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BACKCOUNTRY RECREATION SITE AND TRAIL CONDITIONS: HALEAKALĀ NATIONAL PARK

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Final Report for the National Park Service, U.S. Department of the Interior

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TABLE OF CONTENTS

FIGURES

TABLES

INTRODUCTION

National Park Service accommodates nearly 300 million visitors per year, visitation that presents managers with substantial challenges. The increasing number of visitors inevitably contributes negative effects to fragile natural and cultural resources and to crowding and conflicts that degrade the quality of visitor experiences. “Providing opportunities for public enjoyment is an important part of the Service’s mission; but recreational activities and other uses may be allowed in parks only to the extent they can take place without causing impairment or derogation of a park’s resources, values, or purposes” (NPS, 2001). This statement, from the National Park Service (NPS) *Management Policies*, provides a strong mandate to guide recreation management decisions in protecting park resources and values at some 388 park units. This policy guidance recognizes the legitimacy of providing opportunities for public enjoyment of parks. However, the *Management Policies* also acknowledge that some resource degradation is an inevitable consequence of visitation and direct 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, 2001).

At Haleakalā National Park, changing visitor use levels and patterns have contributed to an increasing degree of visitor use impacts to natural and cultural resources in specific areas of the park. To better understand the extent and severity of these resource impacts and identify effective management techniques, the park sponsored this research to develop monitoring protocols, collect baseline data, and identify options for management strategies. The park has adopted the NPS Visitor Experience and Resource Protection (VERP) carrying capacity framework to guide these studies. In addition to informing overall park management efforts, the VERP study data will contribute to a separate and ongoing Commercial Services Plan (CSP). Although the VERP study is much broader in scope than addressing the data needed for the CSP, the scientists are working closely with the CSP project manager to ensure that the proper resource impact and social science data are collected for use during the CSP planning effort.

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 visitor use and associated resource impacts, 2) helping to identify potential indicators and standards of quality for natural resources, 3) developing monitoring protocol for potential natural resource indicator variables, and 4) evaluating the effectiveness and acceptability of management strategies for 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 resource impacts associated with backcountry areas, trails, campground/visitor cabin areas, and other use areas.
2. Identify options for potential indicators and standards of quality based on resource impact measurements. As described above, indicators of quality are measurable, manageable variables that help define the quality of natural resources. Standards of quality represent the minimum acceptable condition of indicator variables. Data will be gathered to help

managers identify indicators and standards for natural resource conditions at Haleakalā National Park.

3. Develop options for monitoring protocol of the recommended indicators and standards. The monitoring protocol options will include frequency, timing, sampling scheme and data collection instruments.
4. Provide training of park staff for the recommended monitoring protocol.

The basic concept of 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 1999, Stankey & Manning 1986, Shelby & Heberlein 1986, Graefe et al. 1984). The NPS VERP decision framework (see Figure 1) is designed to guide decisions needed to protect park natural and cultural resources while maintaining the quality of the visitor experiences (National Park Service 1997). Additional legislative and management guidance on carrying capacity decision making is provided in the Justification for Monitoring section.

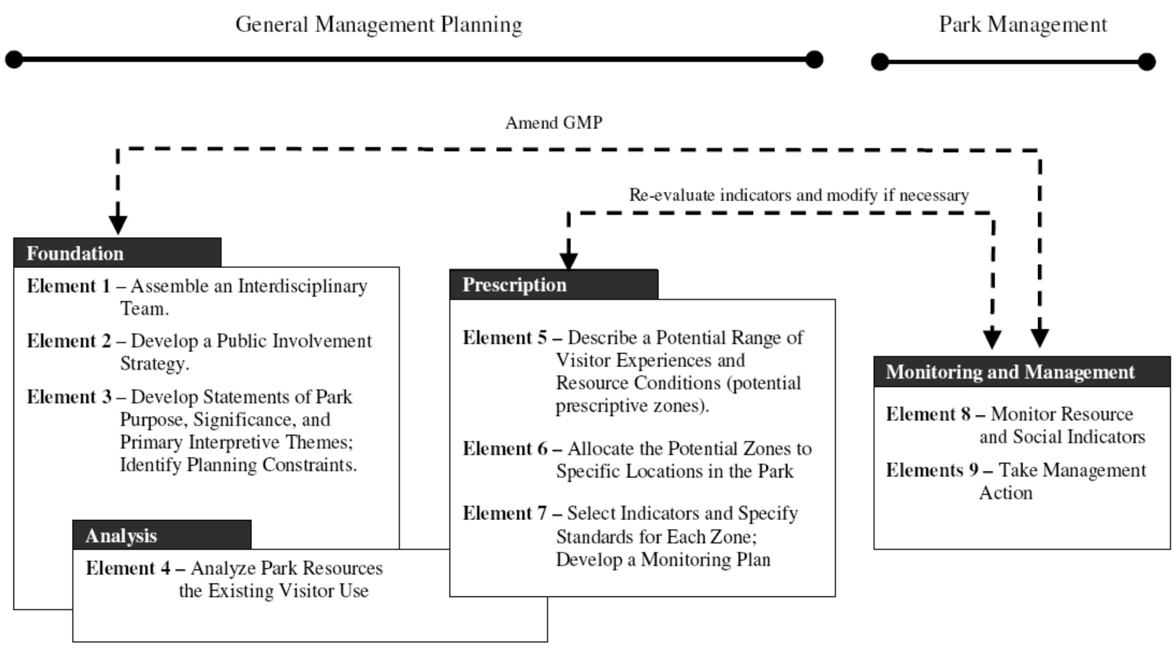

Figure 1. The NPS Visitor Experience and Resource Protection framework used to address carrying capacity decision making.

Assessments of visitor-related resource impacts provided by this study can document baseline conditions for trails and recreation sites 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.

During the management phase, research can evaluate alternative visitor impact assessment methods and procedures; select or develop and refine procedures that are scientifically credible, accurate, precise, and efficient; prescribe a reliable monitoring sampling design; and apply the procedures during the first monitoring cycle to collect, analyze and summarize data on baseline conditions. Relational analyses of the collected data can also identify the role and influence of causal factors (e.g., type and amount of use) and non-causal yet influential factors (vegetation or soil type resistance/resilience, topography, site management practices, visitor regulations and educational efforts). Greater insights into the influence of these factors can lead to the selection of more effective management actions.

This report contains a review of the relevant scientific literature describing trail and recreation site impacts, criteria for selecting appropriate impact indicators, trail and recreation site impact assessment methods, and a review of the study area and methods employed in this study. This report presents only data from phase 2 of the research study pertaining to backcountry use. This includes data from resource condition assessments of all backcountry recreation sites (including vista and cave sites), visitor cabin sites, campsites, and formal trails located in the Haleakalā Wilderness and non-wilderness Crater and Kīpahulu areas. Condition assessments for the Sliding Sands and Kīpahulu Horse Trails and their associated recreation/vista sites were included in the Phase 1 report (Marion and Hockett, 2007). The data collected in this study document baseline resource conditions for comparison to future assessments to detect trends in resource conditions or evaluate the effectiveness of management interventions. These data also support the selection of indicators and standards as part of a carrying capacity planning and management decision-making framework. Study implications and options for park planning, management, and monitoring are provided.

JUSTIFICATION FOR MONITORING

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 reviews legislative mandates, management policies and guidelines, carrying capacity, visitor perceptions of recreation resource conditions, and monitoring program capabilities. The purpose of this review is to describe legislative and management intent regarding visitor impact monitoring and its role in balancing visitor use and resource protection objectives. This section is included to assist in justifying implementation of a recreation site and trail monitoring program and to describe its utility to enlist organizational support for sustaining such a program over time.

Legislative mandates challenge managers to develop and implement management policies, strategies, and actions that permit recreation 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

Park Service backcountry management policies are guided by external documents as well. For Haleakalā National Park, 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). These acts overlay park designation and are intended by Congress to protect certain areas of the park singled out for exceptional ecological or social value.

With the federal designation of the park in 1931, a mandate was given to preserve wilderness and the plants and animals in a primeval manner, which was further supported when 99% of the park was designated as federal wilderness in 1976. The wilderness areas are managed under the Wilderness Act of 1964 (Public law 88-5) so as to protect their natural resources and processes and to provide visitors with high quality 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 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. . . ."

Finally, 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* (NPS 2001) 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 so 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 degree practicable, adverse impacts on park resources and values.
>
> 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, in decisions that variously describe it as making “resource protection the primary goal” or “resource protection the overarching concern”… (*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. (*Section 1.4.5*)
>
> Impacts may affect park resources or values and still be within the limits of the discretionary authority conferred by the Organic Act. However, negative or adverse environmental impacts are never welcome in national parks, even when they fall far short of causing impairment. For this reason, the Service will not knowingly authorize a park use that would cause negative or adverse impacts unless it has been fully evaluated, appropriate public involvement has been obtained, and a compelling management need is present. In those situations, the Service will ensure that any negative or adverse impacts are the minimum necessary, unavoidable, cannot be further mitigated, and do not constitute impairment of park resources and values.” (*Section 8.1*)

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 use the results of monitoring and research to understand the detected change and to develop appropriate management actions". (*Section 4.1*)
> “Further, 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 its 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 to provide reference points for comparison with other environments and time frames.
- Use the resulting information to maintain-and, where necessary, restore-the integrity of natural systems" (*Section 4.2.1*).

The National Park Service 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 has been implemented to ensure 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. See the following website for more information:
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 determine carrying capacities for each park 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. Regulations implementing the National Forest Management Act of 1976 (P.L. 94-588) dictate that, in wilderness management planning, provision be made "for limiting and distributing visitor use of specific areas in accord with periodic estimates of the maximum levels of use that allow natural processes to operate freely and that do not impair the values for which wilderness areas were created."

As previously noted, the NPS employs the Visitor Experience and Resource Protection (VERP) planning and decision-making framework (see Figure 1) for formal evaluations of the acceptability of visitor impacts and for establishing carrying capacity limits on visitation (NPS 2001, Section 8.2.1; USDI 1993). 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 (Stankey & others 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 the *Management Policies*:

> "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 prevent park uses that may unacceptably impact the resources and values for which the parks were established. For all zones, districts, or other logical management divisions within a park, superintendents will identify visitor carrying capacities for managing public use. Superintendents will also identify ways to monitor for, and address, unacceptable impacts to park resources and visitor experiences.
>
> When making decisions about carrying capacity, superintendents must utilize 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 general management planning process will determine the desired resource and visitor experience conditions that are the foundation for carrying capacity analysis and decision making. If a general management plan is not current or complete, or if more detailed decision making is required, a carrying capacity planning process, such as the Visitor Experience and Resource Protection (VERP) framework, should be applied in an implementation plan or an amendment to an existing plan.
>
> As use changes over time, superintendents must continue to decide if management actions are needed to keep use at acceptable and sustainable levels. 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 can be tolerated 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 recreation sites, just as are managers (Lucas 1979, Marion & Lime 1986, Vaske & others 1982). Legislative mandates set high standards when they direct managers to keep protected natural areas "unimpaired" and human impacts "substantially unnoticeable." Seeing trails and recreation sites, particularly those in degraded condition, reminds visitors that others have preceded them. In remote areas even the presence of trails and recreation sites reduce perceived naturalness and can diminish opportunities for solitude. In accessible and popular areas the proliferation and deterioration of trails and recreation sites 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 recreation sites 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 recreation sites, 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 recreation site trees were among the most highly rated indicators affecting the quality of recreational experiences (Roggenbuck & others 1993). Amount of vegetation loss and exposed soil around a recreation site were rated as more important than many social indicators, including number of people seen while hiking and encounters with other groups at recreation sites. Hollenhorst and Gardner (1994) also found vegetation loss and bare ground on recreation sites to be important determinants of satisfaction by wilderness visitors.

Monitoring Program Capabilities

Visitor impact monitoring programs can be of substantial value when providing managers with reliable information necessary for establishing and evaluating resource protection policies, strategies, and actions (Figure 2). Data from the first application of impact assessment methods 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 recreation sites 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 resource conditions standards of quality.
- 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 recreation sites and trails are reviewed, and prospective indicators and measurement units are presented. Common recreation site and trail impact assessment procedures are also reviewed.

Visitation-Related Resource Impacts

Visitors participating in a diverse array of recreation activities, including hiking, camping, wildlife viewing, biking, and boating, 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 recreation sites.

Trail Impacts

Resource impacts associated with trampling on trails [and recreation sites] 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 and livestock 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.

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

The exposure of soil on natural surfaced 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 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.

Recreation Site Impacts

Recreation sites include day use sites (e.g., vista locations) and overnight use sites (e.g., campsites and visitor cabins) that receive concentrated visitor use (Leung & Marion 2004). Many recreation sites, even sites designated by land managers, were originally selected and created by visitors. As with trails, many recreation sites are poorly located with respect to resource protection considerations and are thus susceptible to environmental impacts from trampling. Most site 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, tree damage, and campfire related impacts where fires are permitted.

Recreation sites 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 recreation sites 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 trampling can alter microclimates and create sunny disturbed locations that give invasive vegetation a start.

The scientific literature and management experience reveals an extensive list of resource impacts attributed to campfires. Campfires are an especially challenging issue for public land managers because fires remain an important aspect of many visitors' camping experience, despite recent findings that show an increasing preference for cookstoves for cooking purposes (Christensen & Cole 2000). Campfires result in aesthetic and ecological impacts to protected natural areas. Although the most obvious impacts tend to be focused on specific areas within recreation site boundaries, wood collection and wildfire impacts resulting from campfires are more broadly distributed and affect larger areas.

Campfires alter soil properties. Fenn & others (1976) measured the effects of campfires on soil regimes and concluded that intense campfires can reduce organic matter content to a depth of 10 cm or more. The researchers also found that campfires result in substantial alterations of soil chemistry. The reductions in organic matter and subsequent chemical changes diminish soil fertility and water holding capacity, making the soil prone to erosion and compaction (Fenn & others 1976). Firesites also attract litter and garbage when visitors attempt to dispose of wastes through burning (Reid & Marion 2005). The combustion of plastic, paper and metal garbage can contribute chemical contaminants to firesite ashes. Davies (2004) analyzed gas emissions and ash content from 27 products commonly burned in campfires and found greatly increased levels of a variety of toxic materials, including some that pose a threat to human health. Partially burned food items retain odors, thereby promoting attraction behavior among area wildlife.

Firewood collection also degrades natural resources over a larger area for impacts such as vegetation trampling and tree damage, including the felling of trees. Tree damage, including broken or cut limbs, hatchet wounds and girdling, is an aesthetic impact associated with campfires, but such wounds make trees more susceptible to insect and fungal attacks that can lead to tree mortality (Cole & Dalle-Molle 1982, Reid & Marion 2005). Felled trees due to wood gathering efforts may reduce habitat for cavity-nesting birds while also affecting aesthetic qualities of an area (Cole & Dalle-Molle 1982). Hall and Farrell (2001) assessed the extent of woody material depletion in the Cascade Mountains of Oregon and found a significant reduction in woody materials adjacent to recreation sites when compared to controls. Bratton and others (1982) investigated the effects of trampling and firewood gathering in Great Smoky Mountains National Park and concluded that the collection of downed wood likely affects nutrient cycling over a 50-70 year timeframe, but has negligible effects in the short term.

Monitoring studies often use the number of informal trails connected to recreation sites as an indicator of the extent of adjacent off-site vegetation trampling. While these trails may be used for firewood gathering, they are also used to access the site, water, other sites, restroom areas and scenic features. Census surveys of recreation sites 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 recreation sites include:

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

Are recreation site 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?

Is the visitor dispersal policy effective in preventing the establishment of new recreation sites and trails?

Before a monitoring program can be developed, appropriate resource indicators must be selected. A single, direct measurement of a recreation site's or a trail's condition is inappropriate because the overall condition is an aggregate of many components. Typically, then, monitoring evaluates various soil, vegetation, or aesthetic elements of a trail or recreation site that serve as indicators of that facility's condition. 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 recreation site'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 recreation sites 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 trail that is 36 inches wide it twice the width as a trail with an 18 inch width. 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?

Figure 3. Criteria for selecting indicators of resource condition. Adapted from Cole (1989b), Marion (1991), Merigliano (1990), O'Connor & Dewling (1986).

Potential indicators of resource condition are numerous and there is great variation in our ability to measure them with *accuracy*, *precision*, and *efficiency*. 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, recreation site 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, can detract unacceptably from environmental and 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 of trail or recreation site conditions. Table 2 includes a listing of commonly employed indicators for assessing resource conditions on trails and recreation sites 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 resource condition 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 recreation site indicators are the number or density of visitor-created recreation sites and recreation 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 recreation site use (Hammitt & Cole 1998, Marion & Merriam 1985). The area of vegetation loss is perhaps the best indicator of vegetation disturbance (Cole 1989a).

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 recreation site, the number of damaged trees or stumps, the number of fire scars or fire rings, 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, the most ecologically significant trail impact, can be assessed at sample points by measuring maximum incision or cross sectional area. Similarly, tread muddiness can be assessed at sample points as a percentage of tread width.

Table 2. Potential indicators of recreation site and trail conditions and measurement units.

Recreation Site Indicators	**Measurement Units**
Informal Recreation sites	#/unit area, #/unit length along formal trails
Recreation Site 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
Tread Width	Max. value, value/unit length, running avg./unit length
Maximum Incision	Max. value, value/unit length, running avg./unit length
Cross Sectional Area	Max. value, value/unit length, running avg./unit length
Muddiness	Max. % of tread width, avg. %/unit length, running avg. %/unit length

In summary, managers must consider and integrate a diverse array of issues and criteria in selecting indicators for monitoring impacts on recreation sites. Indicators will rarely score high on all criteria (Figure 3), 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 & others 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 can be easily predefined or are infrequent (e.g., excessive width or secondary treads), particularly when information on the location of specific trail impact problems is needed.

Types of Recreation Site Impact Assessment Systems

Systems for assessing recreation site 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 effects of backcountry visitors (Magill & Twiss 1965). Photographic methods are generally easy to establish, require little time for repeat photographs, and yield easily understandable visual records of recreation site 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 recreation site condition. Measurements for many indicators are completed within permanently referenced recreation site boundaries, allowing substantially greater precision.

STUDY AREA

Haleakalā National Park is located on east Maui and includes the summit of Haleakalā volcano (10,023 feet) and extends eastwards to sea level at ‘Ohe’o Gulch, Puhilele and Ka`äpahu. Haleakalā covers 30,183 acres and is divided into two areas (Figure 4). The Summit Area includes a large volcanic plateau to the east, portions of its outer slopes, and the upper sections of the Kaupō and Ko`olau Gaps. The volcanic plateau is generally referred to as the “Haleakalā Crater” though geomorphologically it is not a crater. The wetter Kīpahulu Area includes Kīpahulu Valley, Manawainui and Kaumakani planezes, the upper Häna rain forest, ‘Ohe’o Gulch, and the recent Puhilele and Ka`āpahu addition. The majority of the park, 24,719 acres, is congressionally designated Wilderness. Annual park visitation over the last 10 years has ranged from 1.4 million up to 2.0 million. Visitation is year-round with very little variance seasonally.

Various private landowners (e.g., Haleakalā Ranch, Kaupō Ranch, East Maui Irrigation Company and The Nature Conservancy of Hawai’i) and Federal agencies (e.g., the Federal Aviation Administration), as well as the State of Hawai`i share boundaries or own lands adjacent to the park. The majority of area surrounding the park is sparsely populated and used primarily for conservation, recreational and ranching activities. Adjacent to the Summit Area is “The Haleakalā Observatories,” a multi-institutional collection of observatories and antennas located on state land just southwest of the park.

Haleakalā was established August 1, 1916 as part of Hawai’i National Park. Legislation established Hawai’i National Park “as a public park or pleasure ground for the benefit and enjoyment of the people of the United States…and to provide for the preservation from injury of all timber, birds, mineral deposits, and natural curiosities or wonders within said park, and their retention in their natural condition as nearly as possible.” In July 1961, Haleakalā was redesignated as a separate National Park. Legislation enabled Haleakalā National Park to be administered in accordance with the Organic Act of 1916. Thus, the purpose of Haleakalā is also reflected in a key provision of the Organic Act—“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.” The park was designated an International Biosphere Reserve in 1980.

Since becoming its own national park, Haleakalā's biological resources have gained special attention within the scientific community. The park harbors a rich assemblage of native plant and animal communities with tremendous species diversity. Ecosystems include an alpine cinder desert, sub-alpine shrublands, sub-alpine grasslands, montane bogs and ponds, perennial and intermittent streams, cloud and rain forests, a mesic forest, and the coastal strand. Haleakalā is home to 30 federal threatened and/or endangered species, with 5 candidate species and 3 species of concern.

Many areas within Haleakalā are culturally and spiritually important to Native Hawaiians. These areas have been used by Native Hawaiians for a wide range of activities for over 1200 years and continue to this day. These areas also have a history of use by non-Hawaiians and Federal agencies. Thus, Haleakalā contains a wide variety of Hawaiian and non-Hawaiian cultural resources including archeological sites, historic structures, museum objects, cultural landscapes,

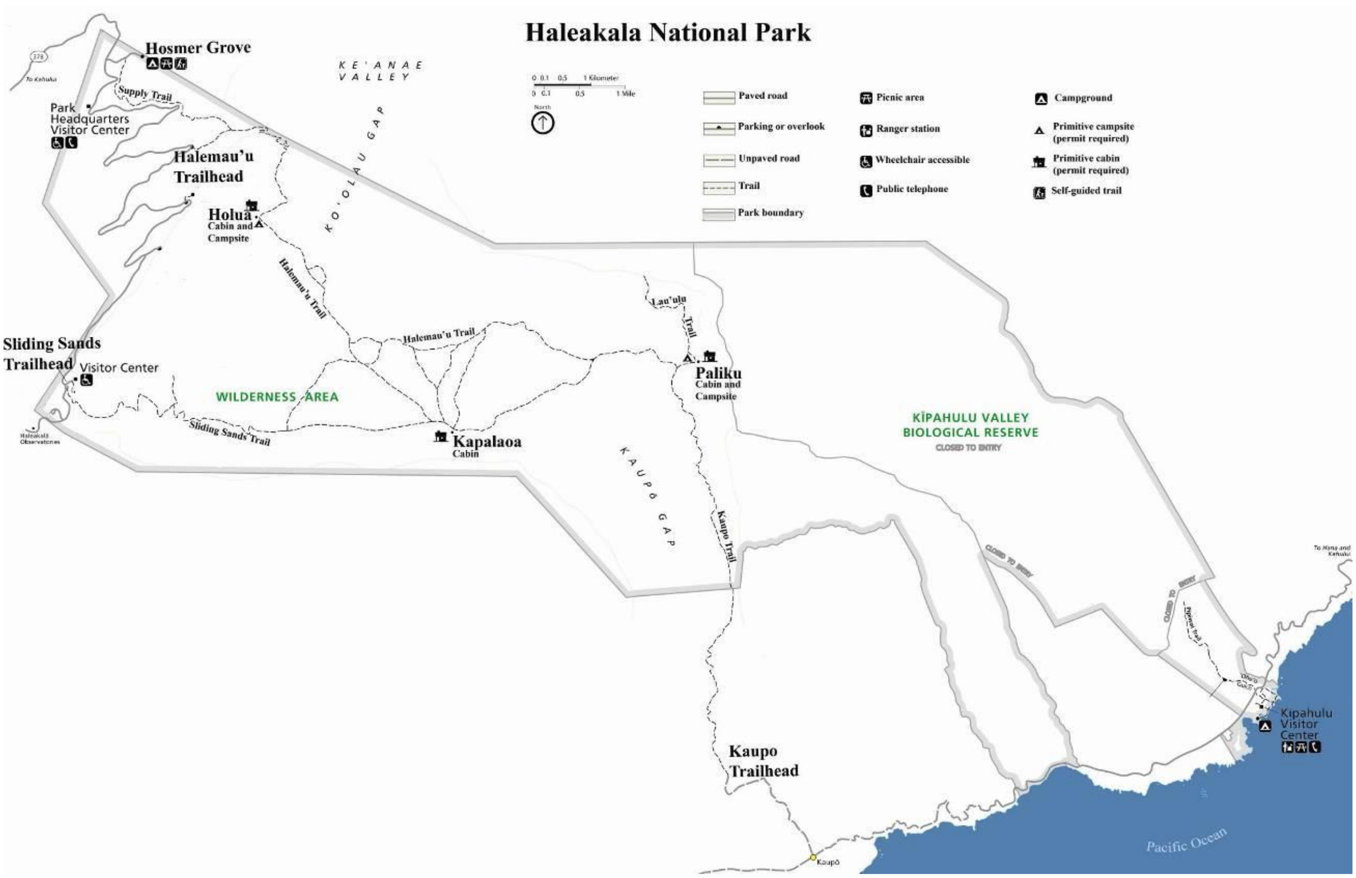

Figure 4. Haleakalā National Park map.

and ethnographic resources. Many of these cultural resources are located within two historic districts. The Crater Historic District is listed in the National Register of Historic Places (NRHP) and encompasses all of Haleakalā Crater. The Kīpahulu Historic District is eligible for listing in the NRHP and encompasses the lower portions of Kīpahulu Valley, 'Ohe'o Gulch and Puhilele.

The Park offers two very different experiences for the visitor:

<u>The Summit Area</u>

The Summit area starts at 6,800 ft. el. This area is reached by traveling along a county road up the slopes of the 10,023 ft. Haleakalā Volcano. There are more than 12 miles of Park roadway within the Summit area, allowing visitors access to two visitor centers, two overlooks, one front-country campground and two backcountry trailheads. Short hikes in native subalpine shrublands and a non-native planted grove provide the visitor an experience of changes in resource values over the past century and the interplay of native and non-native species' struggle for survival. Within the Haleakalā Crater, two backcountry campgrounds and three historic visitor cabins are accessed by a trail system of over 30 miles, exposing the outdoor enthusiast to the wonders of unique flora and fauna and cultural sites and features which are culturally and spiritually important to Native Hawaiians.

The Kīpahulu Area

The Kīpahulu area begins at the coast at Ka`āpahu and the pools of 'Ohe'o and ends in a nearly pristine rainforest at 8,000 ft elevation; however, the area above 1,000 ft. is a Scientific Research Reserve, closed to visitor entry. Visitors reach this area by driving over 60 miles on a long and winding county road. Once in the Kīpahulu area, visitors have access to a visitor center, over three miles of trails, pools, a day-use picnic area, and a campground. Environmental and Native Hawaiian cultural and land stewardship programs are provided for visitors to experience, understand and respect the scientific and cultural value of Kīpahulu.

The following summarizes some of the resource impacts of concern in specific areas of the park.

Cultural Resources and Values

Cultural resources such as archeological sites and cultural landscapes, as well as areas and features that have cultural and spiritual value to Native Hawaiians, are being impacted by expanded and overcrowded park use areas. Cultural resources located near trails and other visitor use areas are at risk from potential vandalism and accidental damage. Visitor impacts to these features and sites adversely affect the cultural and spiritual significance of these resources to Native Hawaiians, as well as their traditional use of them.

Campgrounds and Visitor Cabins

Camping and visitor cabins are co-located at two areas within the Haleakalā Crater. This plateau and some surrounding lands are contained within the Haleakalā Wilderness. However, the cabin/campground areas and associated water systems are located in development enclaves.

Hōlua Cabin and Campground are located along the base of the western Crater floor at 6800 ft. elevation. The surface substrate in this area is mostly dense cinder/pāhoehoe volcanic material, shallow in depth and resistant to repeated use. A variety of cultural resources are located around this area. Native Hawaiians are actively using some of these resources because of their cultural and spiritual significance. Vandalism and accidental damage from visitor use of this area is adversely affecting the preservation, protection, and traditional use of these resources. While a pit toilet is provided, and campers are encouraged to use Leave No Trace (LNT) ethics, refuse is still found, which draws introduced insects and mammals to forage near native species boroughs, nests and colonies.

Kapalaoa Cabin is located at the base of the southern Crater wall and there is no camping allowed in this area. Impacts to cultural and natural resources and values are similar to those experienced at Hōlua, however the soil substrate is a deeper fine to coarse cinder- soil type and is easily eroded.

Palikū Cabin and Campground are located at the base of the eastern Crater floor at the edge of subalpine grasslands and rainforest environments. The soil is deep and the vegetation is pastoral with a mix of native and non-native grasses, shrubs, and tree species. This habitat is ideal for the endangered Nēnē (Hawaiian goose). The grassland, which is vital to Nēnē nesting, is also desirable to visiting campers. Conflicts between nesting activities and camping are infrequent; however, the close proximity of campers to nesting Nēnē has caused nest abandonment. Feral cats have also been found in this area of the Park, encouraged by improperly disposed provisions of campers and cabin users. Visitor use of an unmaintained trail in the area also affects natural and cultural resources and values.

Sunrise at the Summit

Sunrise at the top of Haleakalā is one of the highest recommended visitor activities promoted by the visitor industry on Maui. On busy days, this area of the park receives over 1000 visitors at sunrise. Sunrise visitation has increased to a point that visitors in private vehicles are now being turned away on a regular basis because existing parking areas are filled beyond capacity. With the absence of designated overflow parking areas, visitors double park, park in "no parking" areas, and pull off roadways to park on road edges. Commercial tours have also increased exponentially to a point that the number of commercial vehicles exceeds the number of designated commercial parking areas, resulting in commercial vehicles parking in private vehicle parking areas.

Another impact of high visitation in concentrated areas is inappropriate disposal of refuse. Food scraps exacerbate the non-native insect problem, and wrappers and other paper and plastic waste impact the endangered birds that forage and nest nearby. The feeding of native and non-native birds also has an impact.

Other Summit Area Concerns:

Throughout the day, there are other significant peaks of visitation that result in the parking lots at the summit and park headquarters being filled beyond available stalls by visitors arriving on commercial tours or in private vehicles. Impacts to natural and cultural resources and values, such as running over native plant and animal habitat, and blocking viewsheds with vehicles parked along road edges, degrade the National Park experience and offend cultural resource values.

Hikers and commercial tour activities are also affecting Park trails. The trails in the cinder desert do not hold up well to excessive use and multiple users. Current commercial use permits limit group size, but do not regulate numbers of trips per day or per week. Manure is gathered periodically along the Sliding Sands Trail but its presence until picked up results in resource and visitor experience impacts. Commercial operators are also not currently using weed-free feed.

Kīpahulu Area

Natural and cultural resources and values are being impacted by numerous visitors entering the pools at 'Ohe'o Gulch. The highest visitation occurs during mid-day and early afternoon, as visitors make their way along the winding Hana Highway to Kīpahulu. Many of the visitors then migrate to the 'Ohe'o stream and pools. These crowds of visitors in a stream ecosystem have potentially damaging effects upon the riparian zone and endangered aquatic species.

Other Kīpahulu Area Concerns:

High rainfall in this area causes deep trenching on park trails and creates very slippery conditions for visitors. Trails in Kīpahulu are often muddy and routed beneath an over-story of broad branching non-native trees. While the trees provide shade and shelter, they shade out the drying effect of the sun. Many of the trees also have exposed roots across the trail. Visitors often seek dryer, less troublesome pathways, thereby promoting off-trail resource impacts.

Presently, commercial use activities in the Kīpahulu District include guided hikes along the park's existing visitor trails and horse tour guided trips. Current commercial use permits allow for 12 riders per horse-guided group.

METHODS

Given park objectives and their intent to implement a VERP planning and decision-making framework we emphasized measurement-based procedures in our selection and development of trail and recreation site monitoring procedures. To maximize flexibility in the future selection of appropriate trail condition indicators and comparisons to the baseline conditions documented by this study we developed and applied procedures for a diverse array of potential indicators.

Impact assessment procedures were developed and applied to all backcountry recreation sites (including vista and cave sites), visitor cabin sites, campsites, and formal trails located in the Haleakalā Wilderness and Kīpahulu areas. Condition assessments for the Sliding Sands and Kīpahulu Horse Trails and their associated recreation/vista sites were included in the Phase 1 report (Marion and Hockett, 2008). Chris Carr and Logan Park conducted fieldwork for this report from November 16-27, 2007, with substantial logistical and field assistance provided by Ron Nagata. The following sections describe the sampling design, field methods, and analysis procedures applied to collect and analyze the impact assessment data.

Recreation Site Assessment Procedures

Standardized procedures were developed and refined for assessing visitor impacts associated with activities that create recreation sites around overlooks in backcountry areas, along trails, and associated with backcountry campsites for incorporation into a long-term monitoring program. These procedures emphasize a multi-parameter measurement-based approach but also incorporate condition class assessments and photographs from permanent photopoints. The multi-parameter assessment procedures provide more quantitative information on an array of recreation site impact indicators (Appendix 1). Photographs provide for visual comparisons of changes on individual sites over time.

The survey's primary objective was to assess and document resource conditions at all backcountry recreation sites within the specified areas. Sites were defined as areas of obvious vegetative, organic litter, or soil disturbance that in the judgment of survey staff was caused by visitor activities. Furthermore, the disturbance had to be of such extent to produce a discernable boundary between disturbed and undisturbed areas. Site size was measured using the variable radial transect method in the crater and the geometric figure method at the Kipahulu area (Appendix 1). The faster but less accurate geometric figure method was used because of the desire to measure all impacts in a very limited time. Indicator conditions were typically assessed only within the established boundary of the site, with additional procedures to allow for assessments of any "satellite" use areas. Fixing the area of interest within site boundaries increases the precision of assessments.

Recreation site impact indicators were selected on the basis of earlier recreation ecology and visitor impact perception studies, indicator selection criteria, and discussions with park staff. For soil, the percentage of exposed soil was assessed according to a six-category cover-class scale (Appendix 1). Where present, the number of trees with moderate to severe root exposure were counted within delineated site boundaries as an indication of soil compaction and erosion. For vegetation, the percentage of ground covered by non-woody vegetation on-site and off-site was estimated according to the six-category cover-class scale. Refer to Appendix 1 for descriptions of other indicators and assessment methods. A six-category condition class rating system was also applied to each recreation site to provide a general classification of the ground cover conditions (Table 3).

Table 3. Condition Class rating descriptions applied to recreation sites.

Rock:	Site is predominantly on rock surfaces. Clear boundaries based on trampling disturbance cannot be easily discerned.
Class 0:	Site barely distinguishable; no or minimal disturbance of vegetation and /or organic litter. Often an old site that has not seen recent use.
Class 1:	Site barely distinguishable; slight loss of vegetation cover and /or minimal disturbance of organic litter.
Class 2:	Site 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.

Data Analysis

Data were input into an Excel spreadsheet and several new indicators were calculated. Spreadsheet formulas or GIS routines were used to calculate recreation site sizes based on the variable radial transect data in the crater and geometric figure method at Kipahulu (see Appendix 1). Area of exposed soil was calculated by multiplying site size by the percentage estimate of exposed soil within recreation site boundaries. An estimate of the recreation site area over which vegetation cover had been lost was calculated by subtracting the mid-point value of the onsite percent vegetation cover category from its offsite (control) counterpart, then multiplying this percentage by recreation site size. Data were imported to the SPSS Statistical package for analyses, including frequencies and descriptive statistics. Use of trade, product, or firm names does not imply endorsement by the U.S. Government.

Trail Assessment Procedures

The trail system in the Haleakalā "Crater" area (including both Wilderness and non-wilderness areas) was sampled by dividing all designated trails into 38 segments, each about 0.6 mile long, with approximately 13 in each of three regions (west side, central crater, east side). The three regions were established to account for a pronounced gradient in rainfall and soil moisture that increases from west to east. Segment numbers 2-5 (see Figure 5) were purposively sampled to provide park staff with complete information on the portion of the Halemau'u Trail that descends from the rim to the Crater floor, a primary access trail. This facilitates comparison to the Sliding Sands Trail, the other primary rim to Crater floor access trail surveyed previously, with results

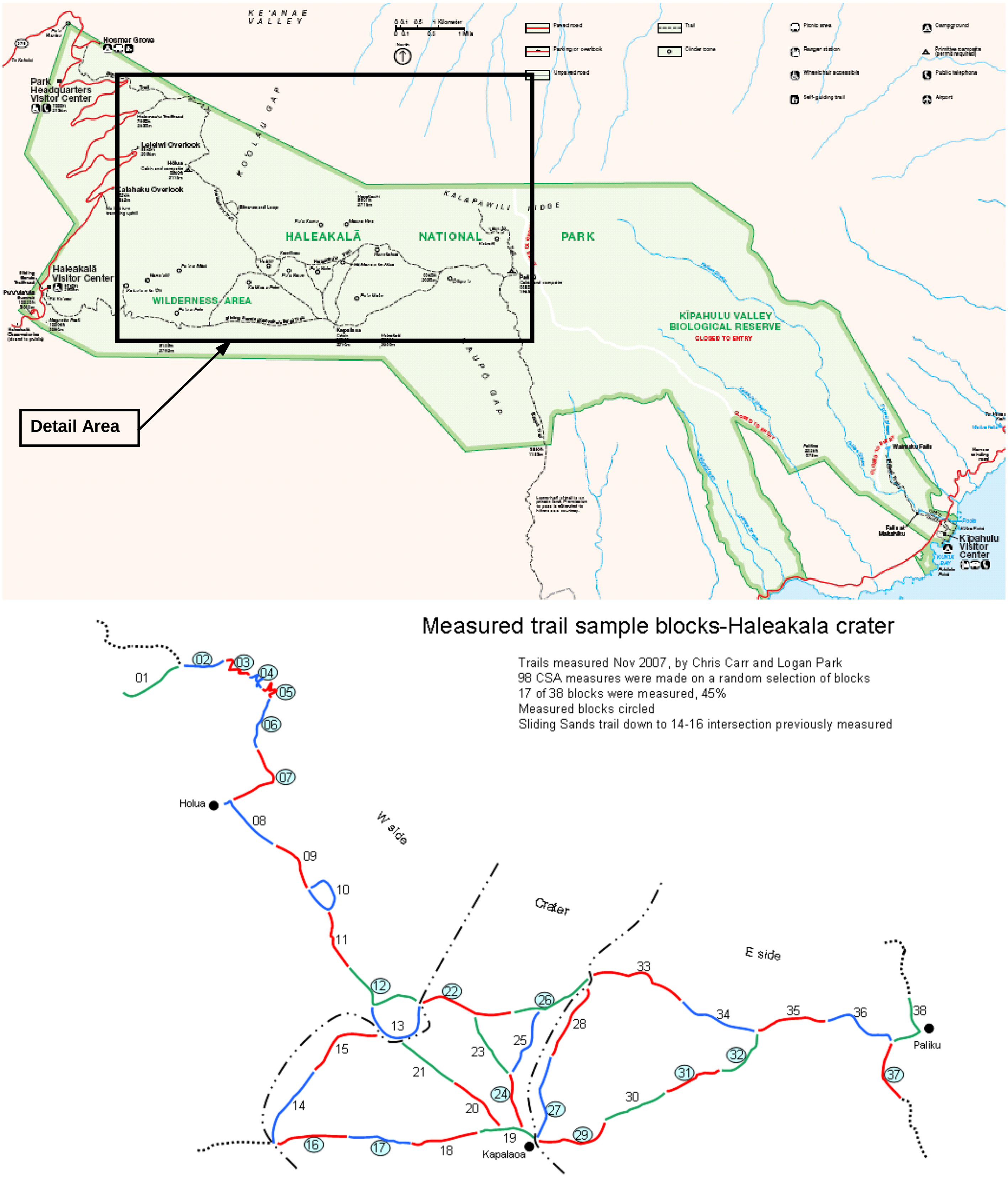

Figure 5. Haleakalā Wilderness area map (top) and enlargement of the Crater (bottom) showing trail segment divisions (~0.6 mi each) with sampled trails shown by circled segment numbers for the West side, Central Crater, and East side regions. Segments 2-5 were purposively selected.

included in the Frontcountry report (Marion and Hockett, 2008). Random sampling yielded a selection of 13 trail segments (Figure 5), including 9 miles of trail that were assessed to characterize conditions of the Wilderness trails located on the Crater floor, a 40% sample. The 1.7 mile Pīpīwai Trail in the Kīpahulu area, and the nearby new Kapahu trail (not currently open to use), were also assessed as part of this backcountry survey effort.

A detailed description of the condition assessment procedures applied to formal trails is presented in Appendix 2 and summarized here. A *point sampling method* with a fixed interval of 500 ft, following a randomized start, was employed to assess trail conditions (Leung & Marion 1999b; Marion & Leung, 2001). A Garmin GPSMap 60CSx Global Positioning System device was used to navigate to trail sample points and to collect position data for all trails and transect locations. At each sample point, a transect was established perpendicular to the trail 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 pronounced disturbance to organic litter and/or soils. Representative photos promoted consistent judgment. The objective was to select visually obvious boundaries caused by trampling disturbance that contained the majority (>95%) of traffic. Temporary stakes were placed at these boundaries and the distance between was measured as trail 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 loss from erosion, soil displacement, or compaction (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 fixed interval method (Cole 1983) (Figure 6, See Appendix 2 for detailed procedures). CSA volume provides a more accurate measure of trail soil loss that can be extrapolated to provide an estimate of total soil loss from each trail (ft^3). Soil loss includes soil lost by water or wind erosion, displacement, and compaction. CSA was calculated from the data collected at each sample point using spreadsheet formulas.

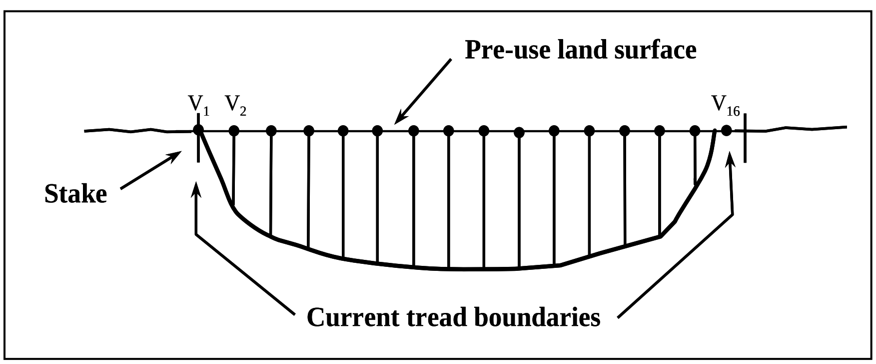

Figure 6**.** Illustration of the variable interval CSA method for assessing soil loss at each transect.

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 trail 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.

Trail condition measures were calculated for each trail and for all trails combined, including area of disturbance, CSA, and mean trail width and depth (Table 4). For example, "area of disturbance," an estimate of the land area intensively disturbed by trail traffic, was calculated by multiplying trail length by mean trail width. CSA volume, an estimate of aggregate soil loss (CSA ft^3), was calculated by multiplying mean CSA (converted to ft^2) by trail length.

Table 4. Description of trail impact indicators and calculation methods.

Trail Length	Total length of the trail segment being assessed, summed to obtain an aggregate measure for each study area.
Trail Width	Width of trail that captures about 95% of all traffic, including trail-sides up to the pre-use land surface for fall-aligned trails or up to the estimated post-construction tread surface for side-hill trails. Assessed at sample points along each trail and averaged for each trail to obtain mean trail width.
Area of Disturbance	The mean trail width times the trail length.
CSA	An estimate of soil loss at each sample point from erosion, soil displacement, or compaction, assessed through vertical measurements at a fixed interval across the trail width from the pre-use or post-construction land surface to the current tread surface. Mean CSA is calculated as the average of CSA values measured at the sample points for each trail segment.
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.

Informal trails are trails that visitors have created to access features such as streams, scenic attraction sites, cliffs, vistas, cultural sites, or to cut switchbacks. A survey of these informal trails was conducted in the Crater and along the Pīpīwai Trail. Informal trails were assessed a condition class rating (Table 5) and width and were walked with the GPS in tracking mode to record their location and length.

Table 5. Condition Class rating descriptions applied to informal trails.

Class 0: Trail barely distinguishable; no or minimal disturbance of vegetation and /or organic litter.

Class 1: Trail distinguishable; slight loss of vegetation cover and /or minimal disturbance of organic litter.

Class 2: Trail obvious; vegetation cover lost and/or organic litter pulverized in primary use areas.

Class 3: Vegetation cover lost and/or organic litter pulverized within the center of the tread, some bare soil exposed.

Class 4: Nearly complete or total loss of vegetation cover and organic litter within the tread, bare soil widespread.

Class 5: Soil erosion obvious, as indicated by exposed roots and rocks and/or gullying.

Data Analysis

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

Point Sampling Dataset: CSA in^2 for each transect and CSA volume ft^3, yd^3, and yd^3/mi for each trail. 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 250 ft in both directions (with special calculations to account for the first and final segments that differ in length from the fixed interval of 500 feet).

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

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 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

Recreation Site Conditions

A total of 45 day use recreation sites were located and assessed in the backcountry areas of Kīpahulu and within the Haleakalā Crater. Resource conditions on most sites were rated as intermediate to poor, with 23 (51%) of the sites rated Condition Class 4, and 13 (29%) rated Class 3, but only 3 (7%) rated Class 5 (Table 3, Table 6). Three types of recreation sites were defined, day-use recreation sites (N=24), and overnight campsites (N=18) and visitor cabin sites (N=3). These sites were found in backcountry settings along the Kīpahulu Pīpīwai Trail (N=8) and within the Crater area (N= 37) (the cabins and campsites are in enclaves excluded from the wilderness). The camping area at Pipiwai was not included. The staff cabins in the crater and in the Pipiwai area, not being recreation areas, were also not included in this study.

Table 6. Condition Class ratings by park area and site type.

Condition Class	Haleakalā Crater			Pīpīwai Area	Totals	
	Day Use Recreation Sites	Campsites	Visitor Cabin Sites	Day Use Recreation Sites	#	%
0	0	1	0	0	1	2 %
1	0	0	0	0	0	0 %
2	1	2	2	0	5	11 %
3	4	8	1	0	13	29 %
4	10	7	0	6	23	51 %
5	1	0	0	2	3	7 %
Totals	16	18	3	8	45	100 %

The park's three backcountry visitor cabins, each with a capacity of 12 visitors, are available through an advanced reservation lottery:

Hōlua Cabin. Located in the dry western end of the Crater, 3.7 miles down the Halemau'u Trail. A campground here has 13 campsites. (Figure 7).

Kapalaoa Cabin. Located on the central south side of the Crater at the base of the cliffs. Camping is not permitted outside the cabin (Figure 8).

Palikū Cabin. Located at the mesic eastern end of the Crater at the base of a cliff, a 9.3 mile hike from the Haleakalā summit. A campground here has four campsites. A fifth site was assessed with no discernable boundaries (size=0) but evidence of prior use (Figure 9).

The Hōlua and Palikū campgrounds have a maximum limit of 25 people each, with a 12-person group limit. The actual campsites are not designated. The campsites which were identified and measured were established by visitors by their repeated use of the same area. There are undoubtedly other places in the camping area where people have camped, but without leaving a trace. The cabin sites have pit toilets and non-potable water; open fires are not permitted.

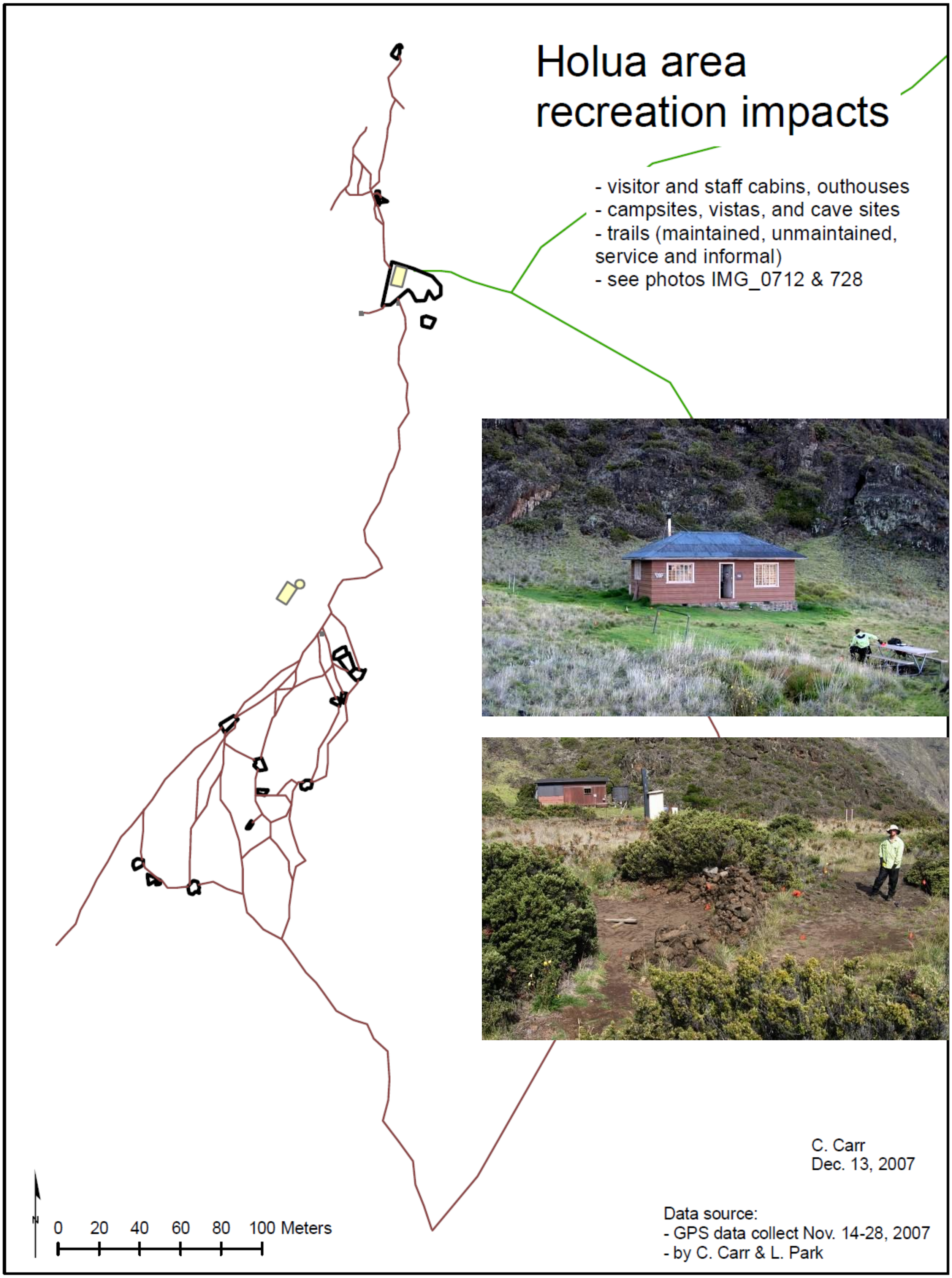

Figure 7. Hōlua cabin and campsite map and photos. Buildings are depicted by yellow rectangles, campsites by black polygons.

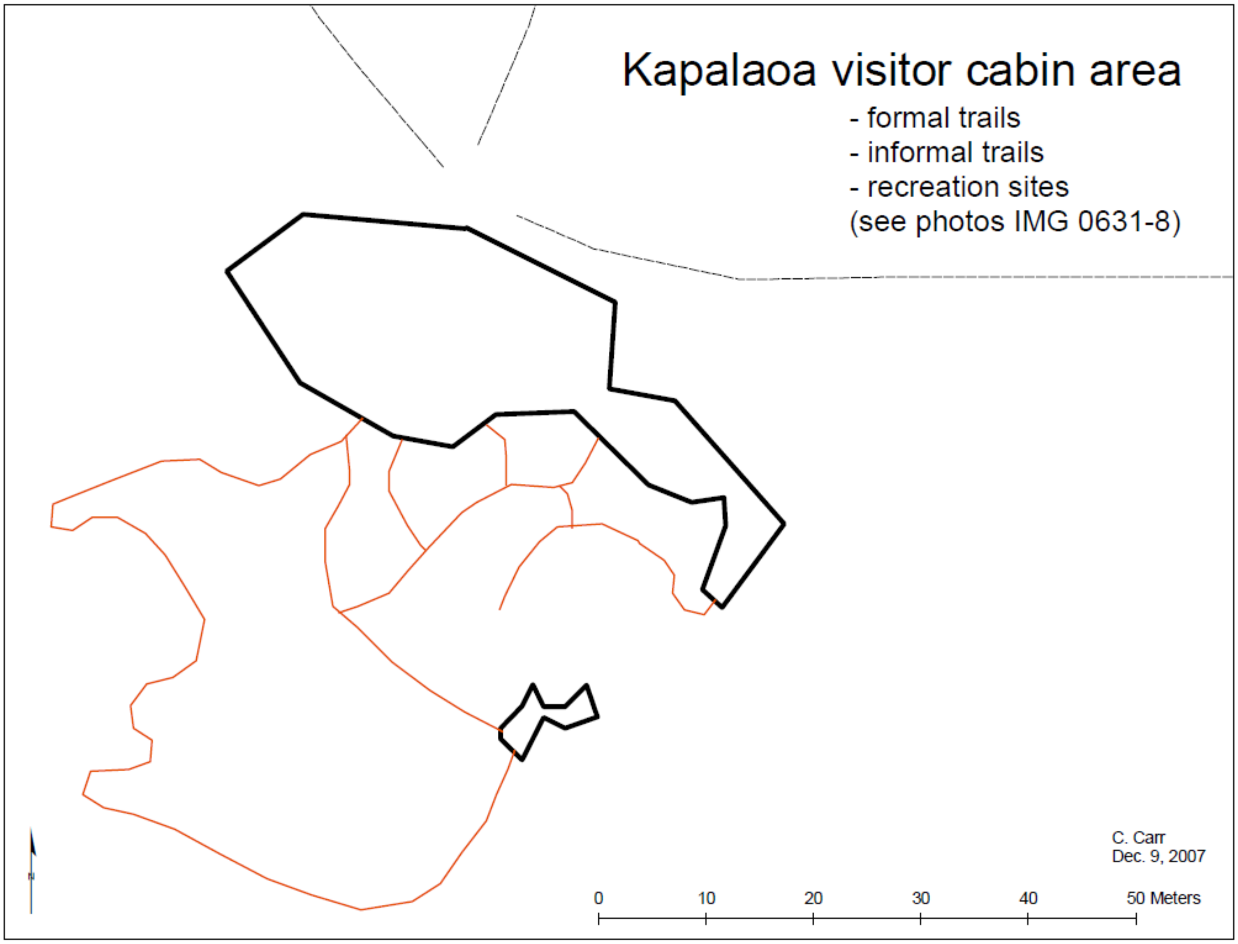

Figure 8. Kapalaoa cabin map and photo.

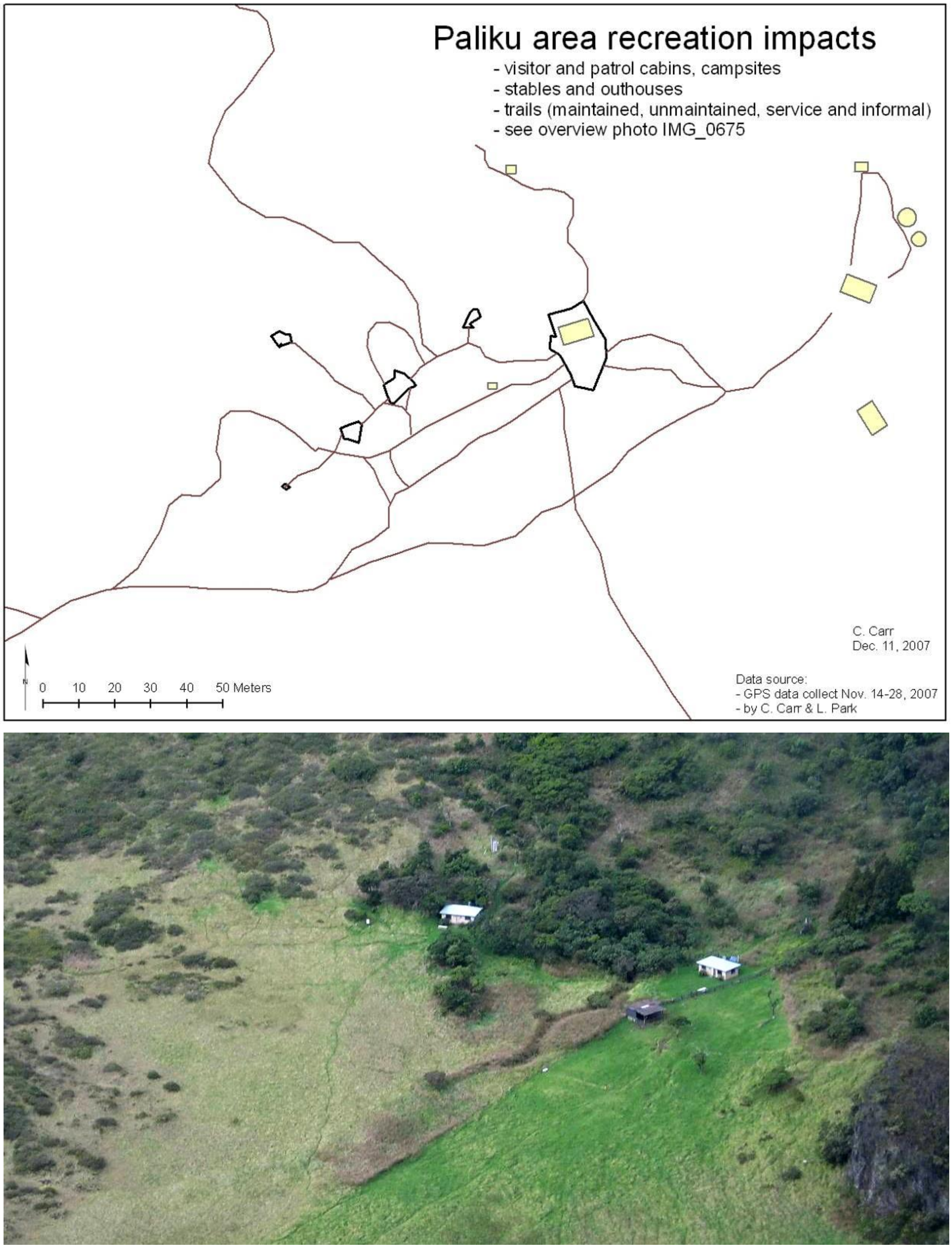

Figure 9. Palikū area cabin and campsite map and photo. Buildings are depicted by yellow rectangles, campsites by black polygons.

Use level assessments for these recreation sites provided by park staff suggest that most sites are well-used, with 28 (62%) classified as high use and only 7 (16%) as low use (Table 7) (we note that all these sites receive relatively low use compared to many other NPS backcountry campsites). Only two of the visitor-developed recreation sites were assessed as low use but 8 (44%) of the campsites were assessed as low use, suggesting a possible excess in capacity. All sites were also assessed for their potential to expand in size based on surrounding topography, substrates, and vegetation density. These ratings indicate a low potential for expansion among the recreation sites in the Crater area, 12 of 16 sites (75%) assessed as having poor potential to expand (Table 7). Among the designated campsites expansion potential was mixed, with 8 sites rated with good expansion potential, 4 as intermediate, and 6 as poor. Two of the cabin sites were also rated as having good expansion potential. The higher potential for expansion is largely related to their placement within large open areas of flatter terrain.

Backcountry settings are often managed to provide opportunities for solitude and natural quiet, particularly when camping overnight, so field staff assessed the distance from each campsite to the nearest other campsite. These data reveal that the campsites are closely spaced, with 9 campsites located less than 10 yards from nearest other site, 3 within 11-20 yards, and 6 within 21-40 yards.

Table 7. Inventory indicator assessments by park area and site type.

Inventory Indicator	Haleakalā Crater			Pīpīwai Area	
	Day Use Recreation Sites	Campsites	Visitor Cabin Sites	Day Use Recreation Sites	Totals
Use Level					
High	10	8	2	8	28
Medium	4	2	1	0	10
Low	2	8	0	0	7
Site Expansion Potential					
Good	2	8	2	3	15
Moderate	2	4	1	4	11
Poor	12	6	0	1	19
Distance to Nearest Other Site (ft)					
Not applicable	16	0	3	8	27
<10 yd	0	9	0	0	9
11-20 yd	0	3	0	0	3
21-40 yd	0	6	0	0	6
41-60 yd	0	0	0	0	0
>60 yd	0	0	0	0	0

Condition class ratings provide a general indication of overall site conditions but field staff also conducted more detailed measurements and assessments of conditions for site condition indicators that provide more quantitative documentation. Of particular importance is the total area of trampling disturbance associated with the recreation sites, assessed as 36,030 ft^2 when summed across the 45 backcountry sites (Table 8). Surprisingly, more than a third of this total disturbance is associated with the three cabin sites, which have a mean size of 4653 ft^2 and account for 13,960 ft^2 (39%) of the total area of disturbance. In contrast, the campsites are extremely small, with a mean size of only 212 ft^2, while mean sizes for the day use recreation sites in the Crater (692 ft^2) and in the Pīpīwai area (898 ft^2) are intermediate (Table 8).

Table 8. Impact indicator conditions assessed on recreation sites by park area and site type.

Impact Indicator	**Haleakalā Crater**			**Pīpīwai Area**	
	Day Use Recreation Sites	**Campsites**	**Visitor Cabin Sites**	**Day Use Recreation Sites**	**Totals**
N	16	18	3	8	45
Site Size (ft^2)					
Mean	692	212	4653	898	801
Sum	11,072	3816	13,960	7182	36,030
Range	36 - 7722	0 - 449	2771 - 7086	78 - 4480	0 - 7722
90% Percentile	2816	433	*	*	
Vegetation Loss (ft^2)					
Mean	78	57	-1122	857	217
Sum	1252	1023	-3366	6859	9134
Range	0 - 267	-16 - 227	-3366 - 0	74 – 4278	0 - 4278
90% Percentile	258	217	*	*	
Exposed Soil (ft^2)					
Mean	606	62	423	367	334
Sum	9701	1109	1270	2936	15,016
Range	6 - 7568	0 - 255	69 - 1098	3 - 1702	0 – 7568
90% Percentile	258	217	*	*	
Access Trails (#)					
Mean	2.2	3.4	7.3	2.3	3.0
Sum	36	61	22	18	137
Range	1 - 5	0 - 10	6 - 8	1 - 3	0 - 10
90% Percentile	4.3	7.3	*	*	

* Could not be calculated.

Two other important measures of recreation site conditions relate to assessments of how much vegetation cover has been lost within site boundaries and the extent of bare soil exposure. Vegetation loss is calculated as a difference in percent cover between the recreation site and an adjacent “control” site reflecting the conditions that would be present had the site not been used by visitors. The percent difference is then multiplied by site size to provide an estimate of the area over which vegetation cover has been lost, reported in Table 8. These values indicate that vegetation loss is minimal on the Crater area recreation sites and campsites, with a substantial increase in vegetation cover on the cabin sites (negative vegetation loss values indicate that onsite vegetation cover exceeds offsite cover). Finding increased vegetation cover in the areas around the cabins (see Figure 8) is somewhat unusual; we suspect that this finding must be related to greater fertility, soil moisture, or seeding with non-native grasses in these areas. The substantially higher vegetation cover loss occurring on the Pīpīwai area recreation sites is attributed to their location in the wetter forests that support substantially higher amounts of ground vegetation. Additionally, these sites are predominantly located under forest canopies and numerous studies have shown that the broadleaved vegetation groundcover in shady settings is substantially more susceptible to trampling than grassy groundcover growing in open, sunny locations (Cole 1987, Leung & Marion 2000).

The amount of exposed soil on the sites varied with vegetation cover, but also with the presence of organic litter and rock. Aggregate soil exposure was 15,016 ft^2, with a substantial proportion accounted for by the Crater area day use recreation sites (9701 ft^2, 65%) and the Pīpīwai area recreation sites (2936 ft^2, 20%) (Table 8). However, 10,368 ft^2 (69%) of the exposed soil is accounted for by just two recreation sites and one visitor cabin site, suggesting that this is an isolated problem. Finally, field staff counted the number of access trails connecting to recreation site boundaries, tallying 137 for an average of 3 per site (Table 8). The heavily visited cabin sites have the most access trails (22, 7.3/cabin), followed by the campsites (61, 3.4/campsite).

Trail Conditions

Field staff assessed a total of 11.73 miles of designated backcountry trails (Table 9). Mean width and depth are 46 in. and 3.5 in, respectively, with a total area of disturbance estimated at 245,399 ft^2 (5.63 acres). Aggregate estimated soil loss on these trails is 69,270 ft^3, which translates to 2566 yd^3 or 256 dump trucks (Table 10). Predominant trail substrates include unconsolidated cinder for the Haleakalā Crater trails, with rock for the Halemau’u Trail section coming down the Crater wall, exposed soil for the Pīpīwai Trail, and vegetation cover for the new unopened trail (Kapahu) in Kīpahulu (Table 11).

The Pīpīwai trail, located in the Kīpahulu area, is 1.74 mi long and provides access to Makahiku Falls and Waimoku Falls. The trail passes through native rainforests and patches of non-native bamboo forests. Boardwalks of recycled plastic are provided in areas with wet soils. Survey data reveal the mean width for this trail as 39 in, reasonably good for the high traffic it receives (Table 9). Mean depth is 3.2 in. and mean maximum incision is 10.4 in. (Table 10), an intermediate level of erosion, as also evidenced by the presence of tree root exposure (Table 11). Erosion is likely occurring due to the high rates of rainfall, a steep mean grade (11.4%), and alignments that are often close to the fall-line (i.e., parallel rather than perpendicular to landform slopes). This is indicated by the TSA values in Table 9; low values (0-30 degrees) indicate fall-aligned trails and high values (60-90) indicate side-hill or contour-aligned trails. Estimated

Table 9. Point sampling data for trail width, area of disturbance, grade, and trail slope alignment angle (TSA).

Trail or Region	**Trail Width** *Mean, in*	**Area of Disturbance** *ft^2*	**Area of Disturbance** *ft^2/mi*	**Trail Grade** *Mean,%*	**TSA** *Mean, degrees*
Pīpīwai Trail (1.74 mi)	39.2	35,942	20,698	10.4	32
Kapahu Trail (0.99 mi)	20.6	10,033	10,091	11.4	22
Halemau'u Trail[1] (2.06 mi)	54.8	49,720	24,120	11.5	78
Western Crater Trails (1.46 mi)	37.7	24,247	16,600	5.6	34
Central Crater Trails (2.82 mi)	66.6	82,545	29,304	4.2	38
Eastern Crater Trails (2.66 mi)	36.7	42,911	16,141	6.1	22
All Trails (11.73 mi)	46.3	245,399	20,924	7.5	39

1 – Only the portion from the rim to the Crater floor is included to provide a more direct comparison to the Sliding Sands Trail.

Table 10. Point sampling data for trail depth, maximum incision and cross sectional area soil loss (CSA).

Trail or Region	**Trail Depth**	**Maximum Incision**	**Cross Sectional Area**			
	Mean, in	*Mean, in*	*Mean, in^2*	*Sum, ft^3*	*Sum, yd^3*	*yd^3/mi*
Pīpīwai Trail	3.2	3.6	126	7990	296	170
Kapahu Trail	0.4	0.5	9	312	12	12
Halemau'u Trail[1]	6.5	9.8	356	26,939	998	484
Western Crater Trails	3.6	5.2	136	7345	272	186
Central Crater Trails	1.6	2.8	103	10,755	398	141
Eastern Crater Trails	4.6	4.4	168	15,930	590	222
All Trails	3.5	4.7	164	69,270	2566	219

1 – Only the portion from the rim to the Crater floor is included to provide a more direct comparison to the Sliding Sands Trail.

Table 11. Point sampling data for trail tread substrates, mean percent cover.

Trail or Region	**Exposed Soil** *Mean, %*	**Rock** *Mean, %*	**Vegetation Cover** *Mean, %*	**Litter** *Mean, %*	**Roots** *Mean, %*	**Mud** *Mean, %*	**Other**[1] *Mean, %*
Pīpīwai Trail	54.2	5.3	2.5	9.4	0.8	0.0	22.2
Kapahu Trail	0.0	0.0	40.0	30.0	0.0	0.0	30.0
Halemau'u Trail[2]	15.0	37.9	20.7	0.0	0.0	5.2	1.0
Western Crater Trails	2.7	20.0	10.7	0.0	0.0	0.0	66.7
Central Crater Trails	0.0	0.0	0.0	0.0	0.0	0.0	100
Eastern Crater Trails	1.9	0.4	18.7	0.0	0.0	0.0	79.1
All Trails	11.4	9.9	12.8	3.9	0.1	0.9	56.7

1 – Includes unconsolidated cinder substrates for Crater soils and boardwalks for the Pīpīwai Trail.

2 – Only the portion from the rim to the Crater floor is included to provide a more direct comparison to the Sliding Sands Trail.

aggregate soil loss values are intermediate compared to the other trails, for example, 125 in^2 for CSA (Table 10). Predominant substrates are exposed soil and plastic wood (coded as “Other”) that is used in boardwalk construction, which is extensive along this trail. Exposed tree roots were common in some areas.

Field staff also assessed the new 0.99-mile Kapahu Trail that attaches to the Pīpīwai Trail but mostly is not yet open to use. As might be expected, this trail was very narrow (mean width 21 in.) (Table 9) with essentially no erosion (Table 10). For example, mean depth is 0.4 in and mean CSA is only 9 in^2. Tread substrates were predominantly vegetation (40%) and organic litter (30%) reflecting its limited traffic.

The Halemau’u Trail, like the previously assessed Sliding Sands Trail, provides primary access to the Haleakalā Wilderness and non-wilderness camping areas, containing the large volcanic plateau referred to as the Crater east of the Haleakalā summit. We assessed the summit rim to Crater floor portion of this trail (Table 9) to allow a more direct comparison to the data collected for the Sliding Sands Trail, which provides rim to floor access across a much longer distance on substrates that are predominantly unconsolidated cinder. This portion of the trail is 2.06 miles long and has a series of switchbacks, some in areas with deeper soils (15%), others in rocky substrates (38%) with adjacent cliffs (Table 11). This trail segment is generally wide (mean width 55 in.) and deeply incised (mean depth 6.5 in.). Subsequently, the estimated soil loss is quite large, 356 in^2, with a cubic yard per mile soil loss estimate (484 yd^3/mi) that is more than twice as large as the other trails surveyed (Table 10). However, this soil loss estimate is less than the Sliding Sands Trail (549 yd^3/mi) and its mean width is also substantially less (55 in. vs. 83 in.) (Marion and Hockett 2008). This trail segment is largely well-designed as a side-hill trail (TSA = 78 degrees), allowing for the removal of water from its tread - though incision does prevent water drainage and an adequate density of grade reversals or water drainage features must be installed and maintained. However, the mean trail grade is the highest of all trails surveyed (11.5%) and soil loss increases exponentially with increasing grade. Finally, rocky substrates comprise only 38% of the tread substrates (lower section of trail), indicating that much of the trail (predominantly the upper section) is located on erodible soils. High use and traffic by horses also contribute to the higher soil loss found on this trail.

The remaining trails are within the Haleakalā Wilderness and non-wilderness enclaves, distributed across a large open valley with volcanic cones and ancient lava flows. This Crater region was divided into three areas along a west to east gradient of increasing moisture: labeled Western Crater, Central Crater, and Eastern Crater. As described in the Methods section, trails within these areas were divided into approximately 0.6-mile long segments and a 40% random sample was assessed, with results summarized by area to characterize trail conditions. The Central Crater trails are the widest, with a mean width of 67 in., contributing to a substantially wider area of disturbance (29,304 ft^2/mi) in comparison to the Eastern and Western Crater trails (Table 9). This is likely attributable to the lack of topographic relief and vegetation, which inhibit trail widening, and to the unconsolidated cinder substrates (100%, Table 11) present in the Central Crater area. Mean trail grades in the Crater range from 4.2 to 6.1%. Mean trail depths range from 1.6 for the Central Crater trails to 4.6 for the Eastern side trails, the latter likely have greater soil loss due to greater rainfall, though these trails have the lowest TSA values (22 degrees) and highest grades (6.1%).

Informal Trails

Though not required by the research agreement, field staff did explore and GPS many of the informal trails within the Haleakalā Crater, though these were not formally assessed. The park website and printed visitor information indicates that “Hiking off designated trails or taking shortcuts is prohibited,” because “Off-trail hiking causes erosion and damages fragile life forms.” Field staff found ample evidence that adherence to this rule is poor in the non-wilderness enclaves around the cabins and campsites and along the switchbacks on the Halemau’u Trail. There were only a few instances of informal trails in other parts of the Wilderness. For example, Figure 10 illustrates that some informal trails lead to vistas while others are associated with shortcutting switchbacks. Other informal trails lead to the tops of small volcanic cones within the Crater, volcanic lava tube caves, and a number of informal trails (also called non-maintained trails) have been created by park staff performing resource management functions (e.g., wildlife monitoring survey work). Trails associated with resource management work often had highly visible flagging along them which, within Wilderness, seems inappropriate and may also call attention to them by visitors. Many of the informal trails leading to vista sites occur in very steep terrain on highly erosive soils, often unconsolidated cinder. These showed evidence of severe erosion in many places. Extensive networks of informal trails are also present in the vicinities of each cabin and within the campground areas.

In the Kīpahulu area, field staff surveyed all informal trails that branched from the Pīpīwai Trail (Table 12, Figure 11). The majority of these trails access vistas overlooking the stream, some are for exploration, and others access shade trees where visitors take resting breaks. Condition class ratings assessed for the 37 informal trails reveal they are well-used and highly impacted, with 54% rated Class 4 or 5 and a mean width of 3.1 ft. More than a quarter of the trails (27%) are at least four feet wide.

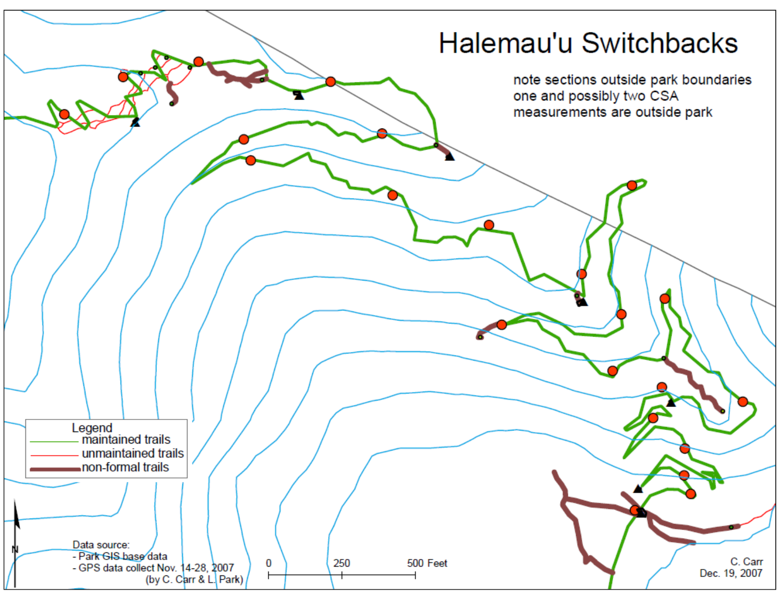

Figure 10. Field staff found numerous informal trails, some led to vistas or attraction features, and others are caused by shortcutting switchbacks.

Table 12. Condition class rating and trail width data for informal trails branching from the Pīpīwai Trail.

Pīpīwai Trail		Condition Class Rating				
		1	2	3	4	5
Informal Trails (# / %)	37 (100%)	4 (11%)	6 (16.2%)	7 (18.9%)	12 (32.4%)	8 (21.6%)
	Tread Width (ft)					
	1	2	3	4	5	6+
Informal Trails (# / %)	6 (16.2%)	9 (24.3%)	12 (32.4%)	5 (13.5%)	2 (5.4%)	3 (8.1%)

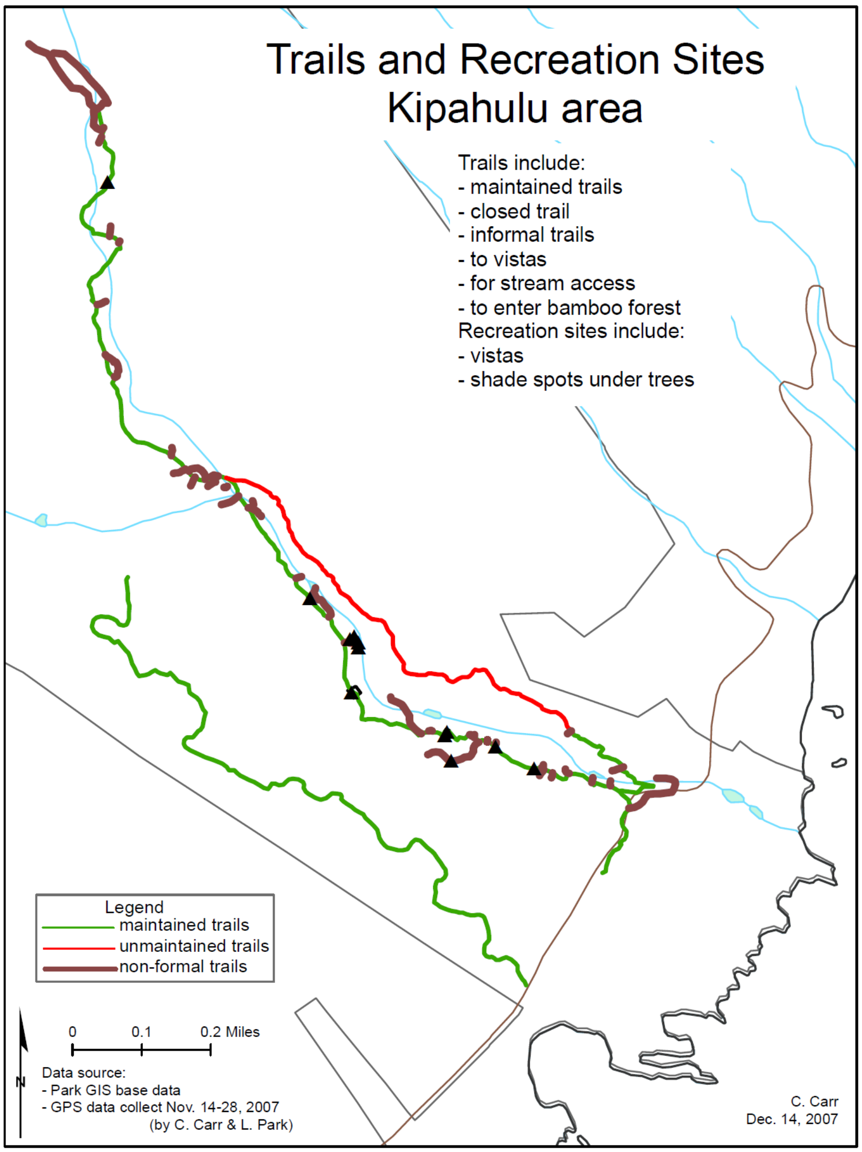

Figure 11. Formal and informal trails and recreation sites in the Kīpahulu area. The Pīpīwai Trail parallels the stream and is shown in green; the new Kapahu Trail is shown in red. Recreation sites are shown as black triangles.

Guidance for Selecting Indicators and Standards

Recreation sites

Based on a review of the criteria for selecting LAC/VERP indicators (Figure 3), considerations regarding selection of preferred indicators (pg. 18), the data from Haleakalā recreation sites, and professional judgment, indicators recommended for consideration include:

Recreation site Size – This is perhaps the best single indicator reflecting the total area of recreation-related disturbance. Management efforts to minimize the area of trampling disturbance will promote the health of surrounding vegetation and soil, prevent the merging of impact areas from separate sites, and limit the potential for soil erosion. Indicators related to the proliferation of visitor-created sites and site density might also be considered. For example, is the creation of additional vista sites or campsites over time acceptable? Furthermore, success in restricting site size would increase trampling intensity and further reduce percent vegetation cover while increasing the percentage of exposed soil. Additional indicators such as area of exposed soil or vegetation loss may be unnecessary, since there is little vegetation cover or organic litter in some areas of the park. Such measures are also limited by and strongly correlated with recreation site size measures, so their use as additional indicators is of questionable need.

Maximum size standards could be set for the size of individual recreation sites, for an aggregate measure of all sites in a particular area of the park, an aggregate for all the sites of a certain type (e.g., recreation sites, campsites, or visitor cabins), or a combination of these. Establishing standards for individual recreation sites would prevent any single site from growing too large; establishing a standard for aggregate size permits greater flexibility, allowing expansion of one site provided it is offset by reductions in the sizes of other sites. Table 8 includes data characterizing the recreation site size, including range data and 90th percentiles (where permitted), and Figure 12 provides boxplot data illustrating the distribution of site size values. All monitoring data will also be provided electronically, including Excel files and GIS datasets, which can also be consulted if indicator standards are selected.

Trails

Based on a review of the criteria for selecting LAC/VERP indicators (Figure 3), considerations regarding selection of preferred indicators (pg. 22), the data from Haleakalā trails, and professional judgment, indicators recommended for consideration include tread width, tread incision, and cross sectional area. This section presents additional data characterizing the distribution of values for these potential indicators to facilitate management deliberations on selecting appropriate measures and values for standards of quality. Selecting an indicator standard is an inherently value-laden and subjective process. However, presentation of representative data characterizing the distribution of indicator values, when available, can greatly assist the process used to evaluate and select quantitative standards. The following presentation of data for these potential indicators explores different methods for characterizing the distribution of values.

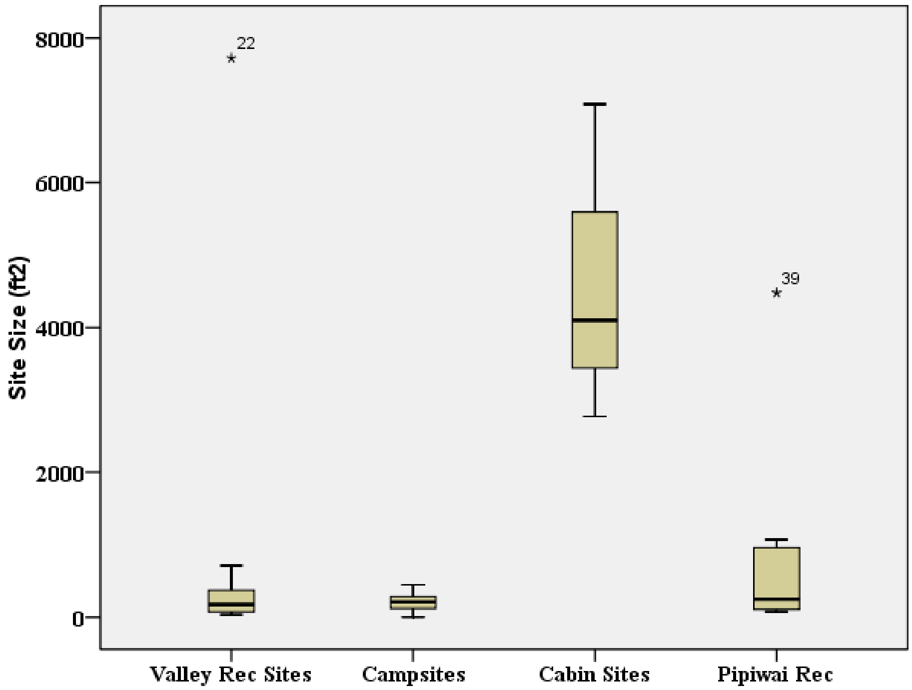

Figure 12. Boxplots of site size for the four site types.
Note: Boxes represent first (lower line) and third (upper line) group quartiles; lines inside the boxes represent the overall mean for each group; vertical lines ("whiskers") represent the range of values; and outliers lay beyond the value indicated by the end of the upper whisker.

Table 13 presents indicator data for the formal backcountry trails. Indicator measures include the range of values, mean, standard deviation, and the 90% and 95% percentiles. The standard deviation is a statistic used as a measure of the dispersion or variation in a distribution, defined as the average amount by which scores in a distribution differ from the mean, ignoring the sign of the difference. Percentiles describe the percent of values that lie below, i.e., the 95th percentile means that 95% of the values are smaller and 5% are larger. Such data can inform individuals in the process of selecting standards by describing the range of indicator values, their mean and level of dispersion, and the percent of values above or below a specified value. Boxplots for each indicator are also included to illustrate the range of values and show outliers (Figures 13-15). Trail data will be provided in Excel and GIS data files, which can also be consulted if indicator standards are selected.

Selection of one or more informal trail indicators that reflect their number, lineal extent, and/or condition is also recommended. For example, 37 informal trails were recorded in the areas along the Pīpīwai Trail; 8 of these (22%) were rated condition class 5, and 5 (13.5%) were 5 feet or wider in width (Table 12). Some trails may be accessing areas of particularly sensitive natural or cultural resources, others may be traversing steep slopes with unconsolidated soils that erode quickly. A standard on the number of these trails will prevent their proliferation over time. A standard on total length can limit aggregate trampling disturbance. A restriction on conditions would focus additional management attention on closing poorly located trails, or converting some high use informal trails to formal runouts to vistas or attraction features.

Table 13. Summary statistics for impact indicators by category of use for backcountry trails.

Trail	Tread Width *in*	Max. Tread Incision *in*	Cross Sectional Area *in²*
Pīpīwai Trail			
Range	24.0 – 80.4	0 – 11.5	0 – 567
Mean	47.0	3.6	125
St. Deviation	21.0	2.9	149
90% / 95% Percentile	80 / *	8.5 / *	419 / *
New Kīpahulu Trail			
Range	12.0 – 39.6	0 – 2.8	0 – 58
Mean	22.9	0.5	10
St. Deviation	10.7	0.9	20
90% / 95% Percentile	* / *	* / *	* / *
Halemau'u Trail[2]			
Range	27.6 – 90.0	2.0 – 20.5	39 – 1083
Mean	54.8	9.8	356
St. Deviation	15.6	5.8	262
90% / 95% Percentile	76 / 88	19.1 / 20.4	708 / 1032
Western Crater Trails			
Range	18.0 – 78.0	1.5 – 18.3	20 – 609
Mean	37.7	5.2	136
St. Deviation	19.5	5.4	192
90% / 95% Percentile	70 / *	16.0 / *	596 / *
Central Crater Trails			
Range	21.6 – 252.0	1.0 – 7.8	18 – 312
Mean	66.6	2.8	103
St. Deviation	55.6	1.8	89
90% / 95% Percentile	147 / 245	5.6 / 7.6	257 / 296
Eastern Crater Trails			
Range	12.0 – 108.0	0 – 24.8	0 - 1599
Mean	36.7	4.4	168
St. Deviation	26.3	5.2	331
90% / 95% Percentile	91 / 106	12.0 / 19.0	593 / 1167

* Could not be calculated.

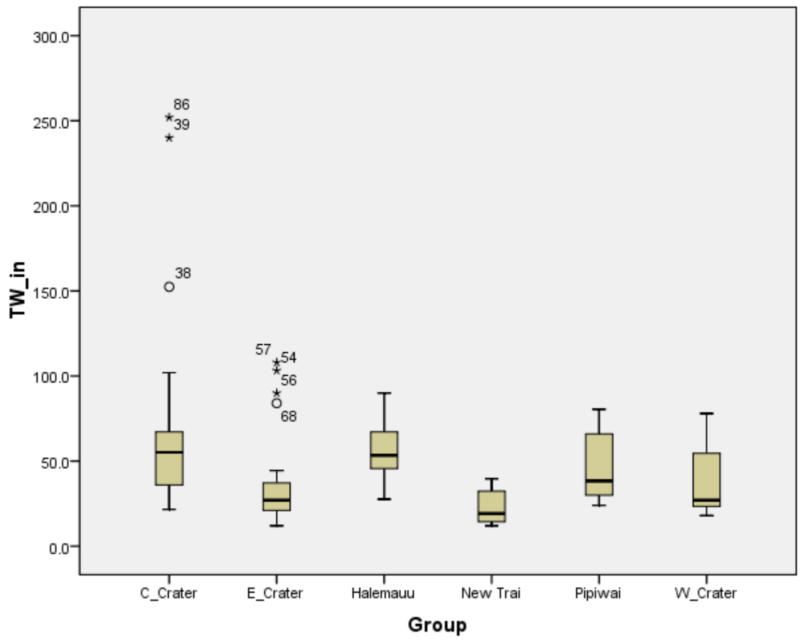

Figure 13. Boxplots of trail width for backcountry trails.
Note: Boxes represent first (lower line) and third (upper line) group quartiles; lines inside the boxes represent the overall mean for each group; vertical lines ("whiskers") represent the range of values; and outliers lay beyond the value indicated by the end of the upper whisker.

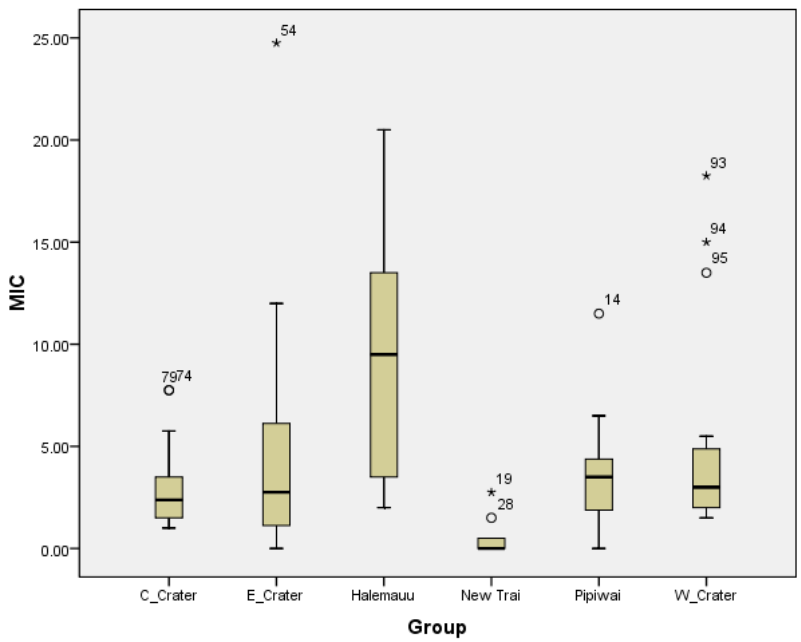

Figure 14. Boxplots of maximum incision (in.) for backcountry trails.
Note: Boxes represent first (lower line) and third (upper line) group quartiles; lines inside the boxes represent the overall mean for each group; vertical lines ("whiskers") represent the range of values; and outliers lay beyond the value indicated by the end of the upper whisker.

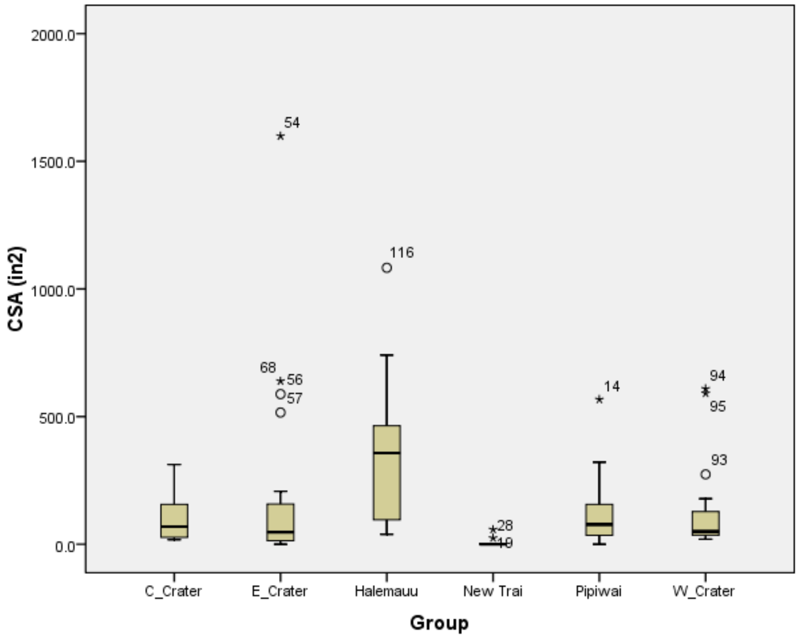

Figure 15. Boxplots of cross sectional area soil loss for backcountry trails.
Note: Boxes represent first (lower line) and third (upper line) group quartiles; lines inside the boxes represent the overall mean for each group; vertical lines ("whiskers") represent the range of values; and outliers lay beyond the value indicated by the end of the upper whisker.

DISCUSSION AND MANAGEMENT OPTIONS

This section of the report reviews and summarizes management options for improving management of recreation sites and trails that can accommodate and sustain a variety of visitor uses while protecting the park's natural resources.

Review and Summary of Findings

Park managers operate under legislative mandates to provide appropriate recreational opportunities while protecting and preserving park resources and natural processes. While a variety of recreational uses, including trail-related activities, are clearly appropriate, park managers must also ensure that they avoid significant impairment of natural and cultural resources. As described in the Introduction section, park managers are charged with applying their professional judgment in evaluating the type and extent of recreation-related impacts when judging what constitutes impairment. This report provides useful information for rendering such determinations and provides a basis for decisions to enhance management of visitors and resources to avoid or minimize recreation impacts.

This research developed and applied state-of-the-art recreation site and trail condition assessment and monitoring procedures and applied them to the park's backcountry recreation sites and trails. A variety of recreation site and trail condition indicators were identified in consultation with park staff for potential use in future VERP carrying capacity planning and decision-making. Protocols were developed, field-tested and applied with results fully summarized for use in selecting standards of quality. Park staff participated in the field assessments and were trained for future application of monitoring procedures.

Management Options

Recreation Sites: While there are a relatively large number of day use recreation sites within the Crater (N=16), they are relatively small in size. The recreation site assessed at Kawilinau, the fenced "bottomless pit" attraction feature, is 7722 ft^2. This area is devoid of natural vegetation and site boundaries were somewhat arbitrarily defined as the areas of most intensive footprints in the unconsolidated cinder substrates. Omitting this extremely large site results in a mean size of only 223 ft^2 for the remaining Crater day use recreation sites. The remaining sites are predominantly vistas, with a few sites associated with lava tube caves, and the tops of volcanic cones. Most of these sites are located on cinder substrates and are naturally devoid of vegetation cover so it is not clear if their continued use represents a significant impact. Some of these sites may be located near archaeological features. Managers could seek to diminish their use through an enhanced educational program designed to discourage off-trail hiking. This might include printed material, visitor center/permit station posters, verbal messages, or signs posted at specific backcountry sites. The latter are generally discouraged for sites located within Wilderness. Site management actions include trailside rock scree-wall borders or low symbolic fencing, to discourage visitors from accessing certain sites, or rock borders at sites to restrict their size. Another option is to designated and accept a limited number of vista's and create single sustainably designed access trails.

One concern related to the day use recreation sites is the proper disposal of human waste. Toilet facilities within the Crater area are limited to the three cabin sites. Field staff found improperly disposed human waste in several backcountry locations that could be easily avoided if visitors followed the Leave No Trace cat-hole disposal practice for burying human waste. Other options include carryout human waste kits or primitive pit toilets, which have been installed in other Wilderness areas.

Campsites: The campsites are located within two designated backcountry campgrounds situated within enclaves excluded from the designated Wilderness. While pit toilets and non-potable water are available nearby, the campsites lack other facilities and campfires are not permitted. The individual campsites are not formally marked or designated, nor are there formal campsite access trails. In fact, it is not clear on arrival at Hōlua where the campground and sites are located; no sign or site map is provided at either campground to inform visitors of the location or number of campsites that are available. It appears that visitors could legally create new campsites in or near these campgrounds, allowing campsite numbers to proliferate over time. Field staff assessed 13 separate campsites at the Hōlua Campground (several located in clusters), and five campsites at the Palikū Campground. Given the maximum capacity of 25 visitors/night at each campground, it appears that some campsite proliferation has occurred at the Hōlua Campground. For example, are 13 campsites truly needed here; are all these sites ever simultaneously occupied? One relatively primitive option to mark the locations of legal campsites is to install 4x4 posts sawn off at an angle at one foot in height with a campsite symbol routed into the cut face.

The campsites are quite small, however, and their average size (212 ft^2) means that a typical site is just under 15x15 feet. The expansion of individual campsites does not appear to be a major problem, though site expansion potential ratings indicate that is easily possible at 8 of the 18 campsites. If campsite numbers are reduced at Hōlua, staff might seek to close those sites that have the greatest potential for expansion or that are closest to other sites to enhance solitude. One final issue to consider is the dense network of informal trails in the campground areas (Figures 7 and 9). A linear arrangement of campsites and/or creation of a more formal campsite access trail network, could aid in substantially reducing the total lineal extent of the informal trail network, total area of trampling disturbance, and the overall "footprint" of each backcountry campground. Since these campgrounds, particularly at Palikū, are both located within the prime habitat of the endangered Nēnē geese, these concerns have greater importance than in other park areas.

Visitor Cabins: The three visitor cabin sites account for nearly half of the total area of disturbance assessed within the Crater, however, these sites have extensive grass cover and little to no exposed soil (see photos, Figures 7, 8 and 9) that appears to attract and benefit the endangered Nēnē geese. For this reason, minimizing the large sizes of these cabin sites could negatively affect the Nēnē. Field staff counted 28 Nēnē in these grassy areas at Palikū one morning. Field staff looked for but could detect no evidence that the Nēnē engaged in food attraction behavior though the companion study that surveyed campsite and cabin visitors did note Nene geese engaged in such behavior. They have little fear of humans and seem to coexist nicely with the cabins, campgrounds, and visitors. Regardless, consultations with wildlife staff are recommended to see if modifications to the overnight facilities or visitor behaviors are needed. There is concern that Nēnē will abandon nests if disturbed by humans so temporal restrictions on entering certain areas have been implemented when the geese are nesting.

<u>Formal Trails</u>: Resource conditions for the designated backcountry trails are generally good, though soil loss and trail widening are problematic in some areas. Park staff could reassess alignments for possible relocations, particularly when trails are aligned less than 20 degrees from the fall line (landform aspect) and when trail grades exceed around 6-8% on unconsolidated substrates. The steeper section of the Halemau'u Trail descending from the rim to the Crater floor has a more sustainable design and substrates than the Sliding Sands Trail, though it traverses through steep rocky terrain, making it potentially more dangerous for horse traffic. The primary problems on this trail are switchback cutting, and an inadequate density and maintenance of grade reversals or tread drainage features. For example, the lower section of switchbacks is deeply incised and was carrying water during the day they were assessed following a nighttime storm. The switchbacks in the upper section are shortcut frequently in many places and it can be difficult in places to distinguish which tread is the official one, in spite of signs admonishing visitors to "Stay on trail."

There is considerable confusion about the different types of trails found within the Crater, including the formal designated trails shown on park maps, service trails that park staff use for conducting monitoring, unmaintained trails that are former designated trails, and informal visitor-created trails. We expect that few visitors are able to distinguish between these different trail types and may be unable to follow the park's guidance: "Hiking off designated trails or taking shortcuts is prohibited." Which of these groupings of trails are visitors permitted to use? Greater clarity is needed.

The trails located within the flatter lower portion of the Crater are generally in good condition, though trail widening is a problem in some areas, particularly in the Central Crater region. In the drier areas that lack vegetation, trails are widest when crossing featureless cinder fields and narrow considerably when crossing rocky lava flows. In the areas with vegetation cover, parts of the Western Crater and most of the Eastern Crater, the trails are narrower. Multiple parallel trails were found in several areas approaching Palikū, caused by horses avoiding the more deeply rutted main tread according to park staff. Erosion in this area is frequently caused by poor alignments that more directly ascend the fall line, from which water cannot be removed, and the somewhat steeper grades.

The Pīpīwai Trail in Kīpahulu shows the wear of its heavy use, including several isolated eroded steep sections with large numbers of exposed roots. This trail is managed as a frontcountry trail, with extensive use of plastic wood decking and steps in places. The new Kapahu Trail, not yet opened to use, is in excellent condition but its alignment angle and grade suggest poor design. Specifically, its mean grade is fairly steep (11.5%) and its slope alignment angle of 22 degrees means that it often lacks a side-hill design that would enable staff to easily drain water from it's tread, leading to either erosion on steep slopes or muddiness in flat areas. A reexamination of these design features are recommended prior to opening this trail. Staff might also consider designing in rolling grade dips and shorter grade reversals, particularly in steeper terrain.

<u>Informal Trails</u>: The development, deterioration, and proliferation of visitor-created informal trails in protected areas can be a vexing management issue for land managers. Formal trail systems never provide access to all locations required by visitors seeking to engage in a variety of appropriate recreational activities. Traveling off-trail is necessary to engage in activities such as nature study and photography. 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 can be severe. Creation of multiple routes to common destinations is another frequent problem, resulting in a spaghetti network of trails that include “avoidable” impacts, such as unnecessary vegetation/soil loss and fragmentation of flora/fauna habitats.

The trails surveyed in backcountry settings are not as severely impacted or numerous as those found in the frontcountry portions of the park. Occasional informal trails leading to vistas are undoubtedly acceptable, as are trails to major attraction features. However, some informal trails are located on unconsolidated substrates and have steep fall-line alignments. Under low use these trails are likely acceptable but some are receiving moderate to heavy use and have become severely eroded. More dense networks of informal trails were found in the vicinity of each cabin and campground area. Some of these trails ascend steep slopes and cliffs to vistas, including multiple routes to the same destinations. Park staff may want to consider formalizing some trails, provided they are sustainably designed, or creating new trails in the vicinity of the cabin/camping sites up to prominent vistas. Such an action would attract and concentrate use to a single sustainable trail from the many current informal trails (some of which are non-sustainably designed).

Informal trails branching off the Pīpīwai Trail were a more serious problem due to their large number (37) and extreme width ($10 \geq 4$ ft wide). While the Pīpīwai Trail is heavily used, it is apparent that exploring off-trail to see the Ohe’o stream, swim, explore, or engage in nature study are common activities (Figure 11). Trails leading away from the stream into adjacent fields may also be from cattle, though we understand that these have or will be removed shortly. Managers may want to make some of the side-trails official and experiment with alternative options for closing the remainder. Trails to popular attraction features (e.g., vistas, swim-holes) will be extremely difficult to close.

As previously noted, the current diversity of trail types in the Crater is likely confusing to park visitors and greater clarity is required. Our experience is that many visitors simply do not recognize the difference between these different classes of trails, including informal trails. Some guidance on managing informal trails is provided here but additional guidance that is more comprehensive is included in Appendix 3.

Some avoidable impact associated with networks of informal trails accessing the same destinations can be avoided by substituting a well-designed and maintained formal trail, provided it is appropriate for visitors to access the attraction features. Alternately, managers can select the best existing informal trail, provide some subtle maintenance where necessary, and seek to discourage use on alternate routes through one or more of the practices described below. A final option for areas that receive low use and have resistant (durable) surfaces, is to ask visitors who need to travel off-trail to avoid faint trails (to allow recovery) and travel on the most resistant surfaces present, including rock, gravel, naturally barren substrates, and grasses.

There are numerous options for closing informal trails; generally, an incremental approach is followed. Sometimes, merely improving, signing, or adding partial borders along a designated trail may sufficiently reduce use on unnecessary trails to allow their recovery. Visitor education is an important component to enable visitors to differentiate between formal and informal trails and to make them aware that creating or using informal trails is a management concern or resource protection problem. Trail markings such as cairns and informational blazes or signs can be employed to identify the designated trail so that visitors can remain on it.

Trails to be closed can be "disimproved" by placing native materials onto treads to hide and deter use of the trail. These actions also lessen soil erosion and speed natural recovery. If ineffective, large rocks can be "ice-berged" (planted deep) at the entrance to informal trails to discourage their use. Temporary signing of the closures can also be effective to inform visitors that the trail is closed to use. Signs that clearly define the appropriate behavior and provide a compelling rationale are more effective than simple "do" and "do not" signs. For example, a sign that says "Please Stay on Designated Trails to Preserve Sensitive Vegetation" can be effective provided visitors can *easily* distinguish between "designated" and "informal" trails. Where necessary, a sign such as "Walking Off of Designated Trails is Prohibited to Preserve Sensitive Vegetation" has been shown to be more effective – even in the absence of enforcement. Another effective method is to cover at least the first 10 feet of the trail with peat moss and jute netting and install signs that say "Restoration in Progress – Please Stay Off."

Trail borders or barriers of various types can also be installed where appropriate to deter off-trail travel, particularly if other alternatives are ineffective. Low trail borders are less obtrusive than high barriers yet provide an obvious visual cue to guide visitor traffic. Higher barriers physically block access to a closed informal trail, including inexpensive nylon string stretched between trees, rope strung through steel stakes with eyelets, log barriers, and various types of fencing. Temporary barriers may be effective in altering visitor distribution patterns and allowing vegetative recovery so that they can be removed.

Related to carrying capacity decision making, it is expected that trail maintenance and visitor education efforts should be able to sufficiently address most trail degradation problems. Subsequently, use limitation could be an effective solution to limiting trail system degradation in instances where visitor education and appropriate trail maintenance practices have been applied but found to be ineffective. Of the impacts investigated, trail widening and creation/proliferation of informal trails, are the indicators most likely to be most strongly related to amount and type of of visitor use, e.g. horse back riding, and least responsive to trail maintenance actions. It is difficult, perhaps impossible, for resource-based research to provide specific guidance on visitor numbers in such a situation. Instead, managers might reduce use incrementally (e.g., 10% reductions) with subsequent monitoring to evaluate improvement in the conditions of indicators whose standards were exceeded.

Low Impact Practices: The current park website makes no mention of low impact practices, such as those addressed by the national *Leave No Trace* program. This material could be added, with links to www.LNT.org. However, the primary park brochure, Trails Illustrated Map, and the "Hiking in Haleakala" book do contain pertinent educational information. In particular, the park brochure provides the most comprehensive information, including rationales for most practices. Visitors who receive backcountry permits are required to view a short interpretive video program, which addresses Leave No Trace practices. Park staff might consider posting additional comprehensive low impact practice information on the outside wall of each cabin and at a campground bulletin board to provide the most timely communication of this information.

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APPENDIX 1: RECREATION SITE MONITORING MANUAL

RECREATION SITE MONITORING MANUAL

Haleakalā National Park[1,2]

(*version 8/22/06*)

This manual describes procedures for conducting inventories and resource condition assessments of recreation sites within Haleakalā National Park. Procedures are also described for future reassessments to allow monitoring of site conditions over time. Three general approaches are used for assessing recreation site conditions: 1) photographs from permanently referenced photo points, 2) a condition class assessment determined by visual comparison with described levels of trampling impact, and 3) predominantly measurement-based assessments of several impact indicators. Additional monitoring practices are described in a companion Trail Monitoring Manual for assessing associated trail impacts.

For the purposes of this manual, recreation sites are defined as areas of disturbed vegetation, surface litter, or soils caused by human use at day-use areas or overnight campsites, excluding associated trails, which are assessed separately. In areas with multiple sites or long linear use areas there may not always be undisturbed areas separating sites and an arbitrary decision may be necessary to define separate sites for measurement purposes.

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, if conducted, should be completed as close in timing to the original year's measures as possible. Generally monitoring should be replicated at about 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)
❑ Tape measure (100 ft. in tenths) and/or Sonin Combo Pro distance measuring device
❑ Field forms, maps, and photographs from previous surveys
❑ Flagged wire pins (25 minimum w/additional set of different color for remeasurement)
❑ Large reference point stake for attaching tape measure
❑ Digital camera, w/fully charged batteries, extra memory cards, computer/cords to download images
❑ 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, USGS Patuxent Wildlife Research Center, Field Station at Virginia Tech/ Department of Forestry (0324), Blacksburg, VA 24061 (540/231-6603) email: jmarion@vt.edu.

2 - Photographs illustrating site 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 Recreation Site Information

1) **Site Number**: Each site must have a unique number. Refer to site 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 and record it on the form. Criteria for locating the permanent reference point are provided in the Variable Radial Transect section of the manual. Reference points will typically be keyed to unique rock features or live trees, with a tag/nail combination used on sites with only soil substrates.

   Site remeasurement - Examine mapped site locations and field forms to determine if each site was present during the previous survey. Relocate permanent reference points with information from the form and use the magnetic pin locator if a tag and nail were buried. 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 site 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/rare 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 its 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.

3) **Inventoried by**: Identify the initials of field personnel assessing the site.

4) **GPS**: Use a GPS device to obtain the position of the permanent reference point and place a check in space to verify it was done. Label the point feature with the site number. If necessary, do an offset to get an accurate site location. Later fill in the UTM Coordinate information.

5) **Date**: Month, day, and year the site was evaluated (e.g. September 1, 2006 = 09/01/06).

   Site remeasurement - Due to phenological and site use changes which occur over the use season, it is critical that sites 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) **Location**: Record the recreation site name and/or number if one exists for this site.

Comments: Comments concerning the site and its location: note any assessments that were particularly difficult or subjective, problems with monitoring procedures or their application, suggestions for clarifying monitoring procedures, descriptions of particularly significant impacts beyond site boundaries (quantify if possible), or any other comments you feel may be useful.

Inventory Indicators

7) **Use Type**: Camping = C, Summit Area Site = S, Trail-related Recreation Site = T, Pool-related Recreation Site = P.

8) **Use Level**: Low = L, Moderate = M, Heavy = H Based on consultations park managers.

9) **Distance to Nearest Other Campsite**: For campsites, record the appropriate category for distance to the nearest other campsite or cabin (campsite boundary to campsite boundary).
(-1 = NA 1 = <10 yds 2 = 11-20 yds 3 = 21-40 yds 4 = 41-60 yds 5 = >60 yds)

10) **Site Expansion Potential**: P = Poor 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 G = Good expansion potential - off-site areas are suitable for site expansion, features listed above provide no effective resistance to site expansion.

11) **Rock Substrate**: Estimate the percentage of rock substrate within recreation site boundaries (see below). The rock may be bedrock, boulders, or cobble and barren or covered with lichens or moss. This category, plus soil substrates should equal 100%.

	0-5%	6-25%	26-50%	51-75%	76-95%	96-100%
Midpoints:	**2.5**	**15.5**	**38**	**63**	**85.5**	**98**

Impact Indicators

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

Step 1. Identify Site Boundaries and Flag Transect Endpoints. Walk the site boundary and place flagged wire pins at locations which, when connected with straight lines, will define a polygon whose area approximates the site area. Include the shelter within site boundaries. Use as few pins as necessary, typical sites can be adequately flagged with 10-15 pins. Look both directions along site boundaries as you place the flags and try to balance areas of the site that fall outside the lines with off-site (undisturbed) areas which fall inside the lines. Pins do not have to be placed on site boundaries, as demonstrated in the diagram in Figure 1. Project site boundaries straight across areas where trails enter the site. Identify site boundaries by pronounced human trampling-related changes in vegetation cover, vegetation height/disturbance, vegetation composition, surface organic litter, and topography (refer to photographs following these procedures). Many sites 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 site 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 and record a 0 for site area (#25).

Step 2. <u>Establish Site Reference Point.</u> Select a site reference point which is preferably: a) visible from all the site boundary pins, and b) a distinctive location on bedrock or on a large immovable boulder. If no bedrock features are available then select a location that is near a tree in soil sufficiently deep to bury a numbered aluminum tag and galvanized nail. Reference this point to at least two relatively permanent and distinctive features. If trees are used select ones that are healthy and unique to the site 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 and site photograph(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 site reference point. Also measure the approximate diameter of reference trees at 4.5 ft above ground (dbh). <u>Be extremely careful in taking these bearings and measurements as they are critical to relocating the reference point in the future.</u> 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 site)

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)

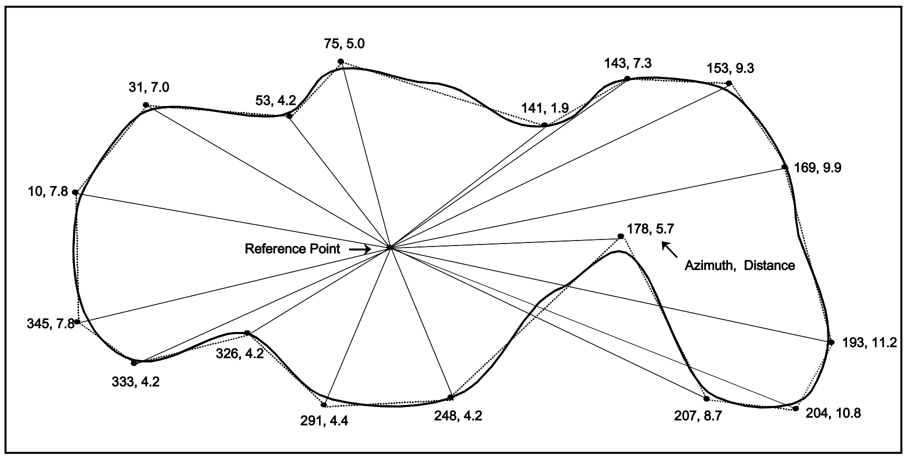

Figure 1. Variable radial transect method.

Step 3. <u>Record Transect Azimuths and Lengths.</u> Standing directly over the reference point, identify and record the compass bearing (azimuth) and distance to each site boundary pin working in a clockwise fashion (<u>in the exact order you would encounter them if you were walking the site boundary</u>). Be careful not to miss any pins hidden behind vegetation or trees. <u>Be extremely careful in identifying the correct compass bearings to these pins as error in these bearings will bias current and future measurements of site size.</u> If a tape measure is used, anchor the end to the large 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. <u>Be absolutely certain that the appropriate pin distances are recorded adjacent to their respective compass bearings</u>. Leave boundary pins in place until you finish all other site measurements.

Step 4. <u>Measure Island and Satellite Areas.</u> Identify any undisturbed "islands" of vegetation ($\geq$ 3x3 feet) inside site boundaries (often due to clumps of trees or shrubs) and disturbed "satellite" use areas ($\geq$ 3x3 feet) outside site boundaries (often due to tent sites or cooking sites). Use site 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 site reference point. Remove the reference point stake. Place a 4 inch long galvanized steel nail through the hole in the site 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 site number on form and in database). Insert the large steel stake at the reference point location and reestablish all former site 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).

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 changes in the shape of site 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.

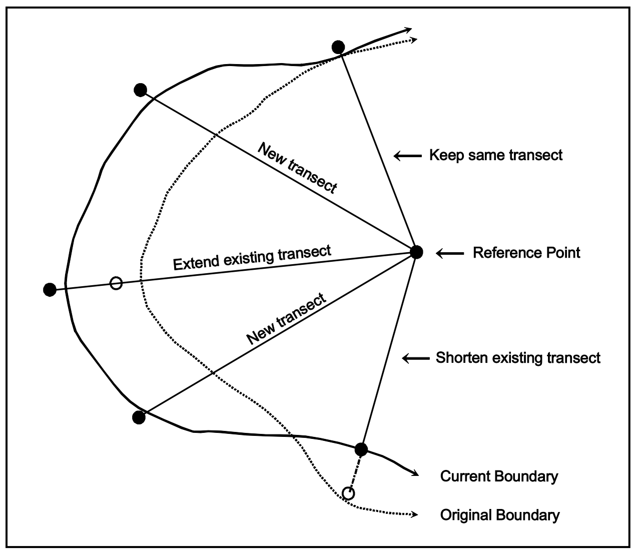

Figure 2. Transect site remeasurement procedures.

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 site 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 site 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 sites or portions of sites where boundaries are not pronounced. These procedures may only be used for sites whose reference points can be relocated.

12) **Condition Class**: Record a site Condition Class using the descriptions below.

Rock: Site is predominantly on rock surfaces. Clear boundaries based on trampling disturbance cannot be easily discerned.

Class 0: Site barely distinguishable; no or minimal disturbance of vegetation and /or organic litter. Often an old site that has not seen recent use.

Class 1: Site barely distinguishable; slight loss of vegetation cover and /or minimal disturbance of organic litter.

Class 2: Site 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.

13) **Vegetative Ground Cover On-Site**: An estimate of the percentage of live vegetative ground cover < 2 ft tall (including herbs, grasses, tree seedlings, shrubs, mosses, and folios (leaf-like) lichens) within the flagged site 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 (6-25%) or category (26-50%), you can simplify your decision by focusing on whether vegetative cover is greater than 25%.

	0-5%	6-25%	26-50%	51-75%	76-95%	96-100%
Midpoints:	**2.5**	**15.5**	**38**	**63**	**85.5**	**98**

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

14) **Vegetative Ground Cover Off-Site**: An estimate of the percentage of live vegetative ground cover < 2 ft tall (including herbs, grasses, tree seedlings, shrubs, mosses, and folios (leaf-like) lichens) in an adjacent "control" area that lacks human disturbance. Exclude crustose lichens, those that closely adhere to rock, as these are difficult to discern and are considerably less susceptible to trampling impacts. Use the categories listed above. The control site should be similar to the site in slope, tree canopy cover (extent of sunlight penetration), and other relevant environmental conditions. The intent is to locate an area which would closely resemble the site 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 tend to select a site with the least amount of vegetation. Note that if some of the substrates on the recreation site would likely be barren due to river flooding or exposed bedrock then the control substrates, or at a minimum, the control vegetation estimates, must reflect that.

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.

15) **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 site 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. Code as for vegetative cover above.

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

16-18) **Tree Damage**: Tally each live tree (>1 in. diameter at 4.5 ft.) within or on site 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 site 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 or worn bark.

Moderate......... Numerous small trunk scars and/or nails or one moderate-sized scar. Abraded bark exposing the inner wood.

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.

19-21) **Root Exposure**: Tally each live tree (>1 in. diameter at 4.5 ft.) within or on site 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 site 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. Generally indicative of soil loss of 2-4 inches.

Severe.............. Three-quarters or more of major roots exposed more than one foot from base of tree; soil erosion obvious. Generally indicative of soil loss of >4 inches

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 procedures are necessary in order to accurately analyze changes in root exposure over time.

22) **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 site 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.

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

24) **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.

25) **Total Site Area**: Using a computer program (contact Jeff Marion), compute the site 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 Site Area. Record this value on the front of the form to facilitate computer data entry.

Recommendations: Describe any site management recommendations or comments related to avoiding/minimizing resource impacts.

Site/Reference Point Photographs: If the site has not been previously surveyed, select a vantage point that provides the best view of the site 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 and point directly at the reference point. Take additional site photos where necessary to capture other parts of the site. 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. Take photos with the camera pointed down to include as much of the site groundcover as possible. The intent of these photos is to positively identify the site, record a visual image of its condition, and to assist in relocating the permanent reference point.

If the site has been previously surveyed, relocate the photo points by looking through the viewfinder and positioning yourself to replicate each earlier site photograph. Frame your photo and adjust the zoom lens if necessary 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. ***Photo description procedures***: Use the photo description space to record the photo numbers and to write something unique about each photo that will allow someone to recognize and label the photo for this site.

* **Bury reference point nail and tag (if used) about 3 inches deep, compact soil with foot. Collect all site 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 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 sites, 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 site's shape, as if you were looking down from above. Mentally superimpose and arrange one or more simple geometric figures to closely match the site 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 site with a rectangular figure, you would have to <u>exclude</u> some of the disturbed area along each side in order to balance out some of the undisturbed area <u>included</u> 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.

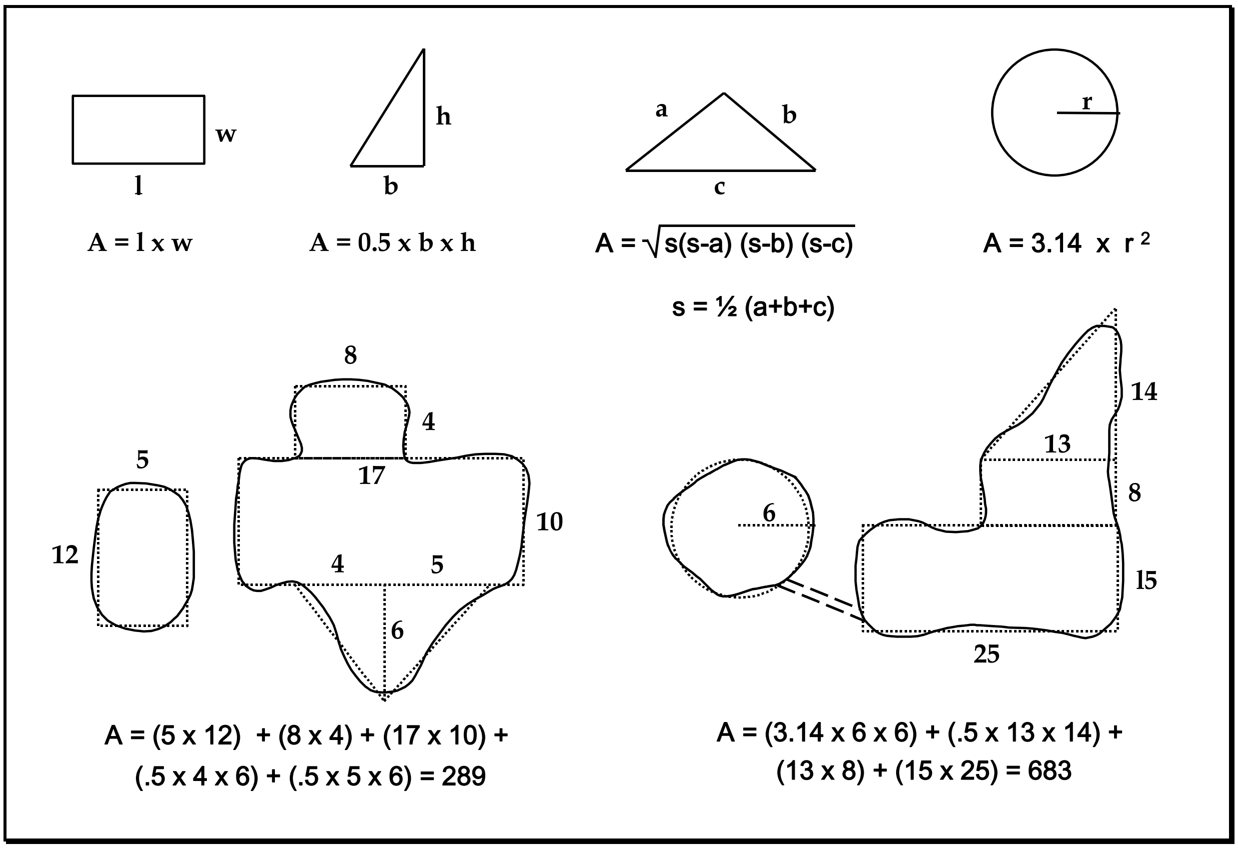

Figure 3. Geometric figure method for assessing site sizes.

Recreation Site Monitoring Form, Haleakalā National Park

ver. 8/22/06

General Site Information

1) Site Tag No. ____________ 2) Site Type ______ 3) Inventoried by: _______________________

4) GPS: ____ UTM Coordinates: ____________________________

5) Date __ __ / __ __ / __ __ 6) Location: ____________________________

Comments: ____

____

____

Inventory Indicators

7) Use Type: Camping = C, Summit Area Site = S, Trail-related Recreation Site = T, Pool-related Site = P ______

8) Use Level: Low = L, Moderate = M, Heavy = H ______

9) Distance to Nearest Other Campsite: (-1=NA, 1 <10 yds, 2 = 11-20 yds, 3 = 21-40 yds, 4 = 41-60 yds, 5 >60 yds) ______

10) Site Expansion Potential: P M G ______

11) Rock Substrate: (%, use item 16 midpoint categories below) ______

Impact Indicators

-- Apply Variable Radial Transect Method --

12) Condition Class (0 to 5) ______ ***Previous B.***

13) Vegetative Ground Cover On-Site (Use categories below) ______ ______

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

14) Vegetative Ground Cover Off-Site (Use categories above) ______ ______

15) Exposed Soil (Use categories above) ______ ______

16-18) Tree Damage None/Slight ____________________ Moderate ______________________ Severe _________

19-21) Root Exposure None/Slight ____________________ Moderate ______________________ Severe _________

22) Tree Stumps (#)______________________ ______

23) Access Trails (#) ______

24) Human Waste (#) ______

25) Total Site Area (Office) ______ft²

Recreation Site Monitoring Form, Haleakalā National Park

ver. 8/22/06

Recommendations:____

____

____

____

Site Photo: Photo: ____

____

Ref. Pt. Photo: ____

<u>Site Reference Point Information</u> <u>Bearing Distance dbh</u>

1)

2)

3)

Bury Nail/Tag ___

<u>Satellite Site Dimensions</u> <u>Bearing Distance</u>

<u>Island Site Dimensions</u> <u>Bearing Distance</u>

Area from computer program ________

+ Satellite Area ________

- Island Area ________

= Total Site 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)		

APPENDIX 2: TRAIL MONITORING MANUAL

TRAIL CONDITION MONITORING MANUAL

Haleakalā National Park[1]

(*version 8/22/06*)

This manual describes standardized procedures for conducting an assessment of resource conditions on formal (designated) and informal (visitor-creation) recreation trails within Haleakalā National Park. For formal trails the principal objective of these procedures is to document and monitor changes in trail conditions following construction. Their design relies on a sampling approach to characterize trail conditions from measurements taken at transects located every 500 feet 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 approximately three 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. Subsequent surveys should be conducted at approximately the same time of year. For informal trails the procedures track changes in the number and lineal extent of informal trails by GPS surveys of existing trails within defined zones. Condition class assessments of each trail are used to track changes in their general condition.

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 .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

General Trail Information

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

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

3) **<u>Surveyors:</u>** Record initials for the names of the rail survey crew.

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

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

6) **<u>Use Type (UT):</u>** 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 might include: Hiking, Horseback, Biking, Other (specify).

<u>Starting/Ending Point:</u> Record a brief description of the starting and ending point of the trail survey. Try to choose identifiable locations like the <u>center</u> of intersections with other trails, roads, or permanent trailhead signs. Record a GPS waypoint and record the WP# for start and end points on the Point Sampling Form. If managers have 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 from 0 to 500. 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 500 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 500 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 closely and stop every 500 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: 1) bedrock or cobble stone areas that lack defined trail boundaries, and 2) uncharacteristic settings, like tree fall obstructions, trail intersections, road-crossings, stream-crossings, bridges and other odd uncommon situations. The data collected at sample points should be "representative" of the 250-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.

Record the actual distance of the substituted sample point and then push the wheel to the next sample point using the original 500 foot intervals.

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) **Erosion Type (ET):** Assess erosion at the sample point as one of the following (see definitions in #14).
0 – Limited erosion < 0.5ft, **RE** – Recent erosion, **HE** – Historic erosion

9) **Trail Grade (TG):** The two field staff should position themselves on the trail 5 ft either side of the transect. 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 (right-side scale in clinometer viewfinder) and record (indicate units used). Note: if conducted by one person then place clinometer on a clipboard with the window facing you. Orient the clipboard to be parallel to the trail grade and record degrees off the visible scale in the window. Be sure to note the units (degrees) and convert the data to percent slope = [tan (degrees)] x 100 after field work.

10) **Landform Grade (LG):** Assess an approximate measure of the prevailing landform slope in the vicinity of the sample point. Follow the one-person procedure described in #9. Note that if the trail is located in a valley bottom with the terrain on both trail sides sloping up then landform grade is equal to the trail grade.

11) **Trail Slope Alignment Angle (TSA):** Assess the trail's alignment angle to the prevailing land-form in the vicinity of the sample point. Position yourself about 5 ft downhill along the trail from the transect and sight a compass along the trail to a point about 5ft past the transect; record the compass azimuth (0-360, not corrected for declination) on the left side of the column. Next face directly upslope (i.e., the fall line where water would flow downhill from a point 15-20 ft away to your feet), take and record another compass azimuth - this is the aspect of the local landform. The trail's slope alignment angle ($<90^0$) is computed by subtracting the smaller from the larger azimuth (done after data entry). Note, if water would flow down to the transect from both sides and there is nothing lower than the trail (i.e., water would drain down the tread), then record the same azimuth measure. If water would flow down to a lower area next to the trail then the trail at that point is still assessed as a side-hill trail.

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

13) **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 trampling-related changes in ground vegetation height (trampled vs. untrampled), cover, composition, or, when vegetation cover is reduced or absent, changes in organic litter (intact vs. pulverized) (see photo illustrations in Figure 1). 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 parallel treads within the transect only when they are not differentiated from the main tread by strips of less disturbed (taller) vegetation or organic litter (see the tread boundary description).

Also pay close attention to selecting boundary points that reflect the extent of soil loss representative for this location along the trail. Soil loss measures will be taken from a tape stretched between the endpoints you select so the tape should be unobstructed. Organic litter or small rocks that obstructs the tape can be removed but large rock or root obstructions will necessitate moving the tape forward along the trail in one foot increments until you reach a location where the tape is unobstructed. Temporarily place stakes at the boundary points and then step back to verify their horizontal and vertical placement as projected along the trail in the vicinity of the sample point.

Measure and record the length of the transect (tread width) to the nearest inch (don't record feet and inches).

14) **<u>Cross-Sectional Area, Current Tread (C-CSA):</u>** The objective of the CSA measure is to estimate soil loss from the tread at the sample point following trail creation. Accurate and precise CSA measures require different procedures based on the type of trail and erosion, some definitions:

Direct-ascent vs. side-hill trails: Trails, regardless of their grade, that more or less directly ascend the slope of the landform are direct-ascent or "fall-line" trails. Direct-ascent trails involve little or no tread construction work at their creation – generally consisting of removal of organic litter and/or soils. Trails that angle up a slope *and* require a noticeable amount of cut-and-fill digging in mineral soil (generally on landform slopes of greater than about 10%) are termed side-hill trails. The movement of soil is required to create a gently out-sloped bench to serve as a tread. Separate procedures are needed for side-hill trails to avoid including construction-related soil movement in measures of soil loss following construction.

Recent vs. historic erosion: Recreation-related soil loss that is relatively recent is of greater importance to protected land managers and monitoring objectives. Severe erosion from historic, often pre-recreational use activities, is both less important and more difficult to reliably measure. Historic erosion is defined as erosion that occurred more than 10-15 years ago and is most readily judged by the presence of trees and shrubs growing from severely eroded side-slopes.

a) <u>Direct-ascent trails, recent erosion</u>: Refer to Figure 2a and follow these procedures. Place two stakes and the transect tape line to characterize what you judge to be the pre-trail or original land surface. Place the left-hand stake at the trail boundary and attach the tape so that the bottom of the tape will fall on what you believe was the "original" ground surface but at the edge of any tread incision, if present (see Figure 1). Stretch the transect line (marked in 0.3 ft (3 5/8 in) intervals) tightly between the two stakes - any bowing in the middle will bias your measurements. Insert the other stake just beyond the first transect line mark on the other side of the trail that is on the original ground surface and will be measured as a 0. The transect line should reflect your estimate of the pre-trail land surface, serving as a datum to measure tread incision caused by soil erosion and/or compaction.

Note: For this and all other options (b-d), if the trail is wide or if the tread surface is relatively homogeneous then the interval between vertical measures can be extended from .3 ft to .5 or even 1.0 ft. Label the field form clearly whenever this option is used so that CSA calculations can be done correctly.

b) <u>Direct-ascent trails w/historic erosion</u>: Refer to Figure 2b – if you judge that some of the erosion is historic then follow these procedures. Generally you will find an eroded tread within a larger erosional feature. Place two stakes and stretch the transect line to reflect and allow measurements of the more recent recreation-related erosion (if present). If there is no obvious recent-erosion tread incision then position the stakes the same as for your tread width measurement and assess incision between tread boundaries (option not depicted in Figure 2b). The left-hand stake can serve as transect 1, record a 0 for this. At the right boundary you must also record a transect with a measure of 0.

c) Side-hill trail: Refer to Figure 2c. The objective of this option is to place the transect stakes and line to simulate the post-construction tread surface, thereby focusing monitoring measuresments on post-construction soil loss and/or compaction. When side-hill trails are constructed, soil on the upslope side of the trail is removed and deposited downslope to create a gently out-sloped bench (most agency guidance specify a 5% outslope) for the tread surface (see Figure 3). Outsloped treads drain water across their surface, preventing the buildup of larger quantities of water that become erosive. However, constructed treads often become incised over time due to soil erosion and/or compaction. The extent of this incision are what these procedures are designed to estimate.

Carefully study the area in the vicinity of the sample point to judge what you believe to be the post-construction tread surface. Pay close attention to the tree roots, rocks or more stable portions of the tread to help you judge the post-construction tread surface. Look in adjacent undisturbed areas to see if roots are exposed naturally or the approximate depth of their burial. Configure the stakes and transect line to approximate what you judge to be the post-construction tread surface. Note that sometimes a berm of soil, organic material and vegetation will form on the downslope side of the trail that is raised slightly above the post-construction tread surface. If present, place the stake and line below the height of the berm as shown in Figure 2c so that it does not influence your measurements. If erosion is severe and/or if the line placement is subjective, use a line level with to configure the line as a 3% outslope (see table of values at right) to standardize the line placement and reduce measurement error. An outslope of 3% is used because actual tread construction is often somewhat less than 5%, and 3% provides a more conservative estimate of soil loss. Measure the left-hand stake as transect 1 with a 0 measure and also record an additional transect beyond the right-hand stake with a measure of 0.

Trail Width	**3% outslope**
20	**0.6”↓**
30	**0.9”↓**
40	**1.2”↓**
50	**1.5”↓**
60	**1.8”↓**
70	**2.1”↓**
80	**2.4”↓**
90	**2.7”↓**
100	**3.0”↓**
110	**3.3”↓**
120	**3.6”↓**
130	**3.9”↓**
140	**4.2”↓**
150	**4.5”↓**

d) Side-hill trail with historic erosion: Refer to Figure 2d - if you judge that the erosion is historic then follow these procedures. Generally you will find an eroded tread within a larger erosional feature. Place two stakes and stretch the transect line to reflect and allow measurements of the more recent recreation-related erosion (if present). Since the current tread is well below the original tread there is no need to use the 3% outslope procedure described above. The left-hand stake can serve as vertical transect 1, record a 0 for this. At the right boundary you must also record a vertical transect with a measure of 0.

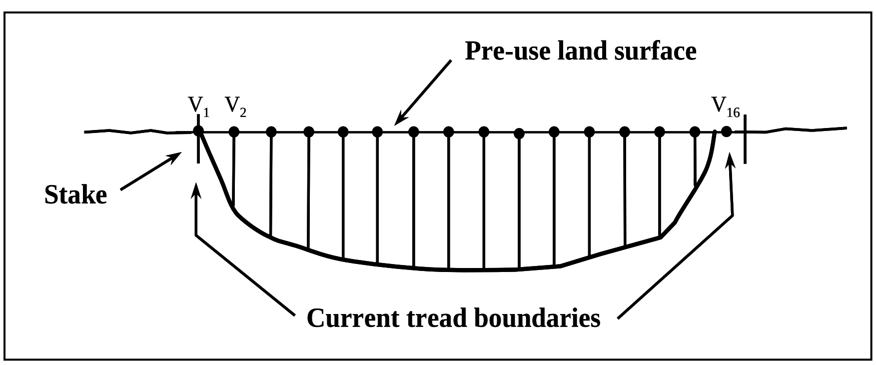

Figure 1. Illustration of the variable interval CSA method for assessing soil loss at each transect.

Measurement Procedure: On the CSA data form, label a new row with the measuring wheel distance for the transect (e.g., D=600 ft). 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, $V_3 \ldots V_n$) (see Figure 1). 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 as shown in the Figure 1 table and using the equation: Area = $(V_i + V_{i+1}) \times I_i \times .5$ for each row and summed to compute CSA (I = interval distance between vertical measurements).

15) **Maximum Incision, Current Tread (MIC):** Measure the maximum incision (nearest 1/4 inch: record .25, .5, .75) from the tape to the deepest portion of the trail tread. Your objective is to record a measure that reflects the maximum amount of soil loss along the transect within the tread boundaries.

16) **Cross-Sectional Area, Original Tread (O-CSA):** If the transect is located at a place with historic erosion (Figures 2b or 2d) then also apply this indicator to assess the extent of historic erosion. Reconfigure the stakes and tape measure to conform to the dashed "original land surface" line shown in Figure 2b or the "post-construction tread surface" line shown in Figure 2d. Repeat the CSA measures, making sure to label the data as P-CSA on the data form. This measure can be made more efficient where needed by lengthening the interval between vertical measures (e.g., extended from .3 ft to .5 or 1.0 ft). Label the field form clearly whenever this option is used so that CSA calculations can be done correctly. If the erosion is over your head then attempt some crude estimates by measuring the dimensions of a rectangle and two right triangles for this location.

17-26) **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.

Collect all equipment and move on to the next sample point. **Be sure to look for and assess information on Informal Trails as you proceed to the next sample point. 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 are accurate. In particular, examine any indicators that may begin before and end after the first sample point.**

27) **Informal Trails (IT):** Record the trail distance from the measuring wheel for each informal (visitor-created) trail that intersects the survey trail segment, and/or occurs within the defined survey zones. Take a GPS waypoint and record the WP# on the form, along with a condition class rating (see below) selecting the most representative category for the entire trail. Turn on the tracking feature and walk the length of the informal trail. If another informal trail branches from the first informal trail then complete the first trail, suspend the tracking function, walk back to the intersection, take another GPS waypoint, record the WP# and condition class for the 2nd trail, turn on the tracking feature and walk that one as well.

Informal trails are trails that visitors have created to access features such as streams, scenic attraction sites1, cliffs, vistas, cultural sites, or to cut switchbacks, avoid mud-holes, rutted treads, steep obstacles, or downed trees, or that simply parallel the main trail. Do not count formal trails, roads of any type, extremely faint trails with untrampled vegetation in their treads, trails <10 ft long, or trails that have been effectively blocked off by managers, and disregard the other end of the trail if it reconnects to the survey trail. Include any distinct animal or game trails as these are generally indistinguishable from human trails and their true origin is likely unknown.

Class 0: Trail barely distinguishable; no or minimal disturbance of vegetation and/or organic litter.
Class 1: Trail distinguishable; slight loss of vegetation cover and/or minimal disturbance of organic litter.
Class 2: Trail obvious; vegetation cover lost and/or organic litter pulverized in primary use areas.
Class 3: Vegetation cover lost and/or organic litter pulverized within the center of the tread, some bare soil exposed.
Class 4: Nearly complete or total loss of vegetation cover and organic litter within the tread, bare soil widespread.
Class 5: Soil erosion obvious, as indicated by exposed roots and rocks and/or gullying

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 (>80%) of traffic, selecting the most visually obvious boundary that can be most consistently identified by you and future trail surveyors.

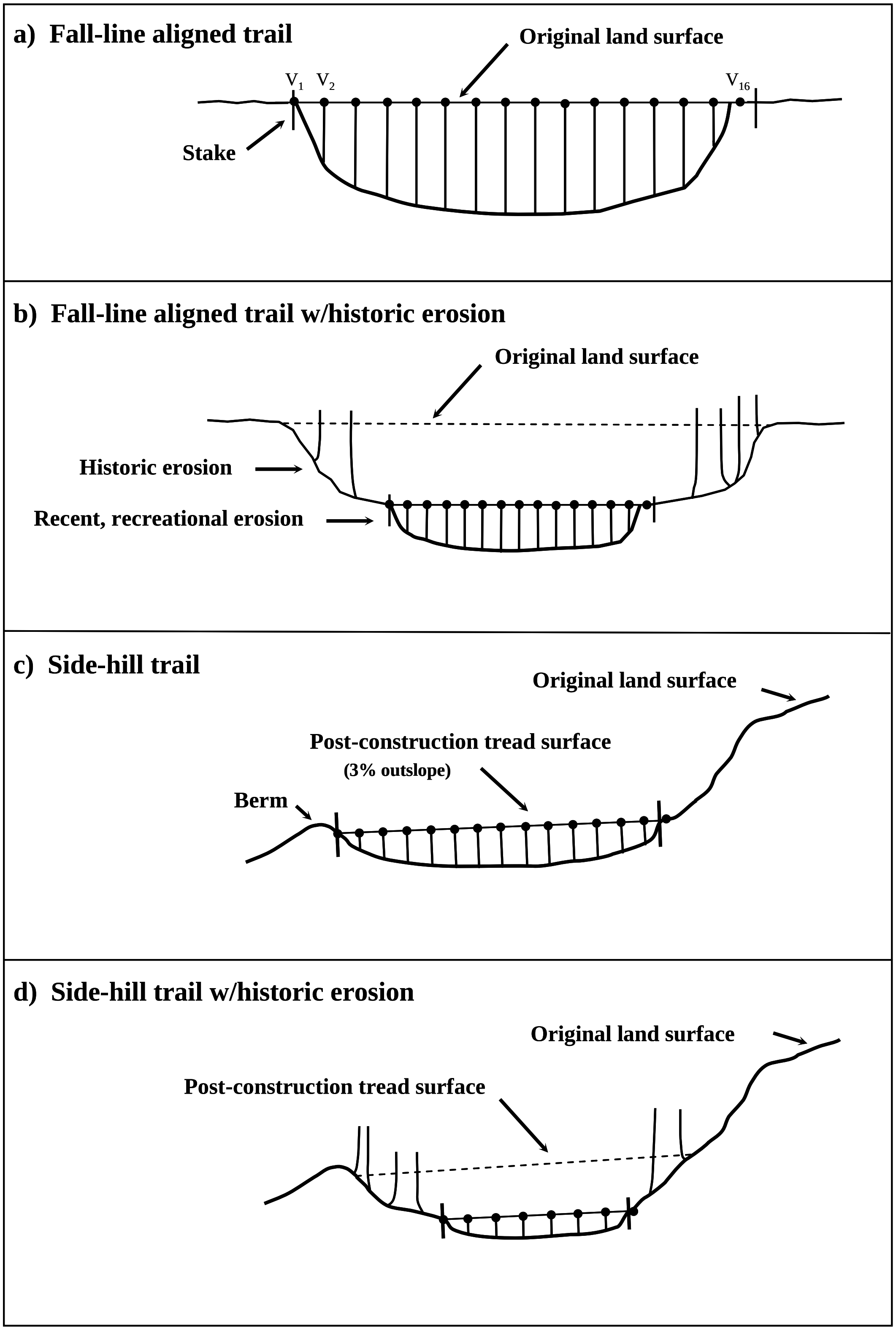

Figure 2. Cross sectional area (CSA) diagrams illustrating alternative measurement procedures for fall-line trail alignments (a & b) vs. side-hill trail alignments (c & d) and for relatively recent erosion (a & c) vs. historic erosion (b & d).

Point Sampling Form

Trail Segment Code ________ **Trail Name** ______________________________ **Surveyors** ______________

Date ________ **Use Level** ________ **Use Type(s):** Hiker ____%, Horse ____%, Bike ____%, Other ____%

Starting Point: **WP#:**______________________

Ending Point: **WP#:**______________________

Dist	ET	TG	LG	TSA	ST	TW	Tread Substrate Characteristics	MIC	C-CSA	O-CSA
				/			. . . .			
				/			. . . .			
				/			. . . .			
				/			. . . .			
				/			. . . .			
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				/			. . . .			
				/			. . . .			
							0 10 20 30 40 50 60 70 80 90 100			

Dist = Wheel Distance
TT = Trail Type (DA, SH)
ET = Erosion Type (RE, HE)form)
TG = Trail Grade
LG = Landform Grade

TSA = Alignment (Trail° / Landform°)
ST = Secondary Treads
TW = Tread Width
MIC = Max. Incision
CSA (calculated from data)

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

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

Cross Sectional Area Form

Trail Segment Code ________ **Trail Name** ______________________________

Informal Trails	CSA		CSA		CSA	
Distances & Condition Class	**Transect (in)**	**Area**	**Transect (in)**	**Area**	**Transect (in)**	**Area**
	D=					
	V_1=					

APPENDIX 3: GUIDANCE FOR MANAGING INFORMAL TRAILS

GUIDANCE FOR MANAGING INFORMAL TRAILS

Jeff Marion, USGS Research Scientist
(jmarion@vt.edu, 540-231-6603)

The development, deterioration and proliferation of visitor-created informal trails in protected areas can be a vexing management issue for land managers. Formal trail systems never provide access to all locations required by visitors seeking to engage in a variety of appropriate recreational activities. Traveling off-trail is necessary to engage in activities such as nature study, fishing, or camping. 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 land managers in evaluating the acceptability of informal trail impacts and in selecting the most appropriate and effective management responses.

Problem Definition: The first step should be an inventory of the informal trail network within an area of management concern. If GPS devices and expertise is available a simple inventory technique is to conduct a walking GPS survey, provided the terrain and forest canopy permit GPS use. 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. If GPS devices cannot be used then an inventory can be made by hand-sketching informal trails onto large-scale maps with lengths assessed by pacing or a measuring wheel.

Where possible, managers may also wish to consider various options for assessing the condition of the informal trails. Many options, ranging from simple condition class evaluations, to trail width and depth measurements, or detailed assessments of soil and vegetation loss are possible. Guidance for assessing trail conditions may be found in the scientific literature (rapid assessment "condition class" options are included at the end of this document) (Cole 1983, Leung & Marion 2000, Marion & Leung 2001). An objective assessment of informal trail conditions can produce quantitative data for indicator variables that can be summarized to characterize current trail conditions, or when replicated, to monitor changes in trail conditions over time. Such data can also be used in formal management decision frameworks such as the Limits of Acceptable Change (LAC) or Visitor Experience and Resource Protection (VERP) (NPS 1997, Stankey et al. 1985). These frameworks are used to guide decisions about the acceptability and management of visitor use and impacts.

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, and sand) (www.LNT.org).

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).

An adaptive management program involving education and site management is recommended when a decision is made to close informal trails. An 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).

Educational programs should 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 1. 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.

Site management actions include maintaining and improving formal or informal trails 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

Figure 1. Examples of an informative trailhead sign (left) and trailside prompter signs that can assist management efforts in closing informal trails.

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 trails.

A variety of site management actions are available for closing 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. Revegetation work conducted before successful closure is a waste of time and materials if visitors continue use of the trail and trample the transplanted vegetation.

For well-used trails, such work generally cannot fully disguise the disturbed substrates and vegetation so additional measures are necessary for effective closures. Construct a visually obvious border along the main trail, such as a row of rocks or a log, to 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 temporary 2 ft tall post and cord symbolic fences can communicate the importance of closures and effectively deter traffic (Figure 2) (Park *et al*. 2006). Taller plastic fencing is also easy to transport and install to discourage traffic on trails that prove more difficult to close.

Placing rocks or woody debris that physically obstructs traffic beyond the beginning of closed trails may be ineffective if visitors are able to circumvent these by walking around them. This can result in new trampling and trails parallel to the “closed” trail – a significant problem if such areas support sensitive or rare vegetation. In such areas it is better for hikers who ignore closures to remain on the “closed” tread than to create new treads on each side (Johnson *et al.* 1987). If the trail is in sloping terrain its closure may require the addition of soil to fill ruts and reestablish the original surface contour. Finally, integrating site management work with temporary educational signs may be necessary to obtain a level of compliance that allows vegetative recovery (Figure 1). 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.

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. Informal trail management actions should be implemented as part of an ongoing adaptive management program Experimentation will be necessary to refine site management procedures that are appropriate in each management zone or location. Some form of periodic monitoring is critical to program success. A 5-year interval could be sufficient for monitoring with quantitative procedures, but annual informal evaluations are needed to effectively guide the application of management actions. Objective monitoring will be needed if any potentially controversial management actions may be needed (e.g., use restrictions or high fencing). In exceptionally high use areas with sensitive resources there is a good probability that such actions will be necessary. For example, a combination of signs and restoration work may be able to keep 95% of visitors on a designated trail but 5% of 2000 visitors/day is 100 visitors/day, a level of trampling that is sufficient to both create and maintain existing informal trails. A regulatory sign that prohibits use of the closed trail and threatens fines may be necessary on trails that are particularly difficult to close. Such situations may also indicate a need for further dialogue with trail users to discover their motives and a review of whether the formal trail system should be extended or modified. Regardless, periodic monitoring provides feedback for gauging the success of management interventions in keeping conditions within acceptable limits. A documented failure of one intervention can be used to justify the use of a more obtrusive or expensive intervention.

Figure 2. Low symbolic post and rope fencing (left) and high fencing designed to physically obstruct access (right).

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