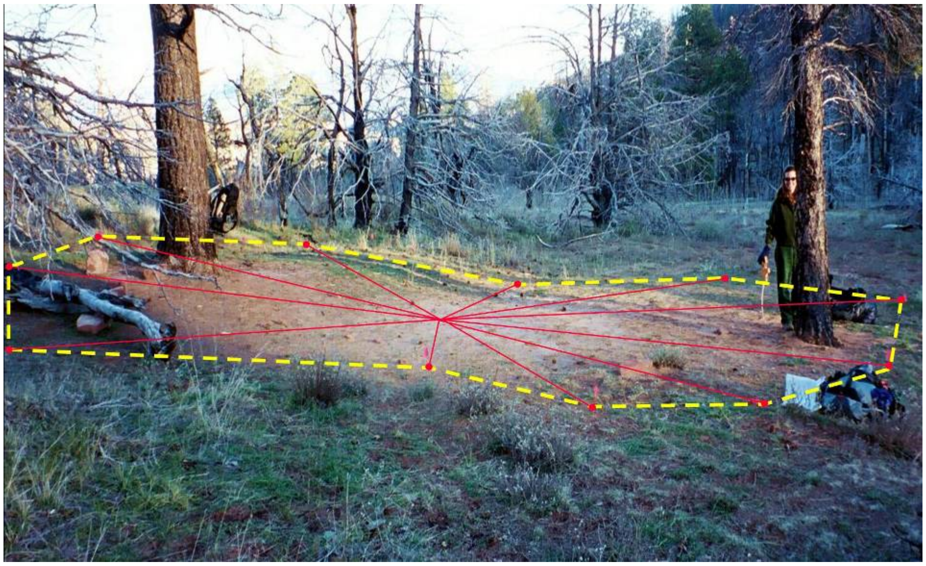
RESEARCH REPORT

TRAIL AND CAMPSITE MONITORING PROTOCOLS: ZION NATIONAL PARK



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Patuxent Wildlife Research Center
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Jeffrey L. Marion
Unit Leader/Adjunct Professor
Virginia Tech Field Unit
USGS Patuxent Wildlife Research Center
Virginia Tech/Forestry (0324)
Blacksburg, VA 24061

Karen Hockett
Research Associate
Virginia Tech/Forestry (0324)
Blacksburg, VA 24061

USGS science for a changing world

Zion National Park
Springdale, UT 84767

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INTRODUCTION

The National Park Service (NPS) accommodates nearly 300 million visitors per year, visitation that presents managers with substantial challenges at some 391 park units and 84 million acres. Such high visitation inevitably contributes negative effects or “impacts” to fragile natural and cultural resources. Resource impacts can degrade natural conditions and processes and the quality of recreation experiences. According to the 1916 Organic Act, the NPS mandate is: “to conserve the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations." However, what might appear to be dual mandates, visitation and resource protection, are clarified in the NPS *Management Policies* to reveal the primacy of resource protection. The *Management Policies* acknowledge that some resource degradation is an inevitable consequence of visitation, but directs managers to “ensure that any adverse impacts are the minimum necessary, unavoidable, cannot be further mitigated, and do not constitute impairment or derogation of park resources and values” (NPS 2006).

The high visitation and increasing popularity of the national park system presents substantial challenges to park managers. Visitation may cause unacceptable impacts to fragile natural and cultural resources, and may cause crowding and other social impacts that can degrade the quality of visitor experiences. How many visitors can ultimately be accommodated in a park and how much resource and social impact should be allowed? These and related questions are commonly referred to as carrying capacity (Manning 2007, Shelby & Heberlein 1986).

Zion National Park is a good example of these issues because it receives high visitation and contains significant natural and cultural resources. The park draws increasing numbers of visitors that could result in significant resource and social impacts. How much and what types of visitor use can ultimately be accommodated in Zion National Park and how can managers avoid or minimize these impacts?

Visitor Experience & Resource Protection

The National Park Service has developed a planning and management decision-making framework titled Visitor Experience and Resource Protection (VERP) for addressing carrying capacity issues and management (National Park Service 1997). As the name suggests, this framework provides park managers with a defensible process for protecting natural and cultural resources while maintaining the quality of visitor experiences. VERP is built upon the same basic principles and concepts that drive other contemporary planning and management decision-making frameworks often applied to address carrying capacity, including the Limits of Acceptable Change (Stankey *et al.*1985).

VERP contains several critical steps that can be supported by research. The first is collecting baseline data on visitor use and associated resource and social impacts. How many and what types of visitor uses are occurring, and what resource and social impacts are associated with these uses? The second step is identification of indicators and standards of quality for natural/cultural resources and the visitor experience. Indicators are measurable, manageable variables that help define the quality of natural or cultural resources and the visitor experience. Standards of quality define the minimum acceptable condition of indicator variables. The third step is periodic monitoring of indicator conditions. When monitoring demonstrates that indicator values (resource or social conditions) are no longer within acceptable standards, one or more corrective management actions must be implemented. The fourth step is selecting and implementing management actions. Management actions could include educational, site management, or regulatory actions, and should be both effective and appropriate given the zone within which they are applied.

VERP was initially applied to Arches National Park as a test case and a model for other units of the national park system (Hof *et al.* 1994, Manning *et al.* 1995). This application resulted in a management plan that has been implemented (National Park Service 1995). A second application of VERP resulted in a plan for managing the carriage road system at Acadia Natural Park (Manning *et al.* 1998) and VERP has since been applied at many other units of the national park system.

Study Objectives

The purpose of this study is to gather information to support implementation of the VERP framework for Zion National Park's backcountry resources. In particular, study objectives will focus on the four elements of the VERP framework that can benefit the most from empirical data: 1) collecting baseline data on visitation-related resource impacts, 2) identifying indicators and standards of quality, 3) monitoring indicator variables, and 4) management of visitor use to ensure that the standards of quality are maintained. Specific study objectives are as follows:

1. Determine baseline conditions of visitor-use associated resource impacts - data will be gathered to characterize and monitor trail and campsite degradation.

2. Identify indicators and standards of quality. Data will be gathered and summarized to assist managers in identifying indicators and standards of quality for trail and campsite conditions.

3. Management implications of the research findings related to the selection of effective management actions for avoiding or minimizing trail and campsite impacts will be described.

JUSTIFICATION FOR MONITORING

Monitoring is an essential element of decision-making and management using the VERP framework. However, sustaining any type of long-term natural resource monitoring program over time can be exceptionally challenging for agencies due to changing personnel, management priorities, and budgets. This section supports implementation of a visitor impact monitoring program by reviewing relevant legislative mandates, management policies and guidelines, carrying capacity directives, visitor perceptions of recreation resource conditions, and monitoring program capabilities. These reviews provide information intended to assist managers in justifying implementation of park visitor impact monitoring programs and to enlist organizational support for sustaining such programs over time.

Legislative mandates challenge managers to develop and implement management policies, strategies, and actions that permit visitor use without compromising ecological and aesthetic integrity. Furthermore, managers are frequently forced to engage in this balancing act under the close scrutiny of the public, competing interest groups, and the courts. Managers can no longer afford a wait-and-see attitude or rely on subjective impressions of deterioration in resource conditions. Professional land management increasingly requires the collection and use of scientifically valid research and monitoring data. Such data should describe the nature and severity of visitor impacts and the relationships between controlling visitor use and biophysical factors. These relationships are complex and not always intuitive. A reliable information base is therefore essential to managers seeking to develop, implement, and gauge the success of visitor and resource management programs.

Although numerous reasons for implementing a visitor impact monitoring program are described in the following sections, the actual value of these programs is entirely dependent upon the park staff who manage them. Programs developed with little regard to data quality assurance or operated in isolation from resource protection decision-making will be short-lived. In contrast, programs that provide managers with relevant and reliable information necessary for developing and evaluating resource protection actions can be of significant value. Only through the development and implementation of professionally managed and scientifically defensible monitoring programs can we hope to provide legitimate answers to the question, "Are we loving our parks to death?"

Legislative Mandates

Current legislation and agency documents establish mandates for monitoring (Marion 1991). Recent legislative mandates allow managers more latitude to make proactive decisions that can be defended in court if necessary. Managers who make proactive decisions should be prepared to prove the viability of their strategies, or risk public disapproval or even legal action against the agency. Survey and monitoring programs provide the means for such demonstrations.

Agency Organic Act

The National Park Service Organic Act of 1916 (16 *United States Code* (USC) 1) established the Service, directing it to:

> "promote and regulate the use…[of parks]…to conserve the scenery and the natural and historic objects and the wildlife therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations."

These provisions were supplemented and clarified by the Congress through enactment of the General Authorities Act in 1970, and through a 1978 amendment expanding Redwood National Park (16 USC 1a-1):

> "the protection, management, and administration of these areas shall be conducted in light of the high public value and integrity of the National Park System and shall not be exercised in derogation of the values and purposes for which these various areas have been established…"

Congress intended park visitation to be contingent upon the National Park Service's ability to preserve park environments in an unimpaired condition. However, unimpaired does not mean unaltered or unchanged. Any recreational activity, no matter how infrequent, will cause changes or impacts lasting for some period of time. What constitutes an impaired resource is ultimately a management decision, a judgment. The Organic Act's mandate presents the agency with a management challenge since research demonstrates that resources are inevitably changed by recreational activities, even with infrequent recreation by conscientious visitors (Cole 1982 1995, Leung & Marion 2000). If interpreted overly strictly, the legal mandate of unimpaired preservation may not be achievable, yet it provides a useful goal for managers in balancing these two competing objectives.

External Mandating Documents

Several external documents also guide NPS management practices. Relevant external documents include the Wilderness Act of 1964 (PL. 88-577) and the National Environmental Policy Act of 1969 (42 USC 4321 et seq). For example, Congress intended the Wilderness Act to overlay park designation to protect roadless park areas singled out for exceptional ecological or social values. Parks with Wilderness designations are managed with additional protections of their natural resources, processes, and wilderness experiences.

Wilderness, as defined in the Wilderness Act of 1964 (16 USC 1131-1136), is:

> "an area where the earth and its community of life are untrammeled by man . . . which is protected and managed so as to preserve its natural conditions and which generally appears to have been affected primarily by the forces of nature, with the imprint of man's work substantially unnoticeable. . . ."

The Wilderness Act established the same use and preservation management paradox implied by the NPS Organic Act. Wilderness areas:

> "shall be administered for the use and enjoyment of the American people in such manner as will leave them unimpaired for future use and enjoyment as wilderness and so as to provide for the protection of these areas, the preservation of their wilderness character, and for the gathering and dissemination of information regarding their use and enjoyment as wilderness. . . ."

The National Environmental Policy Act of 1969 (42 USC 4321 *et seq*) directs federal agencies to use all practicable means to "attain the widest range of beneficial uses of the environment without degradation, risk to health or safety, or other undesirable and unintended consequences. . . ." Title I of the act requires that federal agencies "monitor, evaluate, and control on a continuing basis their agency's activities so as to protect and enhance the quality of the environment." This amendment also directs agencies to "promote the development and use of indices and monitoring systems to assess environmental conditions and trends, to predict the environmental impact of proposed public and private actions and to determine the effectiveness of programs for protecting and enhancing environmental quality."

More recently, the National Parks Omnibus Management Act of 1998 established a framework for fully integrating natural resource monitoring and other science activities into the management processes of the National Park System. The Act charges the Secretary of the Interior to:

> "develop a program of inventory and monitoring of National Park System resources to establish baseline information and to provide information on the long-term trends in the condition of National Park System resources."

Congress reinforced the message of the National Parks Omnibus Management Act of 1998 in its text of the FY 2000 Appropriations bill:

> "A major part of protecting [park] resources is knowing what they are, where they are, how they interact with their environment and what condition they are in. This involves a serious commitment from the leadership of the National Park Service to insist that the superintendents carry out a systematic, consistent, professional inventory and monitoring program, along with other scientific activities, that is regularly updated to ensure that the Service makes sound resource decisions based on sound scientific data."

Management Policies and Guidelines

Authority to implement congressional legislation is delegated to agencies, which identify and interpret all relevant laws and formulate administrative policies to guide their implementation. A document titled *Management Policies 2006* (NPS 2006) describes these policies to provide more specific direction to management decision-making. For example, relative to the need for balancing visitor use and resource impacts, the NPS *Management Policies* state that:

> “The fundamental purpose of the national park system, established by the Organic Act and reaffirmed by the General Authorities Act, as amended, begins with a mandate to conserve park resources and values. This mandate is independent of the separate prohibition on impairment and applies all the time with respect to all park resources and values, even when there is no risk that any park resources or values may be impaired. NPS managers must always seek ways to avoid, or to minimize to the greatest extent practicable, adverse impacts on park resources and values. However, the laws do give the Service the management discretion to allow impacts to park resources and values when necessary and appropriate to fulfill the purposes of a park, so long as the impact does not constitute impairment of the affected resources and values.
>
> The fundamental purpose of all parks also includes providing for the enjoyment of park resources and values by the people of the United States. The enjoyment that is contemplated by the statute is broad; it is the enjoyment of all the people of the United States and includes enjoyment both by people who visit parks and by those who appreciate them from afar. It also

includes deriving benefit (including scientific knowledge) and inspiration from parks, as well as other forms of enjoyment and inspiration. Congress, recognizing that the enjoyment by future generations of the national parks can be ensured only if the superb quality of park resources and values is left unimpaired, has provided that when there is a conflict between conserving resources and values and providing for enjoyment of them, conservation is to be predominant. This is how courts have consistently interpreted the Organic Act. (*Section 1.4.3*)

The impairment that is prohibited by the Organic Act and the General Authorities Act is an impact that, in the professional judgment of the responsible NPS manager, would harm the integrity of park resources or values, including the opportunities that otherwise would be present for the enjoyment of those resources or values. Whether an impact meets this definition depends on the particular resources and values that would be affected; the severity, duration, and timing of the impact; the direct and indirect effects of the impact; and the cumulative effects of the impact in question and other impacts.

An impact to any park resource or value may, but does not necessarily, constitute an impairment. An impact would be more likely to constitute impairment to the extent that it affects a resource or value whose conservation is

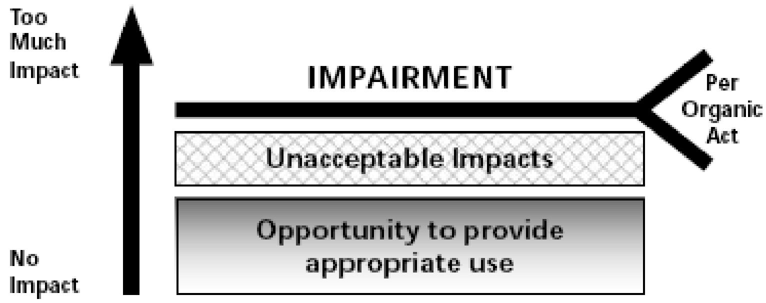
- necessary to fulfill specific purposes identified in the establishing legislation or proclamation of the park, or
- key to the natural or cultural integrity of the park or to opportunities for enjoyment of the park, or
- identified in the park's general management plan or other relevant NPS planning documents as being of significance.

An impact would be less likely to constitute an impairment if it is an unavoidable result of an action necessary to preserve or restore the integrity of park resources or values and it cannot be further mitigated. (*Section 1.4.5*)

The impact threshold at which impairment occurs is not always readily apparent. Therefore, the Service will apply a standard that offers greater assurance that impairment will not occur. The Service will do this by avoiding impacts that it determines to be unacceptable. These are impacts that fall short of impairment, but are still not acceptable within a particular park's environment. Park managers must not allow uses that would cause unacceptable impacts; they must evaluate existing or proposed uses and determine whether the associated impacts on park resources and values are acceptable.

Virtually every form of human activity that takes place within a park has some degree of effect on park resources or values, but that does not mean the impact is unacceptable or that a particular use must be disallowed. Therefore, for the purposes of these policies, unacceptable impacts are impacts that, individually or cumulatively, would

- be inconsistent with a park's purposes or values, or
- impede the attainment of a park's desired future conditions for natural and cultural resources as identified through the park's planning process, or
- create an unsafe or unhealthful environment for visitors or employees, or
- diminish opportunities for current or future generations to enjoy, learn about, or be inspired by park resources or values, or
- unreasonably interfere with
  - park programs or activities, or
  - an appropriate use, or
  - the atmosphere of peace and tranquility, or the natural soundscape maintained in wilderness and natural, historic, or commemorative locations within the park.



(*Section 1.4.7.1*)

> The fact that a park use may have an impact does not necessarily mean it will be unacceptable or impair park resources or values for the enjoyment of future generations. Impacts may affect park resources or values and still be within the limits of the discretionary authority conferred by the Organic Act. In these situations, the Service will ensure that the impacts are unavoidable and cannot be further mitigated. Even when they fall far short of impairment, unacceptable impacts can rapidly lead to impairment and must be avoided. For this reason, the Service will not knowingly authorize a park use that would cause unacceptable impacts.
>
> When a use is mandated by law but causes unacceptable impacts on park resources or values, the Service will take appropriate management actions to avoid or mitigate the adverse effects. When a use is authorized by law but not mandated, and when the use may cause unacceptable impacts on park resources or values, the Service will avoid or mitigate the impacts to the point where there will be no unacceptable impacts; or, if necessary, the Service will deny a proposed activity or eliminate an existing activity. (*Section 8.1.1*)
>
> Superintendents must continually monitor and examine all park uses to ensure that unanticipated and unacceptable impacts do not occur. Superintendents should also be attentive to existing and emerging technologies that might further reduce or eliminate impacts from existing uses allowed in parks.
>
> The National Park Service will always consider allowing activities that are appropriate to the parks, although conditions may preclude certain activities or require that limitations be placed on them. In all cases, impacts from park uses must be avoided, minimized, or mitigated through one or more of the following methods:
>
> - visitor education and civic engagement
> - temporal, spatial, or numerical limitations on the use
> - the application of best available technology
> - the application of adaptive management techniques
>
> If, in monitoring a park use, unanticipated impacts become apparent, the superintendent must further manage or constrain the use to minimize the impacts, or discontinue the use if the impacts are unacceptable.” (*Section 8.1.2*)

Thus, relative to visitor use, park managers must evaluate the types and extents of resource impacts associated with recreational activities, and determine to what extent they are unacceptable and constitute impairment. Further, managers must seek to avoid or limit any form of resource impact, including those judged to fall short of impairment. Visitor impact monitoring programs can assist managers in making objective evaluations of impact acceptability and impairment and in selecting effective impact management practices by providing quantitative documentation of the types and extent of recreation-related impacts to natural resources. Monitoring programs are also explicitly authorized in Section 4.1 of the Management Policies:

> "Natural systems in the national park system, and the human influences upon them, will be monitored to detect change. The Service will evaluate possible causes and effects of changes that might cause impacts on park resources and values. The Service will use the results of monitoring and research to understand the detected change and to develop appropriate management actions. (*Section 4.1*)
>
> Similarly, planning for park operations, development, and management activities that might affect natural resources will be guided by high-quality, scientifically acceptable information, data, and impact assessment. Where existing information is inadequate, the collection of new information and data may be required before decision-making. Long-term research or monitoring may also be necessary to correctly understand the effects of management actions on natural resources whose function and significance are not clearly understood. (*Section 4.1.1*)
>
> The Service will:
>
> - identify, acquire, and interpret needed inventory, monitoring, and research, including applicable traditional knowledge, to obtain information and data that will help park managers accomplish park management objectives provided for in law and planning documents;
> - define, assemble, and synthesize comprehensive baseline inventory data describing the natural resources under NPS stewardship, and identify the processes that influence those resources;
> - use qualitative and quantitative techniques to monitor key aspects of resources and processes at regular intervals;
> - analyze the resulting information to detect or predict changes (including interrelationships with visitor carrying capacities) that may require management intervention and provide reference points for comparison with other environments and time frames; and
> - use the resulting information to maintain – and where necessary restore – the integrity of natural systems." (*Section 4.2.1*).

The NPS has implemented a strategy designed to institutionalize natural resource inventory and monitoring on a programmatic basis throughout the agency. A servicewide Inventory and Monitoring Program ensures that the approximately 270 park units with significant natural resources possess the resource information needed for effective, science-based managerial decision-making and resource protection. A key component of this effort, known as Park Vital Signs Monitoring, is the organization of park units into 32 monitoring regional networks to conduct long-term monitoring for key indicators of change, or "vital signs." Vital signs are measurable, early warning signals that indicate changes that could impair the long-term health of natural systems. Early detection of potential problems allows park managers to take steps to restore ecological health of park resources before serious damage can happen. For additional information see: *http://science.nature.nps.gov/im/monitor/index.htm*.

Carrying Capacity Decision-making

Decisions regarding impact acceptability and the selection of actions needed to prevent resource impairment frequently fall into the domain of carrying capacity decision-making. The 1978 National Parks and Recreation Act (P.L. 95-625) requires the NPS to evaluate carrying capacities for each park and/or zone as part of the process of developing a general management plan. Specifically, amendments to Public Law 91-383 (84 Stat. 824, 1970) require general management plans developed for national park units to include "identification of and implementation commitments for visitor carrying capacities for all areas of the unit" and determination of whether park visitation patterns are consistent with social and ecological carrying capacities.

The NPS defines carrying capacity as "the type and level of visitor use that can be accommodated while sustaining the desired resource and visitor experience conditions in the park" (NPS 2006). Carrying capacity addresses issues related to the amount of visitation that parks can accommodate and the acceptability of associated degradation to resource and social conditions (Manning 2007, Stankey & Manning 1986, Shelby & Heberlein 1986, Graefe *et al.* 1984). The U.S. Forest Service addressed carrying capacity issues in wilderness areas by developing a planning and management decision-making framework known as the Limits of Acceptable Change (LAC) (Stankey *et al.* 1985). The NPS developed a similar framework, Visitor Experience and Resource Protection (VERP) (see Figure 1), designed to guide decisions needed to protect park natural and cultural resources while maintaining the quality of the visitor experiences (NPS 1997).

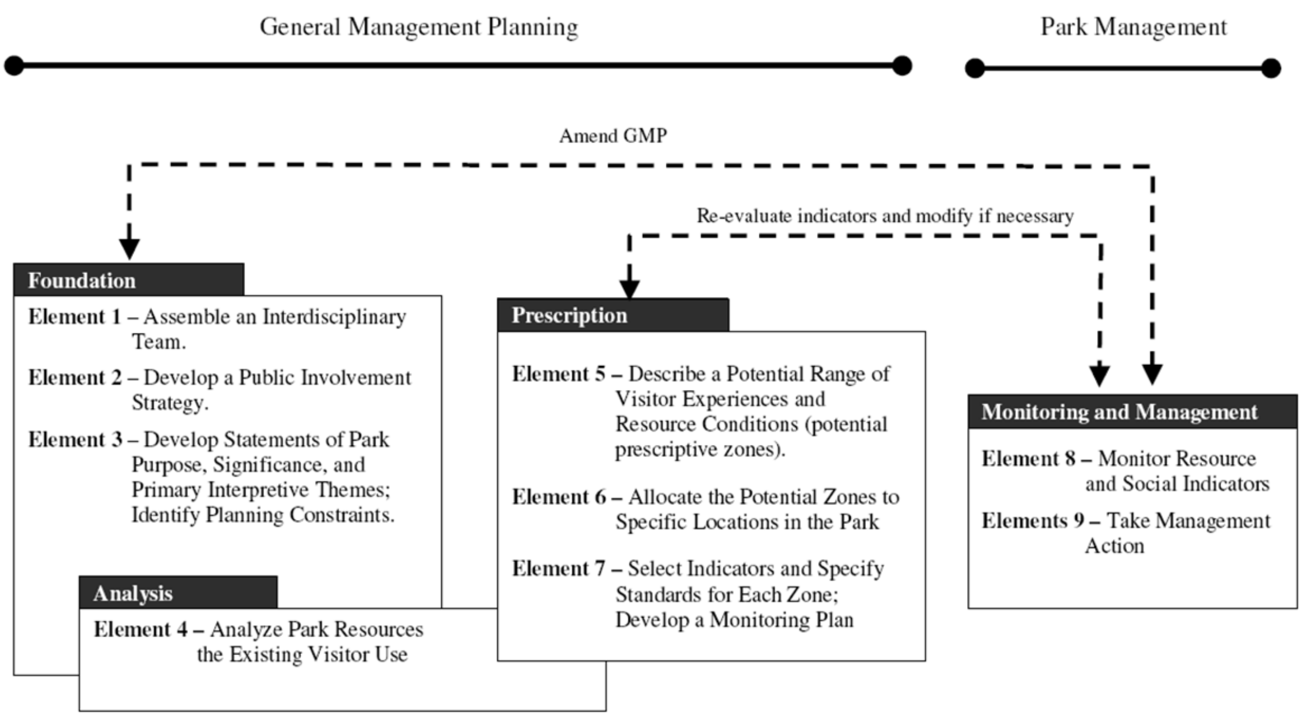


Figure 1. The NPS Visitor Experience and Resource Protection framework used to address carrying capacity decision-making.

The NPS fulfills its legal mandate to address carrying capacity by incorporating VERP Elements 1-7 into its General Management Planning process, Elements 8 and 9 are included in ongoing park management. Research such as this study can assist managers with many elements of the

VERP process. During the planning phase Element 4 requires an analysis of park resources and visitor uses. Assessments of visitor-related resource impacts can document baseline conditions for trails, recreation sites, and campsites and reveal the distribution of various types of visitor uses. These data can also provide partial input to the development of realistic resource condition prescriptions and their allocation through zoning to specific park locations (VERP Elements 5 & 6). Comprehensive assessments of visitor impacts can serve as a core source for selecting appropriate indicators and as a filter for identifying realistic standards. For example, preliminary indicator standards can be compared with baseline data to determine if current conditions exceed proposed standards and if so, to identify the specific locations so that decision makers could visit these sites to judge if they are appropriate.

Visitor impact monitoring programs provide an essential component of such efforts. VERP and other similar frameworks (e.g., Limits of Acceptable Change), evolved from, and have largely replaced, management approaches based on the more traditional carrying capacity model (Marion *et al.* 1985). Under these newer frameworks, numerical standards are set for individual biophysical or social condition indicators. These limits define the critical boundary line between acceptable and unacceptable conditions, establishing a measurable reference point against which future conditions can be compared through periodic monitoring. According to NPS *Management Policies* (2006):

> “Visitor carrying capacity is the type and level of visitor use that can be accommodated while sustaining the desired resource and visitor experience conditions in the park. By identifying and staying within carrying capacities, superintendents can manage park uses that may unacceptably impact the resources and values for which the parks were established. Superintendents will identify visitor carrying capacities for managing public use. Superintendents will also identify ways to monitor for and address unacceptable impacts on park resources and visitor experiences.
>
> When making decisions about carrying capacity, superintendents must use the best available natural and social science and other information, and maintain a comprehensive administrative record relating to their decisions. The decision-making process should be based on desired resource conditions and visitor experiences for the area, quality indicators and standards that define the desired resource conditions and visitor experiences, and other factors that will lead to logical conclusions and the protection of park resources and values. The level of analysis necessary to make decisions about carrying capacities is commensurate with the potential impacts or consequences of the decisions. The greater the potential for significant impacts or consequences on park resources and values or the opportunities to enjoy them, the greater the level of study and analysis and civic engagement needed to support the decisions.
>
> The planning process will determine the desired resource and visitor experience conditions that are the foundation for carrying capacity analysis and decision-making. If the time frame for making decisions is insufficient to allow the application of a carrying capacity planning process, superintendents must make decisions based on the best available science, public input, and other information. In either case, such planning must be accompanied by appropriate environmental impact analysis, in accordance with Director’s Order #12.
>
> As park use changes over time, superintendents must continue to decide if management actions are needed to keep use at sustainable levels and prevent unacceptable impacts. If indicators and standards have been prescribed for an impact, the acceptable level is the prescribed standard. If indicators and standards do not exist, the superintendent must determine how much impact is acceptable before management intervention is required. (*Section 8.2.1*)

Visitor Perceptions of Resource Conditions

Visitors to wildland environments are aware of resource conditions along trails and at campsites, just as are managers (Lucas 1979, Marion & Lime 1986, Vaske *et al.* 1982). Legislative mandates set high standards when they direct managers to keep protected natural areas "unimpaired" and human impacts "substantially unnoticeable." Seeing trails and campsites, particularly those in degraded condition, reminds visitors that others have preceded them. In remote areas even the presence of trails and campsites reduce perceived naturalness and can diminish opportunities for solitude. In accessible and popular areas the proliferation and deterioration of trails, recreation sites, and campsites present a "soiled" or "used" appearance, in contrast to the ideal of a pristine natural environment (Leung & Marion 2000).

Degraded resource conditions on trails and campsites can have significant utilitarian, safety, and experiential consequences for visitors (Leung & Marion 2000). Trails serve a vital transportation function in protected natural areas and their degradation greatly diminishes their utility for visitors and land managers. For example, excessive tread erosion or muddiness can render trails difficult and unpleasant to use. Such conditions can also threaten visitor or packstock safety and prevent or slow rescues, possibly increasing agency liability. Impacts associated with certain types of uses, such as linear rutting from bikes or vehicles or muddy hoof prints from horses, can also exacerbate conflicts between recreationists.

Visitors spend most of their time within protected natural areas on trails and campsites, so their perceptions of the area and its naturalness are strongly influenced by trail and site conditions. Visitors are sensitive to overt effects of other visitors (such as the occurrence of litter, horse manure, malicious damage to vegetation) and to visually obtrusive examples of impacts such as tree root exposure, tree felling, and soil erosion. A survey of visitors to four wilderness areas, three in southeastern states and another in Montana, found that littering and human damage to campsite trees were among the most highly rated indicators affecting the quality of recreational experiences (Roggenbuck *et al.* 1993). Amount of vegetation loss and exposed soil around a campsite were rated as more important than many social indicators, including number of people seen while hiking and encounters with other groups at campsites. Hollenhorst and Gardner (1994) also found vegetation loss and bare ground on campsites to be important determinants of satisfaction by wilderness visitors.

Monitoring Program Capabilities

Visitor impact monitoring programs can be of significant value when providing managers with reliable information necessary for establishing and evaluating resource protection policies, strategies, and actions. When implemented properly and with periodic reassessments, these programs produce a database with significant benefits to protected area managers (Figure 2). Data from the first application of impact assessment methods developed for a long-term monitoring program can objectively document the types and extent of recreation-related resource impacts. Such work also provides information needed to select appropriate biophysical indicators and formulate realistic standards, as required in VERP or LAC planning and decision-making frameworks.

Reapplication of impact assessment protocols as part of a monitoring program provides an essential mechanism for periodically evaluating resource conditions in relation to standards. Visitor impact monitoring programs provide an objective record of impacts, even though individual managers come and go. A monitoring program can identify and evaluate trends when data are compared between present and past resource assessments. It may detect deteriorating conditions before severe or irreversible changes occur, allowing time to implement corrective actions. Analysis of monitoring data can reveal insights into relationships with causal or non-causal yet influential factors. For example, the trampling and loss of vegetation may be greatly reduced by shifting campsites or trails to more resistant and resilient vegetation types instead of more contentious limitations on use. Following the implementation of corrective actions, monitoring programs can evaluate their efficacy.

- Identify and quantify site-specific resource impacts.
- Summarize impacts by environmental or use-related factors to evaluate relationships.
- Aid in setting and monitoring management standards for resource conditions.
- Evaluate deterioration to suggest potential causes and effective management actions.
- Evaluate the effectiveness of resource protection measures.
- Identify and assign priorities to maintenance needs.

Figure 2. Capabilities of visitor impact monitoring programs.

LITERATURE REVIEW

Two primary issues associated with the development of a visitor impact monitoring program are the selection of indicators that will be monitored and their assessment procedures. Criteria for selecting indicators of change related to campsites and trails are reviewed and prospective indicators and measurement units are presented. Common campsite and trail impact assessment procedures are also reviewed.

Visitation-Related Resource Impacts

Visitors participating in a diverse array of recreation activities, including hiking, camping, climbing, and wildlife viewing, contribute to an equally diverse array of effects on protected natural areas resources, including vegetation, soils, water, and wildlife. The term *impact* is commonly used to denote any undesirable visitor-related change in these resources. This study was restricted to assessments of trampling-related impacts to vegetation and soil along trails and at campsites.

Trail Impacts

Resource impacts associated with trampling on trails include an array of direct and indirect problems (Table 1). Even light traffic can remove protective layers of vegetation cover and organic litter (Cole 2004, Leung & Marion 1996). Trampling disturbance can alter the appearance and composition of trailside vegetation by reducing vegetation height and favoring trampling resistant species. The loss of tree and shrub cover can increase sunlight exposure, which promotes further changes in composition by favoring shade-intolerant plant species (Hammitt & Cole 1998, Leung & Marion 2000). Visitors can also introduce and transport non-native plant species along trail corridors, some of which may out-compete undisturbed native vegetation and migrate away from trails (Cole 1987).

Table 1. Direct and indirect effects of recreational trampling on soils and vegetation.

Effects	Vegetation	Soil
Direct	Reduced height/vigor	Loss of organic litter
	Loss of ground vegetation, shrubs and trees	Soil exposure and compaction
	Introduction of non-native vegetation	Soil erosion
Indirect	Altered composition – shift to trampling resistant or non-native species	Reduced soil pore space and moisture, increased soil temperature
	Altered microclimate	Increased water runoff
		Reduced soil fauna

The exposure of soil on unsurfaced trails can lead to soil compaction, muddiness, erosion, and trail widening (Hammitt & Cole 1998, Leung & Marion 1996, Tyser & Worley 1992). The compaction of soils decreases soil pore space and water infiltration, which in turn increases muddiness, water runoff and soil erosion. The erosion of soils along trails exposes rocks and plant roots, creating a rutted, uneven tread surface. Eroded soils may smother vegetation or find their way into water bodies, increasing water turbidity and sedimentation impacts to aquatic organisms (Fritz 1993). Visitors seeking to circumvent muddy or badly eroded sections contribute to tread widening and creation of parallel secondary treads, which expand vegetation loss and the aggregate area of trampling disturbance (Marion 1994, Liddle & Greig-Smith 1975). The creation and use of trails can also directly degrade and fragment wildlife habitats, and the presence of trail users may disrupt essential wildlife activities such as feeding, reproduction and the raising of young (Knight & Cole 1995).

Trails are generally regarded as an essential facility in protected natural areas, providing access to unroaded areas, offering recreational opportunities, and protecting resources by concentrating visitor traffic on resistant tread surfaces (Marion & Leung 2001). Unfortunately, many trails are not properly located, constructed or maintained to sustain their intended uses. Preventing their degradation from recreational uses and natural processes such as rainfall and water runoff is often a substantial management challenge.

Formal developed trail systems rarely access all the locations that visitors want to go so the establishment of informal visitor-created trails is commonplace in heavily visited areas. Often referred to as *social* trails, their proliferation in number and expansion in length over time are perennial management concerns. Furthermore, because informal trails are not professionally designed, constructed or maintained they can contribute substantially greater impacts to protected area resources than formal trails. Many of these impacts are related to their poor design, including alignments parallel to slopes or along shorelines, multiple trails accessing the same destinations, routing through fragile vegetation, substrates, sensitive wildlife habitats, and trampling or disturbance to rare flora, fauna, or archaeological sites. These design attributes also make informal trails far more susceptible to tread impacts, including expansion in width, soil erosion, and muddiness.

Many formal trails were originally created by visitors or individuals who lacked trail design expertise or were directed by objectives in conflict with resource protection goals (Marion & Leung 2004). Poorly located formal trails thus suffer from the same design problems described for informal trails. Even well-designed and managed trails are susceptible to the many forms of degradation described in Table 1.

In summary, most trail-related resource impacts are limited to a linear corridor of disturbance, though impacts like altered surface water flow, invasive plants, and wildlife disturbance, can extend considerably further into natural landscapes (Kasworm & Monley 1990, Tyser & Worley 1992). However, even localized disturbance within trail corridors can harm rare or endangered species or damage sensitive plant communities, particularly in environments with slow recovery rates.

Campsite Impacts

Recreation sites and campsites are an additional recreation facility needed to protect resources when intensive day-use or overnight visitation is accommodated in natural settings (Leung & Marion 2004). Many campsites, even those designated by land managers, were originally selected and created by visitors. As with trails, many campsites are poorly located with respect to resource protection considerations and are thus more susceptible to the environmental impacts of visitor use activities. Most visitor use impacts are caused by trampling and are similar to those previously described for trails (see Table 1). Differences include the nodal configuration of trampling disturbance and campfire-related impacts, including tree damage, fire sites, and offsite firewood collection trampling and wood removal (Reid & Marion 2005).

Campsites can range in size from several hundred to more than 8,000 ft^2 (Marion & Cole 1996), generally more than half of which is non-vegetated and more than one-quarter has also lost most organic litter. These larger expanses of exposed soil are generally in flatter terrain, though sheet erosion can remove large amounts of soil over time. Soil erosion is a more substantial problem when campsites are located along shorelines, where eroded soil from the site and steeper shoreline access trails can drain runoff directly into waterways. Other concerns related to their large size are the loss of woody vegetation and its regeneration over time. Gaps in forest canopies caused by these sites can alter microclimates and create sunny disturbed locations that give invasive vegetation a start.

Monitoring studies often use the number of informal trails connected to campsites as an indicator of the extent of adjacent off-site vegetation trampling. These trails may be used to access the site, water, other sites, restroom or firewood gathering areas, and scenic features. Census surveys of campsites in Great Smoky Mountains and New River Gorge have shown totals of 1087 and 221 informal trails, respectively (Marion & Leung 1997, Leung & Marion 1998).

Indicators and Selection Criteria

Indicators are measurable physical, ecological, or social variables used to track trends in conditions caused by human activity so that progress toward goals and desired conditions can be assessed. An indicator is any setting element that changes in response to a process or activity of interest (Merigliano 1990). An indicator's condition provides a gauge of how recreation has changed a setting. Comparison to management objectives or indicator standards reveals the acceptability of any resource changes. Indicators provide a means for restricting information collection and analysis to the most essential elements needed to answer management questions. Examples of questions related to trails and campsites include:

Are visitors experiencing an environment where the evidence of human activity is substantially unnoticeable?

Are campsite numbers and conditions acceptable given each management zone’s objectives and desired conditions?

Are trail numbers and conditions acceptable given each management zone’s objectives and desired conditions?

Before a monitoring program can be developed, appropriate resource indicators must be selected. A single, direct measurement of a campsite's or a trail's condition is inappropriate because the overall condition is an aggregate of many biophysical components. Cole (1989b), Marion (1991) and Merigliano (1990) review criteria for the selection of indicators (Figure 3), which are summarized here. Management information needs, reflected by the management questions such as the examples above, guide the initial selection of indicators.

Preferred indicators should reflect attributes that have ecological and/or aesthetic significance. Recreational trampling sufficient to expose a campsite's soil, for example, is aesthetically unappealing and renders the site vulnerable to soil compaction and erosion. Similarly, indicator measures should primarily reflect changes caused by the recreational activity of interest. For example, measures of tree damage should exclude damage caused by lightning strikes. However, soil erosion along the shorelines of campsites may be attributable to a combination of recreation use and natural forces, suggesting it would make a poor indicator in this particular setting. Indicators should be measurable, preferably at an interval or ratio scale where the distances between numeric values are meaningful, i.e. a 36-inch wide trail is twice the width of an 18-inch wide trail. In comparison, a categorical ratings system based on subjective assessments rather than quantitative measures provides data at an ordinal scale. Distance between numeric values are not meaningful so computing an average or using them in statistical analyses or testing is not appropriate.

Criteria	**Rationale**
Quantitative	Can the indicator be measured?
Relevant	Does the indicator change as a result of the process or activity of interest?
Efficient	Can the measurements be taken by available personnel within existing time and funding constraints?
Reliable	How precise are the measurements? Will different individuals obtain similar data of the same indicator?
Responsive	Will management actions affect the indicator?
Sensitive	Does the indicator act as an early warning, alerting you to deteriorating conditions before unacceptable change occurs?
Integrative	Does the indicator reflect only its condition or is its condition related to that of other, perhaps less feasibly measured, elements?
Significant	Does the indicator reveal relevant environmental or social conditions?
Accurate	Will the measurements be close to the indicator's true condition?
Understandable	Is the indicator understandable to non-professionals?
Low Impact	Can the indicator be measured with minimal impact to the resource or the visitor's experience?

Adapted from Cole (1989b), Marion (1991), Merigliano (1990), O'Connor & Dewling (1986).

Figure 3. Criteria for selecting indicators of resource condition.

Potential indicators of resource condition are numerous and there is great variation in our ability to measure them with *accuracy*, *efficiency*, and *precision*. All assessments are approximations of an indicator's true value; a measurement method is *accurate* if it closely approximates the true value. *Efficiency* refers to the time, expertise, and equipment needed to measure the indicator's condition. Unfortunately, efficient methods often yield inconsistent results when applied by different individuals. A measurement method is *precise* if it consistently approximates a common value when applied independently by many individuals. Accurate measurements correctly describe how much change has occurred; precise measurements permit objective comparisons of change over time (Cole 1989b, Marion 1991). Indicator assessment methods should also be considered when selecting indicators. When choosing a method managers must balance accuracy and precision, for each places constraints upon efficiency and cost-effectiveness. For example, campsite condition assessments range from highly efficient but subjective evaluations (e.g., photographs or condition class ratings), to rapid assessments (ratings based on numeric categories of damaged trees), to time-consuming research-level measurements (quadrat-based vegetation loss assessments). Regardless of the method selected, comprehensive procedural manuals, staff training, and program supervision stressing quality control can improve both accuracy and precision. However, poorly managed monitoring efforts can result in measurement error that confounds data interpretation or even exceeds the magnitude of impact caused by recreational activities.

Some indicators are less appropriate than others. For example, indicators of depreciative behavior, such as tree damage, litter, and fire construction in areas were fires are banned, detract unacceptably from environmental or social conditions. Unfortunately, indicators that reflect depreciative behavior present difficulties for managers because the resource degradation is often attributable to a small number of visitors whose actions may be less responsive to traditional management actions. These, and other indicators that are temporally dynamic, are also difficult to monitor effectively. For example, the number of fire sites and extent of litter and improperly disposed human waste can vary considerably from one week or month to the next.

Preferred Indicators

From these indicator criteria and knowledge of how recreation affects soil, vegetation, and aesthetics, managers select preferred indicators. Table 2 includes a listing of commonly employed indicators for assessing conditions on trails and campsites using measurement-based approaches. Generally, a small number of indicators are selected for use in LAC or VERP frameworks. However, that does not preclude monitoring of additional indicators or from also assessing various inventory indicators. Generally, travel time to the sampling locations is the most substantial portion of the time budget so assessing a few additional indicators is negligible. A final consideration is the measurement units employed for reporting results and/or setting standards. Measurement-based approaches permit the most flexibility in this respect.

Two of the most common campsite indicators are the number or density of visitor-created campsites and site size. For soil, the area of exposed soil and number of trees with exposed roots are indicators that represent the extent of organic horizon pulverization and loss, and the compaction and erosion of the underlying soil. Many studies have also shown the extent of exposed soil to be linearly correlated with amount of use (Hammitt & Cole 1998, Marion & Merriam 1985). The area of vegetation loss is perhaps the best indicator of vegetation disturbance (Cole 1989a).

Table 2. Potential indicators of campsite and trail conditions and measurement units.

Campsite Indicators	Measurement Units
Informal Campsites	#/unit area, #/unit length along formal trails
Campsite Size	Max. value, value/unit area, aggregate value/unit area
Area of Vegetation Loss	Max. value, value/unit area, aggregate value/unit area
Area of Soil Exposure	Max. value, value/unit area, aggregate value/unit area
Damaged Trees	Max. value, value/unit area, aggregate value/unit area
Trees w/Exposed Roots	Max. value, value/unit area, aggregate value/unit area
Fire Sites	Max. value, value/unit area, aggregate value/unit area
Litter	Max. value, value/unit area, aggregate value/unit area
Human Waste	Max. value, value/unit area, aggregate value/unit area
Trail Indicators	**Measurement Units**
Informal Trails	Length/unit area, % of formal trail length, #/unit length on formal trails [PC]
Tread Width	Max. value, value/unit length, running avg./unit length [PS]
Maximum Incision	Max. value, value/unit length, running avg./unit length [PS]
Cross Sectional Area	Max. value, value/unit length, running avg./unit length [PS]
Excessive Erosion	Length/unit area, % of trail length, length/unit length along formal trails [PC]
Muddiness	Max. % of tread width, avg. %/unit length, running avg. %/unit length [PS]
Excessive Muddiness	Length/unit area, % of trail length, length/unit length along formal trails [PC]

PS = Point Sampling, PC = Problem Census

Although the dynamic nature of many aesthetic and behavioral indicators present assessment difficulties, those that have been shown to be most pertinent to management objectives and visitor concerns are often selected. These indicators include the number of trails extending from a campsite, the number of damaged trees or stumps, and the presence of litter and improperly disposed human waste. Infrequent monitoring can provide a "snapshot" of the conditions for the most dynamic indicators but more frequent monitoring is required to characterize their true condition or to reliably evaluate the effectiveness of management actions.

For trails, the number, length, and density of visitor-created trails, along with tread width, are the most commonly used indicators. Soil erosion, an ecologically significant trail impact, can be assessed at sample points by measuring maximum incision or cross sectional area. An alternative “Problem Census” method assesses the lineal extent along trails of all occurrences of erosion that exceed a pre-defined level. Similarly, tread muddiness can be assessed at sample points as a percentage of tread width or as the lineal extent along trails through a problem census approach.

In summary, managers must consider and integrate a diverse array of issues and criteria in selecting indicators for monitoring impacts on campsites. Indicators will rarely score high on all criteria requiring good judgment as well as area-specific field trials and direct experience. Indicators that score high on some criteria but low on others may be retained in some instances or omitted in others. Tradeoffs are also required, such as a necessary reduction in accuracy so that precision and efficiency may be increased.

Types of Trail Impact Assessment Systems

Formal trail surveys provide information for a number of important management needs. The location and lineal extent of formal and informal trails can be documented and monitored. The number, location and efficacy of trail maintenance features, such as water bars and drainage dips, can be assessed. Trail conditions may be assessed to identify the location, type and extent of trail resource impacts. Information on trail conditions can be used to inform the public about trail resources, justify staffing and funding, evaluate the acceptability of existing resource conditions, analyze relationships between trail impacts and contributing factors, identify and select appropriate management actions, and evaluate changes in trail conditions and the effectiveness of implemented actions.

A variety of efficient methods for evaluating trails and their resource conditions have been developed and described in the literature, as reviewed and compared by Coleman (1977), Cole (1983), and Leung and Marion (2000). At the most basic level, a trail inventory may be employed to locate and map trails and to document trail features such as type of use, segment lengths, hiking difficulty, and natural and cultural features. Trail location information can be accurately documented using a Global Positioning System (GPS) device, which can be input to a Geographic Information System (GIS) for display and analysis of trail attributes (Wolper *et al.* 1994, Wing & Shelby 1999).

Trail facility and maintenance assessments provide information on existing or needed trail maintenance features or work. These assessments may be used to develop databases on signs (e.g., location and text), existing facilities (e.g., bridges) and tread features (e.g., water bars, steps, bog bridging). Prescriptive trail maintenance work log assessments have also been developed to describe recommended solutions to existing tread deficiencies, such as installation of water bars and steps or trail rerouting (Birchard & Proudman 2000, Williams & Marion 1992). Data can be summarized to provide cost and staffing estimates and to direct work crews.

Trail condition assessments seek to describe resource conditions and impacts for the purpose of documenting trends in trail conditions, investigating relationships with influential factors, and evaluating standards or the efficacy of corrective management actions. Leung and Marion (2000) provide a classification of alternative trail impact assessment and monitoring methods. Sampling-based approaches employ either systematic point sampling, where tread assessments are conducted at a fixed interval along a trail (Cole 1983, Cole 1991), or stratified point sampling, where sampling varies in accordance with various strata such as level of use or vegetation type (Hall & Kuss 1989). Alternately, census-based approaches employ either sectional evaluations, where tread assessments are made for entire trail sections (Bratton *et al.* 1979), or problem census evaluations, where continuous assessments record every occurrence of predefined impact problems (Cole 1983, Leung & Marion 1999a, Marion 1994). These two approaches of assessment have been combined in an integrative survey (Bayfield & Lloyd 1973). More elaborate and time-consuming methods for accurately characterizing soil loss (Leonard & Whitney 1977) and vegetation changes (Hall & Kuss 1989) have also been developed.

An evaluation by Marion and Leung (2001) concluded that the point sampling method provides more accurate and precise measures of trail characteristics that are continuous or frequent (e.g., tread width or exposed soil). The problem census method is a preferred approach for monitoring trail characteristics that are easily predefined or infrequent (e.g., excessive width or secondary treads), particularly when information on the location of specific trail impact problems is needed.

Types of Campsite Impact Assessment Systems

Systems for assessing campsite conditions differ significantly in the type of information collected, assessment methods, and assessment time. Three general approaches can be been applied:

1) *Photographic systems* - based on repeat photographs from permanent photo points.
2) *Condition class systems* - based on descriptive visual criteria of general site conditions.
3) *Multi-indicator systems* - based on individual measurements and appraisals of many specific indicators of resource condition.

A brief summary of these approaches and systems follows, see Cole (1989b), Marion (1991), and Leung and Marion (2000) for more comprehensive reviews of these systems.

Photographic systems were among the first applied to document the trampling effects of visitors (Magill & Twiss 1965). Photographic methods are generally easy to establish, require little time for repeat photographs, and yield easily understandable visual records of campsite conditions. Disadvantages include poor comparability due to inconsistent photographic quality, lack of quantitative measurements for specific types of changes, and changes that are missed in areas hidden from view or not photographed. Additionally, assessment of photographic data requires extensive investment of time to handle and compare individual photographs.

Condition class systems have been described by Frissell (1978) and Marion (1991). Such systems consist of a set of statements describing increasing levels of resource change. Observers compare site conditions to these descriptive condition classes and record the class that most closely matches the conditions of the site being assessed. This type of system is easy and quick to apply and provides a useful summary measure of resource condition. However, as with photographic systems, this approach does not provide quantitative measurements of specific resource changes. Furthermore, the visual criteria used in these systems are subjective and require careful training of personnel to achieve consistent results. Perhaps most importantly, the data collected allow for only limited analysis because the differences between condition classes are not related linearly. Instead, they are ordinally related. An ordinal relationship means that a condition class 2 site is not twice as degraded as a condition class 1 site.

Multi-indicator systems are based upon independent assessments of several inventory variables and condition indicators. Several different approaches, including rapid estimation techniques as well as more objective but time-consuming measurement-based approaches have been developed. Rapid estimation rating systems designed by Parsons and MacLeod (1980), Cole (1983), and Marion (1984) consist of 6 to 10 variables, each with 3 to 5 quantitatively defined rating categories reflecting the degree of change in a particular indicator. Evaluators assign ratings to each impact parameter based on estimates or quick measures of impacts and comparison to numerically defined impact categories. Ratings, rather than the measured values, are emphasized with these rapid assessment approaches due to the generally low accuracy of the assessment procedures. Marion (1991) has refined multi-indicator systems that emphasize more accurate area measurements of campsite condition. Measurements for many indicators are completed within permanently referenced campsite boundaries, allowing substantially greater precision.

STUDY AREA

Park Description and Zones

The 148,024 acre Zion National Park (ZION) is located in Utah on the southwestern edge of the Colorado Plateau. The park is characterized by red rock cliffs and mesas, and narrow, deep sandstone slot canyons. Elevations range from 3,666 to 8,726 feet. The park contains a diverse array of nearly 800 native plants, 75 species of mammals, 271 birds, 32 reptiles and amphibians, and several federally listed rare or endangered animals. The park also contains archaeological evidence of Ancestral Puebloans (Anasazi), dating from about 2,000 years ago, and Paiutes from about 800 years ago. Park visitation for 2006 was 2,567,350.

The park is considered mostly backcountry (145,060 acres, 98%) with about 90 percent of the park recommended as wilderness. Visitors experience the backcountry by day hiking and backpacking on trails and along more challenging cross-country routes. The park's backcountry has been divided into one of four management zones (Zion NP 2007):

Pristine Zone: This 119,446 acre zone offers the feeling of being entirely alone in ZION's remote and isolated wildlands. The zone provides visitors a chance to experience a natural landscape. Use of these areas is low and group encounters infrequent.

Primitive Zone: This 16,480 acre zone provides opportunities for visitors to experience wildlands and solitude. The landscape is largely undisturbed, with natural processes predominating. However, compared to the Pristine Zone, access is easier into this zone, there are signs of people, and the area feels less remote.

Transition Zone: A portion of the Transition Zone lies within recommended wilderness and includes the Observation Point Trail, the lower Narrows from Mystery Falls upstream to Orderville Canyon and Timber Creek Overlook Trail. Encounters with other hikers would be high in these areas.

Research Natural Area Zone: This 9,031 acre zone applies the intent of the national network of "research natural areas," which are field ecological areas designated primarily for research and education and/or to maintain biological diversity. Baseline inventory and long-term ecological observations are emphasized in this zone, with the primary purpose of creating an ecological/environmental benchmark over time.

Trails and Campsites

ZION has over 90 miles of designated trails and over 90 miles of non-designated popular routes (Zion NP 2007). The park lacks funding for a trail maintenance crew, so little backcountry trail maintenance is possible, generally to address threats to visitor safety or severe resource damage. Routes accessing slot canyons are generally visitor-created and their lack of design, construction and maintenance have led to significant erosion and safety concerns in some locations.

In higher use backcountry areas camping is restricted to designated campsites to minimize resource damage and improve visitor experiences. Campsite locations, numbers, and visitor capacities for these areas include: Narrows (12 sites for 72 people), LaVerkin Creek (17 sites for 90 people), Hop Valley (3 sites for 26 people – includes 1 site for horse use), West Rim Trail (9 sites for 56 people), and Coalpits/Chinle (6 sites for up to 72 people). Some of these designated sites are located in flood hazard areas where no suitable alternative locations exist.

The majority of the park is open to at-large camping where visitors can camp in any location except:

- within 1-mile of any road,
- within ¼-mile of a spring,
- within ¼-mile of the park boundary,
- within sight of trails,
- under rock overhangs, or
- on private inholdings.

METHODS

Selection of Study Sites

The purpose of this study was to collaborate with park staff in the development of scientifically defensible yet efficient visitor impact assessment protocols for monitoring the condition of backcountry trails and campsites. These procedures were developed, field tested, refined, and applied to the following park areas, which were not intended to be "representative" of the park's backcountry:

Formal Trails (18.17 miles)	**Informal Trails** (4.64 miles)	**Formal Campsites** (n=38)
West Rim (9.67 miles)	Lower Subway (2.18 miles)	LaVerkin (n=17)
LaVerkin (4.86 miles)	Lower Coal Pits (2.46 miles)	West Rim (n=9)
Willis Creek (2.08 miles)		Narrows (n=12)
Hop Valley (1.56 miles)		

Campsite Assessment Procedures

Standardized procedures were developed, field tested and refined for assessing campsite conditions to be used in a long-term monitoring program. These procedures emphasize measurements over ratings but also incorporate condition class assessments and photographs from permanent photopoints. Photographs provide for visual comparisons of changes on individual sites over time. The field assessment manual containing detailed assessment procedures for all campsite indicators is included as Appendix 1.

Campsites were defined as areas of visually obvious vegetative or organic litter disturbance that in the judgment of survey staff was caused by overnight visitor activities. Furthermore, the disturbance had to be of such extent to produce a discernable boundary based on pronounced changes in either vegetation cover, vegetation height or trampling disturbance, vegetation composition, and/or surface organic litter (see Appendix 1 for procedures). Impact indicators were selected based on earlier recreation ecology and visitor impact perception studies, indicator selection criteria, and discussions with park staff. Campsite sizes were measured using a Variable Radial Transect method based on measurements of transect lengths and compass bearings radiating from a reference point to points selected along site boundaries (Marion 1995). Reference points were permanently marked, photographed, and referenced by compass bearings and distances to recognizable permanent features (see Appendix 1).

Conditions for most other indicators were assessed within the established boundaries for each site, with additional procedures allowing assessments of any "satellite" use areas. Fixing the area of interest within site boundaries increases the precision of assessments, however, this approach can reduce measurement accuracy. For example, counts of damaged trees and stumps conducted only within site boundaries increase the efficiency and precision of these assessments for future monitoring efforts but decrease the accuracy of assessing total or aggregate tree damage and felled trees.

Ground vegetation on campsites and in paired environmentally similar but undisturbed control sites, was assessed using six cover classes (Marion & Cole 1996). Surveyors estimated the percent of live non-woody vegetation ground cover (herbs, grasses, and mosses) in each location and recorded the most appropriate vegetation coverage class from pre-defined categories (see Appendix 1 for definitions and procedures). Coverage class midpoints were used to estimate the percentage of vegetation groundcover lost on campsites by subtracting on-site values from off-site values. The area of ground vegetation loss (ft^2) was then calculated by multiplying percentage of vegetation groundcover loss by campsite size. This measure emphasizes the areal extent of vegetation loss: a 50% loss of vegetation on a 2000 ft^2 campsite should be viewed more critically than a 50% loss on a 100 ft^2 campsite. Exposed soil was assessed using the same predefined categories and mid-point transformations as for vegetation loss (see Appendix 1 for definitions and procedures). Exposed soil was defined as areas with very little or no organic litter or vegetation cover. Exposed soil in undisturbed areas is extremely rare, so the area of exposed soil (ft^2) was computed by multiplying percent exposed soil on campsites by campsite size.

Live trees within campsite boundaries were assessed for human-caused damage on all campsites. Surveyors assigned one of three discrete categories to each tree: none/slight, moderate, and severe (see Appendix 1 for definitions and procedures). Moderate and severe damage categories are combined for presentation purposes as precision study results indicate that surveyors are unable to consistently judge the level of damage. For campsites, both the number and percent of damaged trees are presented. The number of damaged trees is emphasized because damage to 20 of 40 trees present on one campsite should be viewed more critically than damage to 2 of 4 trees present on another campsite. The number of damaged trees, 20 vs. 2, conveys this difference, the percentage of damaged trees, 50 vs. 50, does not.

Root exposure was assessed only within campsite boundaries in three categories: none/slight, moderate, and severe (see Appendix 1 for definitions and procedures). All other procedures and comments described for the tree damage indicator are applicable to this indicator as well. Tree stumps and fire sites within campsite boundaries were counted (see Appendix 1 for definitions and procedures). All trails leading away from the outer campsite boundary were counted to assess the general density of related off-site trails (see Appendix 1 for definitions and procedures). Staff also searched adjacent off-site areas to conduct a count of sites with evidence of improperly disposed human waste.

Several additional inventory indicators were also assessed for campsites, including distances to and visibility from formal trails and other campsites, tree canopy cover, campsite slope, and site expansion potential. Procedures for these indicators can be found in Appendix 1.

Trail Assessment Procedures

A detailed description of all trail condition assessment procedures is presented in Appendix 2 and summarized here. Elements of two trail condition assessment methodologies, the point sampling and problem census methods, were integrated in developing the procedures applied to assess selected impact indicators for the sampled formal trail segments. A *point sampling method* with a fixed interval of 300 ft, following a randomized start, was the primary method employed (Leung & Marion 1999b; Marion & Leung, 2001). A trail measuring wheel was used to identify sample point locations. At each sample point, a transect was established perpendicular to the trail tread with endpoints defined by visually pronounced changes in non-woody vegetation height (trampled vs. untrampled), cover, composition, or, when vegetation cover is minimal or absent, by disturbance to organic litter. Representative photos promoted consistent judgment. The objective was to select visually obvious boundaries caused by trampling disturbance that contained the majority (>95%) of traffic.

At each transect survey staff assessed the grade of the trail and the trail slope alignment angle, the difference in compass bearing of the prevailing landform slope (aspect) and the trail's alignment at the sample point (Leung & Marion 1996). A "side-hill" trail aligned along the contour would have a slope alignment angle of 90^o, a "fall-line" trail aligned congruent to the landform slope would be 0^o. Other trail inventory indicators assessed include proximity to tread drainage features, water drainage, and trail position (see Appendix 2 for assessment procedures).

Temporary stakes were placed at tread boundaries and the distance between was measured as tread width; maximum depth from a taut string tied to the base of these stakes to the trail surface was measured as maximum incision, an indicator of soil erosion (Farrell & Marion, 2002). The cross sectional area (CSA) of soil loss (in^2), from the taut string to the tread surface, was also measured using a variable interval method. CSA provides a more accurate measure of trail soil erosion that can be extrapolated to provide an estimate of total soil loss from each trail (ft^3). The variable method is an adaptation of the traditional fixed interval method described by Cole (1983), designed to reduce measurement time. Instead of taking vertical measurements along the horizontal transect at fixed intervals, vertical measurements are taken only at points directly above tread surface locations where changes in tread micro-topography occur (Figure 4). This variable interval method was applied by positioning beads along the transect string over tread locations that, when connected with straight lines, would most accurately represent the cross sectional shape or profile of the tread surface. The number of beads employed varied with tread surface complexity. The distance from each bead to the left boundary stake was recorded, along with the vertical measure of incision under each bead (Figure 4). An Excel spreadsheet macro (available from the author) was developed and used to calculate CSA from data collected at each sample point. These procedures were applied to derive CSA estimates only at sample points where maximum trail incision along the transect exceeded one inch, a decision rule included to further conserve assessment time at locations where soil loss was minimal.

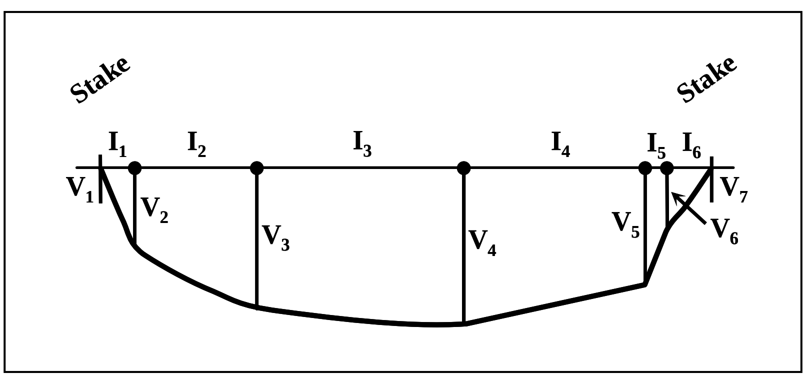


Figure 4. Illustration of the variable interval CSA method for assessing soil loss at each transect.

Trail tread condition characteristics, including vegetation cover, organic litter, exposed soil, muddy soil, water, rock, gravel, and roots, were defined as mutually exclusive categories and assessed across each transect. These indicators were evaluated as a proportion of tread width in 10% categories (5% where necessary). A count of additional secondary trails that paralleled the survey trail at each sample point provided a measure of the extent of trail braiding.

A *problem census method* integrated into the formal trail monitoring procedures provided census information on three specific trail impact problems: excessive erosion, multiple treads, and number of informal trails branching from the formal trail since the last sample point (Leung & Marion 1999b). Excessive erosion was defined as sections of tread (≥10 ft in length) with tread incision exceeding 5 in. Multiple treads are when the main tread separates into two or more parallel treads. Informal trails are trails that visitors have created to access features such as streams, scenic attraction features, and camping areas, or to cut switchbacks, go around mud-holes or downed trees, or that simply parallel the main trail (see Appendix 2 for further details). As they hiked, field staff looked for and recorded the beginning and ending distances from the starting point for all occurrences of these problems (informal trails were simply counted). A trail measuring wheel was used to measure distances. In contrast to the point sampling, this method provides census data on the extent and location of specific pre-defined problems, facilitating management efforts to rectify such impacts.

Fixed interval transect method procedures were developed for monitoring the proliferation and condition of informal (visitor-created) trails in management zones or areas where formal park trails do not exist. A separate set of transect-based procedures were developed to address this need (see Appendix 2). These were experimentally applied at two locations, the lower Subway valley and the lower Coalpits area. These procedures are designed to track the number of new trails created over time and degradation on each individual trail.

Transects were started in the lower Subway at a randomly selected point just upstream from where the trail that descends into the valley first reaches the stream. For the lower Coalpits area the transects were started at a randomly selected point beginning at the park boundary. Transects were assessed beginning to the far right side of the valley when facing upstream. Staff walked the transect, perpendicular to the stream, to the far left side, stopping at each visually obvious informal trail intersected. At each informal trail encountered, staff assessed the following indicators using the same procedures applied to formal trails: tread width, maximum incision, CSA, and tread condition characteristics.

Data Management

Campsites

Data were input into an Excel spreadsheet and several new indicators were calculated. Site sizes were calculated arithmetically from transect data using Excel spreadsheet formulas (available from the author). The area of vegetation loss and exposed soil were calculated as previously described. Data was imported to the SPSS Statistical package for analyses, including frequencies and descriptive statistics.

Trails

Data were input into an Excel spreadsheet and several new indicators were calculated:

Point Sampling Dataset: CSA in^2 for each transect and CSA ft^3, yd^3, and yd^3/mi for each trail (see Table 1 for definitions and calculations). The cubic CSA values provide an estimate of total soil loss for each trail. These estimates are based on the assumption that each sample point is representative of a trail distance of 150 ft in both directions (with special calculations to account for the first and final segments that differ in length from the fixed interval of 300 feet). A tread muddiness indicator was calculated by summing the percent cover values for muddy soil and water for each trail transect.

Problem Census Dataset: The lineal length, cumulative length, feet/mile, and percent of trail length for excessive erosion and muddiness.

Informal Trails Dataset: Data were averaged from all transects assessed within each study area.

Data were imported to the SPSS Statistical package for analyses. Basic frequencies and descriptive statistics were run for all indicators.

Table 3. Description of trail impact indicators and calculation methods.

Trail Width	Width of trail tread that captures about 95% of all traffic. Assessed at sample points along each trail and averaged for each trail to obtain mean trail width.
CSA	The cross sectional area from the pre-use land surface to the tread surface. Assessed at sample points along each trail and averaged for each trail to obtain mean CSA. Mean CSA for study areas was calculated as average of the CSA values measured at the sample points.
CSA Volume	The mean CSA for a trail times trail length – an estimate of the total volume of soil lost from a trail.
Mean Trail Depth	Calculated by dividing mean CSA by mean trail width.

Measurement Error

Readers are cautioned to consider measurement error when reviewing the study results. Every measurement of an indicator consists of two components: (1) a component reflecting an accurate assessment of true conditions, and (2) a component reflecting measurement error. Ideally, indicator measures should be both accurate (closely approximating the true value) and precise (multiple raters should yield similar values). Efforts were made to minimize measurement error through the development of detailed measurement procedures and the hiring, training, and supervision of capable field staff.

Experimental assessments of campsite measurement error were conducted in 1990 (unpublished) and 1993 (Williams & Marion 1995) in Shenandoah National Park using procedures similar to those applied in this study. Results from these exercises have been used to improve the assessment procedures employed in this survey. Regardless, measurement error remains a component of all measures which managers must consider when making decisions based on monitoring data. Further discussion on this issue is provided in Williams and Marion (1995).

RESULTS

Campsite Inventory Indicators

Information on a number of campsite inventory indicators was collected on 38 campsites to characterize campsite location with respect to formal trails and other campsites, vegetation, and visitor impacts. Detailed descriptions of each indicator and data collection methodologies are contained in the Zion National Park Campsite Monitoring Manual (Appendix 1). Campsite inventory indicators are described separately for each of the three study trails: LaVerkin, West Rim, and Narrows.

Distance to Trail and Visibility from Trail

The distance of campsites from the formal trails varied greatly by location. All but one of the 12 campsites (92%) was within 20 yards of the Narrows Trail, but only 35% and 11% of the campsites were that close on the LaVerkin and West Rim Trails, respectively (Table 4). West Rim campsites tended to be the furthest from the trail, with 6 of 9 campsites greater than 60 yards from the formal trail and only 56% were visible from the trail. In contrast, all of the Narrows campsites and 82% of the LaVerkin Campsites were visible from the formal trail.

Distance to and Visibility of Other Campsites

All inventoried campsites on all three trails were greater than 60 yards from any other campsite (Table 4). Only 1 campsite along the LaVerkin trail was visible from another campsite.

Campsite Slope

Field staff used clinometers to evaluate campsite slope, an important factor influencing the potential for soil erosion on campsites with substantial soil exposure. Ideal campsite slopes are in the range of about three to six percent. Campsites with less slope can have problems with surface ponding, sites with greater slope become increasingly vulnerable to sheet and gully erosion. All campsite slopes along the LaVerkin Trail were < 5%. One of 9 campsites along the LaVerkin Trail had a slope of 5-10%; the remaining 8 had slopes of <5% (Table 4). Campsite slope was not evaluated along the Narrows Trail.

Tree Canopy Cover

Tree canopy cover at campsites was highly variable along all three trails, ranging from 0 to 100% (Table 4). Forty-one percent of LaVerkin, 22% of West Rim, and 50% of Narrows campsites had canopy covers greater than 50%.

Campsite Expansion Potential

Adjacent off-site areas were evaluated for their potential to restrict campsite expansion. Campsites along the LaVerkin Trail had the greatest expansion potential, relative to the other trails (Table 4). Only 12% of the LaVerkin sites had a low or poor potential to expand, compared to 44% of West Rim campsites and 42% of Narrows campsites with a low expansion potential. Overall, 10 of 38 campsites (26%) had a high potential to expand beyond their current boundaries.

Table 4. Number and percent of campsites for inventory indicators along three park trails.

Inventory Indicators	LaVerkin (n=17)		West Rim (n=9)		Narrows (n=12)		Total (n=38)	
	#	%	#	%	#	%	#	%
Distance to Trail								
<10 yds	0	0	0	0	2	17	2	5
11-20 yds	6	35	1	11	9	75	16	42
21-40 yds	5	29	2	22	1	8	1	8
41-60 yds	2	12	0	0	0	0	0	2
>60 yds	4	24	6	67	0	0	0	10
Visibility from Trail								
Yes	14	82	5	56	12	100	31	82
No	3	18	4	44	0	0	7	18
Distance to Campsite								
<10 yds	0	0	0	0	0	0	0	0
11-20 yds	0	0	0	0	0	0	0	0
21-40 yds	0	0	0	0	0	0	0	0
41-60 yds	0	0	0	0	0	0	0	0
>60 yds	17	100	9	100	12	100	38	100
Number of Sites Visible								
0	15	94	9	100	12	100	36	97
1	1	6	0	0	0	0	1	3
Campsite Slope								
< 5%	17	100	8	89	NA	NA	25	96
5-10%	0	0	1	11	NA	NA	1	4
> 10%	0	0	0	0	NA	NA	0	0
Tree Canopy Cover								
0-5%	2	12	1	11	2	17	5	13
6-25%	2	12	5	56	4	33	11	29
26-50%	6	35	1	11	0	0	7	18
51-75%	1	6	0	0	2	17	3	8
76-95%	6	35	2	22	2	17	10	26
96-100%	0	0	0	0	2	17	2	5
Expansion Potential								
High	5	29	2	22	3	25	10	26
Moderate	10	59	3	33	4	33	17	45
Low	2	12	4	44	5	42	11	29

Campsite Height Above Water

This indicator was assessed only for the Narrows campsites due to their proximity to the Virgin River and the threat of flooding. We note that site height above the river cannot be easily interpreted to determine a campsite's potential to flood as the canyon width varies considerably between sites. For a given flood event, a campsite located 5 feet above the river in a wide canyon may not flood while a campsite 15 feet above the river in a narrow canyon could. Seven of the 12 Narrows campsites were located 5-10 ft above the water, three were 11-20 ft, and two were 21-30 ft above water. Mean height above water was 12.2 feet.

Campsite Impact Indicators

Condition Class

Assessment methods and results are described for ten impact indicators to characterize the condition of campsites along the LaVerkin, West Rim, and Narrows Trails. No campsites were assessed as condition class 1 (barely distinguishable) or 2 (obvious, but with vegetation cover lost only in primary use areas) (Table 5). Campsites along the West Rim trail appear to be in the best condition, with five sites assessed as condition class 3 (vegetation cover lost over much of the site, bare soil in primary use areas), four sites as class 4 (bare soil widespread), and no class 5 sites (soil erosion obvious). Four of the 12 Narrows sites were assigned Class 5, while only two of the 17 LaVerkin sites were assigned this highest level of impact (Table 5).

Table 5. Number and percent of campsites in five condition classes along three park trails.

Condition Class	LaVerkin (n=17)		West Rim (n=9)		Narrows (n=12)		Total (n=38)	
	#	%	#	%	#	%	#	%
1	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0
3	1	6	5	56	4	33	10	26
4	14	82	4	44	4	33	22	58
5	2	12	0	0	4	33	6	16

Campsite Size

Campsites ranged in size from 287 to 2533 ft^2 with a mean of 1080 ft^2 (Table 6). In spite of their intensive use, campsites in the Narrows are generally smaller (mean = 822 ft^2), likely due to the constricting topography of the cliffs, river, and steep riparian terrain. Interestingly, the West Rim campsites are the largest (mean = 1378 ft^2) even though site expansion potential ratings (Table 4) were collectively lower than the other two park areas. Mean campsite size for sites rated with "good" expansion potential was 1253 ft^2 while mean size of sites rated as "poor" expansion potential was 759 ft^2 (Figure 5). The total area of disturbance from camping (sum of areas for all campsites) is 41,049 ft^2, equivalent to 0.94 acres).

Vegetation Loss

Mean vegetation groundcover on campsites ranged from 4.7% for Narrows to 16% for West Rim with a mean of 8% for all campsites. Onsite vegetation cover is generally sparse; 29 (76%) of the sites have 0-5% vegetation cover while mean vegetation cover in adjacent environmentally similar "control" areas is 66%. Estimated percent vegetation cover loss ranged from 0 to 83 with a mean of 58% (Table 6). While 10 sites lost less than 36% of their estimated original vegetation cover, 25 sites lost 60% or more. Mean percent vegetation loss for the three camping areas is LaVerkin (64%), West Rim (54%), and Narrows (52%).

The area over which vegetation groundcover was lost ranged from 0 to 1474 ft^2 with a mean loss of 594 ft^2 (Table 6). While 13 (34%) of the campsites have lost less than 500 ft^2 of their estimated original vegetation cover, 5 sites have lost cover over more than 1000 ft^2, an area of approximately 31 x 32 ft. The aggregate sum of area of vegetation loss is 22,579 ft^2.

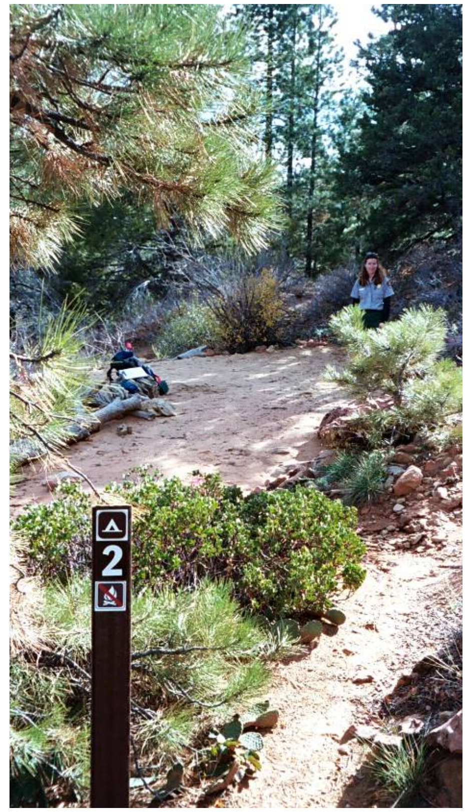


Figure 5. The relationship between campsite expansion potential and site size. Sloping topography and vegetative barriers (right) spatially concentrate camping activities and limit site size. Campsites that lack such constraints (above) remain small only when visitation is low.

Exposed Soil

Exposed soil ranged from 16 to 98% on campsites with a mean of 73% (25 sites had soil exposure of 86%). Soil exposure was comparable on the LaVerkin (83%) and Narrows (80%) campsites, and much lower on the West Rim (44%) sites. Area of exposed soil ranged from 120 to 1778 ft^2 with a mean of 706 ft^2 (Table 6). The aggregate sum of area of exposed soil is 26,829 ft^2.

Damaged Trees, Root Exposure, and Stumps

Tree damage is a relatively infrequent problem on campsites, primarily because campfires are prohibited. The number of damaged trees ranged from 0 (33 campsites) to 8, with a total of 14 trees assessed as damaged. The Narrows drainage had 13 of the 14 damaged trees, located on four campsites and including one site with 8 damaged trees.

Similarly, only 6 trees were assessed as having visitor-associated root exposure, located on three different campsites in the Narrows drainage (Table 6).

A total of 7 stumps were found on 5 campsites, 4 of which were located in the Narrows drainage (Table 6).

Table 6. Number and percent of campsites for impact indicators along three park trails.

Impact Indicators	LaVerkin (n=17)	West Rim (n=9)	Narrows (n=12)	Total (n=38)
Campsite Size (ft^2)				
Mean	1105	1378	822	1080
Median	979	1144	699	897
Sum	18782	12406	9861	41049
Range	378 - 2324	287 - 2533	433 - 2079	287 - 2533
Vegetation Loss (ft^2)				
Mean	671	704	403	594
Median	757	585	384	526
Sum	12124	6334	4835	23293
Range	0 - 1345	174 - 1474	87 - 738	0 - 1474
Exposed Soil (ft^2)				
Mean	846	498	663	706
Median	822	350	550	692
Sum	15032	4479	7961	27472
Range	323 - 1412	120 - 978	253 - 1778	120 - 1778
Damaged Trees (#)				
Mean	0.1	0.0	1.1	0.4
Median	0	0	0	0
Sum	1	0	13	14
Range	0 - 1	0 - 0	0 - 8	0 - 8
Trees w/Root Exposure (#)				
Mean	0.0	0.0	0.5	0.2
Median	0	0	0	0
Sum	0	0	6	6
Range	0 - 0	0 - 0	0 - 3	0 - 3
Stumps (#)				
Mean	0.0	0.1	0.5	0.2
Median	0	0	0	0
Sum	0	1	6	7
Range	0 - 0	0 - 1	0 - 3	0 - 3
Fire Sites (#)				
Mean	0.2	0.1	0.9	0.4
Median	0	0	1	0
Sum	4	1	11	16
Range	0 - 1	0 - 1	0 - 2	0 - 2
Trails (#)				
Mean	4.6	2.9	4.3	4.1
Median	4	2	4	4
Sum	78	26	52	156
Range	1 - 9	2 - 5	2 - 6	1 - 9
Human Waste Sites (#)				
Mean	0.7	1.1	1.8	1.1
Median	0	1	1	0.5
Sum	11	10	21	42
Range	0 - 3	0 - 4	0 - 5	0 - 5

Fire Sites, Trails, and Human Waste Sites

In spite of a prohibition on campfires, survey staff found 16 fire sites, including 4 in LaVerkin, 1 in the West Rim, and 11 in the Narrows (Table 6). A count of the number of trails connecting to campsite boundaries provides a rough measure of off-site trampling. The number of site access trails ranged from 1 to 9 with a mean of 4.1 (Table 6). The West Rim area had the fewest trails (mean=2.8, sum=26), followed by the Narrows (mean=4.3, sum=52), and the LaVerkin area (mean=4.6, sum=78). Finally, the number of improperly disposed human waste sites ranged from 0 to 5 with a mean of 1.1. Human waste sites were found on 19 (50%) of the campsites, with 11 associated with LaVerkin sites, 10 with West Rim sites, and 21 with Narrows sites.

Formal Trail Inventory Indicators

As described in the Methods section, point sampling and problem assessment trail survey methods were applied to assess a sample of formal (designated) park trails. Park staff selected four trails to be surveyed, including the West Rim (9.67 mi., 171 transects), LaVerkin Creek (4.86 mi., 86 transects), Willis Creek (2.08 mi., 37 transects), and Hop Valley (1.56 mi., 28 transects), for a total of 18.17 mi. and 322 transects. The transects refer to the number of sample points located along the study trails at a fixed interval of 300 ft, following random starts. Problem assessments were conducted continuously (a census) along the study trails. Point sampling data are presented for inventory indicators, followed by impact indicators, and problem assessment indicators.

Survey data also reveal that tread drainage features are uncommon, with 84 to 100% of the sample points along the study trails having such features located more than 75ft away (Table 7). When trail treads are outsloped such features may not be necessary, so the percentage of water that would likely flow off the tread during a rain event within 10 ft upslope from each sample point was estimated. These data reveal that water drainage is poor, no water would drain from the trail due to natural terrain features or tread drainage features for the majority of points (64-80%)(Table 7). Good tread drainage (75-100%) was assessed for 0-3.6% of the sample points on these four trails.

It is common knowledge among trail managers and reported in numerous studies that soil loss on trails is strongly influenced by trail grade. The speed of surface water runoff intercepted and carried downhill along trail treads increases exponentially with increasing trail grade (Dissmeyer & Foster 1984). In contrast, trails located in flatter terrain exacerbate the two other core trail impact problems, tread muddiness and excessive widening. The distribution of trail grade values for the study trails can be evaluated to examine susceptibility for all three core trail impact problems. Approximately 17% of these trails are located in flatter terrain (0-2% grade) where treads can be susceptible to tread widening and muddiness problems (Table 8). Fortunately, the drier climate and terrain through which these trails pass generally prevent muddiness, though trail widening can be a problem. Approximately 15% of the study trails have grades exceeding 15% (Table 8). Trail manuals generally recommend keeping trail grades below 10% (Hooper, 1988) or 12% (Hesselbarth and Vachowski, 2000) to limit soil erosion, with rockwork often needed to harden and reduce erosion on treads greater than 15%.

A trail's slope alignment angle, described in the methods section, is the angle between the prevailing landform slope (aspect) and the trail's alignment extending downhill from the sample point. In contrast to trail grade, the influence and importance of this indicator is not widely known or investigated, though recent studies suggest it may be as influential as trail grade (Aust *et al.* 2005, Marion & Olive 2006). Survey data show that 13% of the study trails are aligned within 22^o of the landform aspect or fall-line (Table 8), the path naturally taken by water running down a mountain slope. Figure 6 depicts a fall-line trail with substantial erosion, in comparison to a side-hill trail that has a slope alignment in the 69-90^o range. For those trail segments with fall-line alignments, data suggest that 6.2% are located on grades of less than 11% and 2.7% are located on grades exceeding 15% (Table 8). Table 9 presents mean trail grade and slope alignment angle values for the four study trails. The West Rim and LaVerkin Creek trails have the lower grades (7.8 and 7.4%, respectively) but also have the lowest (less sustainable) slope alignment angles (47 and 44^o, respectively).

Once a fall-aligned tread becomes incised, water becomes trapped within the tread and the laws of physics defy efforts to drain it away. In flatter terrain, such treads are susceptible to muddiness and tread widening. When fall line trail grades are steep, treads are particularly prone to soil erosion unless their substrates are exceptionally rocky or stonework is used. Rerouting fall-aligned sections is generally preferred, though alternative routes may not be possible due to cliff-lines. Fall line trails with grades exceeding 15-20% frequently require significant investments in rockwork and ongoing maintenance to keep them sustainable. However, water will still drain under or over such work, which, in addition to wintertime freezing, can increase danger to trail users or harm and loosen the rockwork.

Table 7. Percent of sample points by trail inventory indicator category by park trail.

Trail Features		**Trails**			
		West Rim	**LaVerkin Creek**	**Willis Creek**	**Hop Valley**
Trail Position		(% of sample points)			
	Valley Bottom	36.3	20.9	27.0	28.6
	Ridge Top	63.7	39.5	0.0	53.6
	Midslope	0.0	39.5	73.0	17.9
Tread Drainage Feature[1]	25ft	4.1	8.1	0.0	7.1
	50ft	1.2	1.2	0.0	3.6
	75ft	0.6	7.0	0.0	3.6
	100ft	94.2	83.7	100.0	85.7
Water Drainage[2]					
	0%	63.7	80.2	64.9	71.4
	25%	25.7	10.5	27.0	21.4
	50%	9.4	7.0	8.1	3.6
	75%	1.2	1.2	0.0	3.6
	100%	0.0	1.2	0.0	0.0

[1] Estimate of the distance to any effective human-constructed tread drainage feature in the up-slope direction.

[2] Percentage of water on the trail, 10 ft above the sampling point, that would tend to flow off the tread during a medium-sized rainstorm.

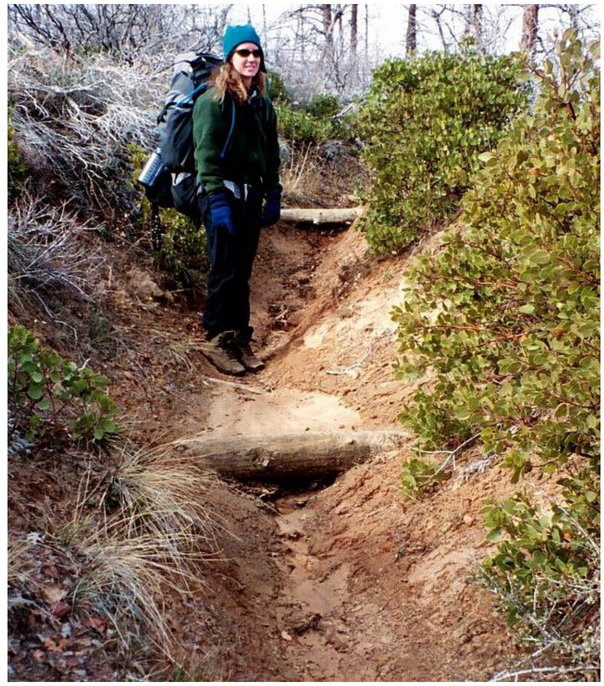


Figure 6. The fall-line alignment of the trail on the left prevents the drainage of water. The side-hill trail alignment depicted in the right-hand photo allows for natural drainage or use of tread drainage water bars or dips.

Table 8. Cross tabulation of trail grade and trail slope alignment inventory indicators.

Inventory Indicators		**Trail Slope Alignment Angle**				
		0-22°	23-45°	46-68°	69-90°	Totals
Trail Grade	0-2%	3, 0.9%[1]	12, 3.7%	25, 7.8%	13, 4.0%	53, 16.5%
	3-6%	11, 3.4%	319.7%	42, 13.1%	28, 8.7%	112, 34.9%
	7-10%	6, 1.9%	19, 5.9%	20, 6.2%	15, 4.7%	60, 18.7%
	11-15%	11, 3.4%	14, 4.4%	15, 4.7%	9, 2.8%	49, 15.3%
	16-20%	4, 1.2%	11, 3.4%	9, 2.8%	0, 0%	24, 7.5%
	21-30%	4, 1.2%	10, 3.1%	4, 1.2%	1, 0.3%	19, 5.9%
	31-100%	1, 0.3%	2, 0.6%	1, 0.3%	0, 0%	4, 1.2%
	Totals	40, 12.5%	99, 30.8%	116, 36.1%	66, 20.6%	321, 100%
Trail Grade:		Mean = 8.4%	Median = 6%	Range = 0-40%		
Trail Slope Alignment:		Mean = 48.3°	Median = 48°	Range = 0-90°		

1 – Number and percent of sample points.

Table 9. Mean trail grade and trail slope alignment angle by park trail.

Trail	**n**	**Trail Grade** (%)	**Trail Slope Alignment Angle** (degrees)
West Rim	171	7.8	47.3
LaVerkin Creek	86	7.4	43.8
Willis Creek	37	10.8	61.6
Hop Valley	28	11.7	50.7

Formal Trail Impact Indicators: Point Sampling Data

The number of informal (visitor-created) trails connecting with the surveyed trails were counted by field staff. This survey was restricted to formal trails so staff did not follow or GPS the distribution or conditions of these trails. Informal trails were most numerous along the West Rim Trail (n=22, 2.3/mi) and least numerous along the LaVerkin Creek Trail (n=7, 1.4/mi) (Table 10). This indicator is intended to gauge the extent of unofficial, visitor-created trails and to monitor their proliferation over time. Such trails are created by visitors for a variety of reasons: to access attraction features such as viewpoints, water, campsites, other trails, and avoid muddy or rutted trails, or to cut switchbacks. The number of secondary or parallel trails, a measure of trail braiding, reveals that this form of trail impact is not currently prevalent. Seven (2.2%) of the sample points had one secondary trail.

Trail width ranged from 17 to 117 inches (9.75 ft) with a mean of 42 inches (3.5 feet) (Table 11, Figures 7-8). However, 32% of these trails exceeded 4 ft in width and 5% exceeded 6 ft in width. Differences in width are relatively small between the study trails (Table 11), though the Willis Creek and Hop Valley trails have much higher percentages of their treads under 3 ft in width (Figures 7-8). The Willis Creek trail was narrowest (mean = 36.1 in), likely because it was the only study trail where horses are prohibited. Trail width is generally a function of constructed or maintained width as affected by use. Most foot trails need not be wider than 24 inches, though horse trails are generally wider, up to 48 inches in width.

Two measures of soil loss were included in the survey. We note that soil loss can be caused by erosion of tread soil by water or wind, compaction, or displacement to trailsides or downslope. A traditional rapid assessment method has been to measure the maximum incision or depth of the trail at each sample point from a taut string attached to stakes placed at trail borders. Incision ranged from 0 to 13.3 inches with a mean of 2.4. The majority of sample points had incision values of less than 2 inches (62%). However, 20% had incision values of more than 4 inches and 6.5% were more than 6 inches deep.

The cross sectional area (CSA) between the string and the tread surface was also measured and computed, providing a more accurate measure of trail soil loss. When maximum incision was 1 inch or less the CSA procedure was not done and a zero was recorded. CSA ranged from 0 to 645 in^2 with a mean of 55.8 in^2. Nearly half (47%) of the study trails had a CSA of 0, while 22% exceeded 100 in^2 and 6% exceeded 200 in^2. For perspective, a CSA of 200 in^2 on a 40 in. wide trail would have an incision of 5 in. across its entire width. Mean CSA varied substantially by trail, ranging from a mean soil loss of 36.1 in^2 on the West Rim trail to 92.4 in^2 on the LaVerkin Creek trail (Table 11, Figures 9-10).

CSA values were also extrapolated based on trail lengths to estimate total soil loss for the surveyed trail segments. Aggregate measures of soil loss reveal the LaVerkin Creek trail to have the greatest soil loss both in terms of total amount (609 yd^3) and cubic yards per mile of trail (125)(Table 11). Soil loss for all study trails summed to 17,977 ft^3 (665 yd^3, equivalent to 66 10 yd^3 single axle dump trucks). An area of disturbance measure was calculated as the product of mean trail width and trail length (Table 11). This indicator provides an estimate of the aggregate area of intensive foot traffic disturbance for each trail (Table 11) and summing to 216,576 ft^2, or 4.97 acres.

Ten categories of tread substrates (e.g., soil, vegetation, rock) were assessed as a proportion of tread width at each sample point. Trail muddiness was evaluated by summing the measures for mud and standing water as mud. Two-thirds or more of each study trail substrate was soil (64-88% cover), followed by litter cover (4.4-17.7%) (Table 12). Rock was common on the West Rim trail (20%) and mud was only found on the West Rim trail (3.5%) and the Hop Valley trail (3.2%). Changes in these indicators can reveal changes in trail condition, i.e., deteriorating trails would be expected to show reductions in litter and vegetation cover with increases in exposed soil, rock, mud or roots.

Table 10. Informal and secondary trails by park trail.

Trail	Informal Trails [1]		Secondary Trails [2]	
	#	#/mile	Range	Mean, #
West Rim	22	2.3	0 - 1	0.03
LaVerkin Creek	7	1.4	0 - 1	0.02
Willis Creek	11	5.3	0	0.00
Hop Valley	6	3.8	0	0.00
Total	46	2.5	0 - 1	0.02

[1] Informal trails intersecting the primary trail were counted between transects.
[2] Secondary trails are the number of parallel treads present at each sample point.

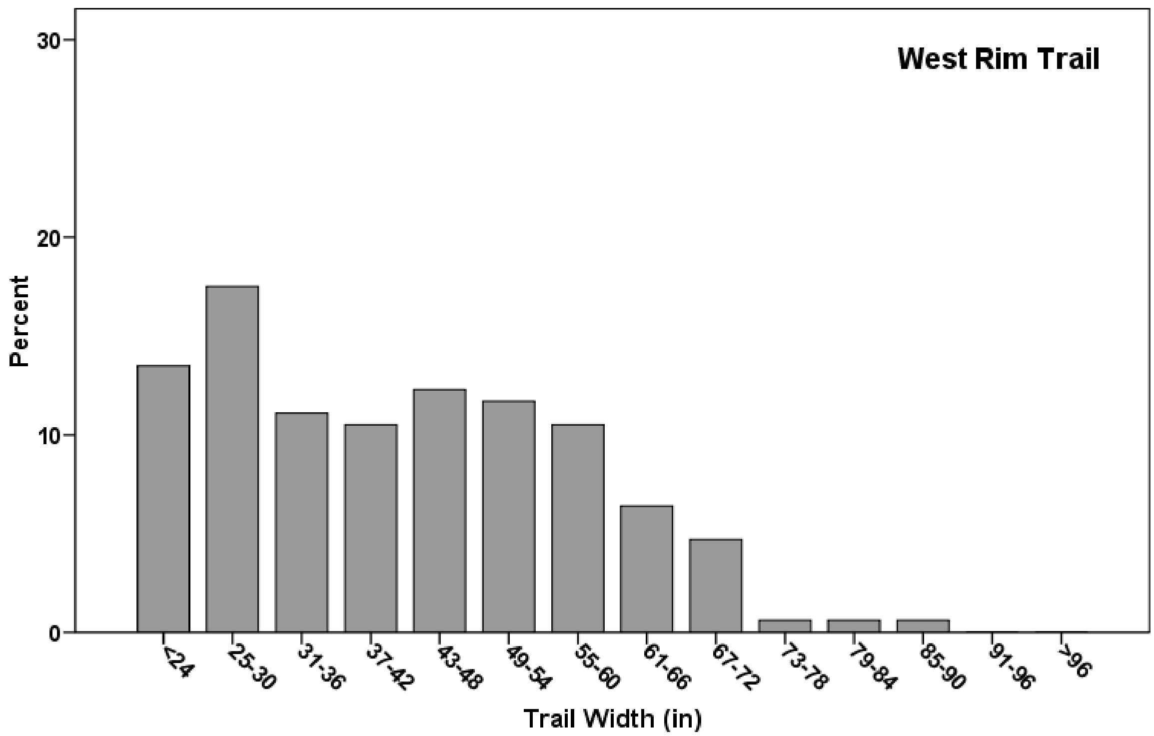
Table 11. Mean trail width, maximum incision, cross sectional area, and area of disturbance by park trail.

Trail	n	Trail Width (Mean, in)	Maximum Incision (Mean, in)	Cross Sectional Areas				Area of Disturbance[1] ft^2
				Mean, in^2	Sum, ft^3	Sum, yd^3	yd^3/mi	
West Rim	171	41.9	1.9	36.1	12,782	473	49	178,192
LaVerkin	86	45.7	3.2	92.4	16,451	609	125	97,768
Willis Creek	37	36.1	2.0	45.7	3471	129	62	33,056
Hop Valley	28	41.6	3.3	77.7	4532	168	108	28,582
Total	322	42.2	2.4	55.8	37,236	1379	344	337,598

[1] Calculated by multiplying the mean trail width by trail length.

Table 12. Mean trail substrate cover as a proportion of transect (tread) width by park trail.

Trail	n	**Exposed Soil** (%)	**Litter** (%)	**Vegetation Cover** (%)	**Rock** (%)	**Mud** (%)	**Roots** (%)	**Wood** (%)
West Rim	171	64.2	8.8	3.3	20.2	3.5	0.0	0.1
LaVerkin	86	88.3	4.4	1.5	5.8	0.0	0.1	0.0
Willis Creek	37	72.4	17.7	4.1	5.5	0.0	0.3	0.0
Hop Valley	28	71.6	14.3	7.9	3.0	3.2	0.0	0.0
Total	322	72.2	9.1	3.3	13.2	2.1	0.1	0.0



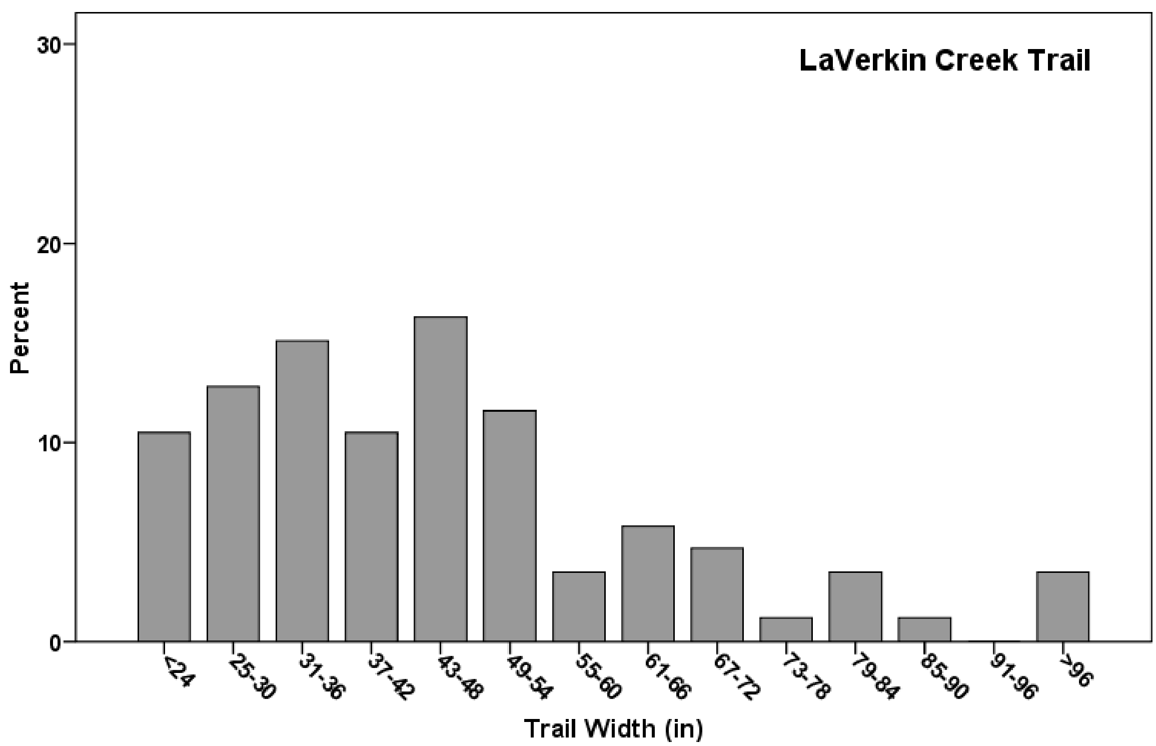
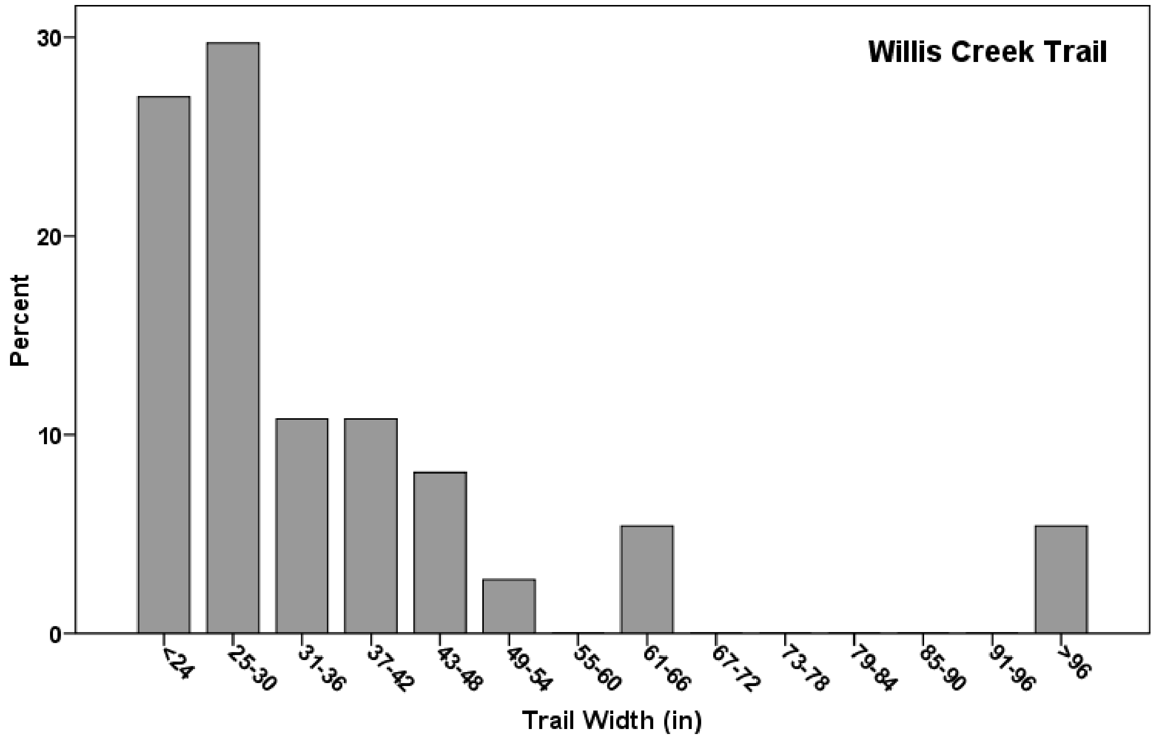


Figure 7. Trail length (%) by trail width category for the West Rim and LaVerkin Creek Trails.



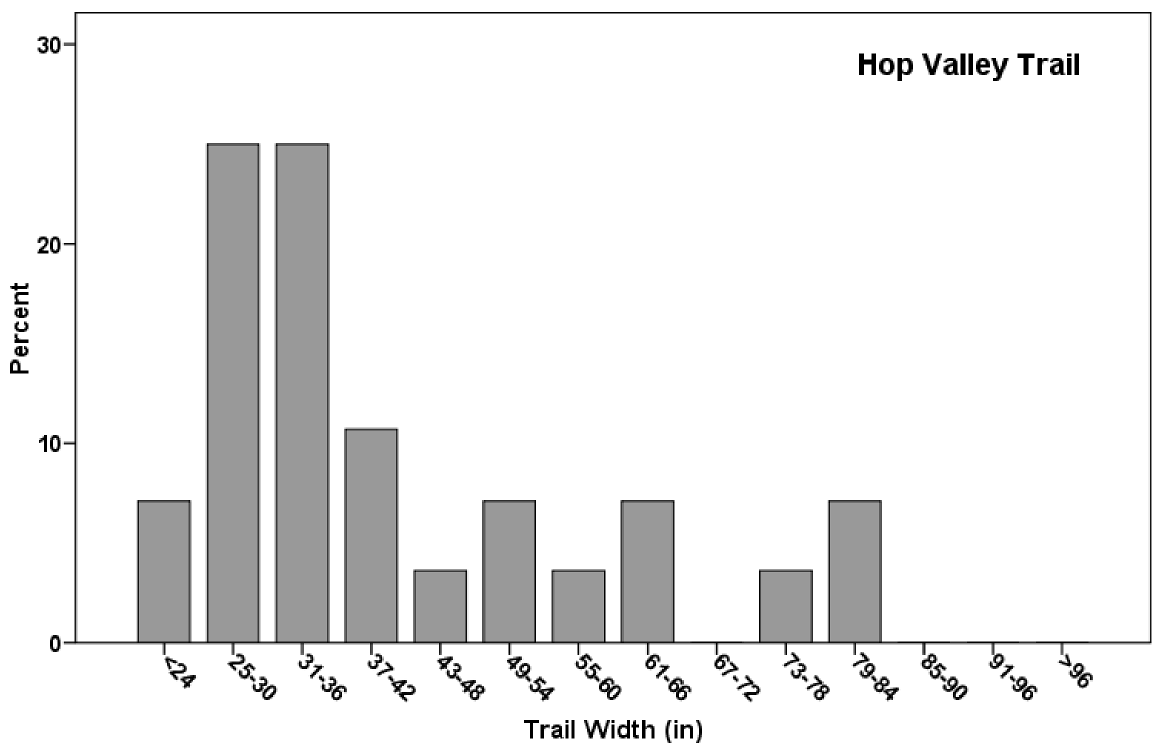
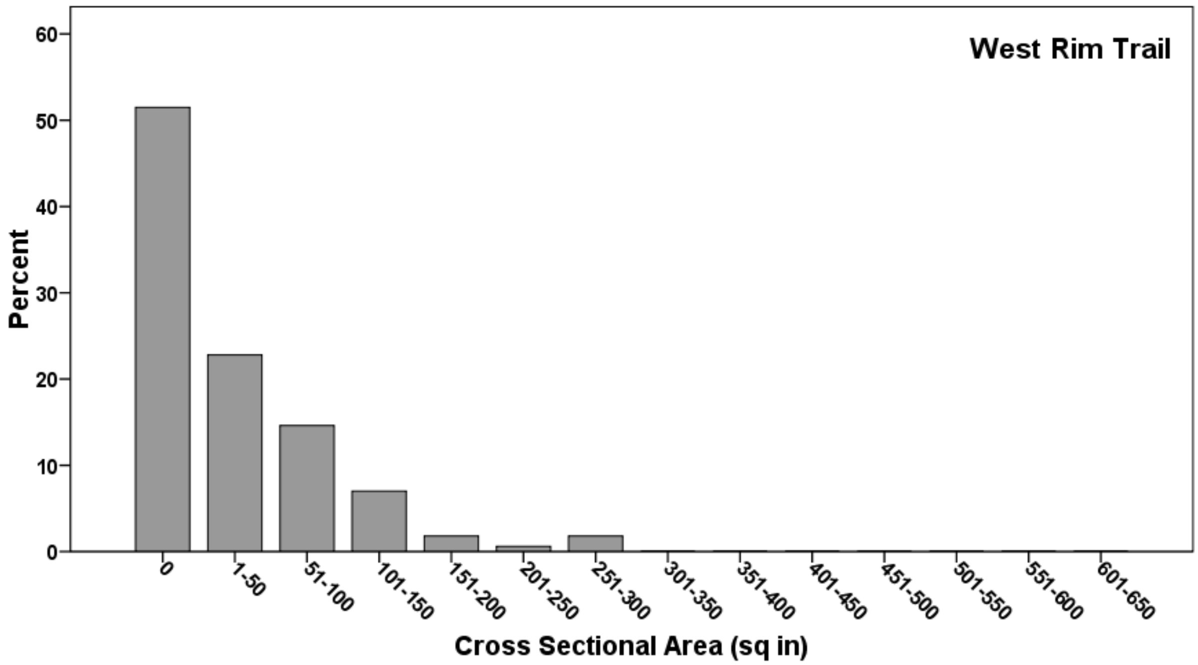


Figure 8. Trail length (%) by trail width category for the Willis Creek and Hop Valley Trails.



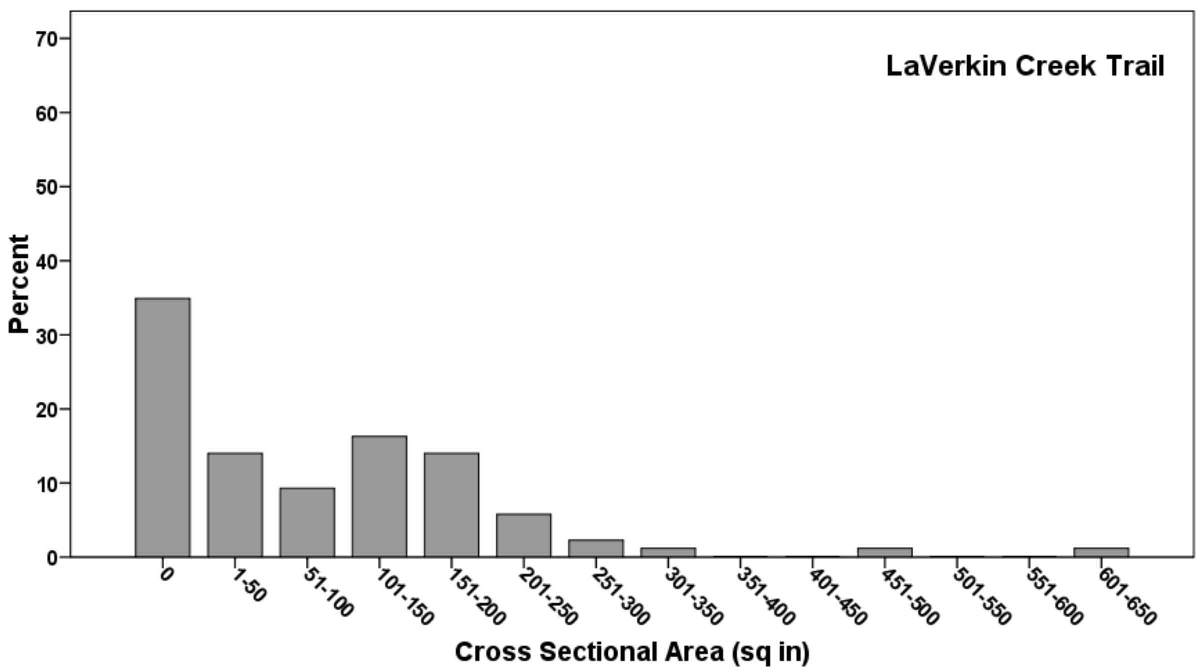


Figure 9. Trail length (%) by soil loss (CSA) category for the West Rim and LaVerkin Creek Trails.

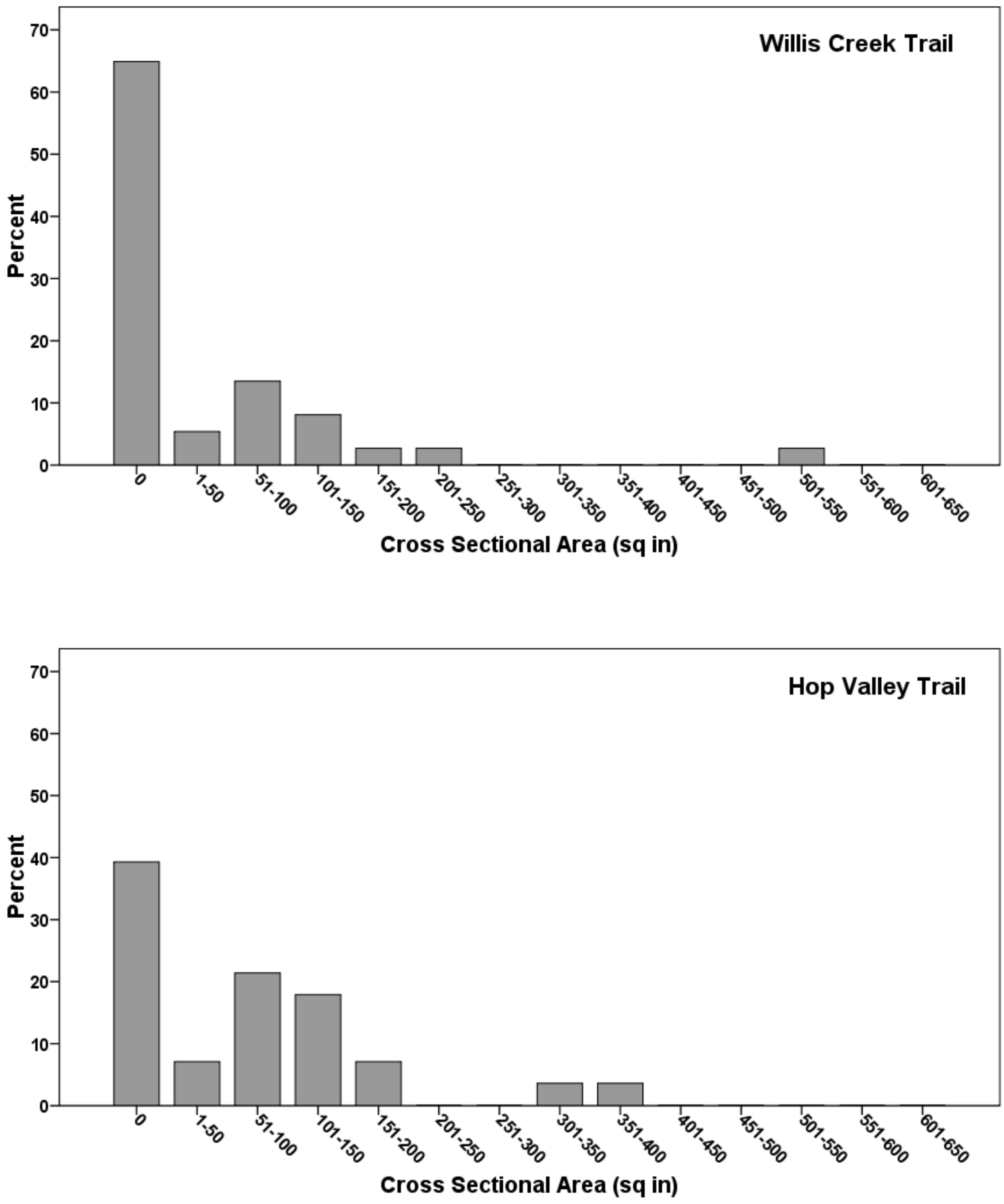


Figure 10. Trail length (%) by soil loss (CSA) category for the Willis Creek and Hop Valley Trails.

Formal Trail Impact Indicators: Problem Assessment Data

Data from the continuous problem assessment survey provides a more comprehensive picture of conditions for the two indicators assessed. The incidence of multiple treads was greatest on the West Rim trail, with 8 occurrences (0.8/mile) and affecting 114 ft/mi and 2.2% of the trail's length (Table 13). In contrast, multiple treads were not found along the Hop Valley trail and only one occurrence was found along the Willis Creek trail.

Excessive tread incision (defined as >5 inches) was more common along each of the study trails. The West Rim and LaVerkin Creek trails had the greatest aggregate lineal extent (4272 and 3987 ft, respectively), but on a standardized ft/mi basis the Hop Valley and LaVerkin Creek trails ranked worst (828 and 820 ft/mi, respectively) (Table 13). As a percentage of their length, incision exceeding 5 inches ranged from 3.6% for the Willis Creek trail to 15.5% for the LaVerkin Creek trail.

Table 13. Number of occurrences and lineal distance for multiple treads and tread incision greater than five inches from problem assessment procedures.

Trail Name	Occurrences		Lineal Distance			
	#	*#/mile*	Total (ft)	Mean (ft)	ft/mi	%
Multiple Treads						
West Rim (9.67 mi)	8	0.8	1100	138	113.8	2.2
LaVerkin (4.86 mi)	7	1.4	358	51	73.7	1.4
Willis Creek (2.08 mi)	1	0.5	25	25	12.0	0.2
Hop Valley (1.56 mi)	0	0.0	0	0	0.0	0.0
All trails (18.17 mi)	16	0.9	1483	93	81.6	1.5
Tread Incision (> 5")						
West Rim (9.67 mi)	76	7.9	4272	56	441.8	8.4
LaVerkin (4.86 mi)	100	8.2	3987	100	820.4	15.5
Willis Creek (2.08 mi)	16	7.7	391	24	188.0	3.6
Hop Valley (1.56 mi)	31	19.9	1291	42	827.6	15.7
All trails (18.17 mi)	223	12.3	9941	45	547.1	10.4
Total: All Problems, All Trails	239	13.2	11424	48	628.7	12.0

Informal Trail Indicators

Somewhat more challenging to monitor are the proliferation and condition of informal (visitor-created) trails within canyons that lack formal trails. For example, many canyons occur within park zones where visitors are expected to be self-reliant, applying route-finding skills to navigate to their destinations. Formal trails are generally not provided within such zones but informal trails often do form when traffic occurs on soil substrates or vegetation. Unfortunately visitors lack the knowledge, will, or time to follow the most resistant or sustainable routes, or to select and use a single route. Popular canyons frequently have multiple high- and low-water informal trails on each side of a stream, trails which are often discontinuous or merge with one another.

Park staff required monitoring methods that could accurately and efficiently assess the number and condition of these types of informal trails. A fixed-interval transect method was developed to address this need. As described in at end of Appendix 2, these procedures were developed and experimentally applied to two selected park areas, the lower Subway and lower Coalpits valleys. Staff walked transects perpendicular to these valleys to locate and assess each intersected informal trail using the standard point-sampling procedures described in Appendix 2. Transects were spaced 500 ft apart, with a random start, with GPS points and photographs taken at each transect to permit their relocation and assessment during future monitoring cycles.

These methods worked well according to field staff and the resulting data are summarized in Table 14. Ten transects were assessed in the lower Subway valley; 7 transects had 2 trails and 3 transects had 3 trails for a total of 23 informal trails. Informal trails had a mean width and incision of 34 inches and 2.8 inches, respectively (Table 14). Fifteen transects were assessed in the lower Coalpits valley; 4 transects had 2 trails, 2 transects had 3 trails, and 1 transect had 4 trails for a total of 26 trails. Informal trails had a mean width and incision of 28.7 inches and 1.7 inches, respectively (Table 14). Extrapolation of mean CSA soil loss (Table 14) to the total length of these canyons surveyed provides the following estimates of aggregate soil loss:

Lower Subway (4500 ft of canyon surveyed) = 1,509 ft^3, 55.9 yd^3, or 65.6 yd^3/mi
Lower Coalpits (7000 ft of canyon surveyed) = 1,338 ft^3, 49.5 yd^3, or 37.3 yd^3/mi.

Table 14. Number and condition of informal trails within the Lower Subway and Lower Coalpits drainages.

Inventory Indicators	**Trail Width** (in)	**Tread Incision** (in)	**Cross Sectional Area** (in^2)	**Informal Trails** (#/transect)
Lower Subway				
(10 transects, 23 trails)				
Range	20.0 - 77.0	0.5 - 8.0	0.0 - 232.5	2 - 3
Mean	34.0	2.8	48.3	2.3
Lower Coalpits				
(15 transects, 26 trails)				
Range	17.0 - 86.0	0.3 - 4.0	0.0 - 106.9	1 - 4
Mean	28.7	1.7	27.5	1.7

DISCUSSION AND MANAGEMENT RECOMMENDATIONS

This survey developed and applied monitoring protocols to assess resource conditions on all designated backpacking campsites in the park, including those in the LaVerkin (n=17), West Rim (n=9), and Narrows (n=12) park areas. User-created campsites were not assessed. Similarly, monitoring protocols were developed and applied to assess resource conditions on four formal trails, including West Rim (9.67 mi.), LaVerkin Creek (4.86 mi.), Willis Creek (2.08 mi.), and Hop Valley (1.56 mi.). Park staff were consulted during the development, refinement, and application of these monitoring protocols to ensure they would be responsive to park information needs related to the selection of appropriate indicators and standards as part of their Backcountry Management Plan (BMP) and VERP decision making process (Zion NP 2007). We note that data from these campsite and trail surveys were presented and provided to park staff during the plan development process, though completion of this report was delayed. The monitoring protocols also had to be well documented, easily applied by park staff, and sustainable over time. Staff training was also conducted during the application of these procedures and the authors remain available for future training and consultation.

Campsites

The survey yielded useful inventory information on campsites, including their distance and visibility from trails and other campsites, slope, tree cover, and expansion potential. Campsites are well distributed from each other but a majority (31, 82%) are visible from formal park trails. This suggests that designated site campers can generally expect a high degree of solitude only during the evenings and early mornings when trail traffic is low. Another issue of some concern was a rating of "high" for site expansion potential for 10 (26%) of the sites, indicating a susceptibility for site enlargement due to the absence of restrictive topography or vegetation.

Ten indicators of site conditions were assessed, providing numerous options for managers in selecting appropriate VERP indicators. Data for these indicators were summarized to characterize baseline conditions and to facilitate the selection of indicator standards. Managers selected three of these indicators, campsite size, trails, and human waste sites, for use in the Zion NP BMP (Zion NP 2007). For campsite size, the standard allows up to a 3% increase from the baseline survey. The standard for trails connected to site boundaries is no more than 4 trails at 90% of the campsites. When the survey was conducted, 24 of the 38 sites (63%) had 4 or fewer trails, so park staff need to reduce trail numbers to no more than 4 at 10 additional sites to remain within standard. The standard for human waste is that 50% of the campsites will have no visible human waste and 90% will have no more than two human waste sites. This survey found no human waste at 19 of the 38 sites (50% - standard met), but 7 sites (3 more than the standard) had more than two human waste sites.

Camping Management Options

A variety of camping management options are available to park managers for achieving their BMP objectives, including site management, educational, and regulatory actions. These actions are summarized here but described in greater detail in the following publications: Hammitt and Cole (1998), Marion (2003), and Leung and Marion (2000). Campsite size is perhaps most effectively addressed by selecting site locations where topographic features constrain site size. Managers could review the site expansion ratings from this study and apply them to nearby alternative locations in the field. Moving sites to alternate expansion-resistant locations is a "one-time" action that can permanently limit future problems with site expansion. Even in the topographically restricted Narrows canyon, survey staff located additional campsite locations that could be used to substitute for less desirable sites or to expand camping capacity: on two river benches downstream from site 1, river right 70 yds past deep grotto cliff hole between sites 5 and 6, river left just upstream from site 7, and river right 100 yrds below site 9.

Managers can consider constructing "side-hill" campsites in sloping terrain when optimal natural locations cannot be found (Marion 2003), a practice which has been implemented successfully in Shenandoah and Great Smoky Mountains National Parks and along the Appalachian Trail. Additional options include positioning large rocks and logs where needed to clarify site boundaries, or applying site improvement practices (e.g., providing smooth, gently sloped tent sites) to identify intended tenting sites and site ruination practices (e.g., ice-berging rocks or creating uneven ground) to discourage use of adjacent non-site areas. Identifying tenting sites with embedded logs or rocks is another option. Educational actions include communicating LNT practices, such as asking visitors to keep their group sizes small, minimize their number of tents, and camp only on the most disturbed and central site areas, avoiding use of peripheral and vegetated areas. Regulatory actions include restrictions on tent sizes and numbers or group size restrictions.

Informal campsite-associated trails result from a variety of activities, including accessing the site and water sources and traveling to off-site areas for exploration or to find privacy for waste elimination. Site management actions are perhaps most effective for limiting the number of these trails. Managers can select and subtlety improve intended site, water, and even bathroom access trails while blocking and restoring unnecessary or impact-susceptible trails. Substantial erosion on some site access trails requires rock steps or the selection of an alternate route. Assess trails to private bathroom sites seem to be a particular problem in the Narrows canyon, where these trails often ascended exceptionally steep and erodible soils. Managers may wish to consider the selection of a single private bathroom site area and trail, with appropriate blazes or markers, to encourage visitors to use their carry-out kits in a single location. Where needed, a simple two-sided privacy fence may need to be constructed or a side-hill site created to minimize trail length and associated resource impacts.

Blocking and restoration work alone may be ineffective to close unneeded informal trails, as visitors may fail to understand management intent and simply move or walk around the materials used to discourage access. Small symbolic "no-step" signs screwed to large logs placed across where these trails connect to formal trails and campsites can be effective in communicating management intent, at least until full restoration occurs. Key *Leave No Trace* (LNT) practices include asking visitors to remain on existing well-established foot trails and to avoid trampling vegetation or cross-country travel near campsites. More comprehensive guidance on this topic is provided in a following section titled "Informal Trail Management Options."

Recommended park human waste disposal practices instruct visitors to dig a cat-hole for the waste and carry out toilet paper or, as requested in the Narrows, to use a provided kit to carry out the fecal material and paper. Enhanced education is likely the most effective action for addressing future human waste management problems. Except for the Narrows, current online and printed educational messages do not emphasize the appropriate LNT waste management practices. The Narrows carry-out program could also be expanded to other park areas, or a regulation to require the use of carry-out kits could be applied to selected areas. Construction of pit or composting toilets may be another option for areas that receive intensive use.

Other impacts of concern to management include damaged trees (n=14), stumps (n=7), and fire sites (n=16). These impacts are primarily related to visitors building campfires, which are illegal within the park's backcountry. However, the existing literature and guidance rarely mention this prohibition, or its rationale. Enhanced education is thus a preferred first response, with additional enforcement employed when needed and where possible. We note that some stumps may be associated with the removal of hazardous trees by park staff.

In less-visited park zones managers could consider dispersed camping or established site camping. Dispersed "pristine site" camping would be a preferred strategy in areas where visitation is low and resource resistance is high, such as areas where camping can occur on slickrock. Since campfires are prohibited, visitors could camp with virtually no evidence of their visits if they camp on non-vegetated rock surfaces and employ LNT camping practices. Other resistant settings for dispersed camping include grasslands and on beds of non-vegetated pine needles in coniferous forests. The success of this strategy would be largely dependent on the park staff's ability to educate visitors in pristine site camping practices and with the visitor's willingness to apply such practices.

In park zones receiving intermediate visitation and/or with fragile substrates, an established site camping policy can be an effective option. Visitors would be asked to camp only on well-established campsites and to avoid creating new sites or using sites with little evidence of impact. This option allows park staff to evaluate the relative resistance and acceptability of existing visitor-created campsites and to close, rehabilitate, and temporarily post closure signs on any sensitive or unnecessary sites, or those that are too close to trails or other campsites. Visitors retain a sense of discovery in locating these primitive sites, which would not be posted with signs or marked on maps. Visitor center staff could identify areas where such sites are located during trip planning, however. Again, communicating and stressing the importance of LNT camping practices would be important to the success of this policy, and if found to be unsuccessful in some locations, a selection of existing sites could be formally designated and managed more intensively.

Trails

Point sampling and problem assessment methods were developed and applied to assess the resource conditions of a large sample (18.2 mi) of formal trails. A transect method was also developed and applied in two drainages to assess the proliferation and condition of informal (visitor-created) trails. Park staff used these procedures and the data they provided to select trail-related indicators, standards, and monitoring protocols incorporated into the park's BMP.

Trail inventory indicator data reveal that park staff have constructed very few tread drainage features along the sampled trails and that water drainage from treads is poor. Approximately 17% of the trails are located in flatter terrain, which are susceptible to tread widening or muddiness, and 15% of the trails have grades exceeding 15%, which are susceptible to soil erosion. Furthermore, 13% of the trail alignments are close to the landform aspect or fall-line, which prevents or increases the difficulty of efforts to remove water from incised trail treads.

Resource condition data from point sampling reveals a number of locations with substantial soil loss (239 occurrences of tread incision > 5 inches in depth) and relatively wide treads (tread width = 42 inches). Data on informal trails seem more acceptable, though these networks are well-established and the existence of multiple parallel treads do represent “avoidable” impact.

For formal trails in the Zion NP BMP, managers selected two indicators, number of informal trails/mile, with a standard of no more than four, and soil loss, assessed by CSA with a moving average standard of 140 in^2 (Zion NP 2007). As shown in Table 10, only the Willis Creek trail, with 11 informal trail junctions along its 2.08 miles (5.3/mi), exceeded a standard of 4 informal trails/mi. The Hop Valley trail, however, has 3.8 informal trails/mi, so managers may wish to consider preventive assessments and actions there as well.

For soil loss, the standard is assessed by a moving average, calculated by averaging five consecutive transect values, dropping the first and adding another at the end. Applying a standard to a moving average avoids the problem of engaging management to address trail condition problems that may occur rarely and/or for short sections of trails (i.e., reflected by higher measures at single transect locations). The number of trail transects included in the average directly influences the sensitivity of this option; the smaller the number the more sensitive to any single point. Since the Zion BMP did not specify this number, we chose a conservative value of five and computed moving averages for each trail to illustrate the application of this standard (

Figure 11). Each trail had one or more moving average values that exceeded the standard of 140 in^2: Hop Valley (2 values, one segment), LaVerkin Creek (16 values, 4 segments), West Rim (3 values, one segment), and Willis Creek (3 values, one segment).

For informal trails such as those in lower Subway and Coalpits, the BMP standard is no more than two over 90% of the route. Our fieldwork did not assess the entire route so we are unable to assess compliance with this standard. However, data in Table 14 suggest that the standard would be exceeded in the lower subway area (mean number of informal trails/transect = 2.3 as assessed over 4,500 ft of the canyon).

Informal Trail Management Options

This section includes some management guidance for addressing problems with the proliferation of informal trails that depart from formal trails and that develop in areas that lack formal trails. The development, proliferation, and deterioration of visitor-created informal trails can be a vexing management issue. Formal trail systems never provide access to all locations required by visitors seeking to engage in a variety of appropriate recreational activities. Unfortunately, management experience reveals that informal trail systems are frequently poorly designed, including “shortest distance” routing with steep grades and alignments parallel to the slope. Such routes are rarely sustainable under heavy traffic and subsequent resource degradation is often severe. Creation of multiple routes to common destinations is another frequent problem, resulting in “avoidable” impacts such as unnecessary vegetation/soil loss and fragmentation of flora/fauna habitats. This guidance is provided to assist managers in evaluating the acceptability of informal trail impacts and in selecting the most appropriate and effective management responses.

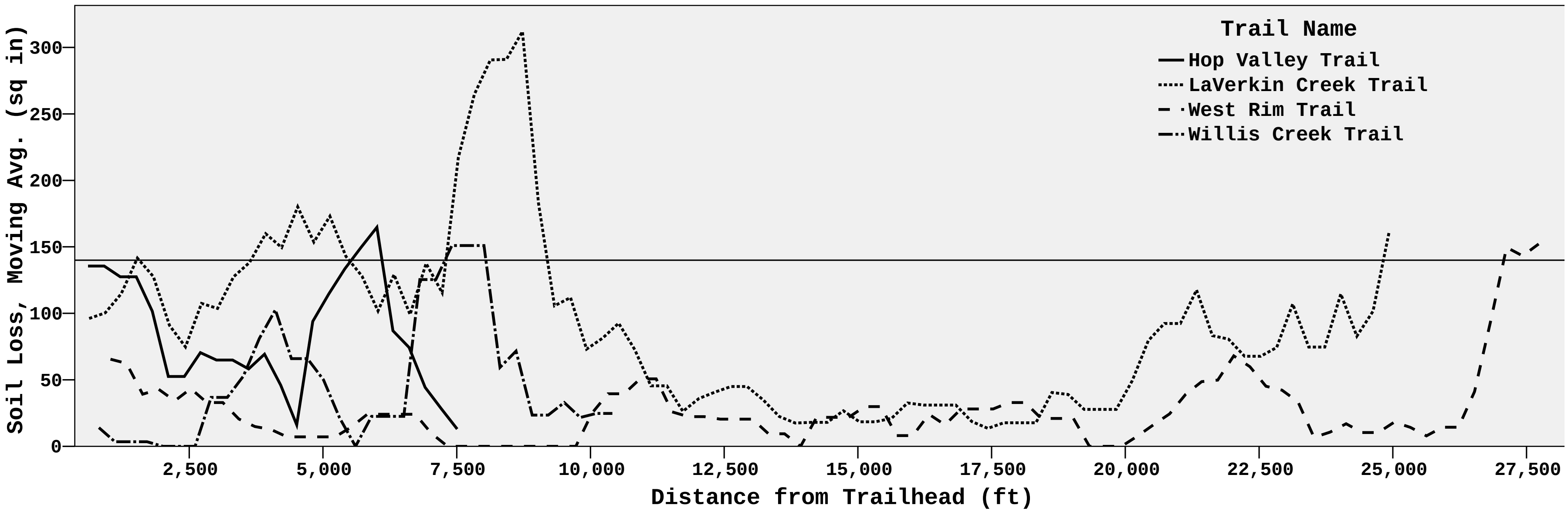


Figure 11. A moving average calculated from each five consecutive transect values for soil loss along the five study trails with a reference line at 140 in^2 to show trail locations that exceed the park standard.

Describe the Problem: A first step should be to characterize the distribution, lineal extent, and resource conditions of informal trail networks. One common option is to conduct a GPS survey, provided the terrain and forest canopy permit accurate GPS use, or a transect assessment as was done in this study. For GPS surveys, GIS software can input, map and analyze the data, providing a visual display of the informal trail network relative to designated trails, roads and other resource features. Computation of the lineal extent of the informal trail network is also possible. In this study, we sought to develop a procedure that provided replicable information in areas where GPS devices may not always work due to high canyon walls. Assessments of informal trail conditions can produce quantitative descriptive data for indicator variables that characterize current trail conditions, allow comparison to standards, and when replicated, reveal trends in trail conditions over time.

Evaluate Impact Acceptability: The acceptability of informal trail impacts can be evaluated informally or formally through a framework like VERP. Managers should first consider the zone and management direction for the area(s) where the informal trails are located. Informal trails located in pristine areas where preservation values are paramount are less acceptable than when located in areas that are intensively developed and managed for recreation use. Trails in areas with sensitive cultural and archaeological resources are particularly unacceptable if they threaten such irreplaceable resources.

Environmental factors should be considered. Informal trails located in sensitive or fragile plant/soil types, near rare plants and animals or in critical wildlife habitats are less acceptable than when located in areas that are resistant to trampling damage and lack rare species. Informal trails that directly ascend steep slopes and/or will easily erode are less acceptable than trails with a side-hill design. Informal trails prone to muddiness and widening are less acceptable, as are trails that may contribute soils to water resources.

Use-related factors should also be considered. Informal trails resulting from illegal or inappropriate types of uses are less acceptable than if they are caused by permitted uses. Is visitor behavior a factor? Impacts that can be easily avoided are less acceptable – such as when three informal trails in close proximity to each other access a location that could be accessed by a single trail. Why is a trail in a particular location and what are the visitors trying to access? Impacts caused by visitors seeking to shortcut a longer, more resistant route are unacceptable, as are impacts caused by visitors who could alternately access their intended destination by staying on resistant durable surfaces (e.g., rocks, gravel, sand).

A careful consideration of these and other relevant factors (e.g., visitor safety) can assist managers in making value-laden decisions regarding the acceptability of informal trail impacts. The acceptability of these impacts, in turn, guides decisions about which trails should be left open, rerouted, or closed and selection of appropriate and effective management interventions.

Selection of Management Actions: No actions are needed for informal trails found to be acceptable to managers. It should be recognized that recreation access and use is an important mandate for parks. Some degree of degradation to natural resources is an inevitable consequence of recreation use, requiring managers to balance recreation provision and resource protection mandates. Roads and formal trails can never provide complete access to the locations visitors wish to see, hence, some degree of informal trail development is inevitable and must be tolerated.

Informal trails created by illegal users, trails with poor designs, or trails that threaten sensitive resources should generally be closed and rehabilitated. If visitor access to the area in question is acceptable, then a qualified trail management professional should identify an alternate route, with review by resource management/protection staff. An existing trail or previously disturbed route is always preferable, though visitors rarely choose the most durable or sustainable routes. Leaving a trail in a poor alignment is only acceptable if management actions (e.g., graveling or installation of steps) that are appropriate for the zone will effectively resolve resource protection concerns and sustain future use. In many instances, relocation to an improved alignment will be a more cost-effective and sustainable long-term solution, even though pristine terrain may be impacted. The ability to effectively close and rehabilitate the existing informal trail is also an important consideration. When rerouting trails, assessments by experienced trail design and maintenance staff should precede any further management reviews or actions. Important considerations include trail alignment to the slope (always favor side-hill designs over direct-ascent alignments), trail grade (<10-15%), and substrates (rocky soil is less erosive).

Unique options at Zion NP include the complete avoidance of informal trail impacts by substituting bedrock routes or rappels for trails that cross steep slopes or sensitive soils and vegetation. For example, the upper Subway trail is predominantly on slickrock but includes some sections that cross vegetation and soil with active erosion evident. Personal communication with Del Smith, a long-time hiker and guide in the area, reveal that alternate slickrock routes largely avoid crossing soil and vegetation. Problems with visitors creating or altering cairns in this and other slickrock areas could be addressed by adopting a single distinctive style for cairn construction and an enhanced educational program asking visitors to not build or alter cairns. Paint blazes on native rock offer another possible method for permanently marking formal trails or routes.

Mystery Canyon provides another example with applicability to other park canyons. The access trails into the upper portion of this canyon are essentially dangerous slides down a long steep slope that unavoidably erodes soils and dislodges rocks that can strike downslope hikers. At the bottom, hiker traffic removes vegetation and organic litter and woody debris that would otherwise retard soil erosion in the initial upper canyon area during rain events. However, an alternative route (noted by park staff) involving 1-3 rappels could be developed to bypass this impact-susceptible portion of the route, avoiding these impacts and threats to visitor safety. Alternately, a new side-hill entrance trail with a 15% maximum grade could replace the existing informal routes, if judged appropriate for this zone. Use of either option should then be required of all Mystery Canyon hikers. Similarly, within central canyon several smaller obstacles can be traversed with either longer walk-arounds or by rappels/hand lines. At least two of the walk-arounds involve traversing steep slopes susceptible to soil erosion that could be hardened and reinforced with natural-appearing rockwork, or possibly blocked to prevent their use. For example, visitors could be instructed to use permanent anchors in such locations whenever they are provided to prevent avoidable resource damage. Implementing actions such as these would largely remove resource protection considerations from capacity decisions, possibly allowing greater visitation if groups could adopt staggered start times.

As another case example, consider the river valley just downstream from the Subway slot canyon (which is also similar to the upper Narrows river valley). Data reveal that this section has up to three parallel informal trails traversing the length of the valley but additional low- or high-water trails on both sides of the river could form in the future. Furthermore, trail alignments include short steep pitches with active erosion and a few locations where treads exceed six feet in width (Table 14). Applying use limitation to address these problems would be relatively ineffective due to the curvilinear relationship between trampling damage and use level (Leung & Marion 2000) and would require substantially lower use limits. If permitted within this zone, a formal trail could be designed, constructed, and maintained to sustain substantially greater use with a reduced aggregate area of disturbance and impact than the current set of informal trails. Alternately, managers could more subtly manage the existing informal trails to reduce their number and impacts (described below).

An adaptive management program involving education and site management is recommended when closing informal trails. The educational component is critical to communicate a clear rationale for closure - that significant resource impacts can occur in some areas if visitors travel off designated trails. Examples of impacts include the trampling of sensitive vegetation or soils, introducing or dispersing invasive plants, or disturbing wildlife or rare species. A rationale message should be followed by a plea for visitors to remain on formal trails, which need to be clearly designated (e.g., blazing, symbolic markers, cairns) to distinguish them from informal trails. Social science research and theory has found that signs with a compelling rationale and clear behavioral plea are more effective than simple "do" and "do not" messages (e.g., "Please Stay on Designated Trails to Preserve Sensitive Vegetation") (Cialdini 1996, Cialdini *et al.* 2006, Johnson & Swearingen 1992, Marion & Reid 2007, Vande Kamp *et al*. 1994, Winter 2006).

In summary, the educational program objectives are to ensure that visitors are aware that: 1) trampling impacts represent a significant threat to resource protection in some areas, 2) remaining on formal trails avoids these impacts, and 3) that formal trails can be distinguished from informal (visitor-created) trails by distinctive markings. Examples of signs that accomplish these objectives and that have received NPS approval for use are depicted in

Figure 12. Note the inclusion of the "no-step" icons that communicate the message with just a glance and are understandable by children and non-English speaking visitors.

Figure 12. Examples of an informative trailhead sign (left) and trailside prompter signs that can assist management efforts in closing informal trails.

Site management actions include maintaining and improving a formal trail or informal trail to more clearly identify the "preferred" trail and reduce use of unnecessary secondary or braided trails, particularly in meadows or wet areas. Maintenance of formal trails to improve tread drainage or clearly mark trail borders with logs, widely spaced rocks, or scree walls, can provide needed visual cues to deter off-trail traffic. Such improvements, along with improved marking on formal trails (e.g., over-blazing) can help visitors remain on the formal trail and distinguish it from informal trails. Most park managers have ignored informal trail networks, particularly with respect to tread maintenance. However, extending maintenance work to informal trails with sustainable designs reduces impacts on trails left open to use. For example, managers can piece together a single sustainable route in an area with numerous braided trails and trim obstructing vegetation, enhance tread drainage, and install natural-appearing rockwork on steep slopes. These actions encourage use and reduce impacts on the sustainable route while reducing use and encouraging natural recovery on alternate non-maintained.

A variety of site management actions are available for closing close informal trails. Close lightly used trails by actions that naturalize and hide their tread disturbance, particularly along initial visible sections where visitors make the decision to venture down them. Effective actions include raking organic debris such as leaves onto the tread, along with randomly placed local rocks, gravel, and woody debris designed to naturalize and hide the tread. These actions also lesson soil erosion and speed natural recovery. On trails that have been effectively closed, transplanting plugs of vegetation at the beginning of wet seasons can hasten natural recovery.

For well-used trails, such work cannot fully disguise the disturbed substrates and vegetation so additional measures are generally necessary for effective closures. Constructing a visually obvious border along the main trail, such as a row of rocks or a log, can communicate an implied blockage for those seeking to access the closed trail. Alternately, embed large rocks or place large woody materials or fencing to obstruct access at the entrance to closed trails to fully clarify management intent. Even simple 2 ft tall post and cord symbolic fences can communicate the importance of closures and effectively deter traffic (Figure 13) (Park *et al*. 2006). Placing rocks or woody debris that physically obstructs traffic beyond the beginning of closed trails can result in new trampling and trails parallel to the "closed" trail unless obstructed by topography and dense vegetation. It's better for hikers who ignore closures to remain on the "closed" tread than to create new ones, particularly when rare or sensitive plants and soils are present (Johnson *et al.* 1987). Finally, integrating site management work with temporary educational signs may be necessary to obtain a level of compliance that allows vegetative recovery (Figure 12). Also, consider signs to communicate the location of a preferred alternate route when visitors are seeking to reach a particular destination and their only visible access trail is closed.

Implementation of these informal trail management actions as part of an ongoing adaptive management program that includes some form of periodic monitoring is critical to program success. A 5-8 year interval could be sufficient for VERP program monitoring with quantitative procedures, but annual informal evaluations are needed to effectively guide the application of management actions when standards are exceeded. The installation and maintenance of educational and site management actions can be assigned as a collateral duty to those staff who spend the most time in the field. Experimentation will be necessary to refine site management procedures that are appropriate in each management zone. A documented lack of success with subtle procedures can be used to justify applying more objectionable procedures, such as signs, fencing, or even reductions in use limits.

Figure 13. Low symbolic post and rope fencing (left) and high fencing designed to physically obstruct access (right).

Trail Soil Loss Management Options

Soil loss on formal trails at levels exceeding the new park VERP standards is occurring at seven locations, including at least one on each of the study trails (Figure 11). Site assessments at each location by a qualified trail management professional are a recommended first step. Examination of the data collected in this study for study transects within areas that exceed the park's soil loss standard indicates that trail grades are frequently above 12% and trail slope alignment angles are occasionally below 23^o. These data suggest poor trail designs that are particularly susceptible to soil erosion. While it is possible that tread drainage and other maintenance actions can provide effective remedies, short relocations to improved alignments will likely provide a more effective long-term solution. Limiting horse traffic, which has been related to significantly higher levels of soil loss (Marion & Olive 2006), is another potentially effective option.

Trail Design and Construction: The most important design specification for limiting soil erosion is keeping trail grades below 10% (Hooper, 1988) or 12% (Hesselbarth and Vachowski 2000, Agate 1996). A design grade up to 10% is recommended for equestrian trails (Vogel 1982, Wood 2007) due to their higher potential for soil loss. Trail segments with steeper grades should be rerouted wherever possible, particularly those receiving moderate to heavy use. Trails that directly ascend a slope (irrespective of trail grade) will be difficult or impossible to drain water from if they become incised. Rerouting these sections is generally the most effective long-term solution. Side-hill trails on the contour or at oblique orientations (45-90^o) are easily drained to minimize erosion and their steeper side-slopes confine use to a narrow tread. The benefits of avoiding or minimizing future resource degradation and the cumulative costs of repetitive short-term maintenance clearly make side-hill trails with grades up to 12% the preferred design for resource protection and sustainable use.

Outsloping treads 5% during construction allows water to drain across and off the tread, rather than accumulate and run down the trail to erode soil (Birchard & Proudman 2000, Hooper, 1988). However, natural processes and trail use eventually compromise tread out-sloping so additional measures are needed to remove water from treads. The most effective and sustainable method for removing water from trails is the Coweeta or grade dip, also known as terrain dips or rolling grade dips (Birchard & Proudman 2000, IMBA 2004, Hesselbarth & Vachowski 2000).

These are constructed by reversing the trail's grade periodically (i.e., a descending trail's grade levels off and ascends briefly before resuming its descent) to force all water off the tread. These generally must be planned during initial construction, though it is sometimes possible to implement on existing trails in areas where grades are not too steep. A sufficient frequency of grade dips, particularly on steeper trail grades and in mid-slope positions, is necessary to prevent the accumulation of sufficient water to erode tread surfaces.

Trail Maintenance: Trail maintenance work addresses post-construction trail management needs – from routine maintenance to the resolution of severely degraded treads. First, analyze and understand the root cause of existing problems, such as low slope alignment angles, steep grades, lack of tread drainage features, heavy traffic, or high-impact types or seasons of use (Bayfield & Aitken 1992). Take a long-term perspective and consider whether the trail should be relocated to avoid future degradation and repetitive high maintenance or if tread reconstruction, drainage work, or hardening will suffice. Options such as seasonal or type-of-use restrictions and controlled (restricted) use should also be considered (Meyer 2002). Recognize that resolving problems with wet soils, deeply incised treads, or uneven tread surfaces will likely also reduce associated problems with trail widening and braiding. Apply intensive tread work including steps, drainage, and armoring with rock or gravel to prevent excessive erosion when topographic features prohibit relocation.

Over time, trails will often lose their constructed cross-sectional "shape" or "profile." Most trail treads are constructed with outsloped treads but soil, rock and organic material generally accumulate along both sides of trails, causing water to run down the trail and erode tread substrates. Slough material on the upslope side of the trail should be removed and the original outsloped tread surface should be reestablished periodically (Birchard & Proudman 2000). Berm material on the downslope side should be cleared when present, allowing water to more quickly move across and off the tread. Use non-organic slough and berm material to fill in eroded ruts or over exposed roots and rocks, and apply rockwork or wooden steps to hold such material in place. Some trails are in-sloped to a ditch and others, particularly in flat terrain, are crowned – reestablishing and maintaining these profiles is critical to removing the erosive effects of water from trails.

Two of the very worst trail problems, soil erosion and muddiness, are caused by water accumulating on trail treads. Even though the park has an arid climate, most soil loss appears to occur during short high rainfall events, so tread drainage features are still critical to minimizing soil loss. Water removal should be a top trail maintenance priority, one that cannot be deferred without the potential for suffering significant long-term and possibly irreversible trail degradation. Grade dips and tread outsloping are the best and most sustainable methods for water removal – both should be original design features and may be difficult to add during routine trail maintenance work (Hesselbarth & Vachowski 2000). Subsequent trail maintenance seeks to enhance the ability of natural features, or to construct and maintain artificial features, that divert water from tread surfaces. Natural features may be roots, rocks, or low points where water can be drained from the trail. Minor ditching at these sites can increase their ability to remove water. Some authors refer to these as "bleeders" (Birchard & Proudman 2000). Artificial tread drainage features include water bars and drainage dips, which are designed to intercept and drain water to the lower sides of trails.

Numerous authors provide guidance on the installation and maintenance of water bars and drainage dips (Agate 1996, Hesselbarth & Vachowski 2000, Birchard & Proudman 2000, Demrow & Salisbury 1998). The U.S. Forest Service (1984, 1991) provides specifications for these installations and other trail construction techniques. Key considerations include their frequency, trail angle, size and stability. Water bars may be constructed of rock or wood (Birkby 1996). Drainage dips are shallow angled channels dug into the tread to drain water with an adjacent downslope berm of soil to increase their effectiveness and longevity. U.S. Forest Service guidance specifies tread drainage frequencies based on trail grade and soil type; for example, every 100 ft for loam soil at 6% grade and every 50 ft for loam soil at 10% grade (Forest Service 1991).

The angle at which water bars and drainage dips are installed relative to the trail alignment is also critical. An angle of 45-60^{o} insures that water will run off the trail with sufficient speed to carry its' sediment load (Hesselbarth & Vachowski 2000). Larger angles will cause water to pool first, dropping sediment loads and filling in drainage channels. Cleaning and reconstruction of tread drainage features must be done at least once each year to maintain their effectiveness. Many parks have developed volunteer trail maintenance programs to assume many trail maintenance duties. Effective water bars must be of sufficient length to extend across the trail and be anchored beyond tread boundaries. This will discourage trail users and surface water from circumventing the drainage feature. For log water bars, a diameter of >6 inches allows 2-3 inches to be embedded with sufficient above-ground material left to divert water from larger storm events. Stability is also critical, rock and wood water bars must be sufficiently anchored to sustain heavy traffic from hikers or horses.

CONCLUSION

This report seeks to inform Zion National Park planning and management decision-making regarding the resource impacts associated with camping and hiking activities. This was accomplished through the development and application of campsite and trail impact assessment methods as part of a long-term monitoring program. Procedures were refined through their application to a large sample of designated campsites and formal and informal trails, and the subsequent dataset was used to characterize existing baseline conditions. Park planners and managers also reviewed the study findings when considering the selection of appropriate VERP indicators and standards. Subsequent application of the standards to the dataset characterized the current status of compliance for some indicators and provided an opportunity to describe alternative park management options for addressing current and future situations when standards are exceeded.

Monitoring manuals contained in Appendix 1 and 2 can be reduced in length by park staff during subsequent reapplication to include only those indicators of interest. Assessment of indicators beyond those included in the VERP process can provide managers with additional information that may be useful in management decision-making. Some procedures in the trail manual were updated to incorporate improved assessment methods while retaining comparability to the earlier procedures.

The future reapplication of the campsite and trail condition assessment procedures will provide a number of benefits to Zion NP managers. First, monitoring data are essential to the objective evaluation of indicator standards specified in the Zion NP BMP. Monitoring data also provide feedback for gauging the success of management interventions that are implemented to avoid or reduce impacts. A documented failure of one intervention can be used to justify the use of a more obtrusive or expensive intervention. Finally, analyses of monitoring data can sometimes provide insights regarding the selection of effective management actions.

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APPENDIX 1: CAMPSITE MONITORING MANUAL

Zion National Park[1,2]

(*version 11/1/02*)

This manual describes procedures for conducting inventories and resource condition assessments necessary to document changes in the condition of backcountry campsites. It was developed for assessing conditions at designated campsites within Zion National Park. Three general approaches are used for assessing campsite conditions: 1) photographs from permanently referenced photo points, 2) a condition class assessment determined by visual comparison with six described levels of campsite impact, and 3) predominantly measurement-based assessments of several impact indicators.

For the purposes of this manual, campsites are defined as backcountry areas of disturbed vegetation, surface litter, or soils caused by human use as overnight camping activities. In areas with multiple sites or use areas there may not always be undisturbed areas separating sites and an arbitrary decision may be necessary to define separate sites.

Monitoring measurements should be taken near the middle or end of the visitor use season but before leaf fall. Site conditions generally recover during the fall/winter/spring periods of lower visitation and reflect rapid impact during early season use. Site conditions are more stable during the mid- to late-use season and reflect the resource impacts of that year's visitation. Subsequent assessments should be completed as close in timing to the original year's measures as possible. Generally monitoring should be replicated at five year intervals, unless conditions are changing rapidly.

Materials

(Check before leaving for the field)

- Topographic maps (1/24,000) with copier enlargements of areas with dense concentrations of sites (cut out and copy scale bars with enlargements)
- Compass, peephole type (not corrected for declination) and/or KVH Data Scope, digital compass
- Tape measure (100 ft. <u>in tenths</u>) and/or Sonin Combo Pro distance measuring device
- Field forms, maps, and photographs from previous campsite surveys
- Flagged wire pins (25 minimum w/additional set of different color for remeasurement)
- Large steel reference point stake
- Camera, digital, with additional photo storage cards as needed.
- Aluminum numbered tags, 4 in. galvanized steel nails
- Clipboard, monitoring manual, blank field forms (some on waterproof paper), pencils
- Backpacking trowel
- Magnetic pin locator (site remeasurement only)

1 - Developed by Dr. Jeff Marion, USDI, U.S. Geological Survey, Patuxent Wildlife Research Center Field Unit, Virginia Tech/Department of Forestry, Blacksburg, VA 24061-0324 (540/231-6603) email: jmarion@vt.edu.

2 - Photographs illustrating campsite boundaries, boundary flag placement, vegetative ground cover classes, soil exposure, tree damage, and root exposure are part of this manual. High quality reproductions of these photographs, some of which are in color, may be found in: Marion, Jeffrey L. 1991. Developing a natural resource inventory and monitoring program for visitor impacts on recreation sites: A procedural manual. USDI, National Park Service, Natural Resources Report NPS/NRVT/NRR-91/06, pages 46-51.

General Campsite Information

1) **Campsite Number**: Each site must have a unique aluminum tag number. Refer to campsite maps and forms from earlier surveys to identify if the site has been previously surveyed. If it has, follow the site remeasurement procedures below. If the site has not been previously surveyed then assign a new number from an aluminum tag and record it on the form. Criteria for locating the permanent reference point are provided in the Variable Radial Transect section of the manual. If it is impossible to bury an aluminum tag (e.g., due to bedrock), the same numbering system as above should be applied as if aluminum tags were used. If a tag is not buried it should be separated and disposed of to avoid confusion at subsequent campsites. If it is a shelter site, bury the tag adjacent to the left front shelter corner post, just under the shelter. Regardless, remarks should be made on the field form indicating whether and/or where a tag was buried.

   Site remeasurement - Examine mapped campsite locations and field forms to determine if each campsite was present during the previous survey. Relocate permanent reference points with information from the form and the pin locator and verify campsite numbers by digging up the number tags. If the site has been previously surveyed but you are unable to locate the nail and tag then record the old number (if positively known) with a note that the nail and tag could not be found. If the reference point can be accurately identified from the previous survey form information and photo then do so, noting this on the new form. Use a new campsite tag and number, however, and record both old and new numbers on the form. If the reference point cannot be identified then proceed as if the site had never been surveyed before, recording new reference site information and the old and new tag numbers.

   Note – Guidance for odd situations: 1) A satellite use area has become the main site and the previous site is now a satellite site or has recovered. Use the same site number from the earlier survey. Relocate and dig up the nail and tag from the old site. Rebury the nail in the original location, moving the tag along with a new nail to a permanent reference point location on the current site (which was formerly a satellite site). Complete all procedures on the current site. Describe the situation in the comments section. 2) The site was rehabilitated by park staff or has recovered on it's own. Complete a new form to allow an evaluation of site recovery for any sites that you can find. Take a photo from previous survey photo points.

2) **Site Type**: Record the most specific applicable code: **L** - current site, also present in last survey; **N** - new site; **S** - current site, satellite in last survey; **RL** - rehabilitated, present in last survey; **RN** - rehabilitated, new site; **SRE** - site is recovered, rehab work evident; **SRN** - site is recovered, no rehab work evident

3) **Location**: Record the location of the campsite, general name for the area, and park site number.

4) **UTM Coordinates**: Record the campsite location using a GPS device

5) **Date**: Month, day, and year the campsite was evaluated (e.g. August 1, 2002 = 08/01/02).

   Site remeasurement - Due to phenological and campsite use changes which occur over the use season, it is critical that campsites be re-measured as close to the initial assessment month and day as possible, preferably within 1 to 2 weeks if early in the use season, 3 to 4 weeks if later.

6) **Inventoried by**: Identify the field personnel responsible for campsite.

Locate/Label Campsite on Topographic Map - Mark the topographic map with a dot precisely indicating the campsite's location and label with its campsite tag number. Be as accurate as possible. At 1/24,000 scale 1/4 inch on map = 500 ft. on ground. Accurate campsite location descriptions are critical to site relocation. For dense clusters of campsites use 150% copier enlargements so that campsites can be more accurately mapped.

Describe Location - Describe the campsite location using local geographic features (trail intersections, stream crossings, large boulders or trees) and paced (or measured) distances. Record the distance of your pace in parentheses, for example: 18 paces (5.5'), each time you record a paced distance. Conversions will be done in the office. Verify your pace periodically. Use sufficient descriptive detail and additional local area maps as so that someone else years later can relocate the site.

Inventory Indicators

7) **Distance to Nearest Other Campsite**: Record the appropriate category for campsite distance (campsite boundary to campsite boundary) to the nearest other campsite or shelter.
(1 = <10 yds 2 = 11-20 yds 3 = 21-40 yds 4 = 41-60 yds 5 = >60 yds)

8) **Distance to Formal Trail**: Record the appropriate category for campsite distance (closest outer boundary) to the nearest formal (designated) trail.
(1 = <10 yds 2 = 11-20 yds 3 = 21-40 yds 4 = 41-60 yds 5 = >60 yds)

9) **Other Campsites Visible**: Record the number of other shelters or campsites, which if occupied, would be visible from the campsite. This is a social variable to assess intervisibility.

10) **Site Visibility from Formal Trail**: Record whether the **campsite, if it were occupied, would be** visible from any of the formal (designated) trail (not informal visitor-created trails). Y or N

11) **Site Expansion Potential**: L= Low expansion potential - off-site areas are completely unsuitable for any expansion due to steep slopes, rockiness, dense vegetation, and/or poor drainage, M = Moderate expansion potential - off-site areas moderately unsuitable for expansion due to the factors listed above, and H = High expansion potential - off-site areas are suitable for campsite expansion, features listed above provide no effective resistance to campsite expansion.

12) **Site Slope**: Record the campsite slope category (F = <5% M = 5-10% S = >10%)

13) **Tree Canopy Cover**: Imagine that the sun is directly overhead and estimate the percentage of the campsite that is shaded by the tree canopy cover. Note: use category 5 for nearly full to full tree canopy cover over the site; use category 6 only if the cover is fairly dense or thick.
(1 = 0-5% 2 = 6-25% 3 = 26-50% 4 = 51-75% 5 = 76-95% 6 = 96-100%)

Impact Indicators

The first step is to establish the campsites' boundaries and measure its size. The following procedures describe the use of the **Variable Radial Transect Method** for determining the sizes of campsites. This is accomplished by measuring the lengths of linear transects radiating from a permanently defined reference point to the campsite boundary. **If the campsite has previously been assessed with the Variable Radial Transect Method, then skip to the Site Remeasurement procedures below.**

Step 1. Identify Campsite Boundaries and Flag Transect Endpoints. Walk the campsite boundary and place flagged wire pins at locations which, when connected with straight lines, will define a polygon whose area approximates the campsite area. Include the shelter within site boundaries. Use as few pins as necessary, typical campsites can be adequately flagged with 10-15 pins. Look both directions along campsite boundaries as you place the flags and try to balance areas of the campsite that fall outside the lines with off-site (undisturbed) areas which fall inside the lines. Pins do not have to be placed on campsite boundaries, as demonstrated in the diagram in Figure 1. Project campsite boundaries straight across areas where trails enter the campsite. Identify campsite boundaries by pronounced changes in vegetation cover, vegetation height/disturbance, vegetation composition, surface organic litter, and topography (refer to photographs following these procedures). Many campsites with dense forest overstories will have very little vegetation and it will be necessary to identify boundaries by examining changes in organic litter, i.e. leaves which are untrampled and intact vs. leaves which are pulverized or absent. In defining the campsite boundaries be careful to include only those areas that appear to have been disturbed from human trampling. Natural factors such as dense shade can create areas lacking vegetative cover. Do not include these areas if they appear "natural" to you. When in doubt, it may also be helpful to speculate on which areas typical visitors might use based on factors such as slope or rockiness. If you cannot discern trampling-related disturbance boundaries for most of the site then skip this procedure, record a 0 for campsite area (#28) and move on to #14.

Step 2. Establish Campsite Reference Point. Select a campsite reference point which is preferably: a) visible from all the campsite boundary pins, b) close to and easily referenced by distinctive permanent features such as boulders or trees, c) at least 6 ft away from fire grates or other steel that would affect compass readings, and d) in a spot permitting the burial of the reference point nail and campsite tag. Reference this point to at least three relatively permanent and distinctive features. If trees are used select ones that are healthy and unique to the campsite area, such as an uncommon species or with unique physical characteristics (forked trunk or large size). Try to select reference features in three opposing directions, as this will enable future workers to triangulate the reference point location. Also take the reference point photograph(s) and reference the photopoint(s) as described at the end of this manual.

For each reference feature, take a compass bearing (nearest degree) and measure the distance (nearest 1/10th foot) from the feature (center of trees or the highest point of boulders) to the campsite reference point. Also measure the approximate diameter of reference trees at 4.5 ft above ground (dbh). Be extremely careful in taking these bearings and measurements as they are critical to relocating the reference point in the future. Record this information on the back of the form.

Examples:
1) Red Maple, 2.9 ft. dbh, 8.9 ft. at 195^{o} (largest tree on campsite)

2) Boulder, 7.9 ft. at 312^{o}, (distance and bearing to highest point)

3) Sycamore, 1.8 ft. dbh, 8.4 ft. at 78^{o}, (only Sycamore in the area)

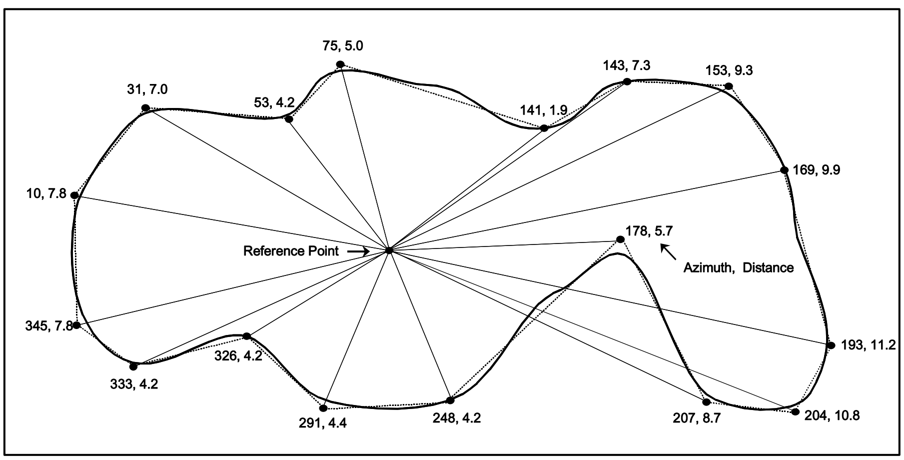

Figure 1. Variable radial transect method.

Options: Some campsites may lack the necessary permanent reference features enabling the point to be accurately relocated. If only one or two permanent reference features are available, use these and take additional photographs from several angles. If you are unable to bury a nail and tag (e.g. bedrock) then select a permanent feature (e.g., some obvious bedrock feature) and use it as a reference point. Complete procedures to reference its location, including photographs. Note your actions regarding use of these options in the Comments section.

Step 3. Record Transect Azimuths and Lengths. Standing directly over the reference point, identify and record the compass bearing (azimuth) and distance to each campsite boundary pin working in a clockwise fashion (in the exact order you would encounter them if you were walking the campsite boundary). Be careful not to miss any pins hidden behind vegetation or trees. Be extremely careful in identifying the correct compass bearings to these pins as error in these bearings will bias current and future measurements of campsite size. If a tape measure is used, anchor the end to the large steel reference point stake and route it via the shortest distance around trees or other obstructions. Record the length of each transect (nearest 1/10th foot), starting with the same boundary pin and in the same clockwise order as before. Be absolutely certain that the appropriate pin distances are recorded adjacent to their respective compass bearings. Leave boundary pins in place until you finish all other campsite measurements.

Step 4. Measure Island and Satellite Areas. Identify any undisturbed "islands" of vegetation ($ 3x3 ft) inside campsite boundaries (often due to clumps of trees or shrubs) and disturbed "satellite" use areas ($ 3x3 ft) outside campsite boundaries (often due to tent sites or cooking sites). Use campsite boundary definitions for determining the boundaries of these areas. Use the **Geographic Figure Method** to determine the areas of these islands and satellites (refer to the Figure 3 diagrams at the end of the manual). This method involves superimposing one or more imaginary geometric figures (rectangles, circles, or right triangles) on island or satellite boundaries and measuring appropriate dimensions to calculate their areas. Record the types of figures used and their dimensions on the back of the form; the sizes of these areas should be computed in the office with a calculator. Also, record the compass bearing and distance from the center of each island or satellite site to the campsite reference point. Remove the reference point stake. Place a 4 inch long galvanized steel nail through the hole in the campsite number tag and bury at the reference point so that the tag is 3 inches deep.

Site Remeasurement - Relocate the reference point using point references, photos, and a magnetic pin locator. Typically the photo will get you in the right area and the pin locator will allow you to pinpoint the buried nail and tag. If you cannot find it then search for the three reference features, go to each and shoot the back azimuth (small number scale in the peep hole compass viewfinder). Use the tape measure to determine the correct distance and draw an arc on the ground. If the pin locator still does not register then repeat procedure from the other reference features and reestablish the reference point with a new tag and nail (note new campsite number on form and in database). Insert the large steel stake at the reference point location and reestablish all former campsite boundary pins using the previous transect data compass bearings and distances. Place wire flags on a single color at each the transect endpoints. Next, reassess these previous boundary locations using the following procedures (illustrated in Figure 2). Place wire flags of a different color at the end of each reassessed transect, both pre-existing and new (including transects whose length has not changed).

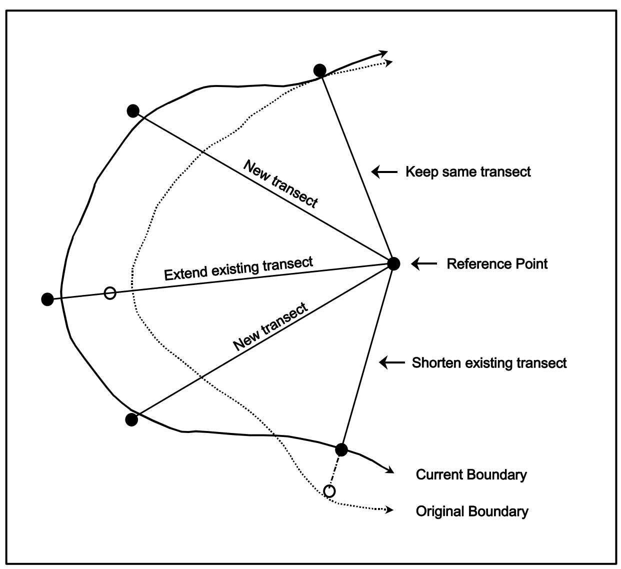

Figure 2. Transect site remeasurement procedures.

a) Keep the same transect length if that length still seems appropriate, i.e. there is no compelling reason to alter the initial boundary determination.

b) Record a new transect length if the prior length is inappropriate, i.e. there is compelling evidence that the present boundary does not coincide with the pin and the pin should be relocated either closer to or further from the reference point along the prescribed compass bearing.

c) Repeat earlier Steps 1 and 3 to establish additional transects where necessary to accommodate any changes in the shape of campsite boundaries. Also repeat Step 4 to account for changes in island and satellite sites. If satellite areas are no longer disturbed, i.e. condition class 0, then note this in the Comments and do not remeasure their size.

d) Take and record new distances and compass bearings for transects that have changed in length and for new transects using the flags denoting current campsite boundaries. For transects that have not changed in length, copy the old transect data to the new forms (reassessing these would introduce measurement error). Record all transect data on the new form in the exact order you would encounter each transect if you walked the campsite boundary in a clockwise direction.

These procedures are designed to eliminate much of the measurement error associated with different individuals making subjective judgments on those campsites or portions of campsites where boundaries are not pronounced. These procedures may only be used for campsites whose reference points can be relocated.

Class 0: Campsite barely distinguishable; no or minimal disturbance of vegetation and /or organic litter. Often an old campsite that has not seen recent use.
Class 1: Campsite barely distinguishable; slight loss of vegetation cover and /or minimal disturbance of organic litter.
Class 2: Campsite obvious; vegetation cover lost and/or organic litter pulverized in primary use areas.
Class 3: Vegetation cover lost and/or organic litter pulverized on much of the site, some bare soil exposed in primary use areas.
Class 4: Nearly complete or total loss of vegetation cover and organic litter, bare soil widespread.
Class 5: Soil erosion obvious, as indicated by exposed tree roots and rocks and/or gullying.

14) **Condition Class**: Record a campsite Condition Class using the descriptions below. If a campsite is underlain entirely by bedrock record "-1" for this item and items 15 - 17 as they are not applicable for bedrock campsites. Include an explanation in the field form under Comments.

15) **Vegetative Ground Cover On-Site**: An estimate of the percentage of live non-woody vegetative ground cover (including herbs, grasses, and mosses and excluding tree seedlings, saplings, and shrubs) within the flagged campsite boundaries using the coded categories listed below (refer to photographs following these procedures). Include any disturbed "satellite" use areas and exclude undisturbed "islands" of vegetation. For this and the following two indicators, it is often helpful to narrow your decision to two categories and concentrate on the boundary that separates them. For example, if the vegetation cover is either category 2 (6-25%) or category 3 (26-50%), you can simplify your decision by focusing on whether vegetative cover is greater than 25%.

	1 = 0-5%	2 = 6-25%	3 = 26-50%	4 = 51-75%	5 = 76-95%	6 = 96-100%
Midpoints:	2.5	15.5	38	63	85.5	98

Site remeasurement - Also evaluate vegetative ground cover within the campsite boundaries identified during the last measurement period.

16) **Vegetative Ground Cover Off-Site**: An estimate of the percentage of live non-woody vegetative ground cover (including herbs, grasses, and mosses and excluding tree seedlings, saplings, and shrubs) in an adjacent but largely undisturbed "control" area. Use the categories listed above. The control site should be similar to the campsite in slope, tree canopy cover (extent of sunlight penetration), and other environmental conditions. The intent is to locate an area which would closely resemble the campsite area had the site never been used. In instances where you cannot decide between two categories, select the category with less vegetative cover. The rationale for this is simply that the first visitors would have selected a campsite with the least amount of vegetation.

Site remeasurement - Start by reexamining the off-site vegetative cover estimate from the last measurement period. Use this value only if it remains an appropriate estimate.

17) **Exposed Soil**: An estimate of the percentage of exposed soil, defined as ground with very little or no organic litter (partially decomposed leaf, needle, or twig litter) or vegetation cover, within the campsite boundaries and satellite use areas (refer to the photographs following these procedures). Dark organic soil, the decomposed product of organic litter, should be assessed as bare soil when its consistency resembles peat moss. Assessments of exposed soil may be difficult when organic litter forms a patchwork with areas of bare soil. If patches of organic material are relatively thin and few in number, the entire area should be assessed as bare soil. Otherwise, the patches of organic litter should be mentally combined and excluded from assessments. Soil covered by a shelter should be counted as exposed soil. Code as for vegetative cover above.

Site remeasurement - Also evaluate exposed soil within the campsite boundaries identified during the last measurement period.

18-20) **Tree Damage**: Tally each live tree (>1 in. diameter at 4.5 ft.) within or on campsite boundaries to one of the tree damage rating classes described below (refer to the photographs following these procedures). **Include** trees within undisturbed "islands" and **exclude** trees in disturbed "satellite" areas. Assessments are restricted to all trees within the flagged campsite boundaries in order to ensure consistency with future measurements. Multiple tree stems from the same species that are joined at or above ground level should be counted as one tree when assessing damage to any of its stems. Assess a cut stem on a multiple-stemmed tree as tree damage, not as a stump. Do not count tree stumps as tree damage. Take into account tree size. For example, damage for a small tree would be considerably less in size than damage for a large tree. Where obvious, assess trees with scars from natural causes (e.g., lightning strikes) as None/Slight.

None/Slight ..... No or slight damage such as broken or cut smaller branches, one nail, or a few superficial trunk scars.
Moderate......... Numerous small trunk scars and/or nails or one moderate-sized scar.
Severe............. Trunk scars numerous with many that are large and have penetrated to the inner wood; any complete girdling of tree (cutting through tree bark all the way around tree).

Site remeasurement - begin by assessing tree damage on all trees within the site boundaries identified in the last measurement period. Place boxes around each tally for trees in areas where boundaries have moved closer to the reference point, i.e., former site areas which are not currently judged to be part of the site. Next, assess tree damage in areas where boundaries have moved further from the reference point, i.e., expanded site areas that are newly impacted since the last measurement period. Circle these tallies. These additional procedures are necessary in order to accurately analyze changes in tree damage over time.

21-23) **Root Exposure**: Tally each live tree (>1 in. diameter at 4.5 ft.) within or on campsite boundaries to one of the root exposure rating classes described below. **Include** trees within undisturbed "islands" and **exclude** trees in disturbed "satellite" areas. Assessments are restricted to all trees within the flagged campsite boundaries in order to ensure consistency with future measurements. Where obvious, assess trees with roots exposed by natural causes (e.g., stream/river flooding) as None/Slight.

None/Slight ..... No or slight root exposure such as is typical in adjacent offsite areas.
Moderate......... Top half of many major roots exposed more than one foot from base of tree.

Severe............. Three-quarters or more of major roots exposed more than one foot from base of tree; soil erosion obvious.

Site remeasurement - Begin by assessing root exposure on all trees within the site boundaries identified in the last measurement period. Place boxes around each tally for trees in areas where boundaries have moved closer to the reference point, i.e., former site areas which are not currently judged to be part of the site. Next, assess root exposure in areas where boundaries have moved further from the reference point, i.e., expanded site areas that are newly impacted since the last measurement period. Circle these tallies. These additional procedures are necessary in order to accurately analyze changes in root exposure over time.

24) **Number of Tree Stumps**: A count of the number of tree stumps (> 1 in. diameter at ground and less than 4.5 feet tall) within or on campsite boundaries. **Include** trees within undisturbed "islands" and **exclude** trees in disturbed "satellite" areas. Do not include windthrown trees with their trunks still attached or cut stems from a multiple-stemmed tree.

Site remeasurement - begin by assessing stumps within the site boundaries identified in the last measurement period. Place boxes around each tally for stumps in areas where boundaries have moved closer to the reference point, i.e., former site areas which are not currently judged to be part of the site. Next, assess stumps in areas where boundaries have moved further from the reference point, i.e., expanded site areas that are newly impacted since the last measurement period. Circle these tallies. These additional procedures are necessary in order to accurately analyze changes in stumps over time.

25) **Number of Fire Sites**: A count of each fire site within campsite boundaries, including satellite areas. Include old inactive fire sites as exhibited by blackened rocks, charcoal, or ashes. Do not include locations where charcoal or ashes have been dumped. However, if it is not clear whether a fire was built on the site, always count questionable sites that are within site boundaries and exclude those that are outside site boundaries.

26) **Access Trails**: A count of all trails leading away from the outer campsite boundaries. For trails that branch apart or merge together just beyond campsite boundaries, count the number of separate trails at a distance of 10 ft. from campsite boundaries. Do not count extremely faint trails that have untrampled tall herbs in their tread.

27) **Human Waste**: Follow all trails connected to the campsite to conduct a quick search of likely "toilet" areas, typically areas just out of sight of the campsite. Count and record the number of individual human waste sites, defined as separate locations with human feces present. The intent is to identify the extent to which improperly disposed human feces is a problem.

28) **Total Campsite Area**: Using a computer program (contact Jeff Marion), compute the campsite size using the transect data. Using a calculator, compute and sum the area of each island and satellite site (see the *Geometric Figure Method* sheet for procedures and formulas). Record these values in the spaces provided on the back of the form and calculate the Total Campsite Area. Record this value on the front of the form to facilitate computer data entry.

Comments: An informal list of comments concerning the campsite: note any assessments that you felt were particularly difficult or subjective, problems with monitoring procedures or their application to this particular campsite, suggestions for clarifying monitoring procedures, descriptions of particularly significant impacts beyond campsite boundaries (quantify if possible), excessive litter, human waste, or any other comments you feel may be useful.

Campsite/Reference Point Photographs: If the campsite has been previously surveyed, relocate the photo point and use it again. Frame your photo and adjust zoom lens to include the same area depicted in the earlier photo(s). If the site has expanded to areas that are not visible in the viewfinder then turn the camera to capture these areas or move back if necessary (and remeasure photo point distance). If the site has not been previously surveyed, select a vantage point that provides the best view of the campsite and reference point location. Try to select a location that clearly shows the reference point location in relation to nearby trees or boulders. It is best to have a person stand at the reference point with no one else in the photo. Also take a separate reference point photograph from a closer position that clearly identifies this point in relation to permanent site features. Place the tape measure or some other object against the reference point stake so that it is clearly visible in the camera viewfinder. For both photos leave the camera lens set at a consistent, preferably wide angle, focal length. Take photos with the camera pointed camera down to include as much of the campsite groundcover as possible. If a camera with a date/time option is used (preferred), record the date/time on the field form. ***Photo description procedures***: Use the photo description space to record the photo numbers, date/time, and to write something unique about the photo that will allow someone to recognize and label the photo for this campsite.

Record the compass bearing and distance from the permanent reference point to the campsite photopoint (you may be able to use one of the campsite boundary flags as the photopoint). The intent is to obtain a photograph that includes as much of the campsite as possible to provide a photographic record of campsite conditions. The photo will also allow future workers to make a positive identification of the campsite and assist in relocating the permanent reference point. The location of the reference point photo does not need to be measured or recorded. Be sure to back-up and archive all photographs for future reference.

* **Bury reference point nail and tag about 3 inches deep, compact soil with foot. Collect all campsite boundary pins, the reference point stake, and all other equipment.**

Equipment Use Procedures

Use of Peep Hole Compasses: Hold the compass level with the viewfinder close to your eye and away from any metal objects. The top of the white floating scale should be centered in the viewfinder. With your chin over the reference point, align the object with the vertical black line in the viewfinder. Hold the compass very steady, allowing the compass scale to come to a rest. Read and record the bearing to the nearest degree. Be careful in reading the bearing from the scale, use large numbers (small numbers are the back azimuth) and note that scale values decrease from left to right. Large-scale interval is 5 degrees, smallest interval is 1 degree. Practice and periodically compare compass readings with your partner to verify their accuracy. (Cost: $42)

Use of KVH Datascope: Read Datascope manual. We will only use the compass bearing function (the distance function is intended only for estimates of long distances). Remove and safely store both lens caps. Hold the datascope approximately level (though it is gimballed for tilt angles up to "20$^{o)}$ and away from metal objects. Focus on target by turning rubber eyecup. Turn unit on by pressing any button (it shuts off automatically after 2 minutes of inactivity). If necessary, press the white "mode" button until you see the "Bearing" mode inside viewfinder. Push both green and black buttons so that the word "Bearing" begins flashing, it is now in continuous scanning and averaging mode. Sighting through the unit, superimpose the vertical line on your target, hold the unit very steady. Read and record the compass bearing to the nearest ½ of a degree. Replace lens caps and store in protective case following use. Accuracy is "0.5^{o}, *if used correctly*. The Datascope is waterproof and shockproof but lets not do any product testing - be careful! **Batteries**: Carry spare batteries (3 3-volt #2025 lithium). Unit must be recalibrated each time batteries are replaced or used in a location where the magnetic field is widely different from where it was last calibrated - see manual for procedures. (Cost: $470)

Use of Sonin Combo Pro: Read the Sonin manual. We will only use it in the target or dual unit mode. Turn main "receiver" unit on by pressing switch up to the double icons, turn "target" unit on and slide the protector shield up. The units power down automatically after 4 minutes of inactivity. Position units at opposite ends of segment to be measured, pointing the receiver sensors in a perpendicular orientation towards the target sensors. **Note:** The measurement is calculated from the base of the receiver and the back of the target, position units accordingly so that you measure precisely the distance your intended. Press and hold down the button with the line over the triangle symbol. The receiver will continue to take and display measurements as long as you depress the button. Wait until you achieve a consistent measurement, then release the button to freeze the measurement. Measures initially appear in feet/inches. To obtain conversions, press and hold the "C" button until the measure is converted to the units you want (tenths of a foot). Turn both devices off and store in protective case following use. Unit range is supposed to be 250 ft.; be careful and take multiple measures for distances over 100 ft. Under optimal conditions accuracy is within 4 in. at 60 ft. Device can be affected by temperature, altitude and barometric pressure, and noise (even strong wind). The units are not waterproof. **Batteries**: Carry spare batteries (2 9-volt alkaline). (Cost: $185)

Geometric Figure Method

This method for determining the area of campsites, disturbed "satellite" sites, and interior undisturbed "island" sites is relatively rapid and can be quite accurate if applied with good judgment. Begin by carefully studying the campsite's shape, as if you were looking down from above. Mentally superimpose and arrange one or more simple geometric figures to closely match the campsite boundaries. Any combination and orientation of these figures is permissible, see the examples below. Measure (nearest 1/10th foot) the dimensions necessary for computing the area of each geometric figure. It is best to complete area computations in the office with a calculator to reduce field time and minimize errors.

Good judgment is required in making the necessary measurements of each geometric figure. As boundaries will never perfectly match the shapes of geometric figures, you will have to mentally balance disturbed and undisturbed areas included and excluded from the geometric figures used. For example, in measuring an oval campsite with a rectangular figure, you would have to exclude some of the disturbed area along each side in order to balance out some of the undisturbed area included at each of the four corners. It may help, at least initially, to place plastic tape or wire flags at the corners of each geometric figure used. In addition, be sure that the opposite sides of rectangles or squares are the same length.

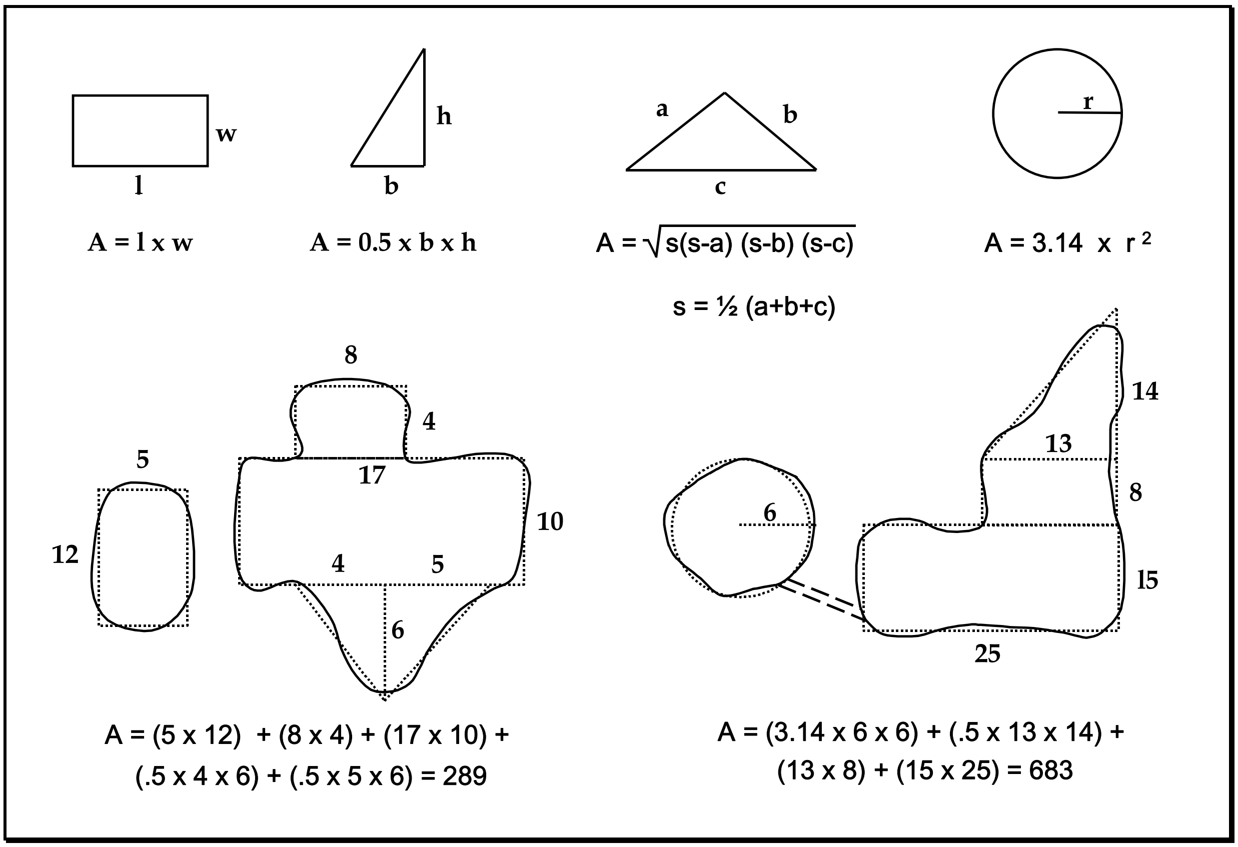

Figure 3. Geometric figure method for assessing campsite sizes.

Zion National Park Campsite Monitoring Form

ver. 11/1/02

General Campsite Information

1) Campsite Tag No. __ __ __ __ 2) Site Type _______ 3) Location ____________________

4) UTM Coordinates ____________________

5) Date _ _ / _ _ / _ _ 6) Inventoried by: _________ Locate/Label Site on Map

Describe Location: ____

____

____

Inventory Indicators

7) Distance to Nearest Other Campsite (**1**=<10 yds **2**=11-20 yds **3**=21-40 yds **4**=41-60 yds **5**=>60 yds) _____

8) Distance to Formal Trail (**1**=<10 yds **2**=11-20 yds **3**=21-40 yds **4**=41-60 yds **5**=>60 yds) _____

9) Other Campsites Visible (#) _____

10) Site Visibility from Formal Trail Y / N _____

11) Site Expansion Potential: H M L _____

12) Site Slope: (**F** = <5% **M** = 5-10% **S** = >10%) _____

13) Tree Canopy Cover (**1**=0-5% **2**=6-25% **3**=26-50% **4**=51-75% **5**=76-95% **6**=96-100%) _____

Impact Indicators

-- Apply Variable Radial Transect Method --

14) Condition Class (0 to 5) _____ ***Previous B.***

15) Vegetative Ground Cover On-Site (Use categories below) _____ _____

	(**1**=0-5%	**2**=6-25%	**3**=26-50%	**4**=51-75%	**5**=76-95%	**6**=96-100%)
Midpoints:	2.5	15.5	38	63	85.5	98

16) Vegetative Ground Cover Off-Site (Use categories above) _____ _____

17) Exposed Soil (Use categories above) _____ _____

18-20) Tree Damage None/Slight ____________ Moderate ____________ Severe _______

21-23) Root Exposure None/Slight ____________ Moderate ____________ Severe _______

24) Tree Stumps (#)______________ _____

25) Fire Sites (#) _____

26) Access Trails (#) _____

27) Human Waste (#) _____

28) Total Campsite Area (Office) _____ft^2

Zion National Park Campsite Monitoring Form

ver. 11/1/02

Comments/Recommendations:____

____

____

____

Campsite Photo: Photo # ____ Bearing ____ Distance _____ ft Date/time: ___________

Description: _______________________

Ref. Pt. Photo #: ____ Description ____

Campsite Reference Point Information

1)

2)

3)

Bury Nail/Tag ___

Satellite Site Dimensions	Bearing	Distance

Island Site Dimensions	Bearing	Distance

Area from computer program ________

+ Satellite Area ________

- Island Area ________

= Total Campsite Area ________ ft^2

Transect Data

	Bearing	Distance (ft)
1)		
2)		
3)		
4)		
5)		
6)		
7)		
8)		
9)		
10)		
11)		
12)		
13)		
14)		
15)		
16)		
17)		
18)		
19)		
20)		
21)		
22)		
23)		
24)		
25)		

Zion National Park Campsite Monitoring Form - Narrows

ver. 11/1/02

General Campsite Information

1) Campsite Tag No. __ __ __ __ 2) Site Type _______ 3) Location ____________________

4) UTM Coordinates ____________________

5) Date _ _ / _ _ / _ _ 6) Inventoried by: ______________ Locate/Label Site on Map

Describe Location: ____

____

____

Inventory Indicators

7) Distance to Nearest Other Campsite (**1**=<10 yds **2**=11-20 yds **3**=21-40 yds **4**=41-60 yds **5**=>60 yds) _____

8) Distance to River (**1**=<10 yds **2**=11-20 yds **3**=21-40 yds **4**=41-60 yds **5**=>60 yds) _____

9) Other Campsites Visible (#) _____

10) Site Visibility from River Y / N _____

11) Site Expansion Potential: H M L _____

12) Tree Canopy Cover (**1**=0-5% **2**=6-25% **3**=26-50% **4**=51-75% **5**=76-95% **6**=96-100%) _____

Impact Indicators

-- Apply Variable Radial Transect Method --

13) Condition Class (0 to 5) _____ ***Previous B.***

14) Vegetative Ground Cover On-Site (Use categories below) _____ _____

	(**1**=0-5%	**2**=6-25%	**3**=26-50%	**4**=51-75%	**5**=76-95%	**6**=96-100%)
Midpoints:	2.5	15.5	38	63	85.5	98

15) Vegetative Ground Cover Off-Site (Use categories above) _____ _____

16) Exposed Soil (Use categories above) _____ _____

17-19) Tree Damage None/Slight ____________ Moderate ____________ Severe _______

20-22) Root Exposure None/Slight ____________ Moderate ____________ Severe _______

23) Tree Stumps (#)____________ _____

24) Fire Sites (#) _____

25) Access Trails (#) _____

26) Human Waste (#) _____

27) Total Campsite Area (Office) _____ft²

28) Site Height Above River Bottom (ft) _____

APPENDIX 2: TRAIL MONITORING MANUAL

Zion National Park

(version 3/11/08)

This manual describes standardized procedures for conducting an assessment of resource conditions on recreation trails. The principal objective of these procedures is to document and monitor changes in trail conditions following construction or creation. Their design relies on a sampling approach to characterize trail conditions from measurements taken at transects located every 300 feet (91 meters) along randomly selected trail segments. Distances are measured with a measuring wheel. Measurements are conducted at sample points to document the trail's width, depth, substrate, slope, alignment and other characteristics. These procedures take between 3 to 6 minutes to apply at each sample point. Data is summarized through statistical analyses to characterize resource conditions for each trail segment and for the entire trail system. During future assessments it is not necessary to relocate the same sample points for repeat measures. Survey work should be conducted during the middle or end of the primary use season during the growing season. Subsequent surveys should be conducted at approximately the same time of year. Note: this manual was updated to incorporate some new procedures following fieldwork. The revisions do not affect comparability of data to the original assessments conducted in 2002.

Materials

(Check before leaving for the field)

- This manual on waterproof paper
- Field forms - some on waterproof paper
- Topographic and driving maps
- Clipboard
- Pencils
- Tape measure (12ft)
- Measuring wheel
- Peep-hole Compass
- 20 ft fiberglass tape measure marked off every 0.3 ft
- Stakes (3)
- Clinometer

Point Sampling Procedures

Trail Segments: During the description of amount and type of use (indicators 5 & 6 below) be sure that the use characteristics are relatively uniform over the entire trail segment. Sampled trails may have substantial changes in the type or amount of use over their length. For example, one portion of a trail may allow horse use or a trail may join the study trail, significantly altering use levels. In these instances where substantial changes in the type and/or amount of use occur, the trail should be split in two or more segments and assigned separate names and forms, upon which the differences in use can be described. This practice will facilitate the subsequent characterization of trail use and statistical analyses.

Also collect and record any other information that is known about the trail's history, such as original construction, past uses, type and amount of maintenance, history of use, etc.

1 - Developed by Dr. Jeff Marion, USDI, U.S. Geological Survey, Patuxent Wildlife Research Center, Virginia Tech Field Station, Dept. of Forestry (0324), Blacksburg, VA 24061 (540/231-6603) Email: jmarion@vt.edu

1) **Trail Segment Code:** Record a unique trail segment code (can be added later).

2) **Trail Name:** Record the trail segment name(s) and describe the segment begin and end points.

3) **Surveyors:** Record initials for the names of the trail survey crew.

4) **Date:** Record the date (mm/dd/yr) the trail was surveyed.

5) **Use Level (UL):** Record an estimate of the amount of use the trail receives, relative to all trails in the park, from the most knowledgeable park staff member: High, Medium, Low. Work with them to quantify these use levels on an annual basis (e.g., low use, < 100 users/wk for the 12 wk use season, < 30 users/wk for the 20 wk shoulder season, < 10 users/wk for the 20 wk off-season = < 2000 users/yr).

6) **Use Type (UT):** Record estimates for the types of use the trail receives (including any illegal uses) using percentages that sum to 100%. These should be provided by the most knowledgeable park staff member. Categories include: Hiking, Horseback, Other (specify).

Starting/Ending Point: Record a brief description of the starting and ending point of the trail survey. Try to choose identifiable locations like the center of intersections with other trails, roads, or permanent trailhead signs. If possible, record a GPS waypoint and record the WP# for start and end points on the Point Sampling Form. If the park has an accurate and current map of the surveyed trail it is not necessary to GPS it again.

Measuring Wheel Procedures: At the trail segment starting point, select a random number from 0 to 300. Record this number on the first row of the form. This will be the first sample point, from which all subsequent sample points will be located in 300 foot intervals. This procedure ensures that all points along the trail segment have an equal opportunity of being selected. Once you get to the first sample point, reset the wheel counter and use it to stop at 300 foot intervals thereafter.

Push the measuring wheel along the middle of the tread so that it does not bounce or skip in rough terrain. Lift the wheel over logs and larger rocks, adding distance manually where necessary to account for horizontal distances. Your objective is to accurately measure the distance of the primary (most heavily used) trail tread. Monitor the wheel counter and stop every 300 feet to conduct the sampling point measures. If you go over this distance, you can back the wheel up to the correct distance. If the wheel doesn't allow you to take distance off the counter then stop immediately and conduct your sampling at that point, recording the actual distance from the wheel, not the "missed" distance.

If an indicator cannot be assessed, e.g., is "Not Applicable" code the data as -9, code missing data as -1.

Rejection of a sample point: Given the survey's objective there will be rare occasions when you may need to reject a sampling point due to the presence of boulders, tree falls, trail intersections, road-crossings, stream-crossings, bridges or other odd "uncharacteristic" situations. The data collected at sample points should be "representative" of the 150 foot sections of trail on either side of the sample point. Do not relocate a point to avoid longer or common sections of bog bridging, turnpiking, or other trail tread improvements. Use your judgment but be conservative when deciding to relocate a sample point. The point should be relocated by moving forward along the trail an additional 30 feet, this removes the bias of subjectively selecting a point. If the new point is still problematic then add another 30 feet, and so on.

7) **Distance:** In the first column record the measuring wheel distance in feet from the beginning of the trail segment to the sample point.

8) **Informal Trails (IT):** Sum and record your tallies of informal or "visitor-created" trails that intersected with the survey trail since the last sample point. Do not count formal trails or roads of any type, or extremely faint trails. Informal trails are trails that visitors have created to access streams, scenic attraction features, camping areas, or other features, to cut switchbacks, go around mud-holes or downed trees, or that simply parallel the main trail. Count both ends of any informal trails longer than 20 feet that loop out and return to or parallel the survey trail. Include any distinct animal or game trails unless they are distinguishable from human trails. This indicator is intended to provide an approximation of the extensiveness of unofficial, visitor-created trails associated with survey trail.

9) **Secondary Treads (ST):** Count the number of trails that parallel the main tread at the sample point. Count all treads regardless of their length. *Do not count the main tread*.

10) **Tread Width (TW):** From the sample point, extend a line transect in both directions perpendicular to the trail tread. Identify the endpoints of this trail tread transect as the most pronounced outer boundary of visually obvious human disturbance created by trail use (not trail maintenance like vegetation clearing). These boundaries are defined as pronounced changes in ground vegetation height (trampled vs. untrampled), cover, composition, or, when vegetation cover is reduced or absent, as pronounced changes in organic litter (intact vs. pulverized) (see photo illustrations in Figure 1 at the end of this manual). The objective is to define the trail tread that receives the majority (>95%) of traffic, selecting the most visually obvious outer boundary that can be most consistently identified by you and future trail surveyors. Include any secondary treads (see #9) within the transect unless there are undisturbed areas between treads (as defined by the tread boundary definition). In this latter case, establish the transect and conduct measurements for the primary tread. Temporarily place tent stakes at the boundary points. Note: incision and cross-sectional area measures will be taken from this line so it should be unobstructed. If raised up by soil or litter then push down the obstructing materials. If pushed up substantially by rocks or roots then move the line forward along the trail in one foot increments until you reach a location where the line is unobstructed. Measure and record the length of the transect (the tread width) to the nearest inch (don't record feet and inches).

11) **Maximum Incision, Current Tread (MIC):** Stretch the fiberglass tape tightly between the two tent stake pins that define the tread boundaries - any bowing in the middle will bias your measurements. Position the string so that it can be used as a datum to measure tread incision caused by soil erosion and/or compaction. Note that this string will likely not be "level" (i.e., if a bubble level were placed along it). Measure the maximum incision (nearest 1/4 inch: record .25, .5, .75) from the string to the deepest portion of the trail tread. Measure to the surface of the tread's substrate, not the tops of rocks or the surface of mud puddles. Your objective is to record a measure that reflects the maximum amount of soil loss along the transect within the tread boundaries. See Figure 2 (end of manual), noting differences in MIC measures for side-hill vs. non-side-hill trails.

12) **Cross-Sectional Area:** On the Cross Sectional Area form, record the distance from the measuring wheel. Record a 0 in the Area column and skip this procedure if the maximum incision is ≤1 inch. Otherwise complete the following based on the diagram in Figure 3 (end of manual):

Starting on the left side with a "zero" measurement, measure from each vertical transect line marking, a perpendicular transect down to the ground surface (nearest 1/4 in, e.g., .25, .5, .75). If water is present measure to the substrate beneath. Record the values on the data sheet next to their labeled transect numbers (e.g., V_1, V_2, $V_3 \ldots V_n$). Continue measuring each transect height until you reach the far side of the trail and obtain a measure of 0. ***Note:*** The transect line is not likely to be "level" so be cautious in measuring vertical transects that are *perpendicular* to the horizontal transect line.

In the office, use a spreadsheet to compute and sum cross-sectional area values with the following formula for each consecutive pair of vertical transect measures and using the equation: Area = (Vi +

Vi + 1) x Ii x .5 for each row and summed to compute CSA (I = interval distance between vertical measurements). Contact the author for an Excel file with this formula.

13-22) **Tread Condition Characteristics:** Along the trail tread width transect, estimate to the nearest 10% (5% where necessary) the aggregate lineal length occupied by any of the mutually exclusive tread surface categories listed below. **Be sure that your estimates sum to 100%**.

S-Soil:	All soil types including sand and organic soils, excluding organic litter unless it is highly pulverized and occurs in a thin layer or smaller patches over bare soil.
L-Litter:	Surface organic matter including intact or partially pulverized leaves, needles, or twigs that mostly or entirely cover the tread substrate.
V-Vegetation:	Live vegetative cover including herbs, grasses, mosses rooted within the tread boundaries. Ignore vegetation hanging in from the sides.
R-Rock:	Naturally-occurring rock (bedrock, boulders, rocks, cobble, or natural gravel). If rock or native gravel is embedded in the tread soil estimate the percentage of each and record separately.
M-Mud:	Seasonal or permanently wet and muddy soils that show imbedded foot or hoof prints from previous or current use (omit temporary mud created by a very recent rain). The objective is to include only transect segments that are frequently muddy enough to divert trail users around problem.
G-Gravel:	Human-placed (imported) gravel.
RT-Roots:	Exposed tree or shrub roots.
W-Water:	Portions of mud-holes with water or water from intercepted seeps or springs.
WO-Wood:	Human-placed wood (water bars, bog bridging, cribbing).
O-Other:	Specify.

23) **Trail Grade (TG):** The two field staff should position themselves at the sample point and 10 feet upslope along the trail. A clinometer is used to determine the grade (% slope) by sighting and aligning the horizontal line inside the clinometer with a spot on the opposite person at the same height as the first person's eyes. Note the percent grade (left-side scale in clinometer viewfinder) and record.

24) **Trail Alignment (TA):** Assess the trail's alignment angle to the prevailing land-form in the vicinity of the sample point. Use a compass and sight along the trail in the vicinity of the sample point, record the compass bearing on the left side of the column (it doesn't matter which direction along the trail you sight). Next face directly downslope, take and record another compass bearing (aspect). The trail's alignment angle can be computed by these two bearings (done by computer, contact the author for a formula).

25) **Side-hill Construction (SH):** Was side-hill construction (cut-and-fill) work used to construct the trail at the sample point? Yes (Y), No (N), Unsure (U).

26) **Tread Drainage Feature (TD):** In 25-foot increments up to 75 feet, estimate the distance to any reasonably effective human-constructed tread drainage feature located in an up-slope trail direction from the sample point. Record a 100 if no features are present within 75 feet. Tread drainage features could include water bars (wood or rock), drainage dips, grade dips, etc. constructed to move water off the trail tread (do not consider tread out-sloping).

27) **Water Drainage (WD):** During a medium-sized rain storm, about how much of the water on the trail up-slope within 10 feet from the sample point would tend to flow **off** the tread: 1) 0%, 2) 25%, 3) 50%, 3) 75%, or 4) 100%. This could be due to a natural or human-constructed tread drainage feature or to tread out-sloping.

28) **Trail Position (TP):** Use the descriptions below to determine the trail position of the sampling point. Record the corresponding letter code in the TP column.
V - Valley Bottom: The transect is located within a flatter valley bottom setting within 60 vertical feet (three 20ft topo lines) from a stream or river.
R - Ridge Top: The transect is located within a flatter plateau or ridge-top position.
M - Midslope: All other mid-slope positions.

Collect all equipment and move on to the next sample point. **Be sure to count and tally informal trails and record information on indicators 29 & 30 as you proceed to the next sample point.** These indicators are assessed continuously as pre-defined trail tread problems and when found, surveyors record begin and end distances (from the start of the survey) on the Problem Assessment Form. **Note: after data entry and before analysis the data for these indicators need to be corrected to add in the 1st randomly selected interval distance so that location data is accurate. In particular, examine any indicators that may begin before and end after the first sample point.**

Problem Assessment Procedures

29) **Soil Erosion (SE):** Sections of tread (≥10 ft) with soil erosion exceeding 5 inches in depth within current tread boundaries. Record beginning and ending distances on the Problem Assessment form.

30) **Multiple Treads (MT):** Sections of braided tread (≥10 ft) where multiple treads diverge and return to a single tread. Record this indicator only when multiple treads are generally visible from the main tread, typically separated by some feature which divides the trail into two or more treads. Do not record this indicator when a trail branches off a long distance and away from the main tread and then returns, such as for a constructed or visitor-created trail loop that accesses a distant (e.g., 300+ft view point). Record the maximum number of treads. Record beginning and ending distances on the Problem Assessment form.

Informal Trail Transect Procedures

Trail proliferation and degradation in valleys where visitors are free to create their own routes will be monitored with special trail transect procedures. These will be experimentally applied at two locations, the lower Subway and Coalpits valleys. These procedures are designed to track the number of new trails created over time and degradation on each individual trail.

Lower Subway Valley: The first portion of this trail (from the downstream end) is a more developed "formal" trail as it descends into the valley. Therefore, begin the 1st transect at a point just upstream from where the trail first reaches the stream (select a random number between 1-100 ft).

Lower Coalpits Valley: From the parking lot proceed up the drainage to the NPS boundary and then pick a random number (1-100 ft) to start your first transect.

Transect procedures: For each transect, begin to the far right side of the valley when facing upstream. Walk the transect, perpendicular to the stream, to the far left side, stopping at each visually obvious trail you intersect along the transect. Extend your searches along the transect up each valley wall far enough to be sure you don't miss any trails. At each trail, conduct the standard point sampling measures (using the procedures in this Appendix) for the following indicators: tread width, maximum incision, CSA, and tread condition characteristics. Code trail data as follows: Subway T1-1 for Transect 1, trail 1 (on far right when facing upstream), Subway T1-2 (for the 2nd trail) and so on.

After assessing the first transect, choose what you think is the primary or main trail running upstream. Take a positional fix (waypoint) using the park's Trimble GPS for the location of this point (transect/main trail intersection) and at all subsequent transect/main trail points. Also take photos along the trail, showing the transect location, and two others looking directly toward each canyon wall at each transect point so that others can relocate these positions in the future. Beginning here, push the wheel along the main trail and continue to sample new transects upstream every 500 ft for a minimum of 10 transects.

Point Sampling Form

Trail Segment Code __________ **Trail Name** ______________________________ **Surveyors** ___________________________

Date __________ **Use Level** ______________________ **Use Type(s):** Horse% _____ Hiker% _____ Other% _____

Starting/Ending Point:

Dist	IT	ST	TW	MIC	Tread Substrate Characteristics	TG	TA	SH	TD	WD	TP
							/				
							/				
							/				
							/				
							/				
							/				
							/				
							/				
							/				
							/				
							/				
							/				
							/				
							/				
							/				
							/				
							/				
							/				
					0 10 20 30 40 50 60 70 80 90 100						

Dist = Wheel Distance
IT=Informal Trails
ST=Secondary Treads
TW=Tread Width
MIC=Max. Incision, Current Tread

S=Soil
L=Litter
V=Vegetation
R=Rock
M=Mud

G=Gravel
RT=Roots
W=Water
WO=Wood, human placed
O=Other (Specify)

TG=Trail Grade
TA=Alignment (Trail° / Landform°)
SH=Side-Hill construction (Y, N, U)
TD=Tread Drainage feature (25, 50, 75, or 100)
WD=Water Drainage (0%, 25%, 50%, 75%, 100%)
TP=Trail Posit. (Valley=V, Mid-slope=M, Ridge-top=R)

Informal Trail Transect Form

Trail Segment Code __________ **Trail Name** ______________________________________ **Surveyors** ____
Date ___________ **Use Level** ____________________________ **Use Type(s):** Horse% ______ Hiker% ______ Other% ______
Starting/Ending Point:

Transect No.	TW	MIC	Tread Substrate Characteristics	Cross Sectional Area			Cross Sectional Area		
				Transect	Interval	Area	Transect	Interval	Area
			0 10 20 30 40 50 60 70 80 90 100						

Dist = Wheel Distance
TW=Tread Width
MIC=Max. Incision, Current Tread

S=Soil **G=Gravel**
L=Litter **RT=Roots**
V=Vegetation **W=Water**
R=Rock **WO=Wood, human placed**
M=Mud **O=Other (Specify)**

Note: Record Transect Code for each CSA entry.

Problem Assessment Form

Cross Sectional Area Form

Trail Segment Code ________ Trail Name

Soil Erosion		Multiple Treads		Cross Sectional Area			Cross Sectional Area			Cross Sectional Area		
Begin Dist	End Dist	Begin Dist	End Dist	Transect (in)	Inter-val (in)	Area	Transect (in)	Inter-val (in)	Area	Transect (in)	Inter-val (in)	Area

Figure 1. Photographs illustrating different types of boundary determinations. Trail tread boundaries are defined as the most pronounced outer boundary of visually obvious human disturbance created by trail use (not trail maintenance like vegetation clearing). These boundaries are defined as pronounced changes in ground vegetation height (trampled vs. untrampled), cover, composition, or, when vegetation cover is reduced or absent, as pronounced changes in organic litter (intact vs. pulverized). The objective is to define the trail tread that receives the majority (>95%) of traffic, selecting the most visually obvious boundary that can be most consistently identified by you and future trail surveyors.

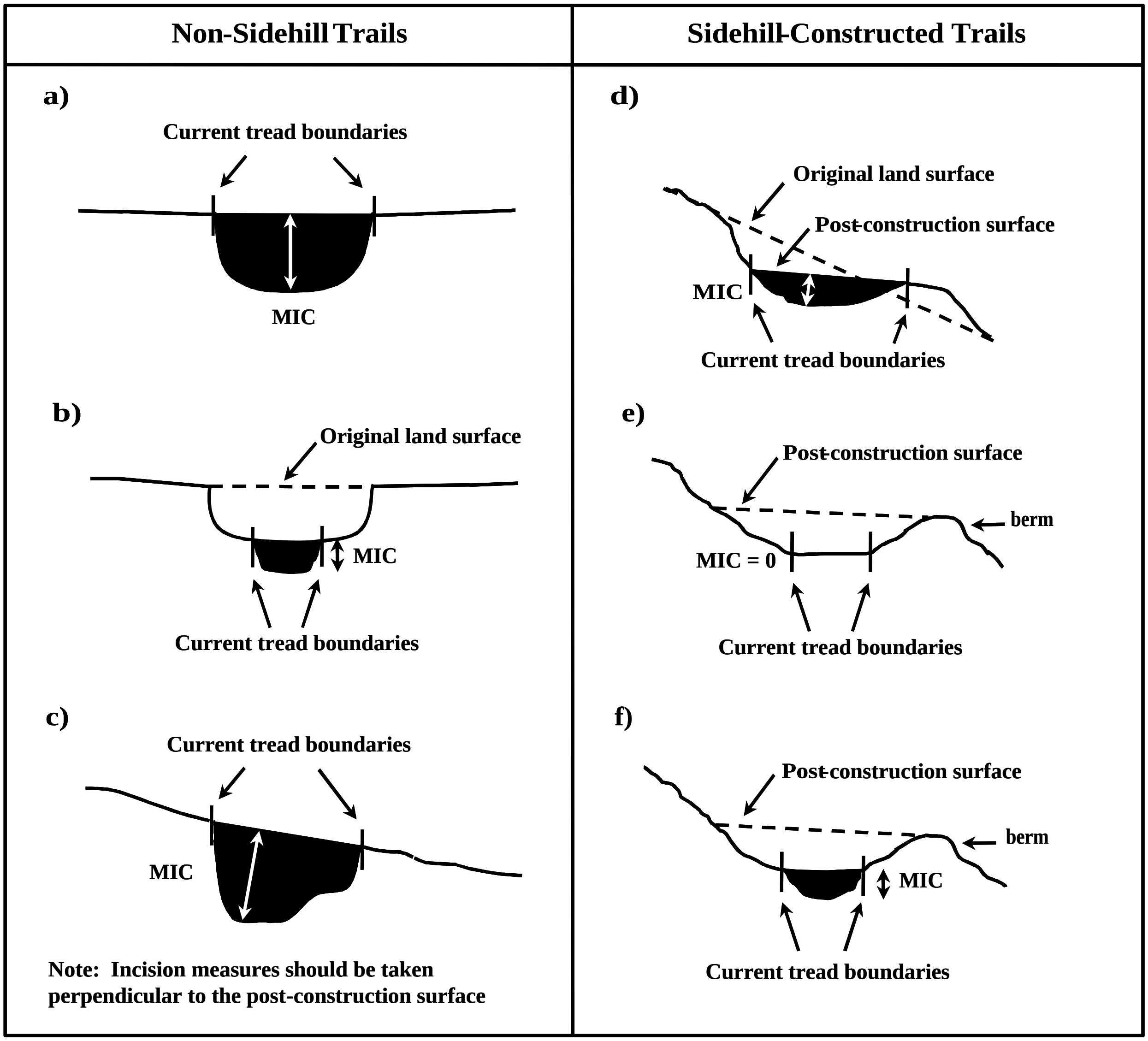

Figure 2. Diagrams illustrating alternative tread incision measurements in terrain where cut and fill work was not performed during tread construction (a-c) and in terrain where sidehill construction involved the excavation of substrate to create a tread surface (d-f).

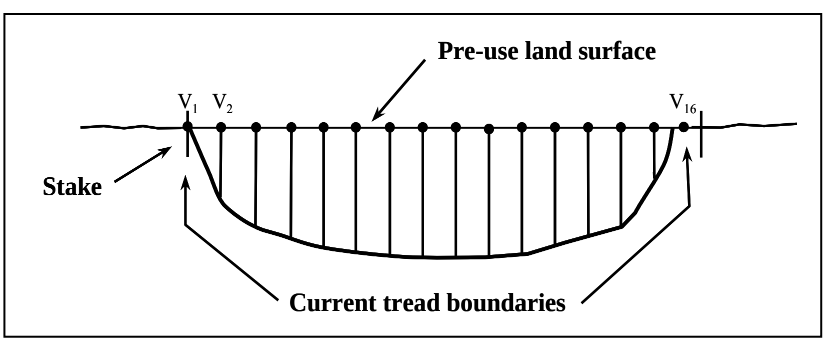

Figure 3. Illustration of the fixed interval CSA method for assessing soil loss at each transect.