropriate in a backcountry and wilderness setting this finding reveals that they also perform a significant *resource protection* function by consistently attracting and spatially concentrating cooking and other activities to a single spot on campsites. In the absence of a table different visitors select different locations and thus enlarge campsites, trample more vegetation, and expose more soil.

Similar findings were documented at Great Smoky Mountains National Park (Marion and Leung 1997). The mean area of disturbance for shelters (3,218 ft^2) is smaller than for either rationed backcountry campgrounds (12,143 ft^2) or unrationed campgrounds (4,638 ft^2), and shelters account for 37% of the overnight visitation but only 10% of the total area of disturbance from camping. In this study the measurements of shelter sites, which are the most popular places to camp in the park's backcountry, *included* all immediately adjacent or contiguous tent camping areas, which confounds this comparison. This is the same situation for the great majority of AT shelters, where overnight visitors who cannot camp inside the shelter commonly sent up tents, tarps, or hammocks in immediately adjacent areas. Within these surrounding areas there are generally no regulations or practices that constrain either campsite expansion or proliferation. An important exception is within the highly-visited White Mountains, where camping has been largely restricted to huts, shelters, and associated areas of either tent platforms, tent pads, or designated campsites. Placing shelters in sloping terrain is a very effective practice but most shelters were originally built in flat terrain. Some shelters, such as the Gooch Mountain shelter in Georgia, were specifically placed in sloping terrain, with side-hill constructed tent pads constructed in the surrounding area.

Tent Pads. Constructed tent pads are a more natural structure that require substantially less funding and staffing to construct and maintain than camping shelters, yet still effectively attract and spatially concentrate camping activities in flat terrain. Tent pads could be a highly effective practice for constraining campsite expansion and proliferation around AT shelters. If there is sloping terrain near a shelter, then a campsite access trail could be constructed to direct visitors to side-hill constructed tent pads. In flat terrain, one to several campsite access trails could direct visitors to tent pads constructed along each trail, with inter-site spacing providing whatever level of solitude and natural quiet are desired.

Rock-lined tent pads are the most natural in appearance, require the least long-term maintenance, and allow water to filter out between the rocks (Figure 13A). Native soil can be used but crushed gravel provides better drainage and is more easily kept level or slightly crowned; wood chips should not be used as these decompose to mucky organic soil that retains water. When rocks are unavailable rot-resistant logs like locust can be cut and embedded to provide a visual cue of intended tent pads (Figure 13B). Treated lumber could also be used, with round timbers being more primitive in appearance than square dimensional lumber. Using two logs with their

joint pointing directly uphill ensures drainage around the tent pad, with drainage from tents free to run downhill. Logs need to be pinned to the ground with two to three-foot rebar to deter campers from using them for firewood. Logs or treated timbers can also be placed on all four sides to create an elevated tent pad, but care must be taken to use crushed gravel or sandy loam fill for drainage or to slope the entire structure and fill substrate to ensure adequate drainage (Figure 13C).

A wooden deck of treated lumber is a final option, though this is more expensive to purchase, transport, construct, and replace and maintainers need to check it periodically for rotten or cracked boards and protruding nails (Figure 13D). Visitors without freestanding tents or those who use tarps or hammocks can have difficulties using tent platforms. Additionally, the use of dimensional treated lumber is the least primitive option and is less appropriate in designated wilderness. Wood decks could be avoided in locations where the previous ground-based tent pad options are viable. However, all these options can effectively attract and concentrate visitor use, particularly when camping must be accommodated in flat terrain. These tent pad options likely represent the most effective practices for addressing chronic campsite expansion and proliferation problems when camping must be accommodated in flat terrain. An alternate and potentially effective regulatory approach is to erect 4x4 campsite posts engraved with the words "Camp within 5 yards" on each side.

Figure 13. A) Rock-lined tent pad, B) Embedded logs pinned with rebar, C) Wood-lined tent pad, and D) Wood-decked tent platform.

Site Maintenance. Land managers have long placed an emphasis on maintaining trails to keep them in good condition for sustaining their intended type and amount of use. Their actions include moving substrates to promote drainage, cutting vegetation, adding and cleaning drainage features, installing rockwork, boardwalks, and signs, and even relocating poorly designed segments. In contrast, maintaining campsites has traditionally been limited to cleaning or removing fire rings, though on designated sites some managers have improved tent pads and added border logs or rocks. Under a containment strategy, campsites retained for use can benefit from routine maintenance just as trails to keep them open and in good condition.

Much of the expertise gained in maintaining trails can be extended to maintaining campsites. Managers can perform maintenance work on campsites to reduce their size, protect visitor safety, minimize erosion, and address campfire-related impacts (Hammitt et al. 2015, Marion and Sober 1987). Site impact evaluations can reveal what problems require maintenance actions, for example, excessive site size may be addressed by subtly improving tenting locations or adding logs to create borders. Visitors will seek out and consistently use smooth and well-drained tent sites (Figure 14). Where necessary, remove protruding rocks or redistribute soil to slightly crown tent pads and improve drainage.

Figure 14. Managers of these designated campsites at North Cascades National Park have improved tent pads by removing rocks and creating effective borders by adding logs and rocks. These actions attract and concentrate activity within intended use areas and protect flat offsite areas that could allow expansion.

Unnecessary portions of campsites can be reclaimed by either repeated efficient actions, such as scattering organic litter, branches, logs, and rocks on these areas (Figure 15 A, B), or by more intensive work such as ice-berging large rocks, felling or dragging dead trees, and installing interpretive signs (Figure 15 C, D). Where rocks are not available, the terrain can be made uneven simply by digging shallow depressions and mounding soil nearby. As previously noted, these actions are likely to be difficult and less effective in extensive flat terrain, so camping may need to be shifted to sloping terrain, including the relocation of formal trails, so that visitors are not shown flat terrain camping options.

Just as for trails, campsite substrates can be subtly shaped to promote water drainage around the perimeter of sites, particularly of tenting areas. Ensure that water is filtered through at least 10 lineal feet of relatively undisturbed ground vegetation and/or organic litter before entering waterbodies (Marion et al. 2018b). A well-place large log along the low side of a shoreline-proximate campsite can often force traffic slightly uphill *and* provide protection to an untrampled band of vegetation and litter to filter campsite runoff. Otherwise close and move the campsite further from water.

Figure 15. A & B) An emerging off-site tenting spot hidden by adding organic litter and branches. C) When repeat use is chronic, partially burying (ice-berging) a large angular rock can be a more effective deterrence. D) Log borders and educational signs can also be effective (use large diameter or somewhat rotten logs to deter their use as firewood.

Stonework to add steps or armor steep or muddy embankments at water sources is another maintenance improvement that can attract and concentrate trampling activity to durable surfaces and protect water quality. Some managers and volunteers have installed rockwork around springs to protect water quality and provided a pipe for filling water containers. While such a facility does protect the water source it is also artificial and could lead visitors to wrongly assume that the water is safe to use without purifying. Creating a simple rock pour-off is likely a better option. A general precaution when pipes are used is to provide a sign clearly stating that water must be purified before use.

Formal or useful and sustainable informal (visitor-created) trails that provide access to overnight camping facilities also require routine maintenance to keep them in a usable condition and minimize associated resource impacts. The objective is to promote consistent traffic patterns within camping areas on well-designed and maintained footpaths and to close and rehabilitate unnecessary and unsustainable informal trails (Figure 16). Many excellent trail maintenance manuals have been developed to guide this work (Birchard and Proudman 2000, Hesselbarth and Vachowski 2007, IMBA 2004). Active trail maintenance reduces impacts by providing a durable tread able to accommodate the intended traffic while minimizing problems with tread muddiness, erosion, widening or multiple tread development.

In areas where dispersed pristine site camping is practiced, routine maintenance consists of locating and removing all fire sites and renaturalizing site conditions to avoid repeated use of the same sites. The management objective in these locations is to avoid the appearance of any campsites. Guidance for restoring campsites is provided in a following section Campsite Closure and Rehabilitation section for specific management practices. In these areas visitors should avoid building campfires or use LNT campfire practices, such as mound fires, to leave no evidence of campfires. *Note:* maintenance actions related to campfire rings is addressed in the following section to keep all related guidance together.

Figure 16. Managers have closed this unnecessary informal (visitor-created) trail with both logs and embedded rocks.

Campsite Amenities. Additional campsite features can also be anchored on campsites, particularly in flat terrain, to attract and concentrate use. These include fire rings, stone fire pits, stove rocks, logs for seating, food storage cables or boxes, picnic tables, and sumps. While these features represent convenience amenities for visitors, they also often confer a substantial resource protection function.

Campfires can be an essential element of a high-quality camping experience for many visitors, particularly youth. Unfortunately, problems related to campfire use, including the development of multiple fire sites (Figure 17A) and large trash-and food-filled fire pits, mounds of charcoal and half-burned logs, tree damage and felled trees, off-site vegetation trampling and wood removal, and the threat of forest fires, have caused an increasing number of managers to prohibit campfires (Cole and Dalle-Molle 1982, Reid and Marion 2005).

Many managers have had success in keeping campfires small and contained to a single location by firmly anchoring small steel fire rings on campsites (Figure 17F). Using the smallest available options (e.g., 18 in diameter) promotes small low-impact campfires that conserve wood and promote using small-diameter sticks that burn completely to ash. Placing fire rings on or near bedrock attracts cooking activities to a durable surface, and near the center of campsites but ideally away from trees, roots, and the best tent sites to lessen the risk of forest fires and sparks reaching tents (Figure 17B). Steel fire rings are also frequently used to identify preferred established or required designated campsites and have been shown to attract and concentrate visitor use to their vicinity, thereby minimizing site size and expansion (Marion 1995).

When rock campfire rings are used, consider ice-berging a few large rectangular rocks around the preferred campfire location (Figure 17C&D) (Reid and Marion 2005). Fixing the fire site's location attracts visitors to a common spot and spatially concentrates use. Multiple fire sites create multiple locations of camping activity; different groups will use different parts of a site, which promotes site expansion. Breaking up all but the intended single fire site will effectively concentrate activity in the same place over time, reducing the area of camping disturbance. Where campfires are permitted, educational messaging can ask visitors to: 1) use stoves and avoid campfires when possible, 2) use only existing fire sites or remove all traces of "new" fire sites, and 3) keep fires small, burn only wood, and leave a small clean fire pit. Some managers have removed all fire sites in areas where campfires are permitted. This practice promotes new fire scars at different locations and should be avoided, except in areas where dispersed pristine site camping is encouraged. Migration of campfire sites is a significant impact because fires cook the underlying soil, kill soil biota, and alter physical and chemical properties (Marion et al. 2016). Cleaning fire sites of built-up charcoal and ashes, trash, and unnecessary rocks is a perennial maintenance function. Whether campfires are permitted or not, consider placing large flat "stove rocks" on campsites to attract intensive cooking activities to a single fixed location (Figure 17E).

While some land managers remove visitor-created logs and rocks (camp "furniture") used for seating or stoves, these features do attract and concentrate intensive visitor use activity to their vicinity and can therefore limit the

Figure 17. A) It is not uncommon for visitors to build multiple fire sites on campsites, or to move fire sites around over time. B) Placing fire sites on exposed bedrock will attract and concentrate intensive cooking activities on durable substrates (though this one is dangerously close to vegetation), C & D) two styles of ice-berged rock fire rings that fix the location of campfires, E) placing a large flat "stove rock" and log seating will consistent attract and concentrate cooking to a single location, F) small anchored fire rings fix campfire locations and can be used to denote preferred established campsites or required designated campsites.

areal extent of impact if left in place. The effect of anchored fire sites, stove rocks, and large logs/rocks for visitor seating should be quite similar to the attraction and spatial concentration of activity effect demonstrated for the picnic tables on Isle Royale National Park campsites (Marion and Farrell 2002). However, they should be kept "simple" and rustic and the use of very large logs and rocks are preferred as these are less likely to be moved around on a campsite.

The Leave No Trace cat-hole method of human waste disposal is the most common universal practice for disposing of human waste in backcountry and wilderness settings (www.LNT.org). However, it is ineffective in some environmental settings (extreme cold, deserts, rocky areas w/little soil, and wet soils), and some visitors are either unaware, unprepared, or unwilling to use the practice effectively (Cilimburg et al 2000). Carry out options are possible due to the development of lightweight toilet kits that have been approved for landfill disposal. The determination of when to place a toilet could be made based on monitoring the extent of improperly disposed human waste sites in adjacent areas. In areas of high use land managers generally find it necessary to provide toilets for fecal waste and a variety of options have been developed, ranging from simple fiberglass models that lack privacy walls to the more elaborate "Sweet Smelling Toilet" (SST) developed by the USFS. A comprehensive review of toilet options is provided in the ATC's Backcountry Sanitation Manual (ATC 2014) and an international workshop proceedings provides additional options (Civil and McNamara 2000). While pit toilets remain common, an above ground moldering privy has provided the best option along the AT, with numerous successful installations.

This issue of greywater disposal from washing dishes and clothing is also described in the ATC Manual (2014) and in Marion (2014). Some land managers provide screened sumps at high use campsites though these remain a rare facility. The most commonly recommended practice is for visitors to filter greywater through a screen and then either broadcast (scatter) the water or pour it into the soil under organic litter at a location more than 100 ft from waterbodies or campsites.

Another common site facility is a cable system for hanging food or a food storage box to prevent wildlife from accessing human food, trash, and other odorous items (e.g., lotions, tooth paste, soap) that create food attraction behaviors (Figure 18). While a fed bear is a dead bear, fed shelter mice reproduce exponentially. The attraction of bears to campsites successfully obtaining food all too frequently ends with threats to human safety and the removal or execution of the bear. Proper food storage, including smaller "micro-garbage," is key to preventing wildlife behavioral changes for a variety of wildlife species, including bears, racoons, skunks, squirrels, rats, mice, and birds.

Some land managers place the burden of food storage on visitors to hang their food from trees with ropes, or to store it in approved bear canisters or bags that they carry. Visitors who lack the willingness or skill to put up effective bear-proof hangs, or the rarity of usable trees in some areas, prevents that policy from being substantially effective and damages trees and underlying ground vegetation. Cable systems are more effective and easier to use but are prone to breakage and require periodic maintenance and replacement (Figure 18). Thick aircraft cable is stretched between two trees about 30-40 ft apart at a height of 20 ft. Visitors can throw their own ropes over this to pull food bags up, taking care to hoist it at least 10 feet high and more than six feet from any tree. Alternately, pulleys and smaller cable can also be installed for hoisting food. Steel food storage lockers placed at campsites are perhaps the best method as they are easy to use, eliminate considerable trampling damage, and require little to no future maintenance, though visitors sometimes leave their trash or excess food in them. The food storage box shown in Figure 18C was placed at the Hawk Mtn. side-hill campsites and has prominent signs with the message: "LEAVE NO FOOD FOR OTHER HIKERS, NOT A TRASH CAN – PACK IT OUT!"

Yet another option are steel poles that resemble 15 ft tall coat racks with multiple arms and hooks for hanging food bags. These should be sufficiently strong and anchored in cement for stability. A 10 ft lifting pole with a hook on the end is provided for placing and retrieving food bags. The lifting pole should be secured to the bear pole with a six-foot length of chain or cable to prevent its loss. The capacity of this system is less than that of cable systems so more than one may need to be provided for larger capacity camping areas.

Figure 18. A & C) Steel food storage boxes. A & B) Steel cables for hanging food. D) Packing food into a bear canister.

Legal Liability. *Note:* This section has been submitted for review by USDA and USDI Solicitors (lawyers) – a cursory look and discussion suggests that there is somewhat greater agency liability than indicated by this current draft.

A federal agency's legal liability must also be considered in decision-making regarding the use of site facilities ranging from overnight shelters to side-hill campsites, and even whether visitors should be encouraged to use established campsites or required to use designated campsites. While promoting public safety in recreation management decision-making is an important consideration, overreacting to liability concerns can result in reduced recreational access and/or acquiescence to substantial levels of avoidable recreation impact. This section reviews relevant laws and case law to provide guidance on achieving an appropriate balance.

The federal government can be sued for wrong doing and the recovery of damages for injuries under the Federal Tort Claims Act (FTCA). McAvoy et al. (1985) provide an overview of the FTCA and several "exceptions" that are provided for in the Act. The "*Discretionary Function exception*" states that Federal agencies have the discretion to make policy decision based on research, budget realities, and agency goals and objectives, and neither they nor

their employees can be held liable if an injury occurs because of those policy decisions. As an example, a Yellowstone NP campground visitor sued the NPS after being mauled by a grizzly bear, arguing that the attack was caused by the NPS's recent closure of a garbage dump, causing the bear to search campgrounds for food. The courts found in favor of the NPS, citing the dump closure as a discretionary policy decision exemption. However, *Operational Decisions*, such as maintenance of a trail bridge or camping shelter, are not excepted or exempt. If an injury occurs due to a lack of proper maintenance the injured party can sue successfully.

A more relevant example is provided in Autery v. United States, 992 F.2d 1523, 1530-31 (11th Cir. 1993) where the discretionary function exception applied to the alleged negligent failure to inspect for hazardous trees in Great Smoky Mountains NP, when a hazardous tree killed a man driving through the park. The court found that: "Whether employees were negligent in making any decisions is irrelevant. Negligence is simply irrelevant to the discretionary function inquiry…" The park had a policy requiring inspection of trees but had no specific mandatory process specifying methods to assess trees for hazards that had been violated (Kozlowski 2015b).

Similarly, in Snider v. United States of America, 2013 U.S. Dist. LEXIS 105580 (W.D. Ok. 6/29/2013), a federal district court also applied the discretionary exception to a case when a hazardous dead tree only ten ft from a picnic table killed a camper at an Army Corps of Engineers (COE) campground (Kozlowski 2015b). The court found that "Decisions involving tree removal can quite clearly be policy-driven matters. On government property (or any other property) that is wooded, there will inevitably be dead trees. Dead tree removal, if it is to occur at all, must get in line for government resources along with all of the other demands on the operator of a campground." COE also claimed a policymaking decision "not to place warning signs of general hazards at campsites" also fell "squarely within the scope of the discretionary function exception." The court concurred: "Faced with limited resources and unlimited natural hazards, defendant must make a public policy determination as to which dangers merit the intrusion of a sign. Too many signs would reduce the impact of individual warnings on the public. Defendant must balance the goal of public safety against competing fiscal concerns as well as the danger of an over proliferation of warnings."

The "*Recreational Landowners Liability Acts"* provide a basis for deciding many other cases and almost every state has enacted some version of this statute that limits the landowner's liability to encourage them to open unimproved property for recreation uses. The FTCA states that the federal government is liable for negligent acts "in the same manner and to the same extent as a private individual under like circumstances" so the courts use the relevant state law in determining liabilities. There are three common exclusions in these state laws:

1) An injured party must demonstrate that the landowner's actions constituted a willful or malicious failure to guard or warn against a dangerous condition, use, structure, or activity.
2) If a fee is charged for admission to an area, then the responsibility to protect the visitor increases.
3) If a landowner merely permits access to their property, they have much less responsibility for visitor safety than if the visitor was expressly invited to recreate there. As an example, a USFS visitor to some thermal pools was attracted by a sign which read: "We invite you to marvel at the natural wonders of this great forest." He left a designated trail, fell into a thermal pool and suffered severe burns, and sued. The court ruled that the sign did not constitute an express invitation and found in favor of the USFS.

McAvoy et al. (1985) conclude that the implications for federal backcountry and wilderness land managers are that if an agency decides to build trails, campsites, or structures then the responsibility to ensure safety increases and the policy decision must be followed by sound operational decisions. The constructed features must be maintained, and the agency has a duty to adequately warn visitors of potential dangers. Such warnings could be placed on wilderness permits, at trailheads, in visitor centers, and in online websites. The courts have held that if visitors choose to enter backcountry and wilderness settings then the visitor assumes responsibility for their own safety.

It's important to distinguish between the specific constructed developments and its natural surroundings. The preponderance of court cases have defined legal liability very narrowly in backcountry and wilderness settings, with the liability directly tied to the design, engineering, and maintenance of the developed facility, like a bridge's

ability to support a string of horses or a camping shelter's ability to tolerate an expected maximum snow load. Kozlowski (2015a) provides a more recent legal review regarding case law associated with two campground visitors in a Colorado State Park (Burnett v. Colorado Division of Parks and Outdoor Recreation, 2015 CO 19; 346 P.3d 1005; 2015 Colo. LEXIS 216 (Colo. 3/23/2015)). These visitors were required to camp in a campground site of their choosing and paid a fee for its use, setting up their tent under the canopy of four mature cottonwood trees. During the night a large limb fell and injured both of them, one severely. This camper sued the state to compensate "for injuries caused by a dangerous condition of any public facility located in any park or recreation area maintained by a public entity."

The camper and the state agreed that the "improved campsite" was a "public facility" but the state denied any liability because they retained immunity for "an injury caused by the natural condition of any unimproved property" (Kozlowski 2015a). The trial court, appeals court, and state supreme court all found in favor of the state. In particular, the state supreme court: 1) distinguished between dangerous conditions arising from manmade and natural objects, 2) it suggests that immunity turns on the precise mechanism of the injury (e.g., injuries cause by negligence in the construction or maintenance of artificial, manmade objects vs. the natural conditions of the land), 3) it expresses a clear intent to exempt public entities from a duty to maintain any natural conditions, and 4) it reaffirmed the policy goals of encouraging public entities to open up to the public unimproved, government-owned property without exposing the entities to the burden and expense of defending claims brought by individuals who are injured while using the property.

More specifically, the state supreme court concluded "the legislature intended to retain immunity for injuries caused by native trees originating on unimproved property regardless of their proximity to a public facility, such as the improved area of the campsite here" (Kozlowski 2015a). The state supreme court noted that courts in other jurisdictions with similar statutory immunity for natural conditions had also concluded that "the exact mechanism of a plaintiff's injury [the tree], not her location at the time of injury [a developed state park campground] determines immunity." Kozlowski (2015a) also relates that the state supreme court held the natural condition provision "does not create a duty to maintain natural features, nor does a duty arise merely because of the features' proximity or contiguity to improved property." The state supreme court further held that "even where the State chooses to maintain unimproved property to protect the public health and safety," they retained immunity *even though* the State had previously pruned the trees bordering the campsite on which the injury occurred. The principal reason supporting these decisions was an explicit recognition of the "limited fiscal resources" to engage in the maintenance of various natural conditions and that the burden and expense of defending claims for injuries would likely discourage public land managers from opening and improving lands for the public to enjoy.

One can never be certain how the justice system will interpret the relevant laws, which also vary by state, but the preponderance of case law reveals that land managers are liable for injuries directly related to their manmade facilities. They are generally not liable to any associated "natural conditions," including hazardous trees, and including in areas where hazardous trees are periodically evaluated, trimmed, or removed. This liability immunity for hazardous trees applies to all types of overnight accommodations, including trees that overhang developed shelters and tent platforms. While this immunity does not require informing participants about the potential dangers associated with camping under forest canopies, the general promotion of public safety includes such warnings, which would also support court rulings in favor of a land management agency. This academic review of relevant case law is not offered as legal opinion or advice: agency counsel should be consulted for such legal opinions and advice with consideration for the state within which the campsites are located.

Using Other Attributes to Limit Impact

Substrates and Vegetation. Several other attributes can be considered in selecting sustainable campsites that limit resource and social impacts. Durable surfaces and vegetation characteristics, including resistance, resilience, and tolerance, have been described and are relatively important considerations. Soil characteristics, including texture, organic content, and moisture, should be considered but are comparatively less critical. For example, if

the overriding management objective is to constrain campsite size, then intensive traffic on the small sites will remove all vegetation and organic matter and highly compact the underlying exposed mineral soil. Placing campsites on soils that are good for growing plants or that won't compact as easily becomes irrelevant, though constraining soil loss is important. While rainfall runs off highly compacted soils, sustainably selected or constructed campsites are small, slightly sloped, and well-drained by design such that soil loss should be minimal.

Soils to avoid include those with substantial sand as they are less compactable and more easily eroded and displaced by foot traffic. Soils with a narrow range of particle sizes, particularly those high in silt and fine sands, are most prone to water erosion (Hammitt and Cole 1998). Dry, somewhat organic soils with a wide range of particle sizes (e.g., sandy-clay loams) are preferred as the smaller silt and clay particles promote soil cohesion and compaction while larger sand particles promote soil drainage. Highly organic soils (peats and mucks) retain water long after rains and can create prolonged muddiness.

Location/Proximity Attributes. Several attributes related to a campsite's location can be critical factors in site selection. The protection of important or sensitive resources is promoted by increasing campsite distances from waterbodies, wetlands, hazardous areas (e.g., cliffs), and sensitive vegetation, soils, rare flora/fauna, wildlife habitats, and cultural/historic sites. Visitors who are camping often have greater free time to roam off-trail and trample or disturb these types of sensitive resources so shifting campsites entirely away from them is often a preferred management option, though visitors may have opposing opinions. Consider a common example - camping set-backs of 100-200 ft from waterbodies are quite common as either regulations or suggestions (Marion et al. 2018b). Unfortunately, compliance is frequently low due to the substantial attraction to waterbodies, and day-use activities like swimming, fishing, and resting breaks are often enough to prevent recovery on shoreline recreation sites. Closure to day-use activities with signs may also be necessary, though efficacy may be governed by the ability to shift use to alternative sites with more durable rock substrates.

Similarly, the protection of experiential conditions is promoted by increasing campsite distances from other campsites, formal trails, camping shelters, popular attraction features (e.g., waterfalls, vistas), and roads or developed areas. Solitude, privacy, and natural quiet are all enhanced by increasing these distances and managers have established regulations or educational messaging to promote set-back distances or inter-visibility guidelines (Cole et al. 1987, Marion et al. 1993). A containment strategy is generally necessary to provide managers with sufficient tools to shift campsites entirely away from some features or achieve a specified minimum distance that promotes high quality visitor experiences. Surveying visitors regarding their camping preferences is suggested, as some visitors, such as some informal "groups" of thru-hikers, prefer to camp near each other. A planning process that establishes desired social conditions by zone can provide guidance for such decision-making.

As previously noted, campsite attributes and area attractiveness for camping is also an important consideration - campsites that do not appeal to visitors may go unused. Selection criteria should be periodically reviewed and modified, particularly as management experience or monitoring data reveals how different campsites stand up to intensive or long-term use.

Current research by the authors is developing campsite sustainability assessment ratings, likely a weighted system that can assist managers in evaluating existing campsites or potential new site locations. An important decision is whether camping should be continued on existing campsites or shifted to new sites. Sustainable existing sites should be used when possible as they are already impacted, and their effective closure may be difficult to achieve. However, existing campsites frequently have one or more significant limitations, such as high expansion potential or proximity to water or other sites. Sometimes closure is necessary for some sites, however, maintenance work on others can adequately address deficiencies to make them usable. Alternately, use could be shifted to new sustainable naturally-occurring or constructed side-hill campsites that resist expansion and provide greater separation to improve social conditions.

Site Capacity and Design. In high use areas where a containment strategy guides camping management policies, it can be advantageous to group camping into larger clusters of sites. However, just as the total amount of use in a management zone must sometimes be regulated to limit the deleterious effects of particularly high use and

peak use, visitor capacities must also be considered when designing and managing areas with clusters of campsites, essentially backcountry campgrounds. Resource and social conditions on campsites are substantially influenced by site design considerations and construction techniques. Site design relates to both capacity (number of campers) and site configuration (arrangement of sites in relation to shelters, other sites, and topography).

Camping capacity is dependent on a variety of factors, including desired resource and social conditions which vary by management zone, local demand for camping, topography, availability of water, and environmental resistance. The process of determining camping capacity should begin with a review and consideration of management objectives and desired future condition statements, which vary by zone. What level of overnight visitation is most appropriate for the area? Given the desired social conditions, how should overnight visitation be structured and arranged in relation to the AT, shelters, and other campsites? What are the maximum capacities for specific campsite/shelter locations? All other considerations ought to be secondary to these strategic factors.

Objective evaluations of other factors are also essential, beginning with documenting existing use within the area. This will normally require field surveys to record overnight visitation by location, groups and group size on a representative sample of typical high use (not peak use) weekends. For example, ridge-runners or club staff might check all campsites within a target area during the evening or early morning hours on four to six good-weather weekends during the most popular season. Data on peak use weekends would also be useful but should not be used for capacity decisions because visitation is often substantially higher. Designing to accommodate peak use would result in creating exceptionally large numbers of sites (and resource impact), many of which would be used infrequently throughout most of the year. Evaluations of use data in relation to the desired future conditions prescriptions will reveal the acceptability of current use levels and the ability to accommodate future growth. It is important to note that capacity decisions are inherently subjective and cannot be derived from scientific research or empirical formulas.

The next step is deciding where overnight visitation should occur and how much will occur at any single location. Critical decisions include the acceptability of co-locating camping with shelters and the maximum number of campers permissible at a single location. Capacity guidance can and probably should be established for management zones to ensure consistent management decisions along the AT. For example, maximum campers per single location might be set at 40 for a Frontcountry zone, 30 for a Backcountry zone, and 20 for a Wilderness zone. Planning for site capacities above 20 to 30 requires careful consideration of options for avoiding bottlenecks at communal facilities such as water sources, toilets, and food storage devices. Water sources with multiple accesses and multiple toilets and food storage devices can alleviate crowding at these locations when larger capacities are planned. Severe limitations for any of these factors should initiate considerations for shifting overnight use to other locations. For example, clusters of 3-6 campsites could be located elsewhere along the AT, including at locations that lack water sources. Additional guidance on site capacity decision-making, particularly related to shelters, is provided by Leonard et al. (1981).

Next, other factors should be examined to determine if the preferred level of camping use can or should be sustained within the area. Topography and the availability of dependable water are important considerations. The significant beneficial influence of topography, including micro-topography (rugosity) in limiting future site expansion and proliferation cannot be overstated. While many existing AT shelters and clusters of campsites are in flat terrain, over time these could be shifted to adjacent or more distant areas of sloping terrain, with trails relocated to hide flat areas and allow natural recovery. Analyses using GIS and LiDAR topographic data are being developed to assist in efficiently identifying the best alternative locations for locating highly sustainable naturally-occurring or constructed side-hill campsites. Terrain slopes of at least 15% are preferred for side-hill campsites.

Careful thought should also be given to the spatial arrangement of campsites relative to waterbodies, shelters, other campsites, and communal facilities like toilets and food storage boxes or cables. This is particularly critical when larger numbers of overnight visitors are grouped within a single area. Travel patterns within the area should be anticipated so that intended use areas can be linked by a limited number of carefully designed and constructed trails rather than a haphazard network of visitor-created trails. Figure 19 illustrates some preferred arrangements

of side-hill campsites when higher demand creates a need for such larger numbers of sites. Such configurations could be established in flat terrain with constructed tent pads or camping posts as previously described, and many other spatial arrangements are possible. Note that the clustered arrangement of sites common when visitors create campsites (see Figure 12A) maximizes intersite trampling disturbance and the creation of informal trails. Where possible, a linear arrangement of sites and facilities promotes traffic along a single trail, protecting surrounding areas from trampling (Figure 12C and Figure 19) (Leonard et al. 1981). Assume that visitors will want to directly access water, restrooms, food storage boxes, and the formal trail - providing fairly direct trails from campsites to these locations will reduce avoidable trampling impacts and informal trail creation.

The ability to select campsite and tent pad locations provides managers with a powerful tool to shape social and experiential conditions on campsites, where visitors spend a considerable amount of time. There is a direct trade-off between intersite spacing required to provide and protect the intended or desired social conditions and the aggregate size or "footprint" of the backcountry campground. Spacing sites a minimum of 100 feet apart enhances visitor solitude and privacy and conversational voices generally become unclear beyond this distance. Such intersite distances could be specified and vary by management zone (e.g., >200 ft in wilderness). When camping is co-located with shelters, managers can separate shelter and tent camping by designing campsite access trails leading away from shelters to sloping terrain, with planned campsites spaced along them to separate camping from the immediate vicinity and viewshed of the shelter.

On individual sites, the area of camping disturbance can be minimized by identifying a desired number of tenting spots that have some separation from one another but are clustered as a campsite for use by a single group (Figure 12B and Figure 19). Care should be taken to ensure that planned campsites embody as many of the necessity, experience, and amenity campsite preferences (see section on Containment) as possible. At a minimum, the construction and long-term maintenance of smooth slightly crowned and well-drained tenting sites will encourage campers to consistently tent on the same sites so that camping activities and disturbance are spatially concentrated (Leung and Marion 1999, Marion and Farrell 2002).

Access trails should also be designed, constructed, and marked to promote use of preferred or designated campsites and to avoid the development of numerous and poorly located visitor-created trails. Individual campsite access trails, generally 25-50 feet long, can branch off this trail when multiple campsites are provided, so that campers do not walk through or around the edge of other visitor's campsites when traveling to their own site.

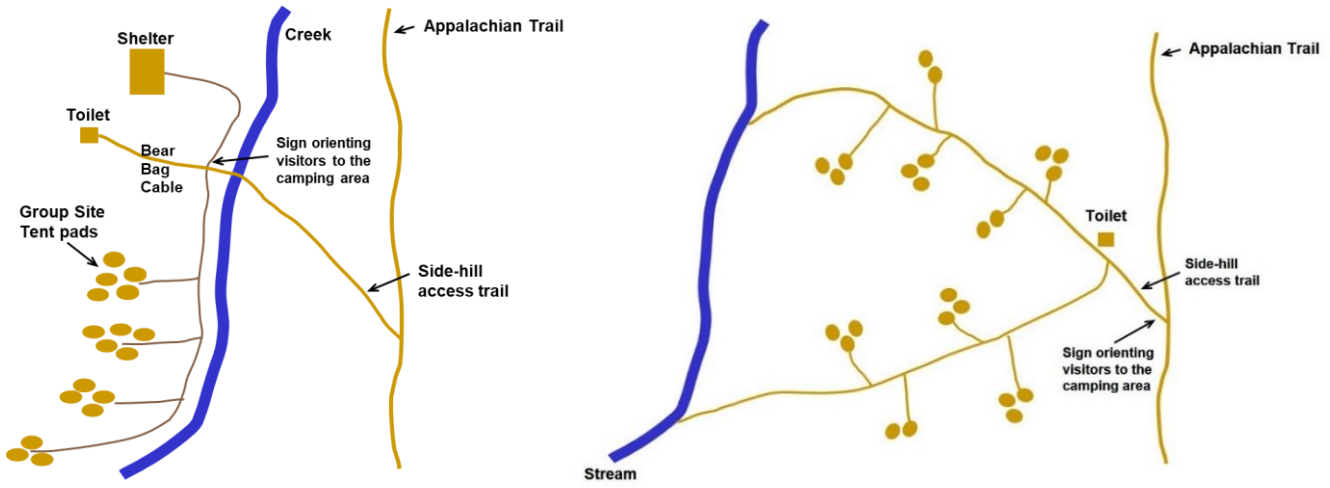

Figure 19. While campsites can be individually located along trails the common need for water often creates high demand for clusters of campsites that when unmanaged often lead to unacceptable resource and social conditions in moderate to high use settings. These alternative site design examples illustrate how constructed side-hill campsites could effectively resolve both resource and social impacts through carefully planned designs.

Main campsite access trails could be marked with a standardized triangular campsite paint blaze and should preferably exit formal trails in a perpendicular fashion to discourage the creation of "short-cut" trails.

When constructing naturally occurring or side-hill campsites look for the flattest existing areas when possible to reduce the amount of excavation needed to create the intended number of tenting spots. During excavation work it is best to remove all organic litter and soils to piles located along the contour on either side of the pad. Add excavated plants as well and water them. Find rock and build stone cribbing along the downhill sides to contain fill material, or substitute rot-resistant logs if rock is unavailable. Excavate uphill and fill in behind the cribbing; any rocks in the soil can be placed deep and covered with mineral soil. Lower the slope of the uphill cut face by digging further uphill - a steep slope will be prone to erosion and is more difficult to revegetate. Avoid making tent pads in precise geometric shapes (rectangles or circles) due to their artificial appearance - uneven sinuous boundaries are preferable. Compact, smooth and gently crown or slope the fill material and dig a shallow drainage dip around the uphill side of the tent pad to collect and drain water. Finally, relocate the organic soil, litter, and any plants to the cut slope uphill from the tent pad. This will naturalize the excavation work and promote natural recovery.

The number of tent sites should match and accommodate the typical range of group sizes for the area, generally one to three pads and up to five for group sites. A separate pad can be created for cooking and a campfire ring in areas where they are permitted. Placement of a flat "stove/kitchen table rock" in the intended cooking area will help to attract kitchen activities to this location. Use of a large heavy rock will help discourage visitors from moving it around and disturbing different areas.

The aggregate area of disturbance will always be greater when camping must be accommodated in flat terrain, but several site construction practices can help to define and constrain camping disturbance. Begin by applying the site selection criteria and site configuration recommendations to identify approximate site locations. Look for locations with features that could help constrain site expansion, including uneven ground, protruding rocks or roots, or slightly sloping terrain. The previously-described tent pad options or camping posts are recommended in flat terrain, with site ruination work in adjacent offsite areas to deter expansion. Anchored fire rings, ice-berged rock fire rings, and stove rocks can assist in attracting and concentrating camping activities. Lining some of the campsite boundaries with large semi-rotten logs or embedded rocks can help clarify campsite boundaries and may even be necessary initially to identify preferred site access trails.

Care should be taken to accomplish all site development work in close cooperation with land management agency staff. Soil and vegetation disturbance generally require environmental assessments and archaeological surveys and approvals, activities that can be expensive and time-consuming. Inquire about a categorical exemption for archaeological surveys when side-hill campsites are constructed in sloping terrain (>15% slope) as prehistoric inhabitants lived almost exclusively in flat terrain or cliff-associated settings. Construction work should strive to use native and/or rustic materials that match natural conditions (Marion and Sober 1987). Avoidance of long straight borders or perfect geometric shapes in campsite boundaries is one of the easiest ways to accomplish this. Using rock or short rot-resistant timbers rather than pressure-treated dimensional lumber is another. There is a fine line between making the intended use areas sufficiently obvious so visitors will consistently use them and artificial or visually obtrusive so that natural values are degraded. However, more artificial work may be justified in high use or flat areas.

Wilderness Character. Camping management decision-making in designated wilderness areas must also consider wilderness character (Landres et al. 2015), including five core qualities:

1) *Untrammeled* – wilderness is essentially unhindered and free from the actions of modern human control or manipulation (e.g., stocking fish, unnatural fire regimes, manipulating wildlife populations).
2) *Natural* – wilderness is substantially free from the impacts of human activity.
3) *Undeveloped* - wilderness retains its primeval character and influence without permanent improvements (e.g., non-recreational structures, motorized equipment, inholdings).

4) *Opportunities for solitude or primitive and unconfined recreation* – wilderness provides for personal challenge and self-reliance, which are degraded by facilities, management restrictions on visitor behavior, and crowding/conflicts with other visitors.
5) *Other features of value* (paleontology, heritage, etc.)

Camping management decision-making related to implementing a containment strategy that employ developed structures or required behaviors must consider and seek to balance the advantages or benefits of such actions against the disadvantages or impact to wilderness character. For example, the resource and social impacts associated with excessive numbers of unnecessary visitor-created campsites and large visitor-created mega-site clusters of campsites in high use areas represents a clear threat to *natural* conditions in wilderness. Shifting camping use to a smaller number of more sustainable campsites with a reduced aggregate area of impact that visitors are encouraged to use improves *natural* conditions and *opportunities for solitude*. If achieving those same benefits in a popular high use area requires the use of designated side-hill sites there is an added "cost" to the *unconfined* quality of recreation associated with requiring the use of designated sites. While the *undeveloped* quality of wilderness might be degraded by using "constructed" side-hill campsites or outhouses and food storage boxes, this quality has been generally defined to exclude recreational structures, including constructed side-hill trails, bridges, and rock staircases or retaining walls.

A containment strategy that emphasizes the selection and use of sustainable campsites offers both advantages and disadvantages for managers and visitors:

Advantages: Mangement benefits include the ability to select sites in settings that are environmentally resistant/resilient, that topographically constrain site expansion and proliferation, promote solitude, and minimize wildlife habitat disturbance. Visitor benefits include knowing where preferred established or designated sites are located, having assurance of a good campsite in designated site areas, the presence of high quality tenting sites and in some areas toilet and food storage facilities.

Disadvantages: Managers must have staffing/funding to identify sustainable sites, construct and maintain sustainable established or designated sites in higher use areas, and provide/maintain camping-related facilities. Visitors may lose the freedom to select a preferred campsite or be bothered by the development of backcountry campgrounds with facilities in backcountry or wilderness areas.

Managers must consider these advantages and disadvantages and achieve a balance that allows them to meet their objectives for protecting natural conditions and processes while accommodating appropriate types and amounts of visitation. Decision-making will vary by management zone. A pure dispersal strategy with pristine site camping may avoid the creation of impact in remote low use zones. Unconfined camping policies can also be employed in these areas, but this policy frequently allows excessive site creation in moderate use zones. A containment strategy with established site camping is frequently a much more successful policy. In high use zones a more intensively implemented established site camping policy can be effective, but in the most popular areas designated site camping is generally necessary, with use rationing to redistribute peak use in time and space. To summarize, *intensive use requires intensive management*, or resource and social impacts are likely to exceed management thresholds of acceptability.

Site Management: Close/Rehabilitate Sites

While minimizing resource impacts on recreation sites and trails is a primary management goal, visitors often create unnecessary sites and trails, sometimes at sensitive or popular but unsustainable locations where impacts may quickly exceed acceptable levels of degradation. Camping closures represent a final resource protection strategy in the management toolbox, generally most appropriate for protecting sensitive environments, rare flora and fauna, and fragile historic or archaeological sites (Hammitt et al. 2015, Marion 2016). Closures, with unassisted recovery and/or active restoration to achieve natural conditions, may also be necessary to limit resource and social impacts near popular attraction features such as lakes, waterfalls, cliff vistas, and hot springs, or to separate overnight campers from intensive day use (Therrell et al. 2006).

Management experience reveals that closures of popular areas and highly-impacted campsites can be ineffective unless recurring enforcement is possible and clearly communicated alternatives are provided. Little recovery will occur unless nearly all overnight and day use is removed, and visitors have frequently created new campsites with the same or greater aggregate impact in nearby areas (Cole and Ranz 1983, Therrell et al. 2006). As previously noted, relocating a formal trail away from an area where a cluster of campsites must be closed can be an effective action. Generally, closures of high-impact areas and sites are warranted only when use is shifted from impact-susceptible locations to impact-resistant locations that constrain site expansion and proliferation, although social considerations (crowding, conflict, or visitor safety) may also provide justification (Cole and Ranz 1983). Successful closure of the old sites can be enhanced by making the new sites more attractive (e.g., improved tent sites), creating and/or signing an access trail, conducting site ruination and naturalization work on the old sites, and temporarily signing them as closed to overnight and day use.

Substantial restoration work on recently closed sites is best avoided until staff can confirm that closure actions have effectively halted nearly all use; continued trampling can quickly negate staff-intensive restoration work and expensive plant stock (Therrell et al. 2006). Applying an incremental or phased process is often the most pragmatic approach. *Phase 1* activity might include efficient naturalization work, such as dragging large woody debris and spreading organic litter across the site (Reid and Marion 2004). When possible, a few larger rocks and partially rotted logs placed across tenting areas or felling large dead trees across the site are even more helpful. The objective is to naturalize and hide the site, and to obstruct tenting with logs or rocks that are not easily moved. Monitoring the efficacy of this work, particularly after busy or peak use weekends is helpful, with reapplication to quickly restore sites that are reused.

If Phase 1 work is ineffective, then more intensive *Phase 2* work is necessary, including actions such as encircling the site with nylon cord as symbolic fencing to deter entry, posting temporary site closure signs, and ice-berging large rocks or digging shallow depressions and mounding soil in the tenting areas. Felling or moving large trees onto the site is also effective if that was not done in Phase 1. Although most commonly applied to restore closed campsites, some of these techniques can also be used on open campsites to close unnecessary portions to reduce their size (Marion and Sober 1987). Discussing the closures with visitors and providing educational messages that convey compelling reasons for the closures can also be helpful. Enhanced visitor patrols, contact, and enforcement activity of site closures may also be necessary for particularly challenging areas.

If sites are effectively closed by the activities described above, then managers may elect to allow natural unassisted recovery to occur over time (Therrell et al. 2006). Recovery rates are dependent on many factors, including length of growing season, soil texture, fertility, moisture, sunlight penetration, elevation, and size of the disturbed area and severity of disturbance (Reid and Marion 2004, Cole 2013b). For example, recovery rates on large highly impacted campsites can require decades in subalpine and alpine ecosystems because of the low rates of plant establishment and growth (Zabinski et al. 2002, Scherrer and Pickering 2006, Willard et al. 2007, Cole 2013b). In contrast, Marion and Cole (1996) found substantial vegetative recovery of moderately impacted campsites over 5 years in a Pennsylvania riparian floodplain.

Phase 3 work that involves expensive or time-consuming modifications to substrates and vegetative plantings is generally deferred until a site has been effectively closed to visitor use (Therrell et al. 2006). In open settings the most efficient practice is to seed grasses, using locally obtained pure sources of native species. Agricultural extension specialists can be contacted to locate companies in the region that provide weed-free sources of native grasses, or they could be collected within the protected area from similar environmental settings. Forbs and woody shrubs and trees can also be transplanted from adjacent areas or they are often cultivated in a greenhouse from local native stock and planted to speed recovery on closed campsites. Soil amendments, including a variety of organic materials, can be added to retain soil moisture and improve soil fertility (Therrell et al. 2006). Therrell and others (2006) and Hanbey (1992) provide more comprehensive guidance of restoration planning, guidance, and methods.

Several recent studies have evaluated the efficacy of various restoration treatments designed to accelerate recovery processes. Cole (2013b) assessed recovery over 15 years on six wilderness campsites in Oregon's Eagle Cap Wilderness, finding virtually no vegetation cover on campsite plots that received no restoration treatments (i.e., unassisted natural recovery). Treatments included soil scarification to 15 cm followed by application of several types of organic mulches and locally collected vegetative transplants or seeds. After 3 years about 85% of the transplants had survived, and their growth and cover were significantly greater on plots with organic and compost amendments than on scarified plots. Scarification improved the establishment of volunteer seedlings, but seedling density on seeded plots was more than 5 times higher. A treatment with organic matter and compost soil increased seedling survival during hot, dry periods and enhanced seedling growth; supplemental watering was also critical during the germination period of the first growing season.

Continued assessments over an additional 12 years found that scarification alone yielded plots with only 4% vegetation cover, whereas plots receiving the most effective treatment (scarification, organic and compost amendments, and transplants) had 28% cover compared with 50% in adjacent undisturbed control plots (Cole and Spildie 2007, Cole 2013b). The authors note that study treatments were not very effective for restoring native plant composition; graminoids comprised 69% of the vegetative cover on closed campsites but only 26% on control plots. A similar study was conducted in Idaho's Sawtooth Wilderness, finding that staff-intensive restoration work can reduce recovery times from more than 100 years to several decades (Cole et al. 2012). This study demonstrated the benefits of using larger transplants, fertilization, and watering during dry periods for the initial years.

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