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With a growing population and increasing demand for recreation resources, managers of public lands face unique challenges in allocating and overseeing resource use. One of the most reliable methods for gathering information from resource users involves surveying. Summaries and applications of survey results typically have not fully addressed the spatial nature of use patterns and user statistics. Where users travel across areas that feature multiple paths and destinations, greater specificity may be needed in examining survey data.

This study presents a Geographic Information System (GIS) application involving the assessment of recreation impacts on visitors to McDonald Forest, a 7,200 acre research and education forest managed by Oregon State University. Data collected from 1,641 forest visitors are examined using methods of statistical data analysis commonly found in carrying capacity research. In conjunction with this analysis, the same data are analyzed and presented through the use of a GIS. Following these analyses, four hypothetical exercises are presented concerning issues that are of concern to forest staff.

Survey results indicated that recreation impact levels were generally acceptable to McDonald Forest visitors. Significant differences were detected in the impact

levels reported for different access points and days of the week. Additional use monitoring revealed that use levels have increased nearly 25% over three years in Oak Creek.

GIS results showed that this approach can assist in the representation and analysis of spatial distributions of McDonald Forest users. The GIS results demonstrated utility in mapping typical recreation impacts including conflicts, crowding, and encounters. In general, recreation impacts were highest in the areas surrounding the main access points to the forest. The spatial distribution data were used to estimate the number of visitors potentially impacted by a proposed harvest, a road closure, and a controlled deer hunt. In addition, the spatial distribution of dogs throughout the forest was mapped.

This study demonstrates a new technique for analysis and display of data collected from recreation users. It demonstrates a departure from typical recreation studies and shows how a GIS might be employed in the management of forest resources.

USING A GEOGRAPHIC INFORMATION SYSTEM (GIS) TO MONITOR RECREATION IMPACTS IN A FORESTED SETTING

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CHAPTER 1. INTRODUCTION

Managers of natural resources face a heavy burden in the landscape of the 1990s. Faced with the increasing demands of a growing population, resources are being taxed as never before. In terms of recreation resources, managers and planners are being asked to accommodate not only increased usage levels but also to adapt to a diverse spectrum of interests and activities. Studies have shown that the public's interest and participation in outdoor recreation has grown over the past few decades (Lucas and McCool 1988, Betz and Cordell 1988, Cole 1996). Due to this growth, the presence of an educated and interested populace, and planning frameworks which encourage and sometimes mandate public input, decisions regarding resource use allocations have come under public scrutiny as never before. Individuals and groups sometimes dedicate their efforts to examining and challenging decisions and the reasons behind them (Shannon 1991, Gericke and Sullivan 1994, Brown et al. 1995). In areas subject to high public use and visibility, these dilemmas may be even more pronounced than in other settings.

The challenges presented by these situations necessitate that managers carefully monitor recreation conditions and actively solicit feedback and opinions from interested users. Knowing use levels and basic user group characteristics is an essential component in effective management (Watson 1990). Results gained from monitoring can help in long-term planning and provide an important barometer in assessing management effectiveness. Monitoring results may also serve as a justification should a management policy or action come under protest. An important method for gathering feedback from users is to poll them through surveys that are administered either on-site, via telephone, or through the mail. While these processes typically involve an expense in time and resources, there is no substitute for the information that can be yielded from data collected directly through survey methodology. Managers need to employ analysis techniques when dealing with survey data that make the most out of data and answer the questions at hand. If new techniques or tools become available for these purposes and are demonstrated to be effective, they should be explored and utilized.

Several recreation planning frameworks have been introduced during the past 15 years and these will be discussed in a subsequent chapter. However, survey techniques involved in traditional recreation research methodology have remained fairly consistent over time. Typically, a survey instrument or set of questions is drafted and administered to a population through a statistically based sampling scheme. The surveys may be conducted by researchers located at the resource in face-to-face interviews with users or through telephone and mail surveys. Completed survey responses are then entered into a computerized system and analyzed through the use of a statistical software package.

Summaries and applications of survey results have typically not fully addressed the spatial nature of use patterns and user statistics (Cole 1989, Confer et al.

1992, Meighen and Volger 1997). Single summary statistics have been used to represent data collected from users or groups of users who have traversed a variety of different paths through large areas, in some cases entire Wilderness Areas and National Forests. While this approach is appropriate for resources that feature narrow geographical extents and/or unified user patterns, it may present shortcomings in many instances that reduce the usefulness of data derived from carrying capacity studies. Where users travel across areas that feature multiple paths and destinations, greater specificity may be needed in examining carrying capacity data. Without greater precision, results assume that conditions within study areas are static. This may result in important information being lost.

Forest planners and managers may benefit from greater accuracy in user density information. Many publicly owned forests must accommodate multiple uses such as timber production, providing recreational opportunities, and serving as a research site. The visual quality of forest landscapes has been found to influence recreational experiences (Vining et al. 1984, Ruddel et al. 1988, Hull 1988). Forest management activities, such as harvesting and road closures, can have the potential to significantly impact recreational conditions. Potential impacts include reduced trees, compacted soils, ground cover removal, increased slash, and the closing of areas for recreational use. With greater knowledge concerning visitor preferences for using roads and trails within a resource, and scheduling activities with density information and user feedback as considerations, planning efforts might avoid or reduce conflicts.

The lack of spatial applications in recreation and other types of research may be attributed to two factors: the lack of available tools specifically suited for this purpose, and the scarcity of professionals who are trained in both the use of spatial analysis tools and in the interpretation of carrying capacity data. These deficiencies result in a high cost for adopting computerized spatial analysis capabilities. However, advances in computer software and hardware have been pronounced during the past decade, so the technical hindrances no longer loom as large. There now exists a suite of spatial analysis software packages that offer the versatility to be used in recreation research. In addition, increasing numbers of universities and colleges are offering coursework related to GIS. These advances have helped create a larger pool of trained GIS operators.

Geographic Information System

The term "Geographic Information System" (GIS) first appeared in the 1960s as a result of Canadian Roger Tomlinson's efforts in building a national spatial analysis system for Canada. From these roots, the use of GIS has become pervasive in today's society. Many industries today are using the technology in ways that its founders probably never intended or imagined. Applications are diverse and examples include:

real estate site selection (Castle 1997);

managing oil and natural gas resources (Grace 1997);

directing medical emergency response teams (Jambrosic 1997);

ensuring environmental compliance (Coley 1997);

predicting areas where crime is likely to occur (Muller 1997);

investigating contraceptive choices (Entwisle et al. 1997);

supporting banking institution direction and decisions (Suzio Jr. 1997).

The application of GIS technology to forest resource management has been profound during the past ten years. Increasingly, organizations involved in forest management are using GIS to capture and analyze spatial phenomena. The growth in GIS use can be attributed to a variety of sources. Drastic advances in computer technology have occurred during the 1990s. Portable Computers (PCs) now have the ability to possess tremendous computational power and to run GIS software that once required mainframe or other powerful and expensive platforms (Harris and Elmes 1993, Betts 1997). Prices for PCs have plummeted as computer manufacturers compete against one another by introducing cheaper and faster models. GIS software has also advanced tremendously, not only in ease of use but also in the number of GIS packages available (Kessler 1995, Croft and Kessler 1996). Many modern GIS packages offer windows-type interfaces that no longer require the rote memorization of numerous commands and the intricacies of unintuitive syntax.

The presence and availability of existing data sources also play a role in the expansion of GIS use (Croft and Kessler 1996). The cost of acquiring GIS data has historically been a major impediment to organizations (Devine and Field 1986). Increasingly, data collected and digitized by federal and state governments are being made available at little or no cost. Organizations such as the United States Geological Survey (USGS), National Park Service (NPS), and USDA Forest Service (USFS) offer World Wide Web (WWW) or File Transfer Protocol (FTP) sites where visitors may access national and regional datasets free of charge. In Oregon, the State Service Center for GIS (SSCGIS) and the Oregon Department of Fish and Wildlife (ODFW) offer a variety of statewide and local data themes also available over the Internet free of charge. Perhaps the greatest contributor to increased GIS use has been the multitude of documented study results that demonstrate the utility and applicability of spatial analysis tools. Many natural resource journals regularly feature articles that detail GIS applications and there are over a half-dozen journals dedicated to this cause. Published, refereed documentation of studies adds credence to GIS use and communicates potential applications and new developments to readers. The tools and capabilities afforded by GIS have been demonstrated to add versatility and precision in addressing issues of resource management and use. Most federal and state agencies involved in natural resource management now have dedicated GIS departments (McLean 1995). Clearly, GIS technology has become entrenched in modern society. It is likely that the use of this tool will continue and expand into other industries (Dangermond 1991, Aitken and Michel 1995).

Study Description

McDonald Forest is a 7,200-acre tract of forested land that is managed by the College of Forestry at Oregon State University. Its proximity to the city of Corvallis (pop. 45,000) makes it a popular recreational destination and a highly visible resource. The forest received an estimated 65,000 visits in 1994 (Wing 1996). The role of McDonald Forest in the eyes of the university is to serve as a research and teaching forest. It is the site of on-going silvicultural experiments, demonstration projects, and harvesting operations. These goals are sometimes at odds with users and those who inhabit the numerous private residences and neighborhoods located on the borders of the forest.

During summer and fall of 1993 and spring of 1994, visitors seen exiting the forest at one of the five major access points were asked to complete a survey. Those agreeing to this request were asked to give their impressions of existing social conditions within the forest and asked to indicate on a map where they had traveled through the forest. This information was digitally encoded and entered into a GIS database, using a technology known as dynamic segmentation, for analysis purposes. This methodology allows the survey data collected for each respondent to be linked to their respective route. The route database can then be accessed either through the visual display representing the routes or via the linked database. This approach can be applied to individual respondents or to groups matching a set of criteria.

This study presents a GIS application involving the assessment of recreation impacts on forest visitors to McDonald Forest. Data collected from forest visitors are examined using methods of statistical data analysis commonly found in carrying capacity research. In conjunction with this analysis, the same data are analyzed and presented through the use of a GIS. Following these results, four hypothetical exercises are presented concerning issues that are presently of concern to forest staff. This study demonstrates a new technique for the analysis and display of data collected from recreational users. It demonstrates a departure from typical recreation studies and introduces how GIS might be employed in the management of forest resources.

Objectives

The goal of this study is to demonstrate how GIS might be used to improve upon traditional means of data analysis in recreation research. GIS will be used to examine results from investigations of the following questions:

1. What are the reported use densities of visitors to McDonald Forest?
2. What are the annual estimated use densities of visitors?
3. Where are conflicts between users likely to occur?
4. What are the perceptions of crowding in the forest?
5. Do forest visitors consider encounter levels acceptable?

Additionally, some hypothetical exercises will be presented to demonstrate other possible applications. These exercises focus on areas that are of current importance to forest staff. Applications include:

6. Viewshed analysis of a proposed harvesting operation.
7. Quantifying the number of visitors potentially affected by a road closure.
8. Quantifying the number of visitors potentially affected by a controlled deer hunt.
9. Mapping use densities of dogs in the forest.

Organization of the Thesis

This study is divided into six chapters. Chapter Two presents a summary of literature regarding carrying capacity research in general and past recreation related research in McDonald Forest. Following sections describe specific GIS applications to forestry research and the body of knowledge that relates to GIS applications in recreation research. Chapter Three presents a description of the study site and brief overview of resource use within the forest. Survey methodology, instruments, and content are also presented. Chapter Four gives results of a carrying capacity study using traditional methods of survey research and presents results of a GIS analysis using the same data. Chapter Five demonstrates how GIS might be employed in four hypothetical exercises that build upon the use density information presented in Chapter Four. Chapter Six presents a summary section, implications of the traditional versus GIS analysis, and suggests directions for future research in related areas.

CHAPTER 2. REVIEW OF LITERATURE

What is a GIS?

Notions about what a geographic information system (GIS) represents and the capabilities of this technology vary dramatically. For some, a GIS represents a management panacea, the "black box" from which solutions to dilemmas spring forth. For others, a GIS may represent another technological hindrance to achieving timely and useful research results. The use of a GIS for forestry related applications has been extensive. However, one field that could benefit from additional GIS applications is recreation research. Although some previous studies have addressed this need and others have called for additional efforts in this area, relatively little has been accomplished.

This chapter provides an introduction to GIS technology, literature, applications, and concerns in forestry. The ability and need for GIS applications in recreation research are discussed. Additionally, some basic concepts regarding recreation research that will be addressed in later chapters of this study will be presented.

A GIS can be defined as a system for entering, storing, manipulating, analyzing, and displaying geographic or spatial data. A GIS provides a link between spatial data (x, y coordinates on maps) and attribute information that describes the spatial data (Congalton and Green 1992, Star and Estes 1990, Avery and Berlin 1992). Spatial data can be represented as points, lines, and polygons, along with their associated attributes. Examples of representations include wells as points, streams and roads as lines, and political boundaries as polygons. GIS data are typically represented in one of two formats, raster or vector. Raster data are in a grid or pixel format that divides digital representations of geographic entities into an evenly-spaced cellular array. Advantages of the raster format include increased manipulation and statistical operations, but this type of data requires large amounts of computer storage space. The vector format uses points or series of points (x, y coordinates) to define the extent of an object. While the vector format is capable of representing geographic features more accurately and requires less digital storage space than raster, these advantages come at the expense of analytical capabilities.

The flexibility of GIS to simulate or model the effects of alternative policy choices on maps makes it an extremely useful tool for forest resource purposes. If base data layers are in place, GIS users can modify their modeling and mapping products to reflect changing attitudes and policies. GIS packages have progressed rapidly, and many modern systems now feature advanced mathematical functions and sophisticated mapping capabilities (Berry 1993). As industry continues to make tremendous strides in the power and price of personal computers and also in the ease with which GIS technology can be learned and implemented, it is likely that GIS technology will be accessible to a wider range of organizations and budgets. Dangermond (1991) reports that by assuming an annual growth in the number of users being between 25 and 40 percent, it is expected that there will be a million GIS users by the end of the century. It is likely that the use of GIS for forestry purposes will account for a significant portion of this expected growth.

GIS Recreational/Social Forestry Applications

GIS applications to the recreation and social dimensions of forestry are still in their infancy. Many of the early examples are merely siting studies that attempt to locate a recreational facility or use boundary given a set of conditions. Recently, work by Confer et al. (1992), Deadman and Gimblett (1994) and Gimblett et al. (1997) has advanced the conceptual development of GIS applications to levels of higher sophistication. The following section presents studies that have used a GIS in answering questions concerning recreational and social forestry issues. It is presented in a chronological order and demonstrates a growing refinement in the use of this technology.

Levinsohn et al. (1987) described a project in which the recreational suitability of a large area (4,856,000 ha) in Canada was appraised. A suitability index was created for the classification of 22 recreational activities. Data were collected from existing computerized geographic databases, the digitizing of existing maps, classification of Landsat data, and government records. Suitability for each activity in each area was assigned through the use of a Recreational Suitability Index (RSI) model. The study area was divided into 15 ha parcels and the database was structured into thematic layers with one recreational activity per layer. The authors concluded the project was cost effective in assessing recreational suitability of large land areas.

Gobster et al. (1987) cited the usefulness of a GIS in evaluating physical and landscape characteristics for designation in the Forest Service's Recreational

Opportunity Spectrum. Based on policy changes in recreation management, the results of a proposed scenario that would maximize the amount of semi-primitive recreational opportunities made available were modeled and demonstrated through the use of a GIS. The utility and flexibility of a GIS in examining policy alternatives was found to be beneficial.

Kim (1990) provided a discussion of GIS capabilities and how they differ from typical data base management systems in being able to contribute a spatial component. A hypothetical planning exercise is presented in which a forest recreation facility is located. Layers representing existing facilities, potential sites, and a distance matrix are overlaid to produce a map of suitable locations. This map could assist planners in making a final decision. Similarly, Cho (1991) reported that potential exists for a GIS to aid planners in park and recreation settings. Examples of uses include siting look-out towers, managing flora and fauna, inventorying resources, identifying areas of overuse, and mapping fire hazard locations.

Chatfield et al. (1990) cited the use of a GIS in analyzing future need for recreational facilities for parks located in Tuscon, Az. Park staff created a GIS database of existing parks and their facilities. Using survey data collected from park users, planners were able to make recommendations for the addition or elimination of facilities and the establishment of new parks to meet expected population growth. The GIS was used to portray proposed park locations and to examine their acceptability with existing uses in the surrounding areas. The results of the GIS analysis were used in the creation of the Master Plan 2000, a document which outlines the future of park development in Tuscon. Chatfield et al. also reported that park staff were able to use the GIS in assisting in day-to-day park operations.

Bristow (1991) described the implementation of a GIS for a greenway planning project in Massachusetts. Greenways are linear parks that join open spaces and natural areas. Although results were still forthcoming at the time of publication, the advantages of a GIS for this purpose are extolled.

Klar et al. (1991) reported on the attempted linkage of data collected during the completion of a Statewide Comprehensive Outdoor Recreation Plan (SCORP) and data digitized from USGS topographic maps. The study was conducted in the Cape Cod and Islands Region in Massachusetts. Software limitations, data collection errors, and data accuracy problems related to scale prevented a complete linkage of all sites identified during the SCORP process. Klar et al. (1991) felt that with proper planning and the knowledge gained through this initial effort, the process would be of future benefit to communities and local and state planners.

Confer et al. (1992) studied the spatially distributed activity patterns and site-specific attitudes of boaters in a lake and in a group of inland bays. Exit interviews were collected with users during a sampling period. Lake users were asked to indicate their type of boating activity (sailboarding, power boating, fishing, etc.) and their most and least enjoyed sites. Bay users were asked for the same information but were also requested to provide avoided sites and the route they navigated during their use. Locations and routes were mapped and visually examined using a GIS. Visual analysis of the maps from the lake data revealed that the least enjoyed sites were more tightly clustered together than the most enjoyed. The inland bay map analysis showed a similar clustering of least enjoyed compared to most enjoyed sites and an even distribution of activities through the bays. Avoided sites also tended to cluster more than the most enjoyed sites. Routes tended to cluster at the locations where the bays met and the inlet to the ocean. Fishing, crabbing, and clamming were the three most popular activities reported by bay users. Routes overlaid on a fishing activity map showed a marked overlap. This helped to identify areas of potential conflict between fishermen and power boaters. Routes overlaid on crabbing and clamming activity maps revealed that the majority of routes occurred away from these locations. The results of the study demonstrated the ability of a GIS to add a spatial component to carrying capacity research.

Grove and Hohmann (1992) discussed the use of a GIS in developing a community forestry program in an urban setting. A GIS was used to plan environmental restoration efforts in parks, neighborhoods, and urban forests in Baltimore, Maryland. A laptop computer with a GIS and data layers representing socioeconomic, biophysical, and geographical information for local neighborhoods was taken to public meetings. Proposed parks and restoration projects were modeled using a GIS and output to maps. These maps defined the parameters of potential projects (ownership considerations, vegetation suitability, urban character, etc.). Meeting participants were able to envision potential outcomes and to become actively involved in the planning and decision making process.

A poster presentation in 1993 by the Forest Service (Burke and Tyler 1993) reported on the use of a GIS in monitoring dispersed recreational uses. Off-road vehicle (ORV) and non-ORV users of Wenatchee National Forest were asked to participate in a mail survey. Respondents were asked to indicate on maps campsite locations and areas of recreational activities. Initial results indicated that numerous factors appeared to influence site selection and activity. A GIS appeared to be an effective tool in organizing and displaying the data used in this project.

Bristow et al. (1993) used a GIS to identify any surpluses and deficits of opportunities and demand for boating and camping at the county level in Massachusetts. They hypothesized that proximity to a recreation resource may explain activity choice and that recreation destinations may be linked to specific activities. Demand statistics were generated using SCORP data. Supply characteristics were created by tabulating the number of boating slips and ramps, and tent camping and trailer sites for all towns. State mean values were created for each category and supply and demand surpluses were encoded into a series of GIS layers. Maps were created to demonstrate results by county. Analysis revealed that, as expected, boating demand exceeded supply near areas that featured boating resources. In addition, tent camping and trailer site demand tended to exceed supply in the majority of counties that were studied.

A GIS was used to map perceptions of wilderness in a study conducted by Kliskey and Kearsley (1993). Drawing on earlier works which attempted to identify the wilderness concept (Stankey and Schreyer 1987, Shultis and Kearsley 1989, Kearsley 1990), four conditions were identified which can be used to identify wilderness: remoteness, artifactualism, naturalness, and solitude. Data were collected from recreational visitors to backcountry locations in New Zealand and from a mail survey. Respondents were asked to complete a survey that measured their perceptions of wilderness according to the four conditions. Results were used to divide respondents into four groups ranging from non-purist to purist. A GIS was used to create wilderness maps of this area for each group according to their aggregated survey responses. Results demonstrated that areas of perceived wilderness decrease as one moves from the non-purist to strong purist group.

Using intelligent agents, discrete event simulation (DEVS) and GIS data, Deadman and Gimblett (1994) presented a model for simulating hiker behavior. They claim that if the behavior of hikers can be modeled and linked to data representing the expectations of hikers, a tool could be developed to represent hiker activity in a certain environment. If successful, this tool could assist those involved in recreation management. A trial simulation was performed using a digital representation of a small area. Hiker agents were to move through a landscape in a recursive five-time unit cycle. At the end of each cycle, the agent received information regarding the number of other hikers in neighboring grid cells. A satisfaction level is then computed and the agent moves on to the next cell. At the end of the simulation, route information and a final satisfaction level is recorded. Deadman and Gimblett (1994) reported varying degrees of success in their modeling attempt. Although hiker agent movements and the recording of satisfaction levels progressed satisfactorily, movements were at times random. This was due to a lack of goal directed behavior being instituted in the agents on the behalf of the programmers. They encourage future development of models that would institute this parameter in simulations.

Harris et al. (1995) examined the use of a GIS to identify locations where recreational users may be invading mountain sheep habitat in wilderness areas in

Arizona. Sheep habitat areas, based on data collected from radio-collared sheep and on topography, were entered into a GIS. Recreational trails were digitized and overlaid on the habitat areas. Preliminary analysis revealed two trails that would intersect habitat areas. A year-long sampling of trail users provided trail use densities and off-trail use. GIS maps were created which visually represented the overlap between recreational use and sheep habitat. Thus, areas of potential conflict were identified.

Gimblett et al. (1997) built on the conceptual approach of Deadman and Gimblett (1994) and presented a framework for modeling recreation conflicts between mountain bikers, hikers, and jeep outfitters in Coconino National Forest. Survey information was collected from each user group regarding physical characteristics, personality traits, previous and expected recreational experience, and expected beneficial outcomes. Although the study is still in progress, intelligent agents representing the three user groups are to be programmed for use in simulations. It is hoped that this development will create simulations in which agents seek recreational goals while evaluating conflicts that they may encounter.

Meighen and Volger (1997) discussed using a GIS to examine boater density on reservoirs. Data were collected through aerial counts from an airplane. Traditional statistical results found that the reservoirs were not crowded on most days. The GIS results revealed that some areas were close to reaching or perhaps exceeding carrying capacity, while others fell far below what was described as the optimum level of recreational use. High use areas tended to be near the shore, in coves, and near dams. The presence of access points, accessibility, and scenic quality were judged to be influential on visitation frequency. The authors concluded that GIS spatial analysis revealed trends that otherwise might have been lost through traditional analysis techniques.

GIS Applications to Forestry

Past and current research in forestry has been concerned with the spatial and temporal distributions of natural resources or phenomena such as forested areas, forest soils, forest fires, wildlife habitats, and recreational areas. For these purposes, a GIS may represent an ideal tool that allows managers and planners to model and display the outcomes of different policy alternatives. The following section provides a sampling of GIS applications related to forestry. The section is designed to expose the reader to some of the multitude of uses to which a GIS can be applied.

GIS Forest Mapping

The ability of a GIS to manipulate and display large amounts of data makes it a valuable tool for mapping extensive forested areas. Teply and Green (1991) developed a GIS database for more than 30 million acres of national forests and parklands. The flexible nature of GIS allowed the creation of old growth maps according to different characteristics of key old growth variables: crown closure, species, structure, and size class. The 2.6 million acre Flathead National Forest has been utilizing a GIS since 1982. Successful projects have included delineating erosion hazards, road viewsheds, and elk calving (Hart et al. 1985). Green et al. (1993)

discuss the use of a GIS for assessing the cumulative effects of timber harvesting on 20 million acres of private and public lands in Washington. Results revealed that watersheds having the highest amount of late-seral-stage wildlife habitat tended to be National Park, National Forest, and wilderness lands. Private, state, and tribal land holdings were found to contain the least.

The U.S. Forest Service has completed a GIS database representing forest distribution for the mid-south states (Alabama, Arkansas, Louisiana, Mississippi, Oklahoma, Tennessee, and Texas). GIS analysis and comparison with historical maps revealed that the extent of the forested areas had drastically declined (McWilliams and Faulkner 1990, Zhu and Evans 1992). The 11-county (three million forested acres) Huron Pines Resource Conservation and Development District (HPRCDD) in Michigan used GIS to assess the changes in timber harvesting that occurred between 1986 and 1989 (Maclean et al. 1992). Results determined that a 15 percent decrease in jack pine and red pine trees had occurred over the three-year period. Several examples of GIS applications in the 200 million acres of federal forests managed by the US Forest Service are provided by Lachowski et al. (1992).

GIS Wildlife Applications

Agee et al. (1989) reported on the uses of a GIS for a grizzly bear study in the North Cascades National Park Service Complex. The locations of historical sightings were used to map where grizzly bears were most likely to be sighted. Vander Heyden (1997) used a GIS to study a population of adult female black bears in the central

Oregon Cascades. Results showed that female black bears were associated with open canopy sapling/pole and mature timber habitats and tended to avoid areas with grass-forb and shrub cover (early seral stages). Stone et al. (1997) used a GIS to determine the home ranges of 12 southern flying squirrels. Due to the ability to incorporate topographic data, the GIS methodology was judged to be superior to traditional planimetric estimates.

GIS Soils Applications

GIS technology has also been used for mapping forest soils. Traditional forest soil maps often lack the detail necessary for specific uses. GIS-generated soil maps can be plotted and displayed at the scale and level of detail desired by the user and can also be completed quickly. Klock (1991) describes the compilation of soils information to facilitate salvage logging within the 25,000 acre Wallowa-Whitman National Forest following a wildfire. Using a GIS, areas of soil management concern were identified. This involved mapping soils which were subjected to a high burn intensity, possessed a severe mass failure probability, and contained slopes over 35 percent. Barrett et al. (1995) used a GIS to determine distribution and ecological relationships between 14 major tree species and soil wetness and texture. Results identified a strong relationship between tree distribution and soil characteristics. Skidmore et al. (1996) describe the use of a GIS integrated with an expert system to map forest soils into five landscape classes. The GIS mapping results were judged to be as accurate as those produced by a soils scientist. Based on this success, the authors urged developing this technique for other applications.

GIS and Fire Applications

The use of GIS for wildfire fighting and control purposes has been widespread. Due to the typically large geographic extent of fire areas and the inherent complex spatial and temporal nature of fire, GIS technology represents the best available tool for research of this type (Green et al. 1995). Jakubauskas et al. (1990) incorporated Landsat MSS and Landsat (TM) data to create a GIS database to assess pre-fire and post-fire maps illustrating changes in vegetation within a Michigan pine forest. Zack and Minnich (1991) used the vector-based ARC/INFO GIS to model the effects of wind on forest fire patterns. Chou et al. (1990) used overlays of multiple GIS layers to derive the explanatory variables for modeling the distribution of wildfires from logistic regression formulas in the San Jacinto Mountains in California. Lachowski et al. (1997) describe the use of a GIS in initiating rehabilitation efforts following fire.

Typical data layers for GIS systems designed for use with fire management practices include four basic types of information: fuels, weather, topography, and hydrology (Hamilton et al. 1989). In all of the above studies, GIS had the ability to combine different layer types that made quick map production possible and allowed for detailed analysis and modeling of fire impacts and processes. Output products were typically created with greater efficiency and accuracy than traditional forest mapping methods that involved visual comparisons of several maps and manual methods of creating displays of combined map data.

Ecosystem, Continental, and Global Change Research

Quigley and Cole (1997) present results from the Interior Columbia Basin Ecosystem Management Project. A GIS was used to analyze over 170 layers of information from 72 million acres of Forest Service and Bureau of Land Management administered lands in order to assess ecosystem health. Conclusions were that: 1) conditions are highly variable spatially, making a single solution impossible, 2) ecosystems feature many linkages between ecological processes; an understanding of these linkages will be necessary for effective management, and 3) active restoration of weakening or failed ecosystems are in accordance with societal and economic needs.

Lachowski et al. (1994) present the concept of ecological units in US Forest Service efforts in managing ecosystems. This framework provides a method for stratifying the earth into progressively smaller areas of ecological capacities. They discuss the usefulness of this application on several national forests.

Green (1992) traces the development of GIS in forestry and identifies two steps in its evolution which GIS-operational organizations have achieved: the acquisition of sufficient GIS hardware and software and the capturing of data. The third step has only just begun and involves the analysis of GIS data layers to provide further knowledge about the complex interactions within forested ecosystems. Green claims that the current GIS users have only scratched the surface in terms of the analytical potential of combining multiple layers. With increased effort in this area that is described as "sensitivity analysis," some of the recognized but still unquantified forest interactions might be better understood.

Verbyla (1991) discusses the potential of a GIS to assess the effects of climate warming on localized forest areas. He proposes the establishment of permanent "cold" and "hot" extremes of vegetation zones to assess temperature effects for such items as forest insect and disease problems or soil properties and processes. Loveland et al. (1991) developed a land-cover representation of the conterminous U.S. using databases encompassing elevation, climate, ecoregions, and land resource themes. The resulting land-cover representation could be manipulated to meet a multitude of study objectives. Brown et al. (1993) examined the methodology and felt that it could be expanded successfully on a global basis.

Dangermond (1991) believes that the development of global GIS-based models will increase. However, studies have examined the ability of GIS to tackle global issues and have found the technology promising but still deficient in some areas (Rhind 1991, Wheeler 1993, Ball 1994). Deficiencies include modeling limitations and the poor integration of environmental models with GIS.

Concerns in Utilizing and Applying GIS Technology

Environmental System Complexities

GIS applications for natural resource analysis are not without problems. Perhaps the greatest complication in employing GIS for forestry and other natural resource research needs is that the environment can't be treated as a laboratory experiment. Environmental modeling efforts can only offer an abstraction of the systems they are intended to portray (Haight 1996, Millette et al. 1997). Many predictive models rely on the notion that environmental processes are known and function regularly. In reality, small scale variations have been shown to influence large scale dynamics. In addition, human induced changes further complicate predictive efforts by introducing variables that may be unaccounted for in modeling exercises. Many processes interact in these settings which are not completely understood, and spatial and temporal variations are common (Rhind 1991). Other related hindrances which complicate environmental modeling include incompatible data sources and formats, shortcomings in GIS analytical capabilities, poor calibration of models, and the failure of models to adopt a spatial component (Wheeler 1993, Macgill 1990).

Data Digitizing and Capture

Digitizing existing source maps is still necessary for many who are involved in developing GIS base maps. When digitized maps and information are not available, it is estimated that as much as 80 percent of the time required to complete a GIS application is devoted to manual digitizing (Devine and Field 1986). Digitizing adds errors into the data capture process with the introduction of a human element. Accuracy depends on operator skill and in some cases, state of mind (Bolstad and Smith 1992). Even if exemplary digitizing skills are present in data gathering processes, features that are digitally represented are inherently abstractions of real-world entities at best.

Tomlinson (1989) predicts that sometime after the turn of the century, manual digitizing will be completely replaced by automated means of data capture. Future data capture methods will likely include the increased integration of remotely sensed data with GIS (Leckie 1990, Lachowski et al. 1992, Johnston et al. 1997).

Data structure considerations also hinder GIS efforts because most systems are limited to particular formats of data and map boundaries. Macgill (1990) suggests that research explore the expansion of GIS flexibility in accommodating different data structures. He believes that the future development of GIS should be more task-oriented and seek to alleviate current problems with incorporating existing data sets.

Accuracy of Data Sources

Accuracy of data sources is a current concern with contemporary GIS applications and will likely be a consideration in the future (Liu and Herrington 1996). The necessary level of data accuracy is dependent upon the parameters of project goals. As GIS projects become more sophisticated, greater emphasis is placed on ascertaining data accuracy (Bolstad and Smith 1992).

Many organizations involved in creating spatially-referenced data collect their own field data and/or use existing hard-copy maps that are made available by federal agencies. Causes associated with data source error in field collections may include instrument error, field error, natural variation, and human limitations in collecting data in the field (Congalton and Green 1992). Digitizing hard-copy maps also poses risks. Determining the accuracy of data or other source maps can be a daunting process (Herrington 1991). Although map accuracy and data standards exist for the U.S., not all maps have used them. Even if accuracy standards, which generally allow for a 15 to 25 percent margin of error, are adhered to, the potential for positional inaccuracies is tremendous. The combination of several existing maps into a digitized composite will compound the errors.

Lack of Trained Personnel

Another problematic area is the lack of personnel trained to operate a GIS effectively (Tomlinson 1989, Blinn et al. 1994). The capabilities of a GIS often exceed the abilities of users to operate it to its fullest capacity. Wheeler (1993) recognizes the potential of GIS technology as a tool for ecological modeling. However, few organizations currently possess the expertise necessary in both complex process modeling and GIS operations for this union to reach fruition.

What can GIS add to recreation research?

GIS technology has been demonstrated to be a useful tool for forestry related applications. It has the ability to provide effective methods of answering research questions. One field that could benefit from additional GIS analysis is recreation research. Few recreation studies involve a spatial component in the collection of data and presentation of research results. This fact is somewhat surprising given the inherent spatial nature of many recreational experiences.

Typical recreation studies cited in the literature involve survey results drawn from a statistically derived sample of visitors to a recreational setting. In many cases, the settings feature large areas and have the potential to offer many different types of experiences. Some study results focus on providing measures of central tendency (means and/or medians) and some form of variance, usually a standard deviation, in addressing hypotheses and comparisons. Others employ statistical procedures such as linear regression, correlation, cluster analysis, or factor analysis in analytical processes.

Carrying capacity research has produced several frameworks for the management of recreational settings (Stankey and McCool 1984, Stankey at al. 1985, Lucas and Stankey 1985, Shelby and Heberlein 1986, Graefe et al. 1986, Graefe et al. 1990, Manning and Lime 1996). The Limits of Acceptable Change (LAC) process is probably the most widely used methodology among these and its principles are similar to those found in other frameworks. It advocates creating subdivisions or zones within areas to represent different recreation opportunity classes. The LAC planning framework states that recreational impacts will vary not only between these opportunity classes but also within them (Stankey et al. 1985).

In spite of the LAC's recognition of spatial influences on recreation impacts, many studies aggregate survey results from users whose trips may have been through different expanses of a resource. Roggenbuck et al. (1993) use three wilderness areas totaling nearly 100,000 acres in their evaluation of encounter measures. Williams et al.

(1992) present user results from four wilderness areas in presenting encounter standards. Williams et al. (1991) present crowding perception results from boaters on a 50-mile stretch of river. Shelby et al. (1983) present summary statistics regarding perceived crowding results from six studies representing five locations. Shelby et al. (1989) use crowding data from 35 studies in 59 different settings or activities from the U.S. and New Zealand. Watson et al. (1991) address conflicts between hikers and bikers and present results from 211 users contacted at one of three trailheads in the 61,000 acre Rattlesnake National Recreation Area. Watson et al. (1993) report on conflicts between hikers and stock users and use survey respondents from three wilderness areas totaling nearly 1.4 million acres. Watson et al. (1994) analyzed results from 515 hikers and stock users in a 580,000 acre wilderness in order to determine the extent of conflict between the groups. While these studies have done an admirable job of presenting summary results of data collected from study locations and, in some cases, comparing statistics between study sites, the routes survey respondents take through a resource are typically not addressed.

The need for a spatial component with greater precision in applying study results has not gone unnoticed by recreation researchers. Meighen and Volger (1997, p. 1583) state:

> Recreation is a spatial activity, occurring at a specific place and time. When recreation planners calculate supply and demand, they should not overlook the spatial nature of the data.

Cole (1989, p. 146) writes:

> Effective management of recreation resources depends on a better understanding of the impacts of recreationists on those resources.

> Geographers can utilize interdisciplinary skills to address many important unanswered questions. They might focus on three research areas for which geographic perspectives and methods seem particularly useful: (1) the spatial variability of site susceptibility; (2) the spatial distribution of impacts; and (3) social and ecological concerns in the development of management programs.

Stankey et al. (1976, p. 40) write:

> Use among the various units of the wilderness system clearly is uneven. But the pattern of use is yet more complex than we have suggested. Knowledge of intra-area use patterns also is crucial for management decisions that will help insure achievement of the goals described by the Wilderness Act.

Manning and Lime (1996, p. 54) write:

> Normative research concerning crowding and carrying capacity should continue to address questions about geographic differences within park and recreation settings as well as temporal patterns.

Confer et al. (1992, p. 103) observe that "there have been few studies of the spatial aspects of recreation activities."

Recreation Management Research

This study uses traditional statistical and GIS tools in examining data collected from recreational visitors to a forest. It offers an example of how a GIS might be used to add greater spatial detail in the reporting of results. The following section offers an overview of key concepts in recreation management research that were mentioned above and will be addressed in later chapters. While references to studies that discuss these concepts in more detail will be provided, the intent of this section is to function as a primer rather than a thorough examination of theoretical concepts in recreation management research.

The quantification of a carrying capacity for a specific area attempts to answer the question, “How much is too much?” The dilemma that most managers face is quantifying the levels of acceptable human impact and the maximum number of people that will cause that impact level (Shelby 1981). Recreation managers are best served by following a consistent, rational approach in dealing with this issue. Traditional recreation management research has provided several models or frameworks for conducting studies during the past fifteen years. The most popular of these models are the Limits of Acceptable change (Stankey and McCool 1984, Stankey at al. 1985, Lucas and Stankey 1985), Carrying Capacity (Shelby and Heberlein 1986), Visitor Impact Management (Graefe et al. 1986, Graefe et al. 1990), and Visitor Experience and Resource Protection (Manning and Lime 1996). All follow a rational planning approach with the identification of objectives and goals and the development of purposeful steps to realize managerial goals.

Indicators and Standards

Central to the workings of each of the research frameworks mentioned above is the identification of indicators and accompanying standards. Indicators are the set of measurable resource and/or social conditions intended to provide high quality recreational opportunities. They pinpoint the conditions to be examined and monitored. Indicators should be specific, easily quantifiable, sensitive to changes in impact, and reflect management goals (Whittaker 1992, Whittaker and Shelby 1992).

Standards or norms are the criteria used to evaluate indicators. Research in this area draws from the work of Jackson (1965), who argued that individuals and groups have quantifiable opinions, which can be labeled as norms, on what constitutes acceptable behavior by others. Jackson identified several characteristics of norms and demonstrated these through a return potential model. These concepts have been expanded, refined, and applied in many different settings in social and ecological carrying capacity research (Vaske et al. 1986, Shelby and Vaske 1991, Vaske et al. 1993, Shelby et al. 1996).

Encounters

Jackson's model was first applied to recreation research in a study by Heberlein and Vaske (1977). Since then, standards research in recreation management has often concentrated on encounters (Shelby 1981, Hammit et al. 1984, Vaske et al. 1986, Patterson and Hammitt 1990, Hammitt and Patterson 1991, Roggenbuck et al. 1991). An encounter occurs when a recreationist comes into contact with another resource user. This contact can be merely visual or can include an actual meeting or other exchange. The amount of time one spends in contact with another party can also be an encounter measure (Shelby 1981).

Crowding

Perceived crowding is a topic that has been addressed in the context of standards in recreational carrying capacity (Shelby 1981, Vaske et al. 1986, Whittaker and Shelby 1988, Shelby et al. 1989). Crowding is a negative evaluation of use density or number of encounters (Stokols 1972). As idenitifed by Shelby and others (1989, p. 273), crowding research suggests that:

1. Crowding varies by time or season of use.
2. Crowding varies by resource abundancy or availability.
3. Crowding varies by resource accessibility or convenience.
4. Crowding varies by type of use.
5. Crowding varies with management actions.

Perceived crowding represents the reaction of a recreationist to the use density in an area and a resulting evaluation. If a person reports that an area is crowded, there is an implication that impacts have exceeded the standards of that person. Although studies have identified use levels as affecting perceived crowding levels (Grafe et al. 1984, Shelby and Heberlein 1986), the number of encounters has been determined to be more influential (Shelby et al. 1989).

Conflicts

Jacob and Shreyer (1980) were among the first authors to advance a definition and theoretical background for understanding recreation conflict. According to Jacob and Shreyer, conflict can be defined as goal interference that results from another's behavior. When individual or group goals are not met and the reasons for this are caused by other individuals or groups, goal interference occurs. Goals are defined as "any preferred social, psychological, or physical outcome of a behavior that provides the incentive for that behavior" (p. 3). In developing a framework for understanding this phenomenon, Jacob and Shreyer identify the sources of conflict as arising from four considerations:

1. Activity style. The importance one places in an activity. The more central an activity is to one's lifestyle, the higher the likelihood that one will possess strong feelings about acceptable behavior.
2. Resource specificity. The greater importance one attaches to the resource, the greater the chance of conflict with someone who places lesser importance.
3. Mode of experience. Those who are intently focused in the pursuit of an activity are more likely to have conflicts with others who aren't as focused.
4. Tolerance for lifestyle diversity. When individuals or groups come into contact with one another and are not willing to share resources, conflicts are more likely to occur.

The goal interference model presented by Jacob and Schreyer (1980) has generally been supported by other studies (Gramann and Burdge 1981, Ruddel and Gramann 1991, Ivy et al. 1992, Watson et al. 1993, Watson et al. 1994). Shelby (1980) concluded that perhaps the central issue in understanding conflict was recognizing the different structural characteristics of contrasting activities. Adelman et al. (1982) examined conflicts between canoeists and motorcraft users and introduced the concept of asymmetric antipathy. They found that the perception of conflict between individuals or groups is not always reciprocal and that differences may exist in the perceptions, use, and motives for use of the resource. Similar findings have been detected in other works (Jackson and Wong 1982, Watson et al. 1991).

GIS Application to McDonald Forest User Inventory

This study demonstrates the use of a GIS in examining use levels and summary statistics that were derived from a user inventory in McDonald Forest. While there are many documented cases of spatial analysis applications to natural resources analysis, the objectives of this study were unique. To address these objectives, a module within ARC/INFO called dynamic segmentation was used. Based on literature reviews and conversations with others involved in GIS research, it is believed that the application of dynamic segmentation to recreation research has not been previously attempted. The following section provides background on dynamic segmentation and details concerning its utilization in this study.

Route information was collected from visitors to McDonald Forest through the use of a hard-copy map (survey methodology and data collection are described in more detail in the following chapter). One of the primary challenges was the transformation of route data into a format that would allow for spatial analysis. GIS was identified as an appropriate tool for this purpose, but traditional GIS data structures posed hindrances to analyzing linear data such as route information. GIS applications typically involve the transformation of information into single covers or themes. An example of this approach would be the creation of a cover representing land ownership. Ownership patterns are generally distinctive and do not cross over onto each other although several entities may have claim to the resource. As long as the boundaries of represented areas do not overlap spatially, this method is effective and appropriate.

In this study, a network of roads and trails was the base theme. While the features in this theme are spatially distinct, the use patterns of those surveyed overlapped considerably along the network. This is due to the popularity of certain roads and trails that attract repeated use over time. To create a separate theme representing each user's route would result in a database containing 1,641 separate themes (the total number of people surveyed at the high use locations). This would create an unwieldy and potentially useless GIS database for analysis purposes.

To counter this limitation, ARC/INFO's dynamic segmentation data structure was used (ESRI 1992). The dynamic segmentation data structure is designed to represent linear features. Traditional uses of this feature include modeling river systems (Huppert 1997, Hargrove et al. 1995), utility distributions (Bennet 1993), and road networks (Dueker and Vrana 1992). Dynamic segmentation allows users to create routes to represent the movement or presence of an entity along a linear network. The network is built on a single linear base theme. The routes are stored as parts of the base theme but do not alter its structure. Linear features in a spatial context are entities such as roads, rivers, and administrative boundaries.

Dynamic segmentation eliminates the need to create a separate theme for each route and allows for increased powers of data handling and manipulation. Underlying the route structure are sections and event tables. Sections are the linear components or segments that, when added together, form a route. Event themes are the data sources or attribute tables that are connected to the routes. The data model has the capability to associate information with any portion or segment of a linear feature. Event themes can take linear or point (single location) formats. Attribute data can be stored, queried, analyzed, and displayed without affecting the base theme structure.

The entire road and trail network was divided into separate segments at all intersections using the ARC/INFO GIS. These segments form the sections mentioned above. Each road and trail segment was assigned a unique numerical identifier. Every section that each person traveled on was digitally encoded into an Excel spreadsheet (Microsoft 1994) using the unique identifier and referenced to the individual reporting the sections. Using the Arc Macro Language (ESRI 1994), a software program was created which would read the contents of the spreadsheet and create a dynamically segmented route system in ARC/INFO. The macro required several hours of processing time to complete the routes for all three survey seasons. The combination of each survey respondent's roads and/or trails that they traveled on constitutes a route which, depending on the popularity of the route or whether the person was traveling alone, may or may not be unique in the entire database of routes, but is unique for that person. The sum of the routes comprises the route system.

Survey data collected from respondents were also entered and converted into a database format. This information was linked to the route system and examined using ArcView 3.0 (ESRI 1996). ArcView 3.0 software has the ability to read and display routes created by ARC/INFO. This GIS package was used for all data manipulations and in the creation of all map figures produced for this study. Summary statistics were tabulated and joined to the route system through the use of event tables. Event tables allow users to manipulate and analyze the data that are connected to ARC/INFO route coverages with greater flexibility than general database tools.

Accuracy of the dynamically segmented routes was determined through a visual comparison of each hard-copy map with its corresponding digital representation. While this process was painstaking and involved examining 1,641 routes, it was also necessary. Initial comparisons of routes revealed that the GIS coverage of trails in McDonald Forest had errors. Trails were misplaced and, in some cases, absent. Conversely, the GIS road network appeared robust. This is apparently due to the emphasis that is placed on current, GPS-collected locations of roads by forest management. To correct the trails coverage, the entire trail network was walked by a researcher and compared to a hard-copy map of the GIS coverage. Deficiencies were noted and corrected through heads-up digitizing.

Visual comparisons of maps and GIS routes revealed errors in the entering of route data. Given the volume of maps and multitude of segments within each map, errors were unavoidable. When an error was detected in the digital representation, corrections were entered in the spreadsheet and the route-creation macro was rerun. This process required a large time investment and multiple iterations but produced a GIS route database that accurately reflected the indicated routes of survey respondents.

Summary

GIS applications for recreational studies have progressed from facility siting exercises to instances where the analytical and computational powers of GIS are being utilized and expanded. Although this area of application is still lacking in scope and sophistication, significant strides have been made in a relatively short time period.

GIS has the ability to make recreation research results more specific to locations within the resource. Results on recreation topics such as density, encounters, crowding, and conflicts can be applied to demonstrate where areas of potential concern occur and where resource conditions are not being taxed. This approach has the potential to provide managers with better information and can assist in directing management efforts to the locations in which they are needed. The visual results that GIS is capable of producing through map output offer a powerful medium for the communication of information. Shelby et al. (1996, p. 119) write:

> The job of researchers is to provide information that is accurate and complete, but at the same time understandable and usable for an audience that may lack statistical sophistication. Analysis and reporting techniques that allow the reader to see the amount of agreement about a particular issue are particularly helpful.

As more agencies embrace GIS technology and the benefits of employing GIS techniques for research related to recreation are demonstrated, efforts in this area should grow.

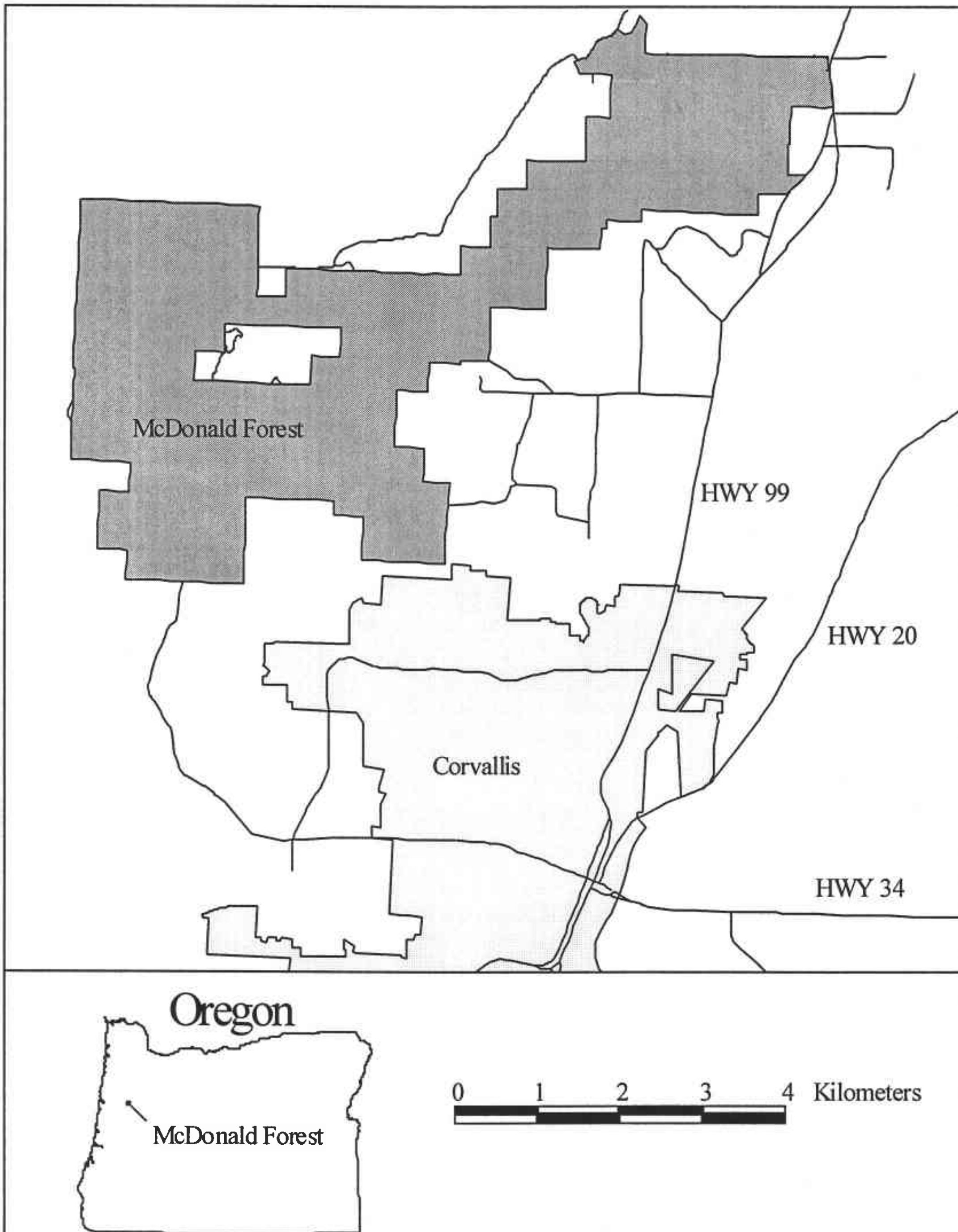
CHAPTER 3. METHODOLOGY

Site Description

McDonald Forest encompasses over 7,200 acres (11.3 square miles) of land and is managed by the College of Forestry at Oregon State University. Situated to the north of Corvallis, Oregon (pop. 45,000), the primary role of the forest is to serve as a research and education site (See Figure 3-1). The vegetative cover and topography in McDonald Forest is typical of the Oregon Coastal Range. Douglas-Fir (*Pseudotsuga menziesii*) is the dominant tree species, although Oak can also be found in abundance throughout the forest. Poison Oak (Rhus diversiloba) also seems to thrive in the mild, wet climate. Elevation fluctuates from about 300 to 2100 feet.

McDonald Forest is home to many uses. Due to its proximity to Corvallis, the forest has become a popular recreational site with dramatically rising use levels. Use has grown from an estimated 5,000 to 10,000 visitors in 1980, to 33,000 in 1989 (Finley 1990) to an estimated 65,000 recreational visits per year in 1994 (Wing 1996). The majority of users come from the Corvallis area, which is predicted to experience almost two percent annual population growth rate in future years (Corvallis Gazette-Times 1995). Due to this growth, an increase in the number of homes being built near the forest boundary, and the increase in popularity of recreating in McDonald Forest, it is likely that use levels will also continue to rise.

Figure 3-1. McDonald Forest and Vicinity.



Though a wide variety of recreational activities take place within the forest, the primary activities are hiking, jogging, mountain biking, and horseback riding. Dogs accompany many users due to the absence of a "leash rule" in the forest at present.

Most recreational visitors use the road and trail network within the forest for their activities. The roads and trails are closed to motorized vehicles with the exception of forest staff. Some trails are also closed during the wet months and others allow only foot traffic. Roads total 64.65 miles in length and trails 24.75 miles with averages of 5.7 and 2.18 miles per square mile, respectively. These figures take into account the Starker Forest property. The property is half a square mile in size and is located in the western portion of McDonald Forest. A popular trail passes through this area and receives moderate use.

Recreation in McDonald Forest is day-use only and facilities are provided only at the major access points. The forest allows hunting during controlled periods and only in portions of the forest. There are several forest-sanctioned recreational events each year that feature activities such as mountain biking or running races.

The McDonald-Dunn Forest Plan was created in 1993 to guide management efforts in McDonald Forest (Oregon State University 1993a). A set of nine goals in this document focuses attention on key issues. These include fostering teaching, research, and educational use of the forest, maintaining ecological integrity, and providing for sustainability. Recreation is included as a sub-topic in Goal 7, which is titled "be a good neighbor," and in Goal 9, which is titled "maintain cultural resources." The sub-topics state, "accommodate and facilitate nonmotorized recreation" and "consider recreational, cultural, wildlife, visual, and stream and water resources consistent with the context of the individual zone objectives" (Oregon State University 1993a, p. 7).

In its role as a research forest, there are numerous on-going silvicultural-related experiments located throughout the forest. Some of these experiments have extended over decades of time and may be located in or near popular recreation routes. Additionally, large volumes of timber are harvested from the forest by forest staff. The proceeds from harvesting activities help to fund research and teaching efforts within the College of Forestry at Oregon State University. Research, harvesting, and other forest operations may sometimes limit access into areas of the forest or close down roads and trails.

Many Corvallis residents live along the borders of the forest, and parts of the forest are clearly visible from the city and surrounding areas. Forest activities such as harvesting or road construction may occur directly adjacent to forest neighbors' properties or may fall within highly visible viewsheds.

Forests located in near proximity to urban centers have been labeled as "near-urban forests." Typically these areas share some common characteristics: relatively small acreage, bordering areas with fragmented ownership, and competing uses and values being placed on the resources within the forest. These characteristics make it difficult for management to serve the users in a manner that all competing parties can deem as equitable (Shands 1991, Johnson et al. 1994).

The combination of uses makes strong demands on the limited resources of McDonald Forest. Consequently, the potential for conflicts between recreational users, research endeavors, forest management operations, and forest neighbors is accentuated. Objections by forest visitors and neighbors on proposed harvesting and management actions have become emotional issues and have spilled into the local newspaper, the Corvallis Gazette-Times.

Survey Methodology

A forest-wide user inventory was conducted over a 12-month period in 1993 and 1994 (Wing 1996). The objectives of the study were to assess: 1) recreational use levels, 2) forest visitors' perceptions of existing use levels and their acceptability, and 3) presence of conflicts between recreational users and others. The results of the study were to be used to create baseline statistics for recreational conditions within the forest and to conduct carrying capacity research. This will assist the forest staff in planning and management efforts and also help to satisfy recreational monitoring requirements set forth by the McDonald-Dunn Forest Plan (Oregon State University 1993a, Oregon State University 1993b).

As part of the forest-wide user inventory (Wing 1996), data were collected directly from forest visitors. Other methods of data collection received consideration but face-to-face interviews appeared to be the most reliable methodology for study objectives. Studies have shown that voluntary trailhead registration and reporting suffers from non-compliance and errors in completing forms (Lucas 1983, Petersen

1985, Parsons et al. 1982). Conducting surveys by phone or mail would have resulted in a time lag between the visitor's trip and the actual reporting of experiences. Details concerning the experience might become less clear or lost during this period.

To conduct the survey, researchers positioned themselves at select access points in the forest. During the times selected for surveying, field researchers asked all people seen exiting the forest to voluntarily complete a survey. In some cases, it was difficult or impossible to get or even ask bikers or runners to participate because their activities were not compatible with this task. Horseback riders also posed a challenge when a horse became unwieldy.

Surveying began on June 21, 1993, and continued through June 20, 1994. For statistical and interpretation purposes, the year was stratified into four survey seasons: summer, fall, winter, and spring. The summer season lasted from June 21 to Oct. 7, the fall season from Oct. 8 to Dec. 21, the winter season from Dec. 22 to March 20, and the spring season from March 21 to June 20. No surveying was conducted during the winter season. The typically cold and wet months of this time of year were not conducive to efficient collection of data. Additionally, holidays (e.g. Fourth of July, Labor Day) and special events such as mountain bike races were avoided. The intent of the study was to capture visitor trends during periods of normal forest use.

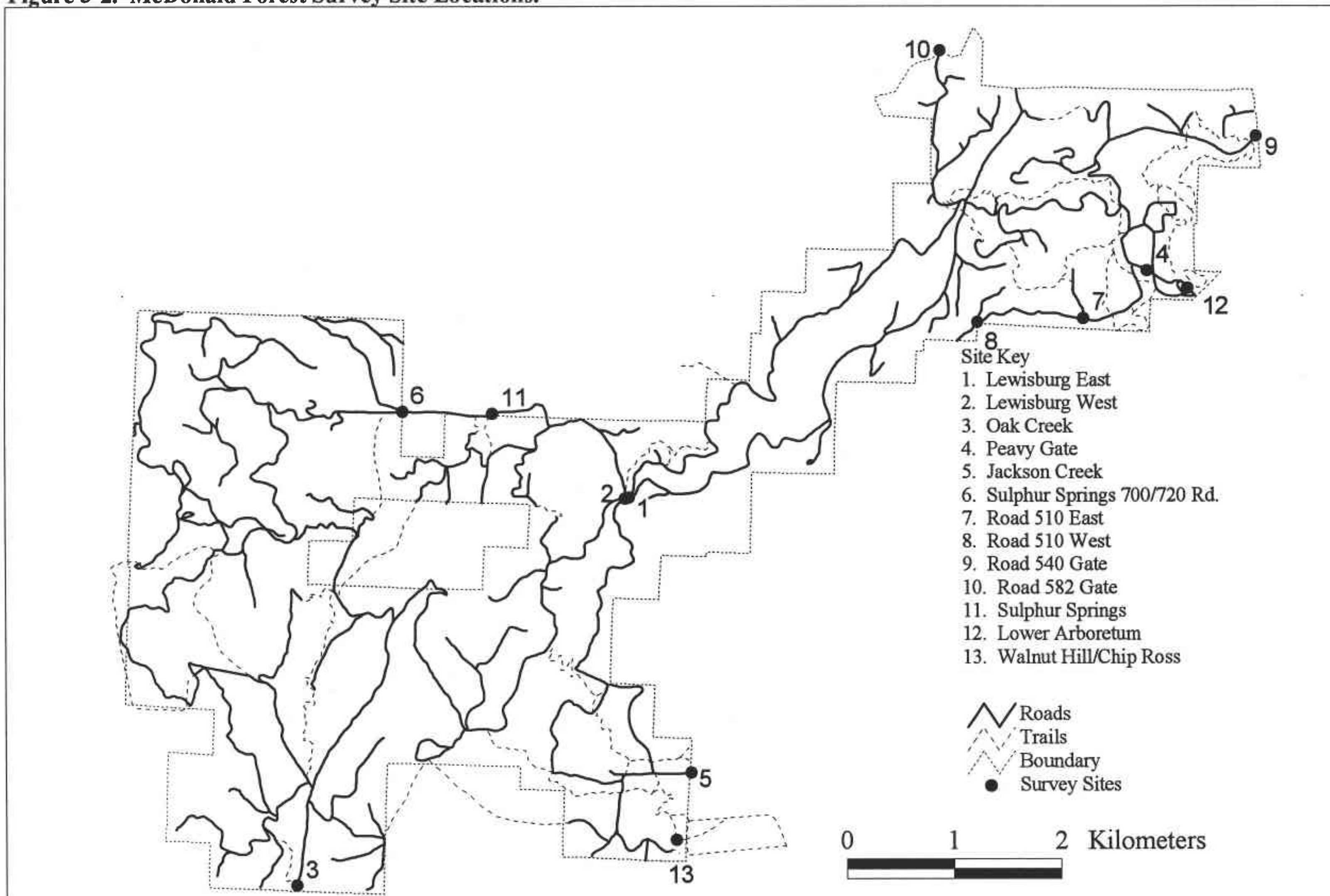
Copies of the survey instrument can be found in Appendices A and B. Appendix A contains the survey that was used during the summer season. For the subsequent fall and spring seasons, a modified survey which included additional questions was used. A copy is included in Appendix B.

During the summer season, five high-use locations and eight low-use locations were identified and selected as sampling locations for forest visitor interviews. These sites were chosen based on previous research findings and on the advice of the recreation forester. The five high-use sites are Lewisburg East, Lewisburg West, Oak Creek, Peavy Gate, and Jackson Creek. The low-use sites include the Sulphur Springs 700/710 Rd., 510 Rd. East, 510 Rd. West, 540 Rd. gate, 582 Rd. gate, Sulphur Springs, lower Peavy Arboretum, and Walnut Hill/Chip Ross Park. See Figure 3-2 for locations of the survey sites.

A total of 1,677 people at the five major access points and at the eight lesser-used sites agreed to complete a survey. All but 36 (2%) were surveyed at one of the five major access points. Of the total, 47% responded during summer, 24% in the fall, and 29% in the spring. Due to the relatively low number of visitor contacts made at the low-use sites, all eight were dropped from the list of survey sites after the summer season. All survey results that follow in subsequent sections use only those people who were surveyed at one of the high-use locations.

In addition to stratifying by season, two additional stratifications were introduced into each season: weekends and weekdays, mornings and afternoons. As the recreation inventory budget only allowed for one full-time field researcher, it was important to allocate researcher resources carefully. Researcher availability was set at five days per week per season. Weekends were expected to draw more use than weekdays and previous research supported this notion. Correspondingly, all weekends except national holidays were surveyed. The remaining available survey times were distributed among weekday times. Stratifying by morning (8 AM to 2 PM) and

Figure 3-2. McDonald Forest Survey Site Locations.



afternoon (2 PM to 8 PM) helped ensure that these two times would be equally represented (50 percent of surveying time was allocated to each). As the length of daylight time varied during the fall and winter seasons, the survey day was adjusted, but always divided in half for survey purposes (e.g. 8 AM to 1 PM and 1 PM to 6 PM).

During the summer season, statistical software was used to determine which sites would be surveyed during weekends. This was accomplished by assigning a numerical identifier to each possible survey block and using the statistical software to randomly select the blocks that would be sampled. Statistical software was also used to randomly select the weekdays that would be surveyed. The number of weekdays selected was based on available researcher time of three weekdays per week. The lists of high-use and low-use sites were systematically assigned to the selected days. Morning or afternoon start times for the survey days were systematically assigned. This process was conducted separately for weekends and weekdays.

For the fall and spring seasons, the sampling scheme was modified to reduce sampling redundancy. Similar to the summer season, all weekends except national holidays were surveyed. However, the weekday selection process was designed to more equally distribute the number of days and morning/afternoon survey blocks assigned to each survey location. The list of survey sites was systematically assigned to selected survey days. Morning or afternoon start times were also systematically assigned to the survey days. Any repetition in sampling (a site being sampled twice during the same weekend or weekday, morning or afternoon time) was avoided. This process was conducted separately for weekends and weekdays.

Data from collected surveys were entered using Excel spreadsheet software (Microsoft 1994) and analyzed using SAS statistical software (SAS Institute 1990, Cody and Smith 1991).

GIS Methodology

For GIS data purposes, survey respondents were asked to indicate the route they had traveled on a hard copy map. The map was presented at the end of the regular survey questions. The map was presented in an 11 by 17 inch format which depicted all roads and official trails which existed during the time of the survey. Survey respondents were asked to use a colored highlighter to trace over the roads and/or trails they had used. This information was digitally encoded into an Excel spreadsheet (Microsoft 1994). A software program created in ARC/INFO's programming language (ESRI 1994) was used to create GIS themes from the spreadsheet data. ARC/INFO is the most widely used GIS software in the world. The data format for these themes utilized the dynamic segmentation module within ARC/INFO (ESRI 1992). This format allows linear features themes to be represented and analyzed as routes on a network. In this study, the collection of all roads and trails represents the network.

Although dynamic segmentation has been used in research related to cultural and natural resources, the use of this technology for recreation research is singularly unique. A more detailed discussion of this technology and its applications is presented in the following chapter.

Survey data collected from respondents were entered into a spreadsheet and converted into a dBase format. This information was linked to the route information using ArcView 3.0 (ESRI 1996). For display and analysis needs, route systems were examined using ArcView 3.0 (ESRI 1995). ArcView 3.0 software has the ability to read and display routes created by ARC/INFO. For data representation, results were tabulated through the use of section table summaries in ArcView 3.0. ArcView 3.0 software was used for all data manipulations and in the creation of all map figures produced for this study. This software package is an economical GIS tool that offers powerful features for the display of spatial data and can be run on most personal computers.

Limitations of Applying Survey Results to Routes

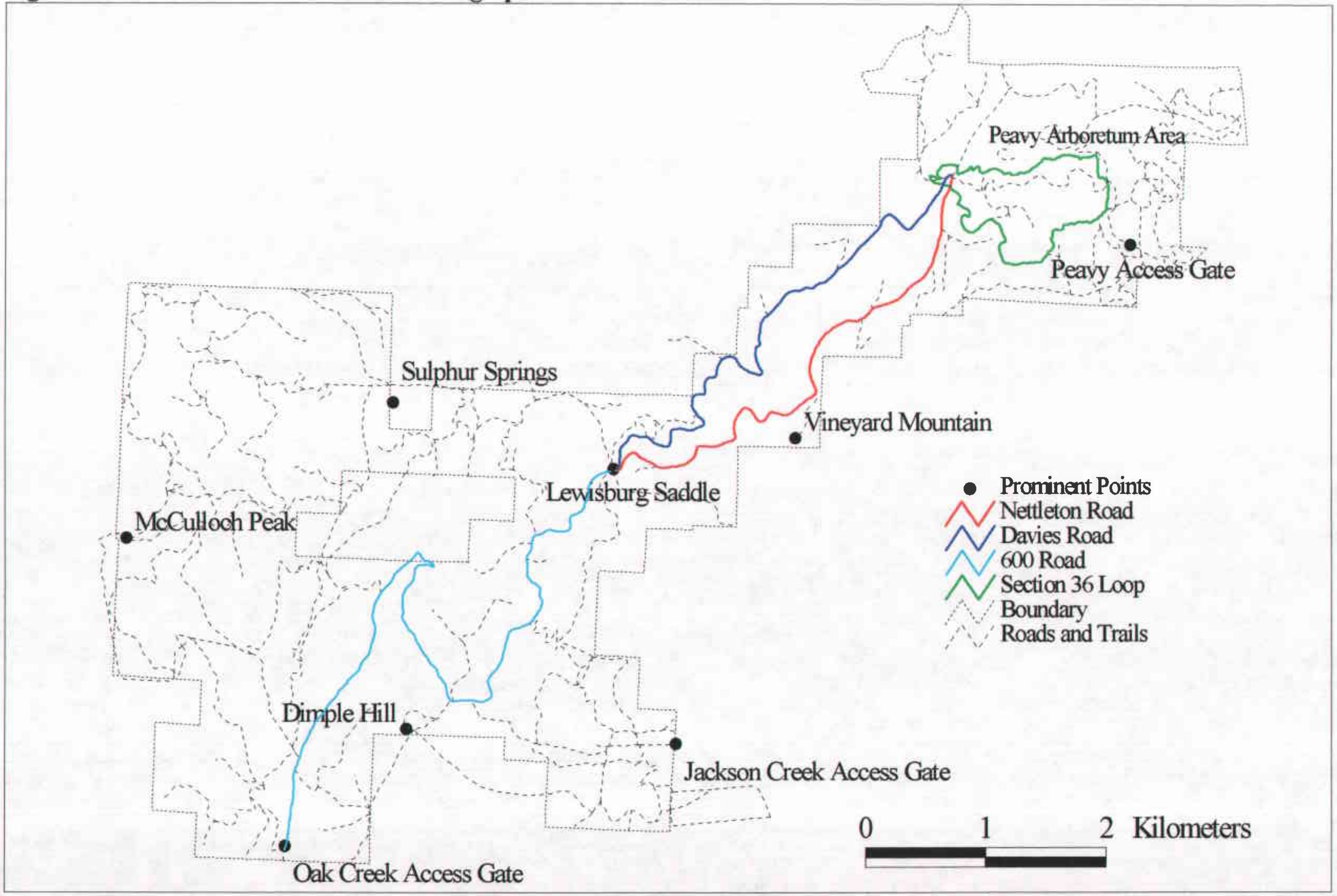
One of the artifacts in connecting survey results to the reported routes of respondents is that the information is attached to every road and trail section in the route. This is desirable for calculating the use that each section receives, but causes ambiguity in summarizing survey responses. For example, one of the following sections discusses the number of encounters respondents reported. If a respondent answered “three” encounters, this count was applied to every section in the respondent’s route, although all three encounters may have occurred on a single section. This ambiguity is avoidable by asking respondents to indicate specifically where the encounters occurred, but the level of effort for both respondents and those administering the survey rises dramatically.

A previous research project in McDonald Forest attempted to have survey respondents identify the actual road and trail segments where impacts occurred (Balfour 1993). Those administering the survey found that respondents had difficulty in accurately locating impacts on the map. Respondent problems with this approach centered on two exercises: remembering where they were when they experienced the impact and being able to locate this occurrence on the map. In many instances, respondents also required assistance to indicate their route through the forest. Based on these experiences, it was determined that respondents would only be asked to indicate their route. The difficulty encountered by visitors in accurately recalling and indicating their routes was also encountered in this study. Researchers involved in the data collection process were frequently asked for assistance in completing route maps.

Presentation of Dynamic Segmentation Results

The next chapter presents figures that were derived from the dynamic segmentation analysis. Figures 3-2 and 3-3 display a map of McDonald Forest and the locations of prominent geographical entities such as roads, trails, access gates, and peaks that are used to describe the results. For map figures, accompanying legends are presented in a five-tier quantile classification. This divides the number of observations equally into five classes. All figures were initially created using an equal interval classification. This method of classification takes the range of values and creates equally sized sub-ranges. This process resulted in some classes having few or no observations and other classes receiving the bulk of the observations. Although the

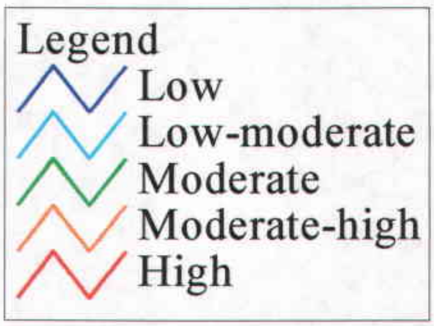
Figure 3-3. McDonald Forest- Prominent Geographic Features.



quantile classification creates legend classifications that fluctuate throughout the figures, it was felt that this representation would be best suited for quantifying response levels. This method produces ranges that can be visually compared against each other with relative ease.

For map figure representations, a scheme using lines colored dark blue, light blue, green, orange, and dark red is used. These colors represent low, low-moderate, moderate, moderate-high, and high levels of the variable represented in the figure, respectively. Table 3-1 depicts the legend scheme for the figures in this chapter.

Table 3-1. Legend for Map Figures.



CHAPTER 4. ON-SITE SURVEY RESULTS

Annual Use Estimate

The annual use estimate is based on researcher observations of visitors at the five high-use access points during the summer, fall, and spring survey seasons. All visitors seen entering or exiting the forest at these sites were inventoried and included for use estimation purposes, whether or not they completed a survey. A total of 3,802 users were seen (3,414 adults and 388 children) at the high-use access points. An additional 141 users (132 adults and 9 children) were seen at the eight low-use sites but are not included in this estimate. The relatively low number of observations for each of these sites makes these figures unreliable and would introduce additional uncertainty into use estimation.

The survey data collection was stratified by season, location, weekend/weekday, and by morning and afternoon. To provide an annual use estimate, each of these stratifications was used. For each location and season, the average number of morning and afternoon visits per weekday was calculated by summing the total visits Monday-Friday, and dividing by the number of days that site was sampled on weekdays:

$$\frac{\text{total \# visitors Mon. - Fri.}}{\text{\# of weekdays surveyed}} = \text{Average visits/weekday}$$

The same process was conducted for weekends:

$$\frac{\text{total \# visitors Sat. - Sun.}}{\text{\# of weekends}} = \text{Average visits/weekend}$$

These calculations were performed for both afternoon and morning observations with the averages being summed to produce a daily estimate of weekday and weekend use. The number of weekdays and weekend days was calculated for each season. These seasonal day counts were multiplied by their respective weekday and weekend averages. These amounts were summed to create a seasonal use estimate for the high-use sites. When the seasonal use estimates are summed, a three season use estimate of 53,367 visits results. Table 4-1a presents average user counts and standard deviations for each major access point. Table 4-1b lists the use seasonal estimations for the five high-use sites.

To provide an estimate of winter use, results from a follow-up mail survey were used (see Wing 1996). A question asked respondents to quantify the frequency of their use of the forest during the four seasons. Results indicated that 16.96 percent of respondents' annual use of the forest occurs during the winter. To estimate visitation at high use sites for winter, the high use totals were summed for each of the three known seasons (53,367) and divided by the percentage of total use attributed by the three known seasons (.83 or 83.03 %). This provides a use estimate of **64,274** at

TABLE 4-1a. Average visits for high-use access points in McDonald Forest.

	Weekday Number of Visitors				Weekend Number of Visitors			
	AM Blocks		PM Blocks		AM Blocks		PM Blocks	
	Avg.	s.d.	Avg.	s.d.	Avg.	s.d.	Avg.	s.d.
SUMMER								
Lewisburg East	7.6	4.3	20.3	17.9	21.5	7.7	39.6	8.5
Lewisburg West	6.2	5.5	5.0	0.0	6.5	0.7	19.0	0.0
Oak Creek	21.2	6.2	48.0	18.1	61.6	18.1	102.0	11.3
Peavy Gate	15.0	6.4	20.0	4.9	41.0	26.8	49.5	0.7
Jackson Creek	3.3	1.5	12.8	7.2	13.0	4.2	18.6	6.4
FALL								
Lewisburg East	2.0	0.0	15.6	8.3	11.0	0.0	23.0	29.7
Lewisburg West	6.5	2.1	7.0	6.0	17.0	0.0	16.0	12.7
Oak Creek	10.5	2.1	29.0	16.5	34.5	31.8	62.0	11.3
Peavy Gate	5.3	2.0	13.0	13.8	12.0	4.2	60.0	32.5
Jackson Creek	2.7	1.8	7.3	7.5	7.5	4.9	11.5	2.1
SPRING								
Lewisburg East	8.2	6.1	13.2	5.2	26.5	3.5	19.6	15.6
Lewisburg West	6.0	3.4	11.0	9.4	17.0	1.4	23.6	14.0
Oak Creek	17.3	3.5	40.0	31.7	45.0	35.3	98.6	48.0
Peavy Gate	4.6	2.3	21.7	16.0	31.0	26.9	78.0	89.1
Jackson Creek	5.7	2.8	8.3	1.1	17.5	7.7	17.6	5.6

the major access points, during the survey year (June 21, 1993 - June 20, 1994). Multiplying this sum by 16.96 percent provides a winter season use estimate of 10,901 visits.

TABLE 4-1b. Seasonal use estimates for high-use access points in McDonald Forest.

	Avg. Visits	Avg. Visits	Season
SUMMER	Weekday	Weekend	Total
Lewisburg East	27.9	61.1	4041.7
Lewisburg West	11.2	25.5	1649.8
Oak Creek	69.2	163.6	10376.8
Peavy Gate	35.0	90.5	5480.0
Jackson Creek	16.1	31.6	2224.5
			23772.8
FALL			
Lewisburg East	17.6	34.0	1684.3
Lewisburg West	13.5	33.0	1441.5
Oak Creek	39.5	96.5	4216.5
Peavy Gate	18.3	72.0	2555.6
Jackson Creek	10.0	19.0	952.4
			10850.4
SPRING			
Lewisburg East	21.5	46.1	2619.3
Lewisburg West	17.0	40.6	2179.3
Oak Creek	57.3	143.6	7519.3
Peavy Gate	26.3	109.0	4573.1
Jackson Creek	14.0	35.5	1852.5
			18743.6
		Total Visits	53367
THREE SEASONS			
Lewisburg East	67.1	141.3	8345.3
Lewisburg West	41.7	99.1	5270.6
Oak Creek	166.0	403.8	22112.6
Peavy Gate	79.6	271.5	12608.7
Jackson Creek	40.2	86.1	5029.4

Use Estimate Limitations

The survey was conducted at a limited number of access points, and was therefore unable to count visitors who entered or exited the forest at other sites. Given the multitude of private residences that surround the borders of the forest and the large number of lesser-used access points, the estimate of 65,136 most likely falls below the actual annual use level. Another limitation involves the extrapolation of on-site observation data to include winter. Because no on-site data were collected during the winter season, it was necessary to estimate use levels for that particular season based on the results from the other seasons and from the mail survey. Appendix A includes a copy of the survey that was used for the summer season. The fall and spring season surveys included additional questions and can be found in Appendix B.

Survey Responses

A total of 1,641 useable surveys were collected from forest visitors over the three-season survey period at the major access points. The season totals were 758 for summer, 399 for fall, and 484 for spring. Although the on-site survey did not include demographic questions, a follow-up mail survey did. Mailing addresses were collected from each person who completed an on-site survey. After removing repeat and out-of-state addresses, a total of 1,152 usable addresses resulted. Respondents who listed out-of-state addresses were exempted from the mail survey due to their probable lack of familiarity with the forest and the increased likelihood of non-response. Out-of-state addresses were rare. For the mailing process, Dillman's (1978) method was utilized with one exception: although Dillman (1978) recommends sending a certified letter as a final attempt to collect completed surveys, no certified letters were sent due to the cost involved.

Throughout the mailing process, confidentiality was maintained by using numbers to keep track of which addresses had responded to the survey. Those addresses returning blank surveys were removed from the mailing list as well as any other returned mail that asked that addressees not be included in the survey. Of the original 1,152 addresses, 78 were returned as undeliverable or were incomplete, and 713 were returned completed. This results in a response rate of 66.4 percent.

Demographic Results

The mean age of respondents was 38.3, with a range that extended from 16 to 82 years. Two surveys from children under sixteen were not counted. Females comprised 47 percent of the sample and 56 percent of respondents were married.

The average respondent had completed four years of college. Educational background varied from a few years of high school (2%) to having earned a Master's degree or higher (39%). Only 19 percent were currently enrolled at Oregon State University (O.S.U.). Average household income was over $45,000 per year.

When asked to characterize their views on domestic policy issues on a scale from very liberal to very conservative, respondents considered themselves slightly to the left of moderate on average, although a significant share (18%) said they were conservative. Thirty percent of respondents said they were members of an outdoor organization, which included such diverse groups as Native Plants of Oregon, Santiam Wilderness Society, Corvallis Environmental Center, and the National Rifle Association. About 11 percent reported that they depended on the timber industry for their or their immediate family's economic livelihood. Respondents reported that they had been visiting the forest for an average of 9.5 years with a range that extended to 55 years. Respondents estimated that their average use in summer slightly exceeded their use in fall and spring, with winter visitation dropping dramatically. Fifty-eight percent reported visiting the forest on weekends over half the time, with 8% restricting use to only on weekends. The mean number of visits per respondent was 58 visits per year (s.d. = 54.5), with half visiting 30 times or fewer in a year.

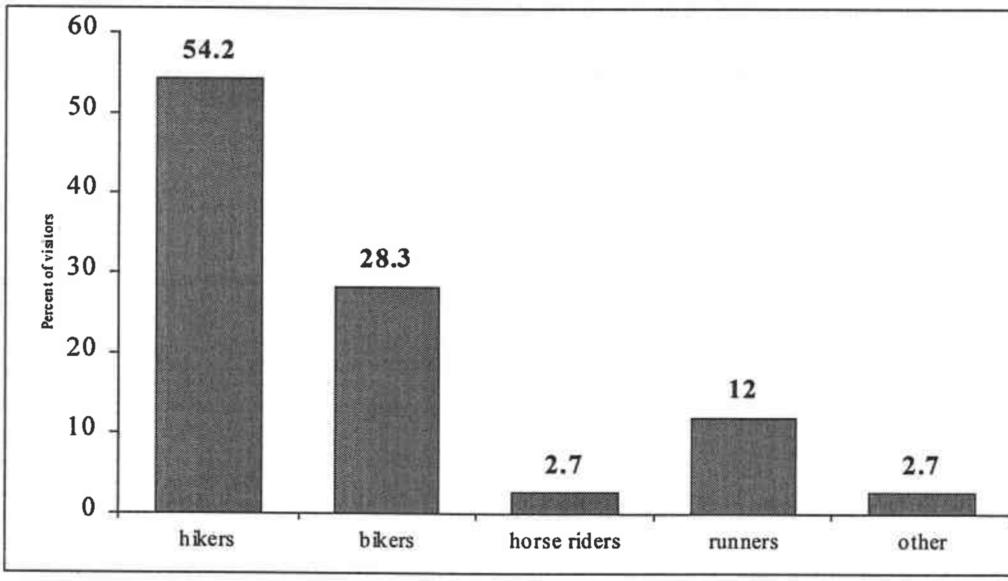
On-Site Survey Responses

Over half (54%) of the respondents indicated they were hiking (dog walkers were included in this category), 28 percent said they were biking, 12 percent said they were runners, and less than three percent were horseback riding (Figure 4-1). About three percent reported participating in other activities (including picnickers, plant collectors, butterfly collectors, mushroom gatherers, and other activities).

GIS Analysis of Use Density for On-Site Survey

For GIS analysis, use statistics were created from the route information collected from survey respondents. Figures were created to represent road and trail use statistics for the primary user groups (hikers, bikers, runners, and horseback riders)

Figure 4-1. Recreational activity of observed visitors.



for each of the three observed seasons (summer, fall, and winter) and for the combined seasons. Due to the low percentage of users (2.7%) and myriad of activities in the other use categories, the following results will only address the primary user groups.

Figure 4-2 represents road and trail use figures for the primary user groups for the three observed seasons (see Figure 3-2 for locations of significant geographic entities used to describe GIS results). In general, use falls in the higher categories in the Oak Creek area and along the network of roads and trails that lead from this location to the Peavy Arboretum. Some instances of high-moderate user counts can also be found in the Jackson Creek and McCulloch Peak areas. Figures 4-3, 4-4, 4-5, and 4-6 represent section use totals for hikers, bikers, runners, and horseback riders, respectively. High use occurs for hikers in the Oak Creek, Lewisburg Saddle, and Peavy Arboretum locations. Use patterns for bikers are more dispersed and moderate

Figure 4-2. Three Season Use Totals for Survey Participants in McDonald Forest: Primary User Groups.

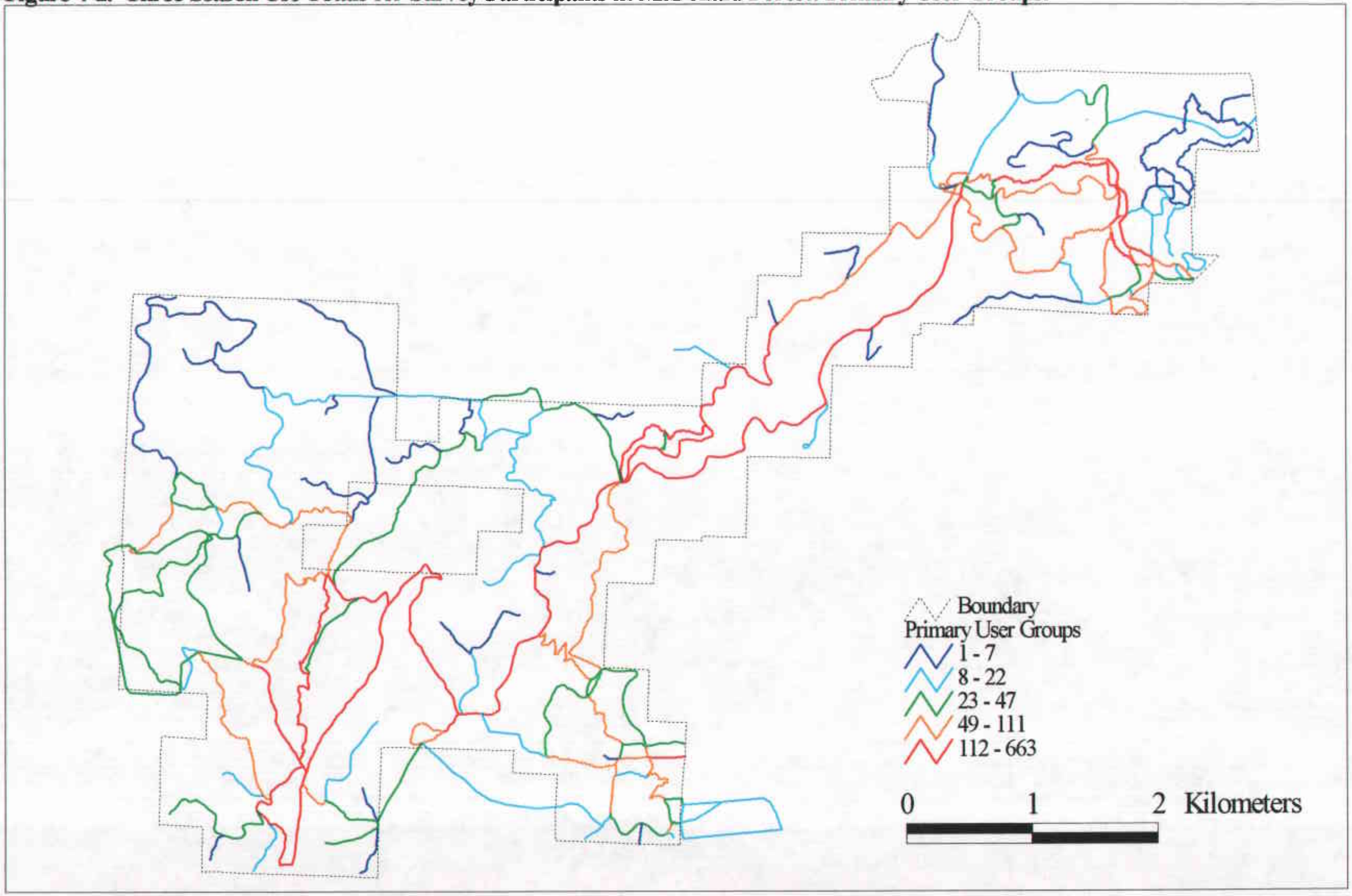


Figure 4-3. Three Season Use Totals for Survey Participants in McDonald Forest: Hikers.

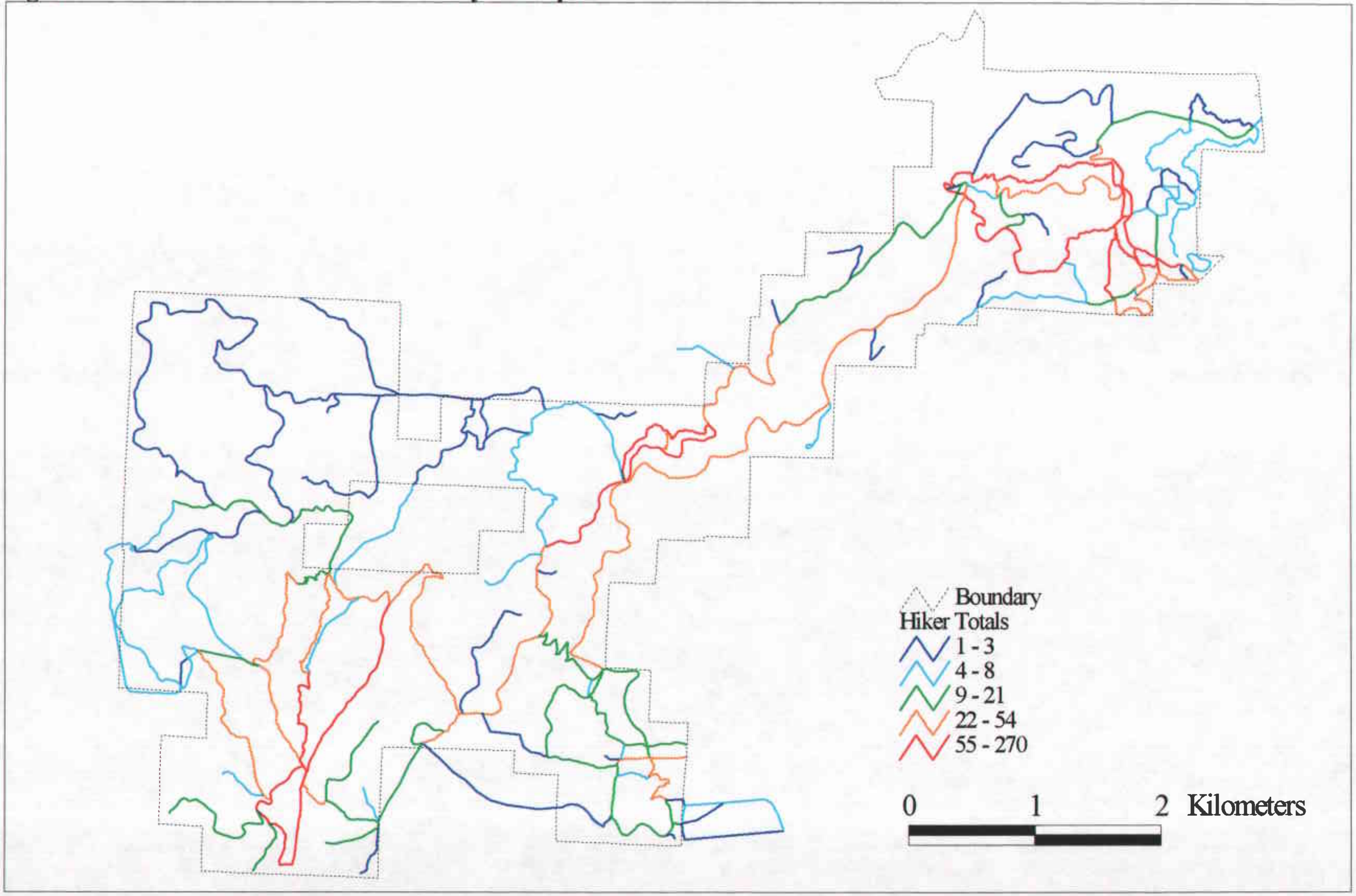


Figure 4-4. Three Season Use Totals for Survey Participants in McDonald Forest: Mt. Bikers.

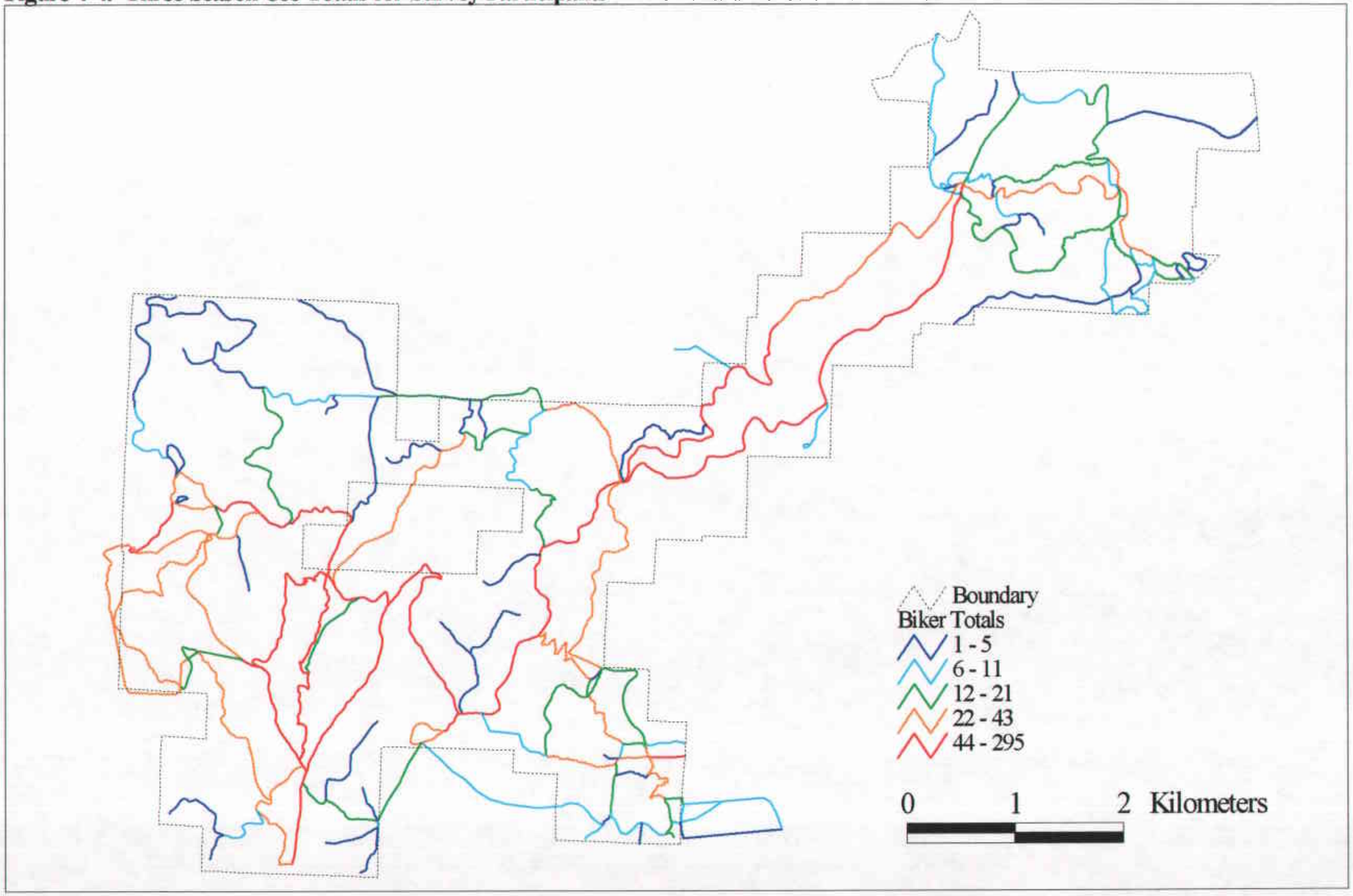


Figure 4-5. Three Season Use Totals for Survey Participants in McDonald Forest: Runners.

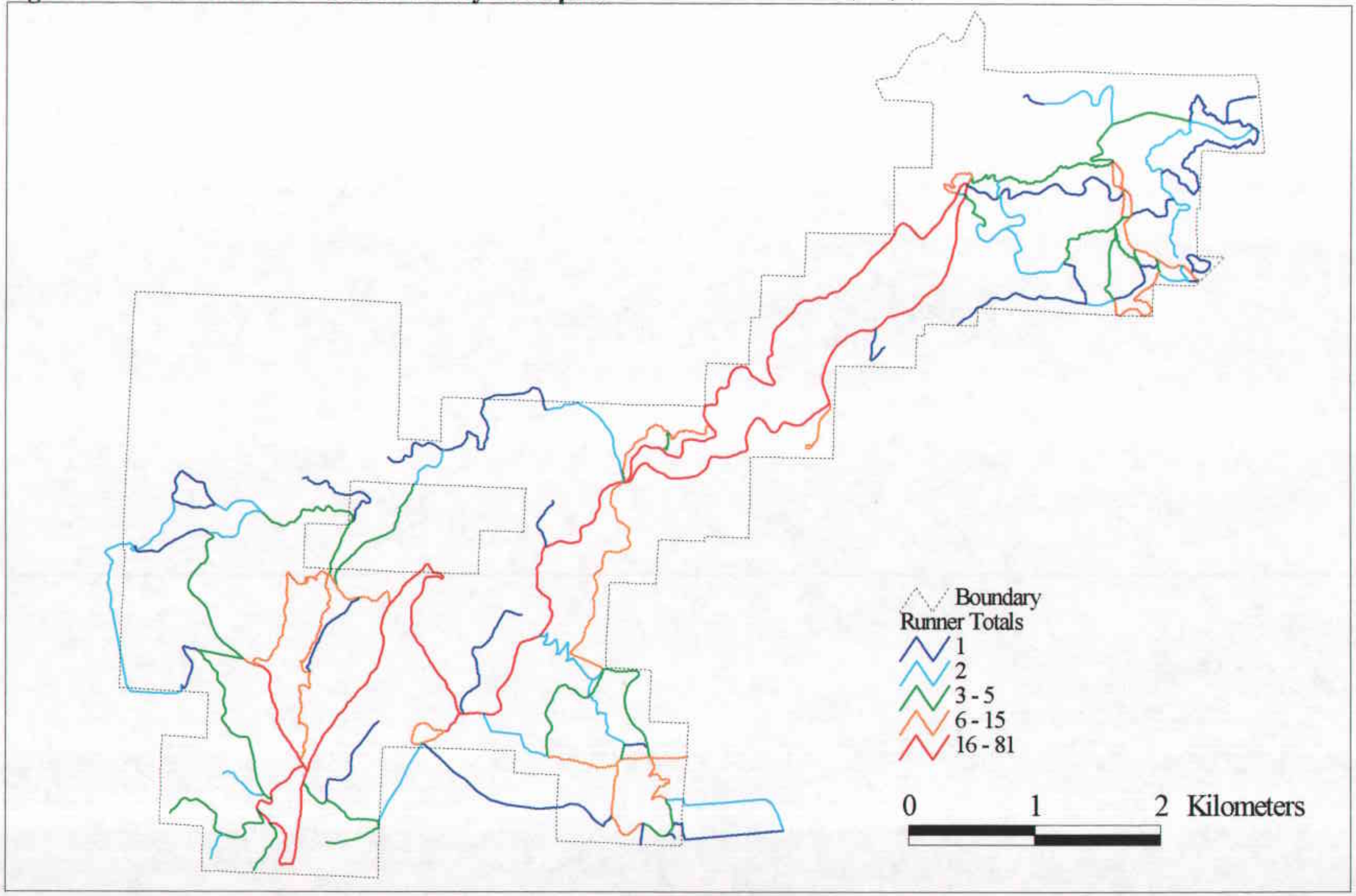
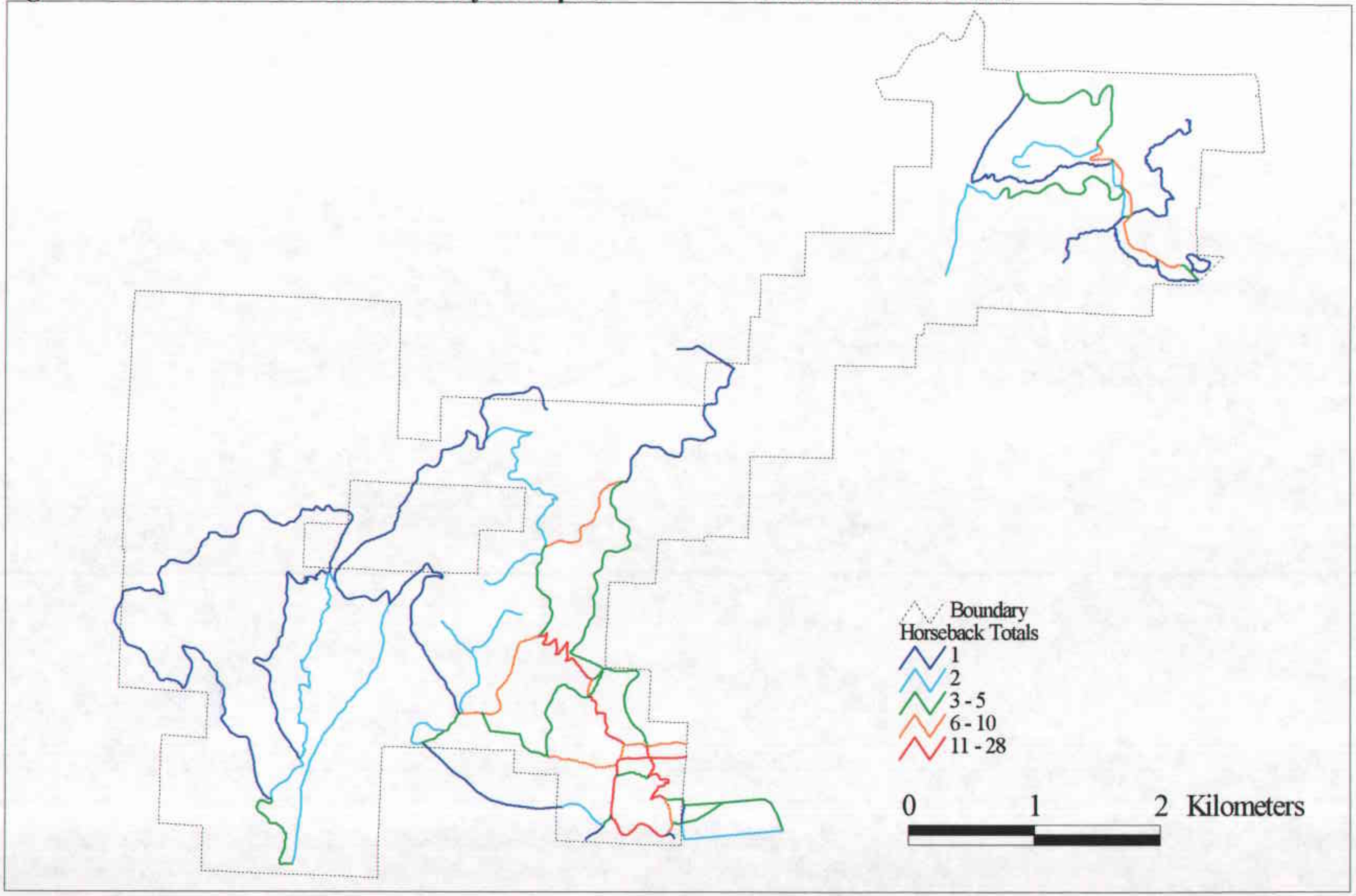


Figure 4-6. Three Season Use Totals for Survey Participants in McDonald Forest: Horseback Riders.



to high use can be observed in much of the Oak Creek and McCulloch Peak areas. Major access roads surrounding the Lewisburg Saddle area also appear to draw high biker use totals. Runners tend to frequent the Oak Creek area and the loop that circulates on the east side of Lewisburg Saddle along the Davies and Nettleton roads. This is henceforth referred to as the Vineyard Mountain Traverse. The loop extends about seven and a half miles and makes for a popular run. Runner use totals are low for the remaining forest areas. Horseback rider totals are low for the entire observed survey period (maximum n=28) but concentrate in the Jackson Creek area. This is probably due to a stable near the Jackson Creek entry gate.

GIS Analysis of Seasonal Use Estimates

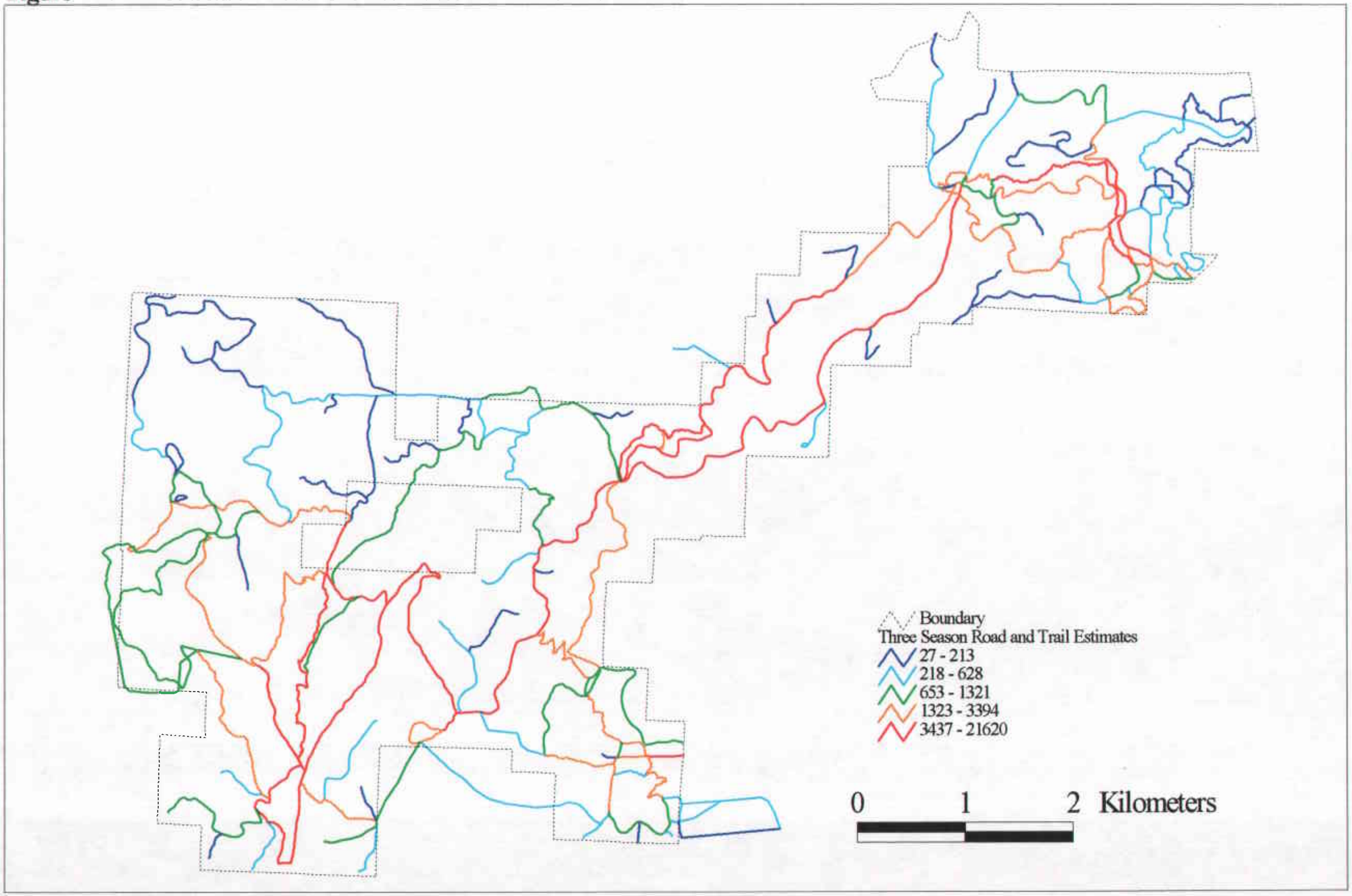
One of the goals of the original on-site survey was to provide an estimate of total seasonal and annual use patterns throughout the forest. To calculate and present results in a GIS format, use figures calculated from on-site survey counts were used in conjunction with the estimated use totals presented above. For each season, the total number of users recorded on each section (road or trail segment) was transformed into a percentage representing the proportion of seasonal use that the section received. For example, section 316 represents the first major road section leading from the access gate at Oak Creek into the forest. Route information was collected from 399 people during the fall season and this section received 151 visits from this group. This represents 37.84 percent of the 399. The total use estimate for fall was 11,015 people and 37.84 percent of this figure is 4,169. Table 4-2 provides a demonstration of this process.

Table 4-2. Section 316 Example for Calculation of Fall Season Sectional Use.

Section 316 Fall Use	/	Total Fall Routes	=	Proportion of Use
151	/	399	=	.3784 (37.84%)
Proportion of Use	*	Total Fall Estimate	=	Section 316 Estimate
.3784	*	11,015	=	4,169 visits

This methodology was applied to each section for each season and the individual seasonal figures were summed to create a total use estimate for the three survey seasons. Figure 4-7 represents total use estimates for the combined three seasons for all users. In general, the combined three season figure demonstrates that the highest use occurs in the areas surrounding the Oak Creek access point. The Lewisburg Saddle and Peavy Arboretum areas also draw moderate to high use, and a section near the Jackson Creek entrance experiences moderate use. These patterns mirror those of the observed use figures already presented, but provide a visual perspective for total use estimates in the forest. Use patterns show slight seasonal variations but remain, for the most part, consistent across the seasons. Figures representing seasonal use patterns are presented in Appendix C.

Figure 4-7. Three Season Total Use Estimates for McDonald Forest.



Length of Stay

The survey asked respondents to estimate the length of their stay, and the mean estimate was 91 minutes. Field personnel recorded the actual length of visits for respondents seen both entering and exiting the forest. On average, the estimated time was ten minutes greater than the observed time elapsed ($t = 11.15$, $p = 0.0001$). This difference could mean that visitors overestimate the time taken on their visit, or simply that visitors count the time in the parking lot (tying shoes, adjusting bikes, talking, etc.) as part of their trip.

Factors Contributing To/Detracting from Visit

Respondents were provided with an open-ended question that asked them to name scenic features that contributed to or detracted from their visit. Responses are given in Figures 4-8 and 4-9. Trees ("old growth," "large trees," "forest"), beauty, and wildflowers most commonly contributed to their enjoyment. Clearcuts and logging activities detracted most often.

Conflicts

When asked whether they had any conflicts with others during their visit, only 3 percent ($n = 49$) of the respondents said they had. Respondents were asked to describe any reported conflicts. Responses consisted primarily of rude words, dislike of the impacts of others' use, and discomfort with seeing an animal or activity. The

Figure 4-8. Scenic features that contributed to enjoyment.

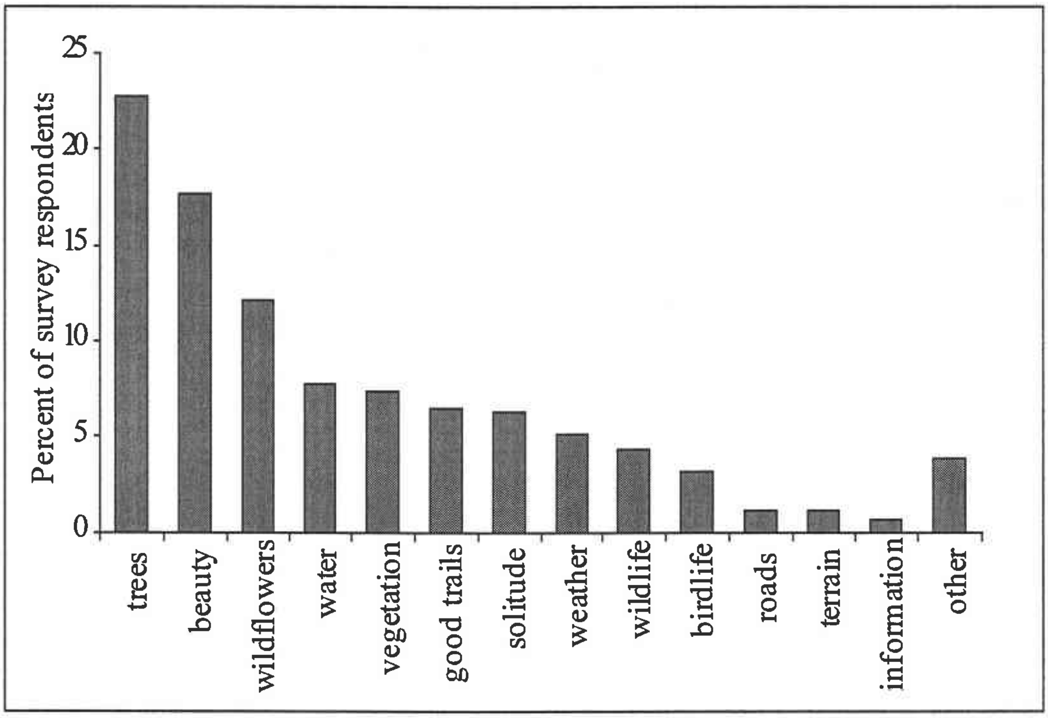
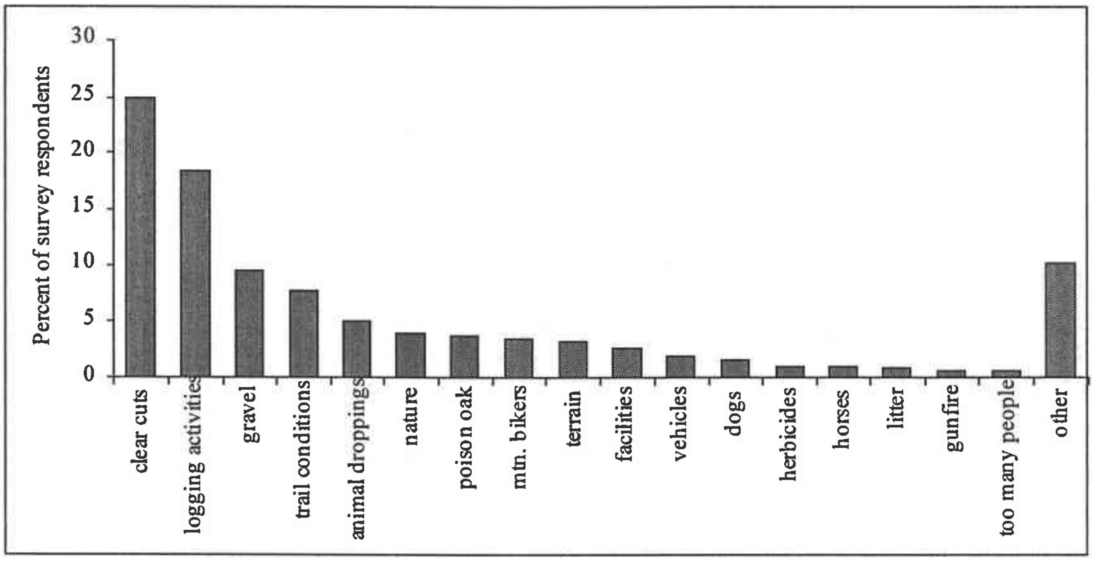


Figure 4-9. Scenic features that detracted from enjoyment.



highest number of people had conflicts with mountain bikers (n = 18, 37% of those reporting a conflict) and dogs (n = 11, 22%), followed by vehicles (n = 5, 10%), hikers (n = 4, 8%), horseback riders (n = 4, 8%), and property owners (n = 4, 8%). Table 4-3 presents these results.

Table 4-3. Conflicts and sources of conflicts for McDonald Forest Visitors.

	Mountain Bikers % (n)	Dogs % (n)	Vehicles % (n)	Hikers % (n)	Horseback Riders % (n)	Property Owners % (n)	Other % (n)
Hikers 27 (3%)*	51.9 (14)	22.2 (6)	7.4 (2)	----	----	7.4 (2)	11.1 (3)
Bikers 12 (2.5%)	8.3 (1)	----	16.7 (2)	33.3	25 (3)	16.7 (2)	----
Runners 8 (40%)	25 (2)	62.5 (5)	12.5 (1)	----	----	----	----
Horseback Riders 0 (0%)	----	----	----	----	----	----	----
Other 2 (4.4%)	50 (1)	----	----	----	50 (1)	----	----
49 (3%)**	(18)	(11)	(5)	(4)	(4)	(4)	(3)

*Percent of activity group **Percent of total users

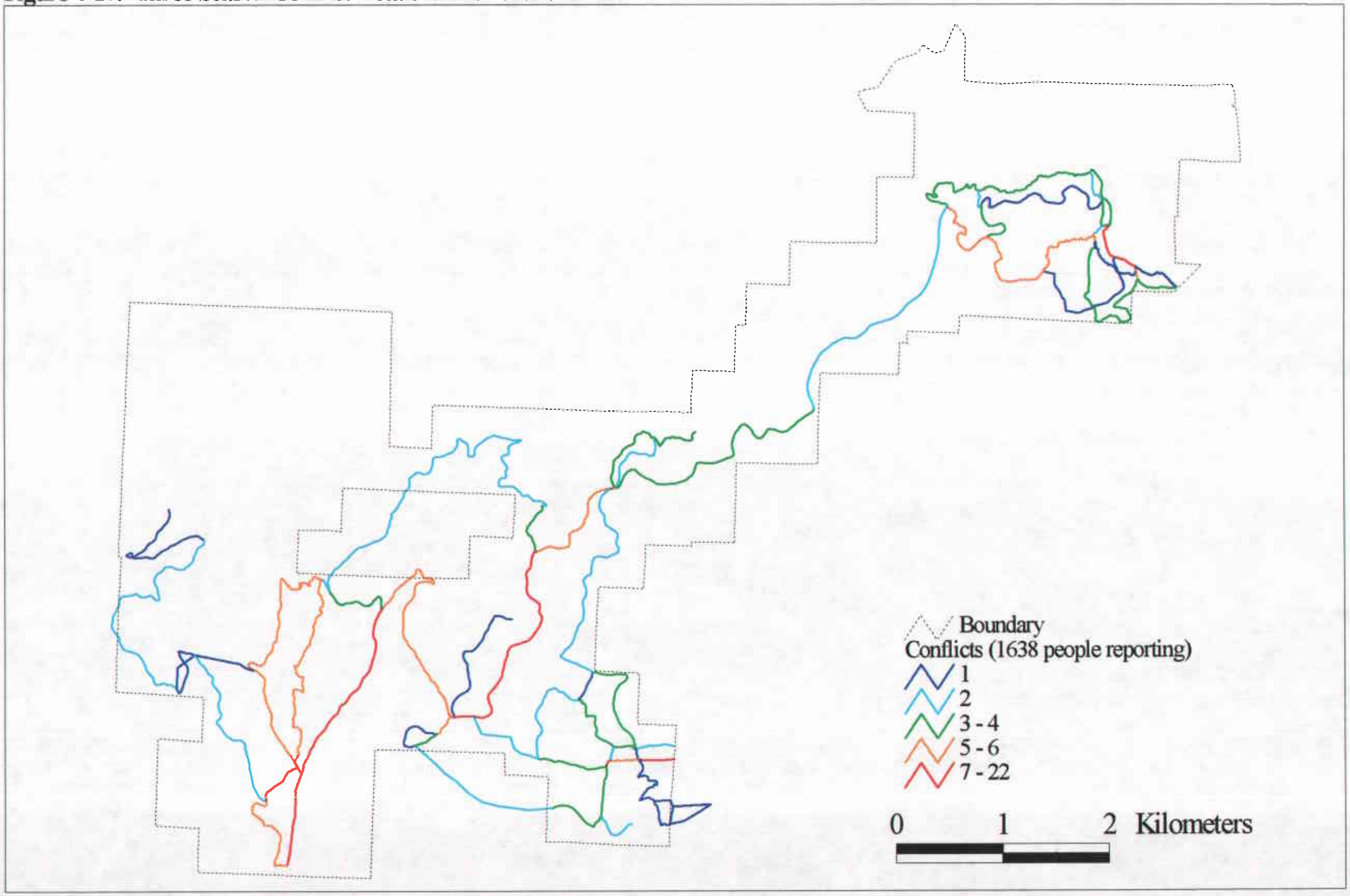
Different activity groups appear to have different kind of conflicts. It is interesting to note that hikers and bikers seem to have the most conflicts with each other (n = 18). Of the possible sources of conflict, runners seem to have the most trouble with uncontrolled dogs.

GIS Analysis of Conflicts

For GIS analysis, the number of visitors reporting a conflict was tabulated for each road and trail section and is presented as a raw count. Due to the overall low number of conflicts reported, raw counts appeared to be the best method of presentation. Figure 4-10 represents the number of conflicts per road and trail segment for the combined three seasons. Not surprisingly, conflicts tend to occur in the segments that are prone to high visitor counts. The largest numbers of conflicts occur in the Oak Creek area and along the 600 road as it winds toward Lewisburg Saddle. The entrance road into Jackson Creek and surrounding roads have moderate to high conflict counts as does the Section 36 Loop and southern Peavy Arboretum segments. Segments running west and east of Lewisburg Saddle also experienced low-moderate to high-moderate conflict levels.

Appendix D contains the conflict totals for segments during the summer, fall, and spring survey seasons. Some slight variations in seasonal distributions can be observed in these figures, but patterns are typically uniform with that of the combined seasons.

Figure 4-10. Three Season Conflict Totals in McDonald Forest.



Crowding

Respondents to the on-site survey were asked to indicate to what degree, on a scale from one through nine, they felt crowded during their visit to the forest. The crowding scale used in this survey has been employed in numerous carrying capacity studies throughout the U.S. (Shelby et al. 1989). Answering this question requires respondents to make an evaluative assessment of the number of encounters they experienced. Accompanying the numerical scale are descriptors intended to serve as reference points. Points one and two are described as "not-at-all crowded," responses three and four as "slightly crowded," five through seven as "moderately crowded," and eight or nine as "extremely crowded." For analytical purposes, responses three through nine are collapsed into a single "crowded" category, because these responses all indicate at least a slight perception of crowding. Responses one and two are recorded as "not crowded." Appendix A contains an example of this question.

Results from this question indicate that respondents generally did not feel crowded during their visit to the forest. The mean level of perceived crowding on the nine-point scale was 1.67, placing the overall statistic squarely in the "not-at-all crowded" category. Out of the 1,671 responses to this item, 84.4 percent felt no crowding (responses 1-2) and 15.6 percent felt some degree of crowding (responses 3-9).

Table 4-4 shows the crowding scores of outdoor recreation studies that have used the same scale (Shelby et al. 1989). The aggregate rounded crowding percentage of 16 percent falls below that of almost every other study cited.

Table 4-4. Perceived crowding at selected areas.

Percentage of visitors reporting crowding	Population	Resource	Location	Resource Condition
100	Boaters	Deschutes River	Oregon	Weekends section 1
97	Boaters	Deschutes River	Oregon	Weekends section 4
94	Anglers	Colorado River	Arizona	Thanksgiving weekend
91	Boaters	Raystown Lake	Pennsylvania	On the lake
88	Boaters	Deschutes River	Oregon	Weekdays section 1
87	Riparian Landowners	Lake Delavan	Wisconsin	Overall Rating
76	Trout anglers	Gun Powder River	Maryland	Opening Day
75	Salmon anglers	Waimakariri River	New Zealand	
75	Boaters	Raystown Lake	Pennsylvania	All attraction sites
74	Salmon anglers	Rakaia River	New Zealand	At river mouth
73	Canoers and boaters	Boundary Waters Canoe Area	Minnesota	Moose Lake
72	Rafters	Grand Canyon	Arizona	1985 Summer
70	Anglers	Klamath River	California	
70	Climbers	Mt. Denali	Alaska	
69	Boaters	Door Country	Wisconsin	
68	Rafters	Rogue River	Oregon	
68	Rock climbers	Seneca Rocks	West Virginia	
66	Boaters	Raystown Lake	Pennsylvania	At put-in location
63	Boaters	Raystown Lake	Pennsylvania	At take-out location
61	Floaters	Wolf River	Wisconsin	
59	Salmon anglers	Rakaia River	New Zealand	All anglers
55	Deer hunters (bow)	Statewide	Maryland	No specific resource
55	Wildlife Photographers	Sandhill	Wisconsin	
54	Recreationists	Lake Delavan	Wisconsin	One-day visit
53	Rafters	Grand Canyon	Arizona	1985 Winter
53	Rafters	Snake River	Oregon	In Hell's Canyon
53	Backpackers	Mt. Jefferson Wilderness	Oregon	
52	Canoers	Brule River	Wisconsin	1975 High-use
49	Backpackers	Eagle Cap Wilderness	Oregon	
48	Pheasant hunters	Bong	Wisconsin	Late Season
45	Salmon anglers	Rakaia River	New Zealand	Upstream
44	Turkey Hunters	Statewide	Maryland	No specific resource
43	Tubers	Brule River	Wisconsin	1975
42	Sailboaters	Apostle Islands	Wisconsin	1985
39	Backpackers	White Mt. National Forest	New Hampshire	Presidential Range
38	Floaters	Klamath River	California	
37	Canoers	Brule River	Wisconsin	1985 Low-use
32	Anglers	Colorado River	Arizona	Midweek
31	Hikers	Dolly Soda Wilderness	West Virginia	Low-use period
27	Goose Hunters	Tukahoe State Park	Maryland	Low-density hunt
26	Rafters	Illinois River	Oregon	
25	Trout Anglers	Savage River	Maryland	Low-use period
24	Backpackers	Great Gulf	New Hampshire	Low-use period
24	Deer Hunters	Sandhill	Wisconsin	1982 Low-density hunt
23	Trout Anglers	Gunpowder River	Maryland	Late Season
17	Goose Hunters	Grand River	Wisconsin	Managed hunt
•16	**Recreationists**	**McDonald Forest**	**Oregon**	**1993-94**
12	Deer Hunters	Sandhill	Wisconsin	1988 Low-density hunt

Perceived crowding results differed depending on the access point that respondents completed the survey (F = 12.17, df = 4, p = 0.0001, Figure 4-11). Lewisburg Saddle's East entrance had the lowest percentage of people who felt some crowding (9.3%, n = 301), and Oak Creek had the highest (21.0%, n = 714). In terms of time of use, more respondents felt crowding on the weekends (17.8%, n = 1049) than on weekdays (11.8%, n = 618). Raw crowding scores were determined to be statistically significant between the two time periods (t = 4.53, p = 0.0000).

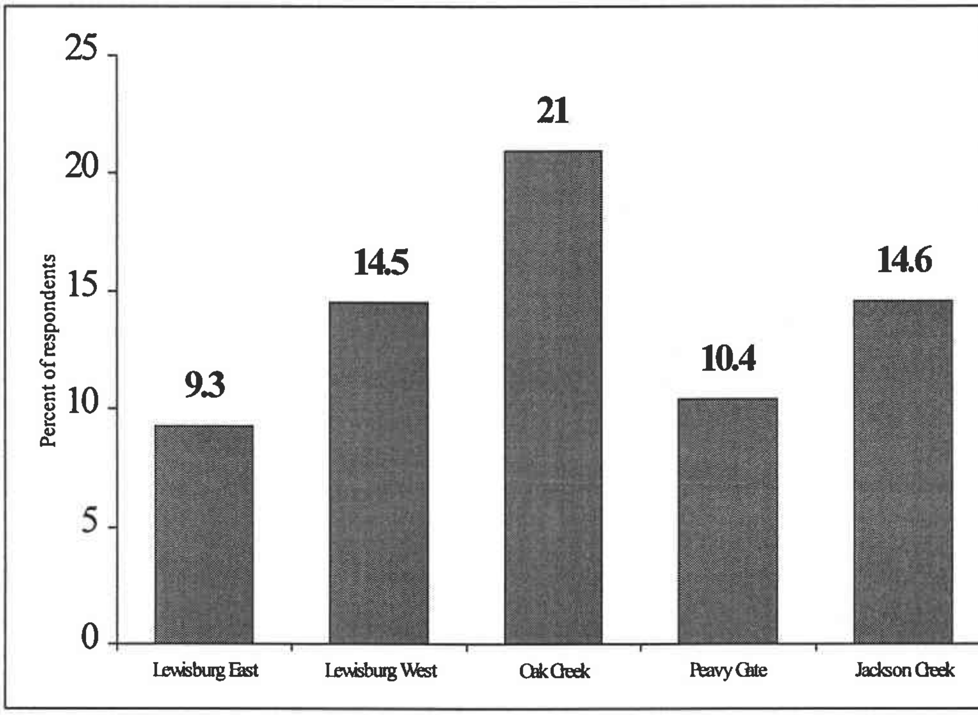
Respondents from different activity groups did not differ in their perceptions of crowding (F = 1.66, df = 4, p = 0.1563). The percent who felt some crowding ranged from 13% (runners, n = 198) to 18% (mountain bikers, n = 474).

GIS Analysis of Crowding Results

For GIS analytical purposes, crowding responses were generated for all three survey seasons, and for the summer, fall, and spring seasons. Crowding results were tabulated as a percentage for each road and trail segment. The tabulation was accomplished by summing the total number of visits each segment received and then dividing this figure by the number of visitors who reported some degree of crowding. The result can be expressed for each segment as the percent of visitors who reported feeling crowded.

Figure 4-12 presents the combined crowding percentages for the three survey seasons. Some of the heaviest percentages of crowding occur in some of the lesser-used segments in the western portion of the forest near McCulloch Peak, near Sulphur

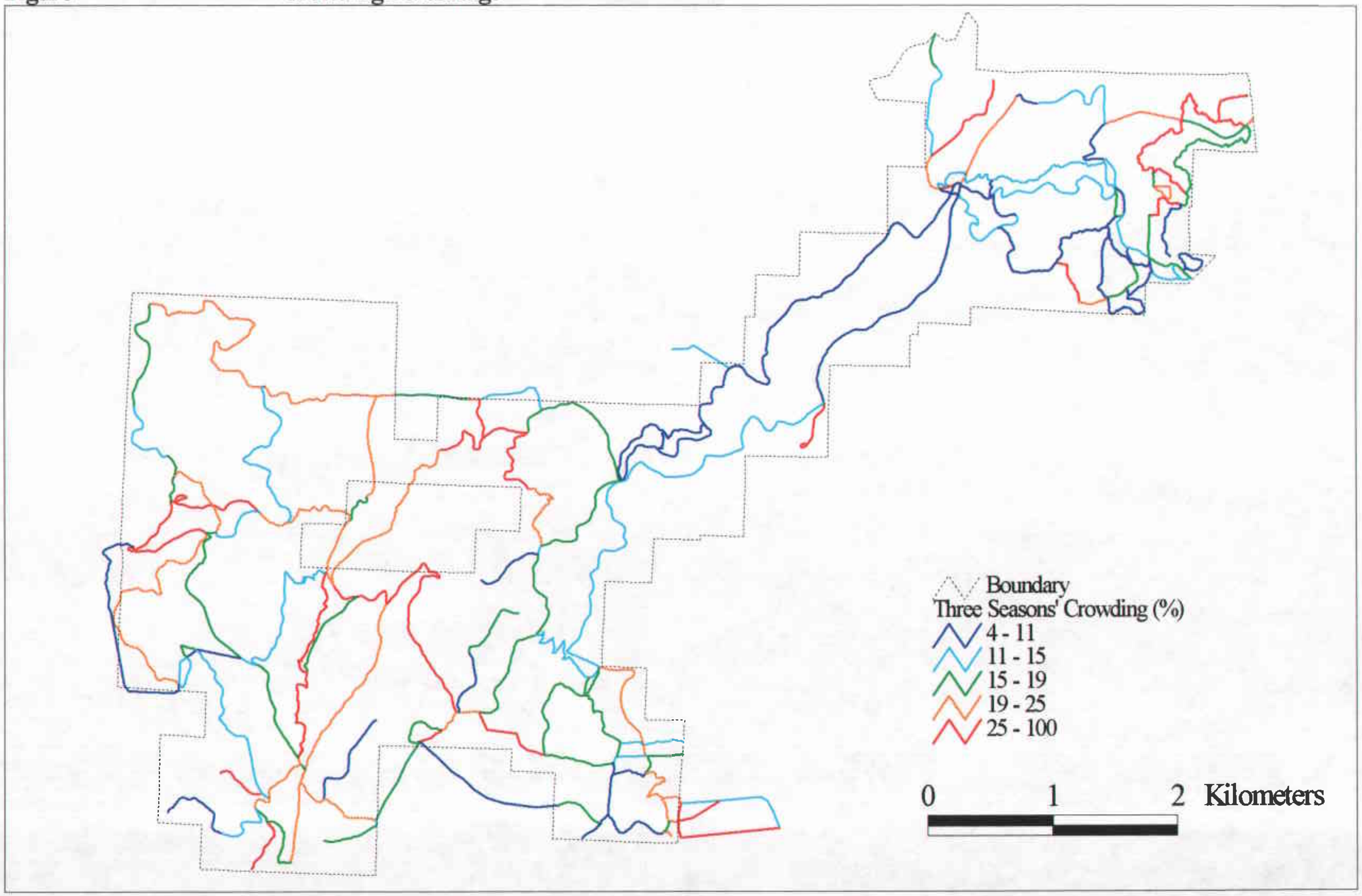
Figure 4-11. Percent respondents who felt some crowding: by access point.



Springs, and in two areas north of the Peavy Arboretum. These segments are results of several users reporting crowding and fall in the higher crowding categories due to the low number of observations. These results must be taken with caution as they may represent users who experienced crowding in other parts of the forest, yet traveled to these lesser-used locations during the course of their trip.

The segments north of Oak Creek and west of the saddle are generally areas of moderate crowding. The Vineyard Mountain Traverse has a low percentage of crowding and the Peavy Arboretum area has low to moderate crowding percentage. Summer, fall, and spring crowding results are presented in Appendix E and show slight seasonal variations in crowding results.

Figure 4-12. Three Season Crowding Percentage for McDonald Forest.



Encounters And Percent Of Time In Sight Of Others

Survey participants were asked to account for the number of times they saw people from other groups during their outing. They were also asked an accompanying standards question which asked them to indicate how many times it would be O.K. to see other groups. Participants were offered the option of choosing "it doesn't matter to me" as a response to the standards question. The comparison of the results from these questions provides insight on whether forest users view current impacts as acceptable.

Respondents appear willing to see more people than they currently encounter in the forest (Figure 4-13 and Table 4-5). The mean number of groups they reported seeing during their visit (3.4, s.d. = 2.4) was less than the number they said it would be "OK to see" (6.0, s.d. = 6.9). This was a statistically significant difference ($t = 28.3$, $p = 0.0001$). The difference may be even greater than it appears from these data. Survey respondents were offered the option of selecting "it doesn't matter to me" in place of a figure. Nearly half (49.8%) of the respondents said "it doesn't matter to me," when asked how many other groups they saw, and were thus not included in the 6.0 average. There is a significant correlation between the number of other groups people actually saw and the number of groups they were willing to see, but the correlation is not a strong one ($r = 0.34$, $p = 0.0001$).

The mean percentage of time in sight of other groups (13.2%, s.d. = 13.2) also appears to be less than the acceptable percentage (26.9%, s.d. = 18.4). This difference was found to be statistically significant ($t = 18.8$, $p = 0.0001$). The correlation between the two was significant yet not very strong ($r = 0.31$, $p = 0.0001$).

Figure 4-13. Mean scores for encounters and percent of time in sight of others.

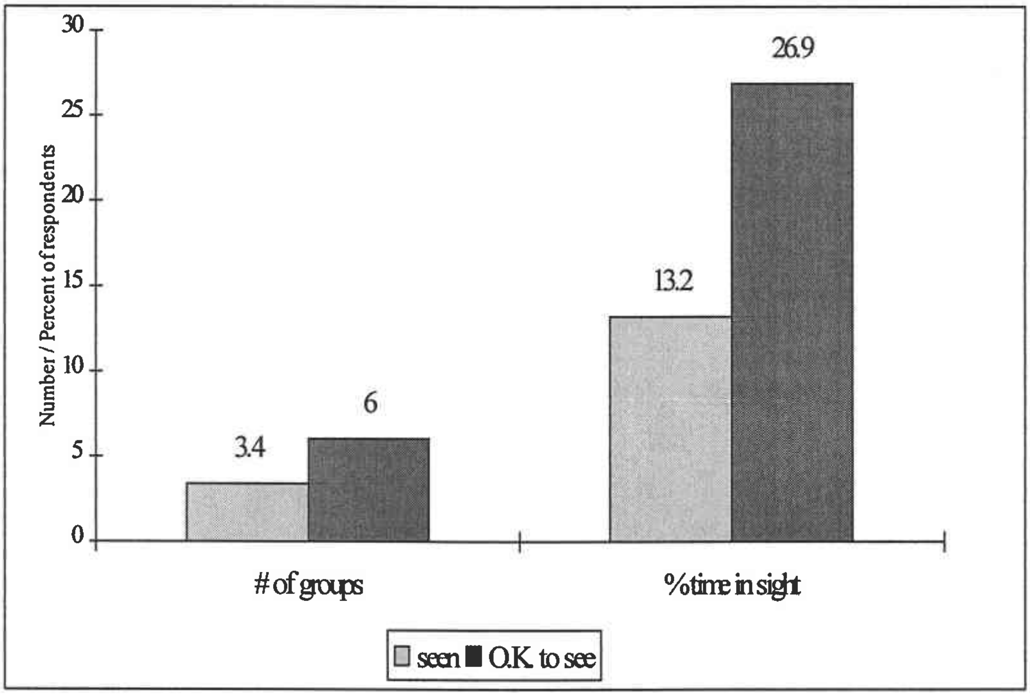


Table 4-5. Results for the number of groups seen and the percent of time spent in sight of others.

	N	MEAN	MINIMUM	MAXIMUM
# of other groups seen	765	3.4	1	25
# of groups OK to see	425	6.0	1	100
% time in sight of others	697	13.2	0.5	100
Acceptable % time in sight of others	860	26.9	2	100

In terms of the number of groups seen and percentage of time spent in sight of others, visitation levels in McDonald Forest seem to be under the amount acceptable to most forest recreationists. The correlations between the current and acceptable numbers may indicate that the more people visitors see, the more they may be willing to see. This could be an artifact of the phenomenon known as product shift, in which visitors change their perceptions and attitudes to match the conditions being offered by an experience (Shelby et al. 1988). It could also indicate that people who have a low tolerance for seeing others choose parts of the forest that currently have few visitors. This is known as displacement, and occurs when users react negatively to a situation and move to another setting that offers the possibility of offering a more satisfying experience (Heberlein and Shelby 1977, Shelby et al. 1988).

Access Point Comparisons

Visitors surveyed at Lewisburg East reported seeing the fewest number of groups, while those at Oak Creek reported seeing the most. Visitors at Jackson Creek reported spending the largest amount of time in sight of others (Figure 4-14). Significant differences were detected in the number of groups seen and percent of time spent in sight of others between the access points (Table 4-6). However, willingness to see other groups and the acceptable percent of time in sight of others were not statistically different between the access points.

Figure 4-14. Average number of groups seen and percent time in sight of others while in McDonald Forest: by access point.

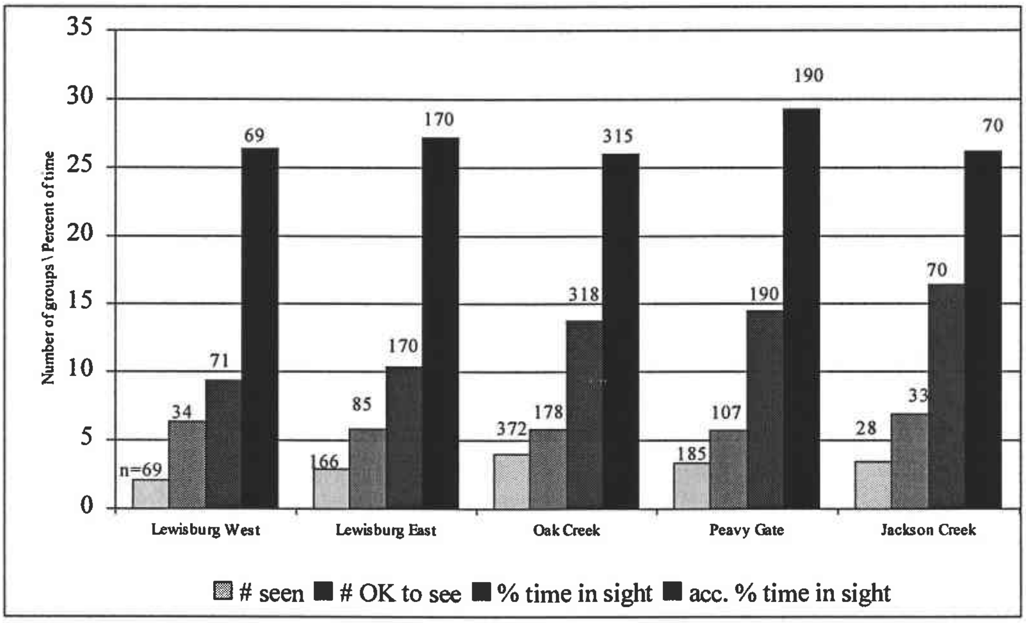


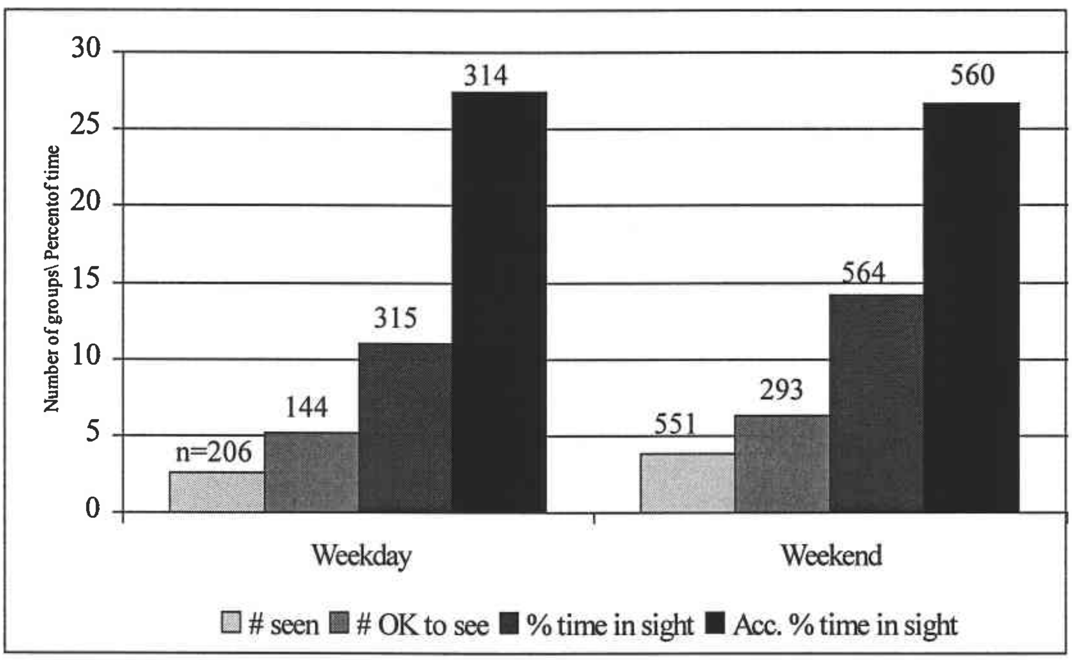
Table 4-6. Anova results for number of groups seen and percent of time in sight of others while in McDonald Forest: by access point.

Variable	Do means differ?	F-Statistic	P-Value Significance
# groups seen	Yes	13.6	0.0001
# groups OK to see	No	0.3	0.9008
% time in sight of other groups	Yes	4.1	0.0028
% time acceptable in sight of others	No	1.1	0.3625

Weekend/Weekday Comparisons

Weekday/weekend results indicated that, as expected, weekend visitors reported seeing more people and spending a larger percent of their time in sight of others than did weekday visitors. However, significant differences were not detected between the standards of these two groups (Figure 4-15 and Table 4-7).

Figure 4-15. Number of groups seen and percent time in sight of others while in McDonald Forest: weekday vs. weekend.



Activity Comparisons

Those visitors engaged in different recreational pursuits did not differ statistically in their opinions of seeing others. Only their estimates of the percentage

Table 4-7. T-test results for number of groups seen and percent of time in sight of others while in McDonald Forest: weekday vs. weekend.

Variable	Do means differ?	T-Statistic	P-Value Significance
# groups seen	Yes	6.9	0.0000
# groups OK to see	No	1.6	0.1137
% time in sight of other groups	Yes	2.9	0.0040
% time acceptable in sight of others	No	0.6	0.5619

of time in sight of other groups differed by activity. Runners reported seeing people the smallest percentage of time, while those engaged in "other" activities (photography, picnicking, bird watching, etc.) reported the largest (Figure 4-16 and Table 4-8).

GIS Analysis of Encounter Results

For GIS analysis purposes, the number of people who reported their standard being exceeded for the number of people from other groups they saw was calculated for each road and trail section. The number of people in this category was low enough that raw counts were chosen over percentages as the means of presentation. Those responding by choosing "it doesn't matter to me" were excluded from this process. This set of questions was asked only of fall and spring survey respondents.

Figure 4-17 displays the combined results of those who reported standards being exceeded during the fall and spring seasons. Responses from 427 people were

Figure 4-16. Number of groups seen and percent time in sight of others while in McDonald Forest: by recreation activity.

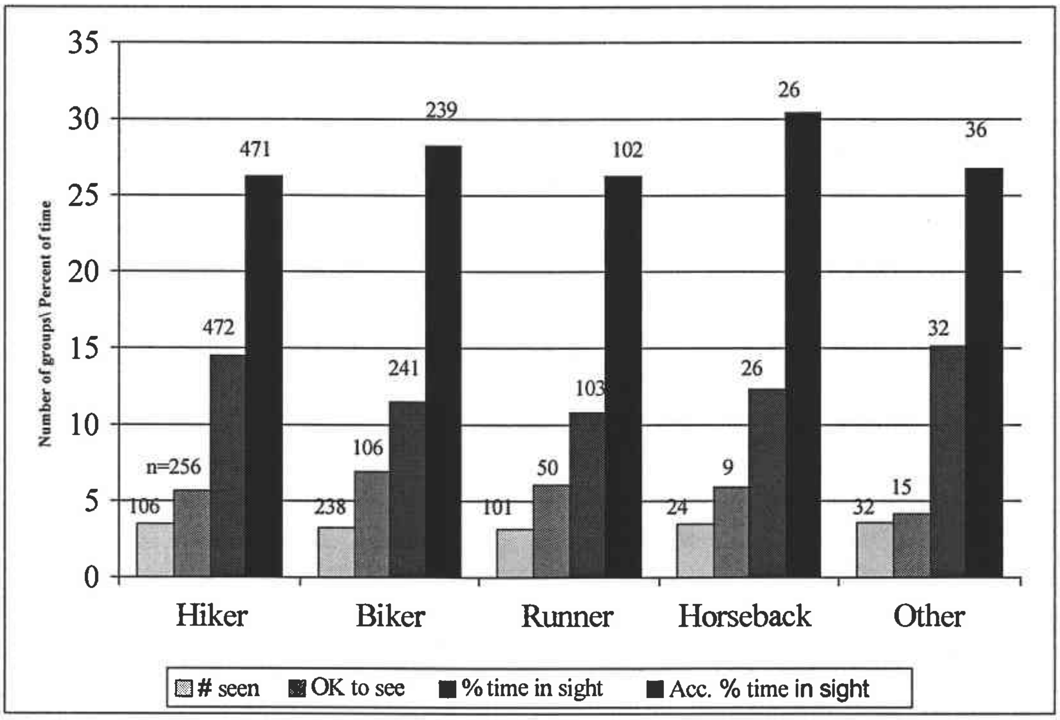
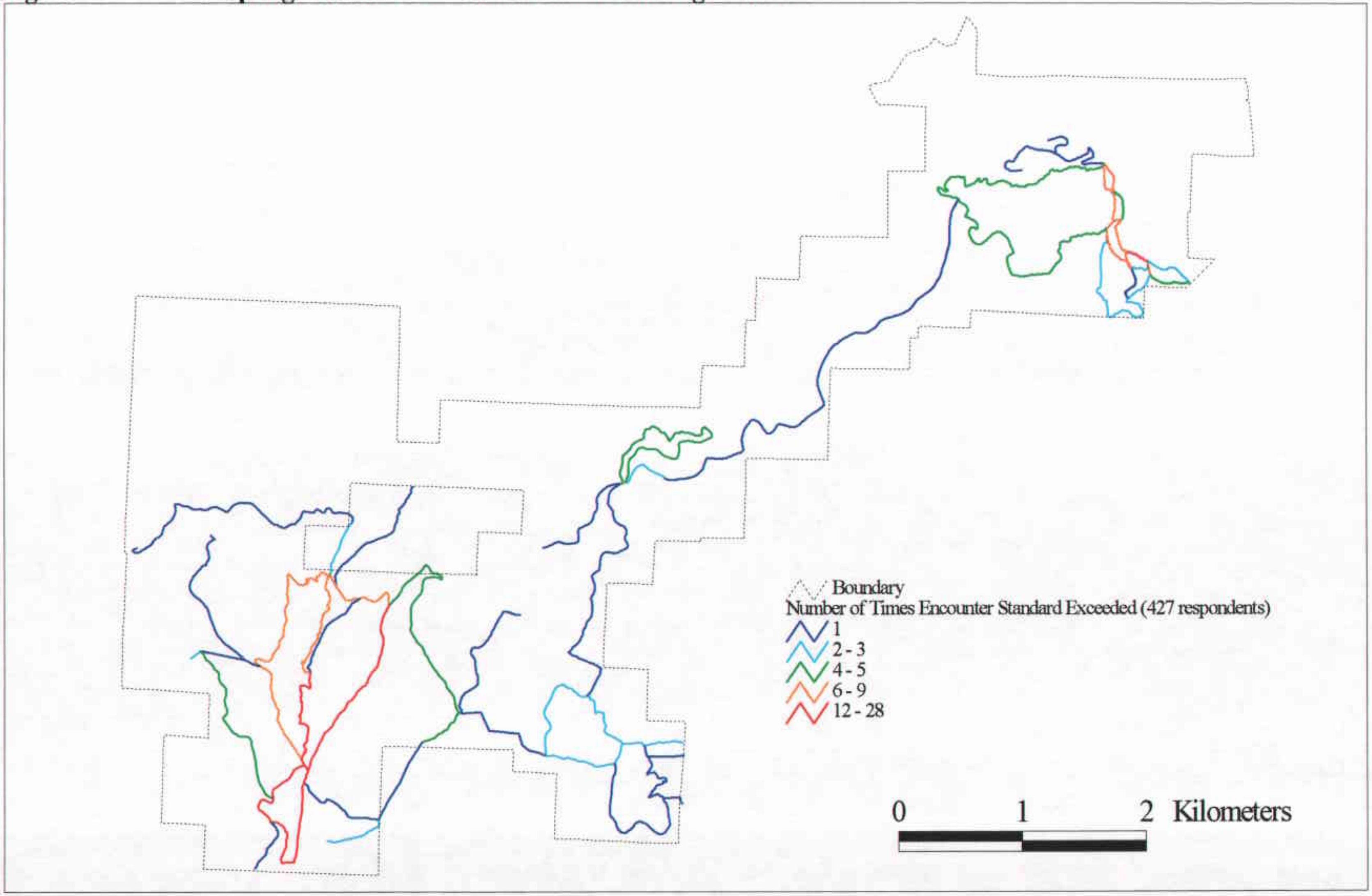


Table 4-8. Anova results for number of groups seen and percent of time in sight of others while in McDonald Forest: by recreation activity.

Variable	Do means differ?	F-Statistic	P-Value Significance
# groups seen	No	0.6	0.7023
# groups OK to see	No	0.8	0.5235
% time in sight of other groups	Yes	2.5	0.0394
% time acceptable in sight of others	No	0.7	0.5718

Figure 4-17. Fall and Spring Locations of Encounter Standards being Exceeded.



used in this analysis. The Oak Creek area shows the highest incidence of standards being exceeded, with moderate to high levels. Several road and trail sections just north of the Peavy access gate also exhibit moderate to high-moderate levels of standards being exceeded. Roads and trails to the east of Lewisburg Saddle exhibit low-moderate to moderate levels of exceeded standards. The remainder of the forest has low to low-moderate levels.

Fall and spring results are presented in Appendix F. Although the number of useable responses was similar in the two seasons (189 in fall and 238 in spring), the spring season witnessed an increased percentage of people reporting their standard being exceeded (9% in fall and 17% in spring). The fall season has moderate to high levels of standards being exceeded in both the Oak Creek and Peavy access gate areas, with moderate levels in the segments west of the Lewisburg Saddle. The spring season has high-moderate to high levels in the Peavy access gate area and also surrounding Oak Creek.

GIS Analysis of Percent of Time in Sight Results

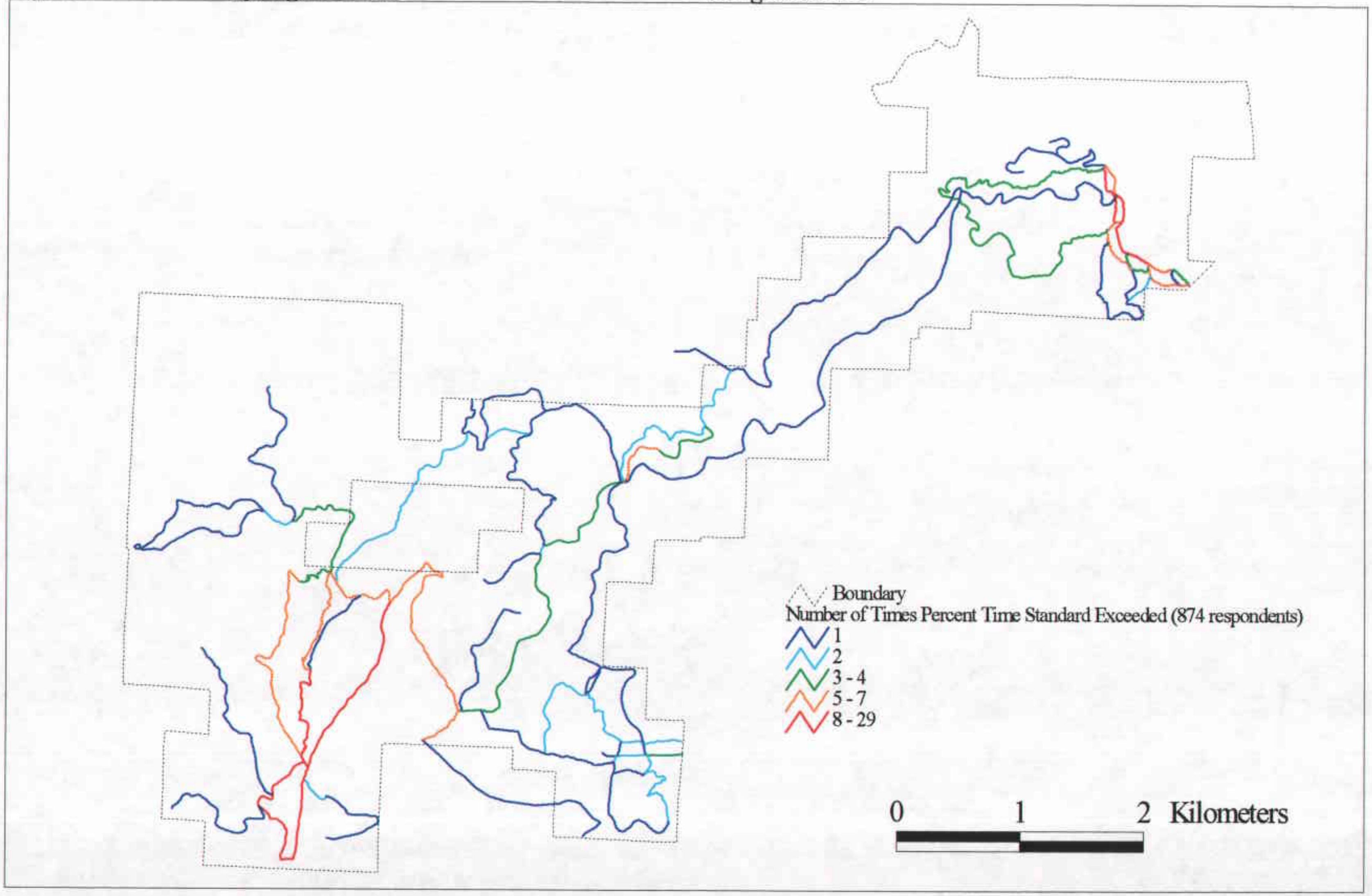
In a question related to encounters, survey respondents were asked to indicate the percent of time they spent in sight of other groups. An accompanying standards question also asked them to report what percentage of time in sight would be acceptable. This question was also only asked of those taking the survey during the fall and spring seasons. Unlike the encounter question, respondents were not allowed the choice of selecting “it doesn’t matter to me” as a response. The number of people who reported their standard being exceeded by the percent of time spent in sight of other groups was calculated for each road and trail section.

Figure 4-18 displays the raw numbers of those who reported having their standard exceeded during the fall and spring seasons. There were 874 useable responses to this question. Oak Creek and the Peavy access gate areas had high-moderate (5-7%) to high occurrences (8-29%) of standards being exceeded. Another high-moderate occurrence is located east of Lewisburg Saddle. Other areas represented fall in the low to moderate categories. Figures representing the responses for the individual fall and spring seasons are presented in Appendix G. Similar to the encounter results, the spring season has a higher number of responses (481 to 393 for fall) and a higher percentage of those reporting their standard being exceeded (8% to 5% for fall). The fall survey has moderate to high levels of standards being exceeded in the Oak Creek, Lewisburg Saddle, and Peavy areas. All other areas are low to low-moderate. The spring season has high-moderate to high levels in the Oak Creek area and low-moderate to high-moderate levels in the Peavy area. All other areas are low to low-moderate.

Route Frequency And Reasons For Selection Of Route

Respondents surveyed during the fall and spring seasons were also asked to list how many previous times they had been on the route they took during that day's trip to the forest. In addition, they were asked to list the two most important reasons for

Figure 4-18. Fall and Spring Locations of Percent of Time Standards being Exceeded.



choosing the route. Of those who responded to this question (n = 830), about 26 percent reported never having been on the route before, 30 percent had been on it between one and five previous times, 12 percent between six and ten times, 11 percent between 12 and 20 times, and 21 percent reported greater than 20 times. The average previous number of visits was 18 times (s.d. = 29.07).

Of those who listed a primary reason for the selection of their route (n = 819), the six most common answers were proximity to the forest (14 %), quiet (11 %), exercise (10 %), companions (8 %), topography (7 %), and discovery (7 %). Among those gave a secondary reason (n=521), scenic values (15 %), solitude (12 %), easy terrain (9 %), exercise (8 %), and topography (8 %) were the most common answers.

CHAPTER 5. FOREST MANAGEMENT APPLICATIONS

This chapter presents spatial exercises that employ the use density data as reported by survey respondents. The previous chapter presented tabular and GIS-created map generalizations of the data and considered some issues related to recreation impacts. The density information contained in the GIS database represents an important data baseline and can be accessed for a variety of applications.

The following sections present applications that analyze the density information to estimate impacts on forest visitors. Four impacts are considered: harvesting of a stand, a road closure, a controlled hunt, and the distribution of dogs throughout the forest. Each of these applications represents an issue that is of current concern to McDonald Forest staff.

All analysis results are derived from the user density GIS themes that were generated through the dynamic segmentation process. The creation of these coverages is described in more detail in Chapters Three and Four. In some cases, additional GIS coverages were obtained from the McDonald Forest GIS Coordinator. These are noted in the application descriptions. For each application, a brief synopsis is provided of the process involved in generating results.

Harvesting of a Stand

Previous research suggests that the quality of outdoor recreation is influenced by the visual quality of the forest landscape (Vining et al. 1984, Ruddel et al. 1989, Hull 1988). Nearly all national and state-managed forests require that scenic values be taken into account in management planning and activities (McCool et al. 1986). The McDonald-Dunn Forest Plan requires that visual impacts be taken into account in planning harvesting activities (Oregon State University 1993b).

Timber harvesting and its associated activities have considerable potential for modifying the visual appearance of forested ecosystems. These modifications include fewer trees, eroded soils, destruction of ground cover, creation of roads, and increases in dead and downed wood, also known as slash. Results from past studies indicate some common trends. In general, it has been found that older forests are generally preferred over younger ones, natural looking or slightly disturbed stands over obviously disturbed, and partial cutting methods instead of clearcuts (Ribe 1989, Brunson and Shelby 1992). The impact of harvesting activities on McDonald Forest visitors is underscored by survey results reported in Chapter Four. When asked to list the scenic features that detracted the most from their experience, survey respondents listed clear cuts and logging activities as the two primary causes.

When planning potential harvests, managers should consider the number of visitors who might come into visual contact with affected areas. If large numbers are potentially affected, methods should be considered which minimize visual impacts or perhaps other sites should receive consideration as alternative locations. If a harvest must take place adjacent to a high-use recreation corridor, managers might want to consider routing visitors through other parts of the forest.

The following example presents a viewshed analysis of a proposed harvest in a stand located southwest of the Lewisburg Saddle area. To conduct the analysis, a stand GIS coverage and a digital elevation model (DEM) coverage were obtained from the McDonald Forest GIS database. The DEM is a raster-based coverage that represents elevation in the forest at a 30-meter resolution (Figure 5-1). Figure 5-2 presents a shaded relief representation of the DEM and the location of the stand that is being used in this analysis. Using the viewshed function in ArcView's programming language, Avenue, all areas in the forest that have a view of the stand and are within a two-mile radius of the stand are identified through a visibility analysis (Figure 5-3). While this is a computationally intensive process, it can be accomplished on a personal computer. The visibility analysis described here required approximately 45 minutes of processing time on a personal computer. This exercise assumes that the vision of forest visitors will not be affected by stands surrounding their path through the forest or surrounding the proposed harvest.

The area returned by the visibility analysis is converted into a single polygon coverage and overlaid on the road and trail network to identify the roads and trails in sight of the harvest and also within a two-mile radius of the stand borders (Figure 5-3). The coverage representing the area in view of the stand was overlaid on the user density coverages from each of the three seasons. A spatial database query of the user density coverages returned the percentage of users for each season that would fit the visibility requirements described above. The percentage of survey respondents whose routes intersected the area in view was 39 percent, 36 percent, and 41 percent, for the summer, fall, and spring seasons, respectively. Multiplying this percentage times the estimated use totals for these time periods results in an estimate of 20,862 visitors potentially being in view of the stand over the three season time period.

Figure 5-1. Digital Elevation Model of McDonald Forest.

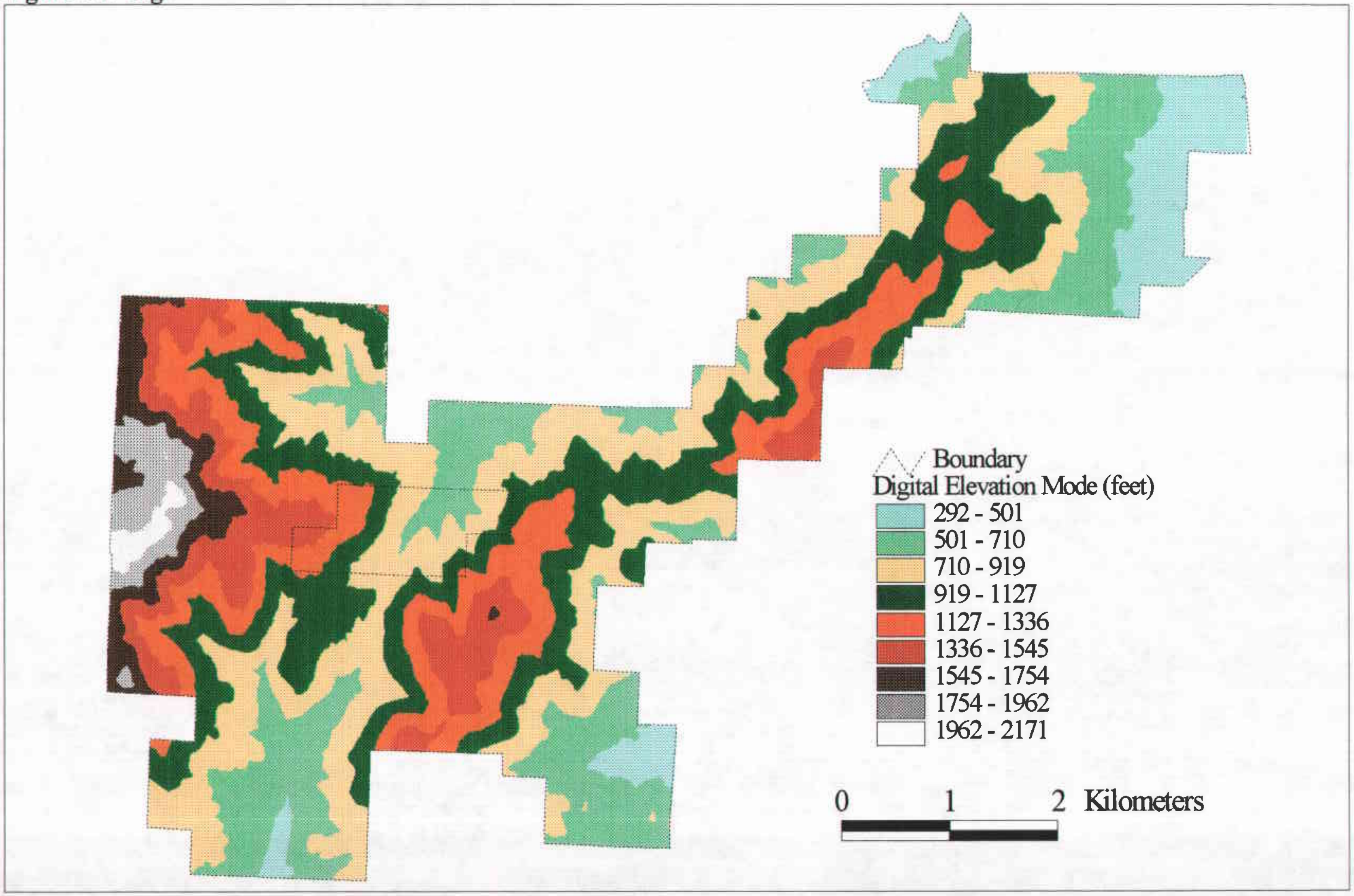


Figure 5-2. Shaded Relief Representation of McDonald Forest.

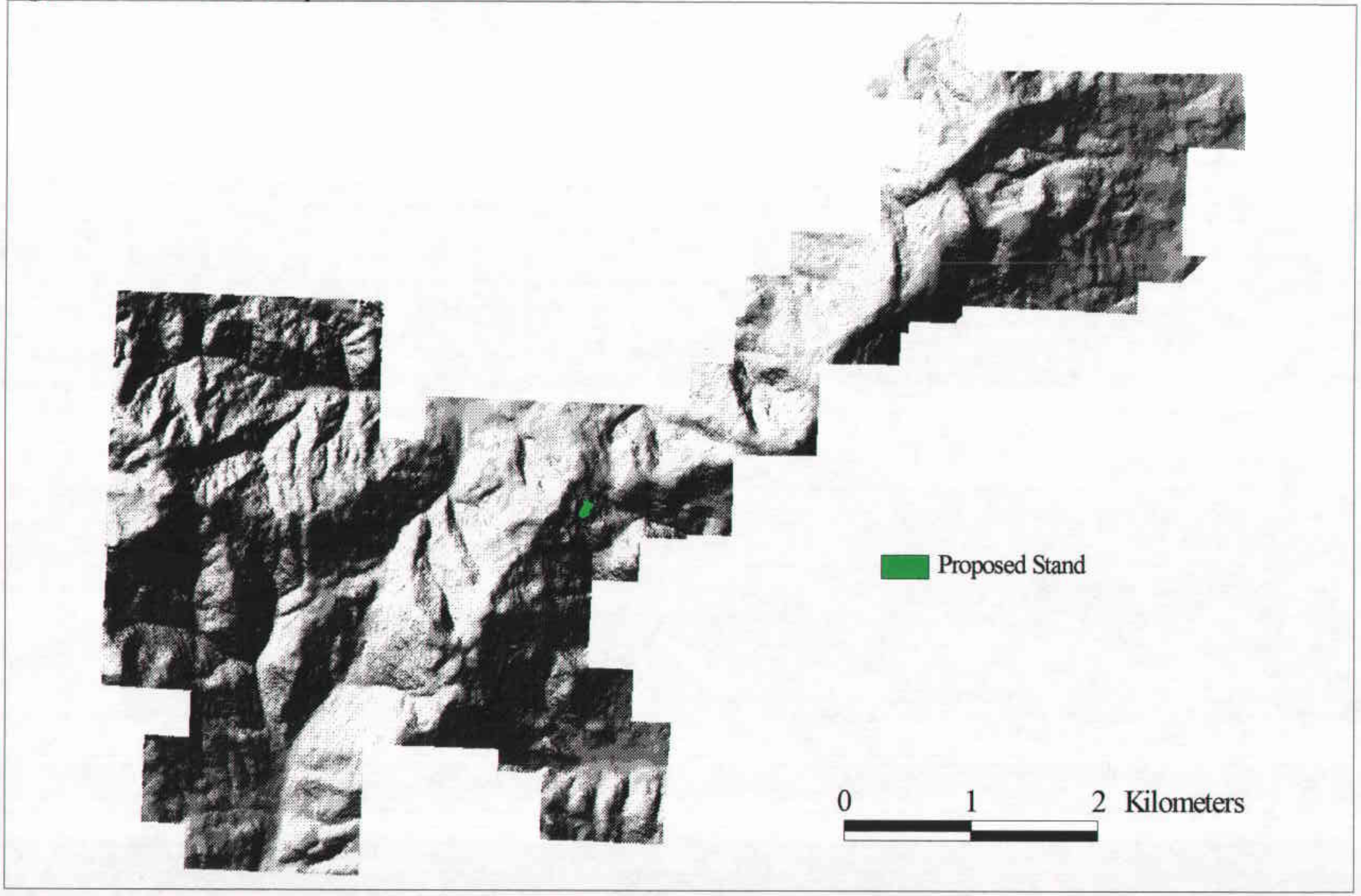
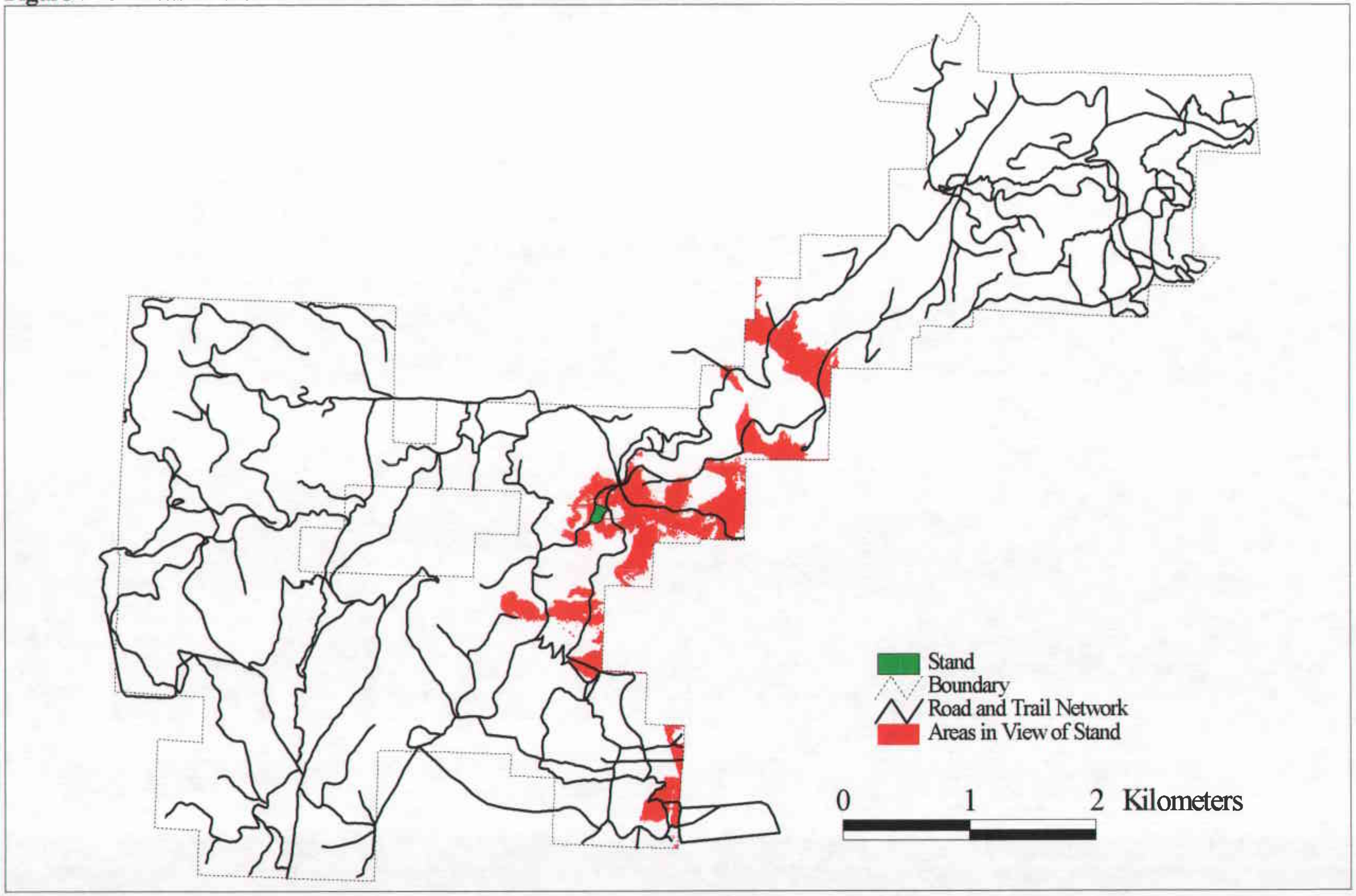


Figure 5-3. Areas in View of Stand and within Two Miles of Stand Borders.



The proposed stand is in a highly visible location in the forest. The figure of 20,862 is nearly 40 percent of the estimated total for the three season survey period. If this were an actual planned harvest, forest staff should consider techniques that minimize the visual impact of harvest results. Given the visibility of this stand, it may make sense to consider other stands.

Road Closures

Harvesting and maintenance operations in the forest occasionally force road closures. Depending on the popularity of the road, closures have the potential to impact the experiences of many visitors. When these situations arise, managers might be better served by knowing in advance how many forest visitors could potentially be affected. If the number appears large, managers might delay road closures until times of less use density or plan on keeping part of the roadway open for visitors to pass by. Another alternative may be to redirect visitors to other routes through the use of information on signboards located at access points. In the following example, a road segment located on the Nettleton Road (eastern side of Lewisburg Saddle) has been selected for hypothetical closure during a weeklong period in April.

To provide an estimate of the spring total use, density information was generated from the GIS database. The number of users who used the road segment during the spring season was derived through a spatial database query on the coverage containing use estimates. This involved using a GIS to select the road segment and return the total estimated use of this road by visitors during the spring season. This produced a total of 1,704 visitors. It was estimated that approximately 18,744 people visited the forest during the spring with 48% (8,993) visiting during the weekdays and 52% (9,750) visiting during the weekends (these results are listed in the previous chapter). Multiplying the weekday and weekend use percentages times the total of users on the road segment produces figures of 817 visitors during the weekdays and 886 during the weekends for spring. There were 66 weekdays and 26 weekend days during the spring survey season. Dividing the user totals by the number of days gives an estimate of 12 visitors per weekday and 34 visitors per weekend day for this roads segment. A week's road closure results in an estimate of 128 visitors being impacted by the road closure. Figure 5-4 presents the location of the road segment.

Deer Hunt

McDonald Forest hosts several hunts annually. During 1997, four authorized hunts occurred: a turkey hunt, a deer bow hunt, a controlled deer hunt, and a controlled anterless elk hunt. Hunting areas are confined to the northwest portion of the forest which effectively creates a no-hunt buffer strip between the forest and its urban interface (see Figure 5-5). The McDonald Forest staff is concerned about the safety of both hunters and recreationists during these events and takes precautions to mediate problems. Notices that announce the hunt and maps of the hunt zones are posted at forest entry points. During controlled anterless hunts, check stations are established and staffed by volunteers and forest staff. Check station workers ask that

Figure 5-4. Road Closure Example.

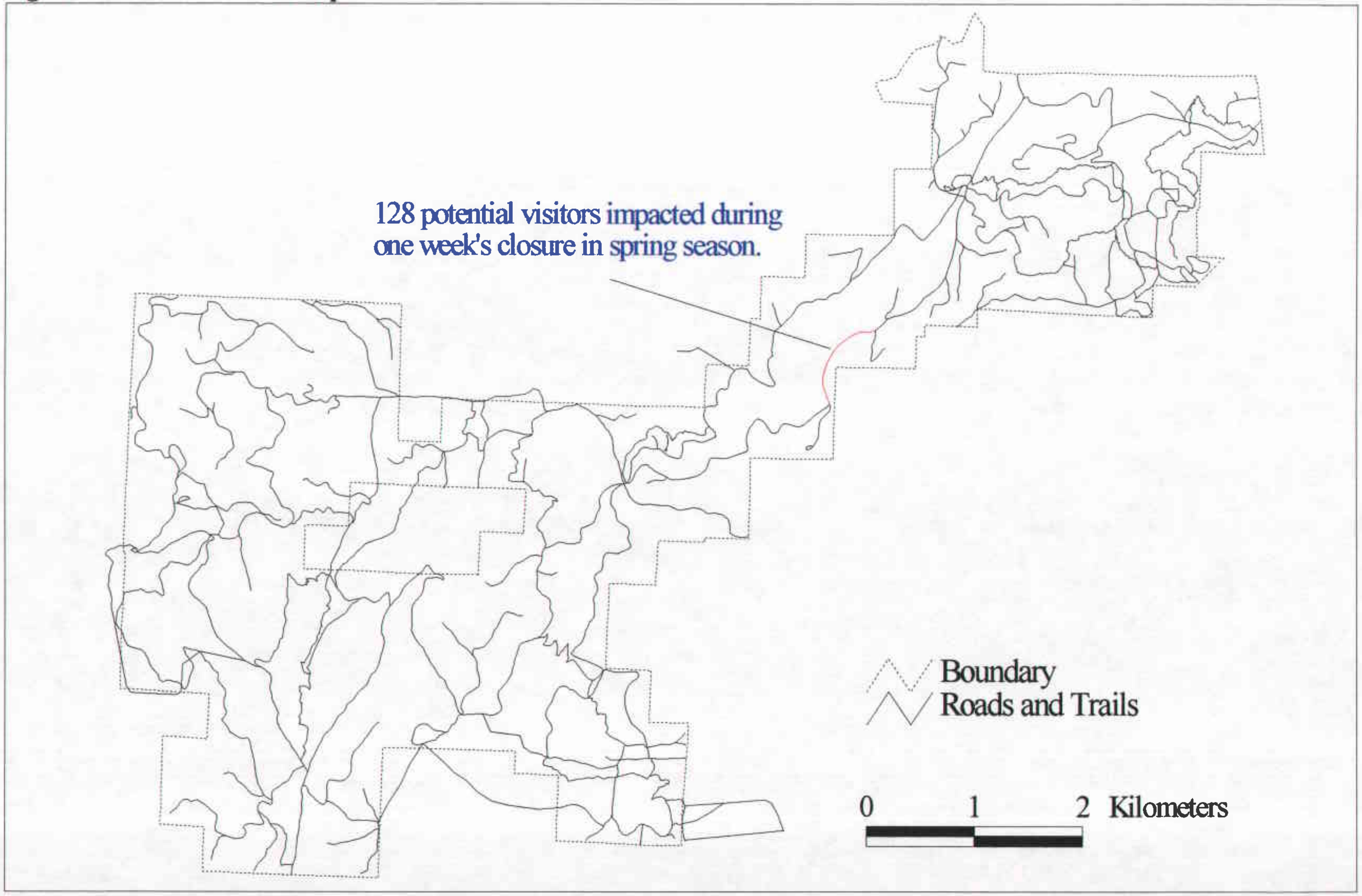
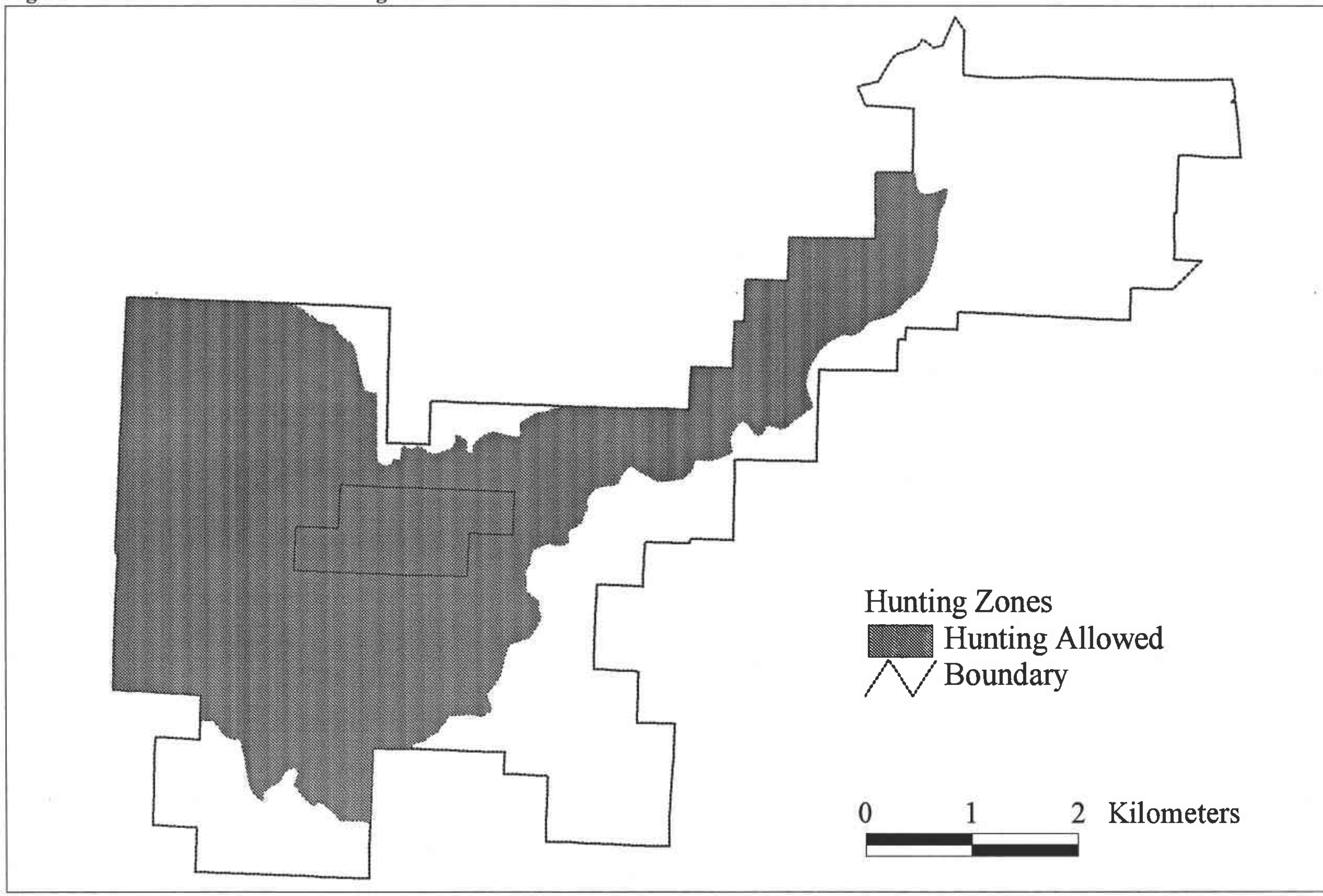


Figure 5-5. McDonald Forest Hunting Zones.



hunters carry the hunt zone maps and make sure that recreationists are aware of the hunts. Recreationists are asked to wear bright clothing should they enter the forest during hunts. Additionally, enforcement patrols are requested from the County Sheriff's and State Police Offices.

Information about the number and types of visitors that normally frequent the hunt zones may be beneficial not only to forest management but also to hunters. Knowing density counts can help the forest in making decisions on where to place check points and what level of effort may be needed to inform visitors about the hunt. Density distribution maps could help guide safety patrols in selecting roads and trails where visitors are most likely to be found. Density maps might also assist hunters in avoiding heavily-used roads and trails or being able to anticipate when encounters with visitors is more likely to occur.

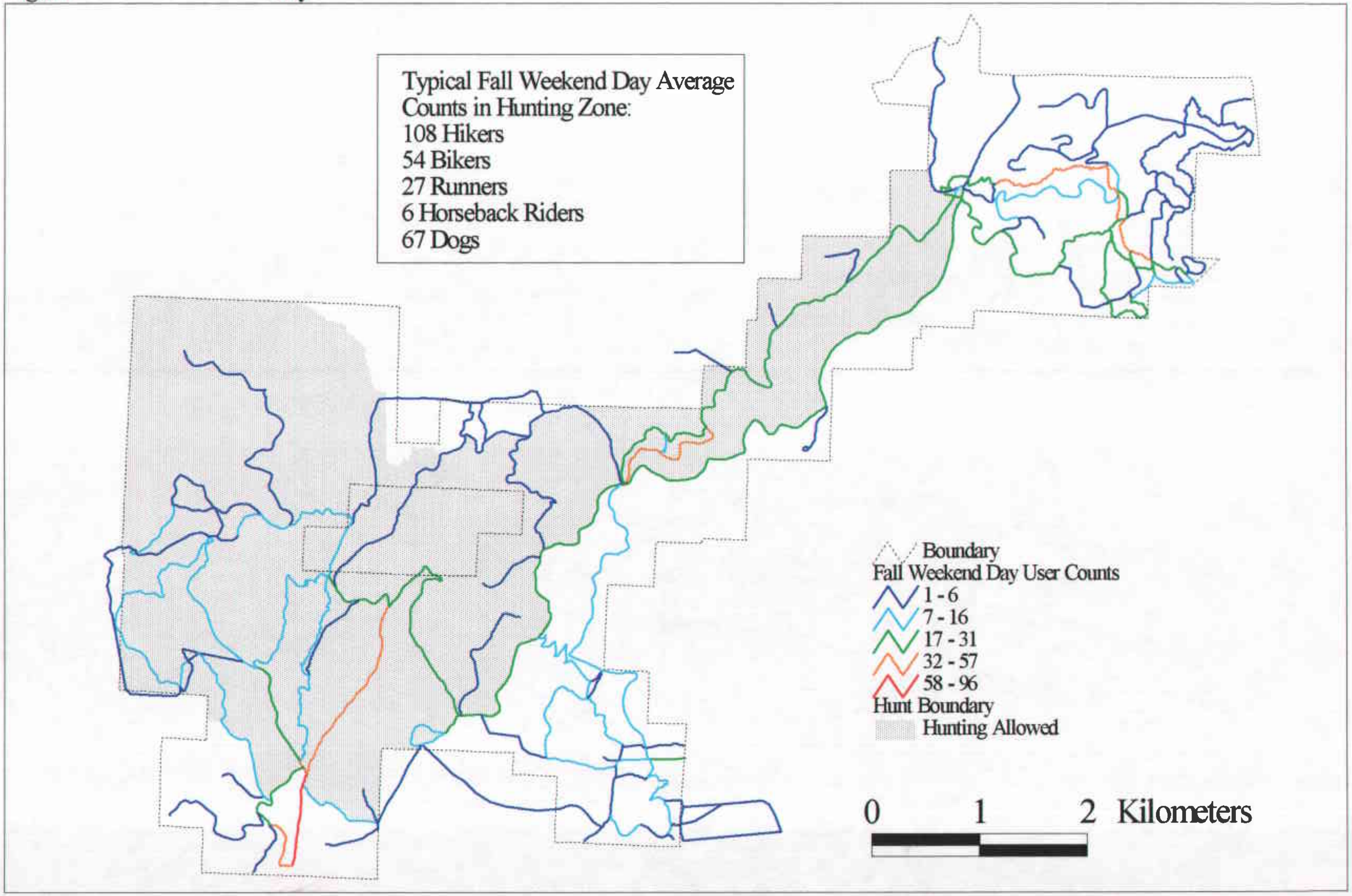
The controlled deer hunt for 1997 occurred during three weekends in December for a total of six days. To estimate the number of visitors that frequent the hunt zones during typical fall weekends, a polygon coverage of the hunt areas was created and overlaid on the road and trail network. The number of visitors was calculated through a spatial query of the overlay results. Approximately 78% (313) of the 399 people surveyed during the fall season reported being on at least one of the roads and/or trails within the hunt area. The user composition is 54% hiker, 37% biker, 13% runners, and 3% horseback riders. In addition, there were 105 dogs reported in the company of this group (34% of the user total). The total estimated usage for the fall season was 10,850 visits with approximately 52% (5,599 visits) of this use occurring on weekends. There were 22 weekend days during the fall survey season. The estimate of total use in the hunt area per weekend day in the fall is 200 visits (5,599 visits * 78% / 22 days). On average, it is estimated that this would include 108 hikers, 54 bikers, 27 runners, 6 horseback riders, and five others involved in various activities (photography, insect collecting, mushroom collecting, and camping). Using the average of 34%, it is also estimated that there would be 67 dogs accompanying the users in the hunt areas. Figure 5-6 demonstrates the estimated average use densities for each road and trail segment within and surrounding the hunt area for a typical fall weekend day.

Distributing the map presented in Figure 5-6 to hunters for use during the hunt may help make them more aware of the need to practice caution during their outing. While it is likely that the actual use numbers will be less than average during a hunt due to people choosing to recreate elsewhere, the map shows that some roads and trails within the hunt boundary are popular routes under normal conditions.

Dog Density Mapping

Dogs have come to be an emerging issue in McDonald Forest (Deagen 1997). The number of complaints has been growing and has concerned safety, wildlife, and waste issues. These occurrences may lead to a re-examination of the current forest policy of allowing dogs to go leash-free. This rule is said to apply to dogs that are under voice-control by their owners. During the time of this survey (1993-1994), dogs did not appear to be a significant problem. The mail-survey (Wing 1996) included a set of questions that asked respondents if they had noticed a particular impact and if

Figure 5-6. Fall Weekend Day Use Estimates.

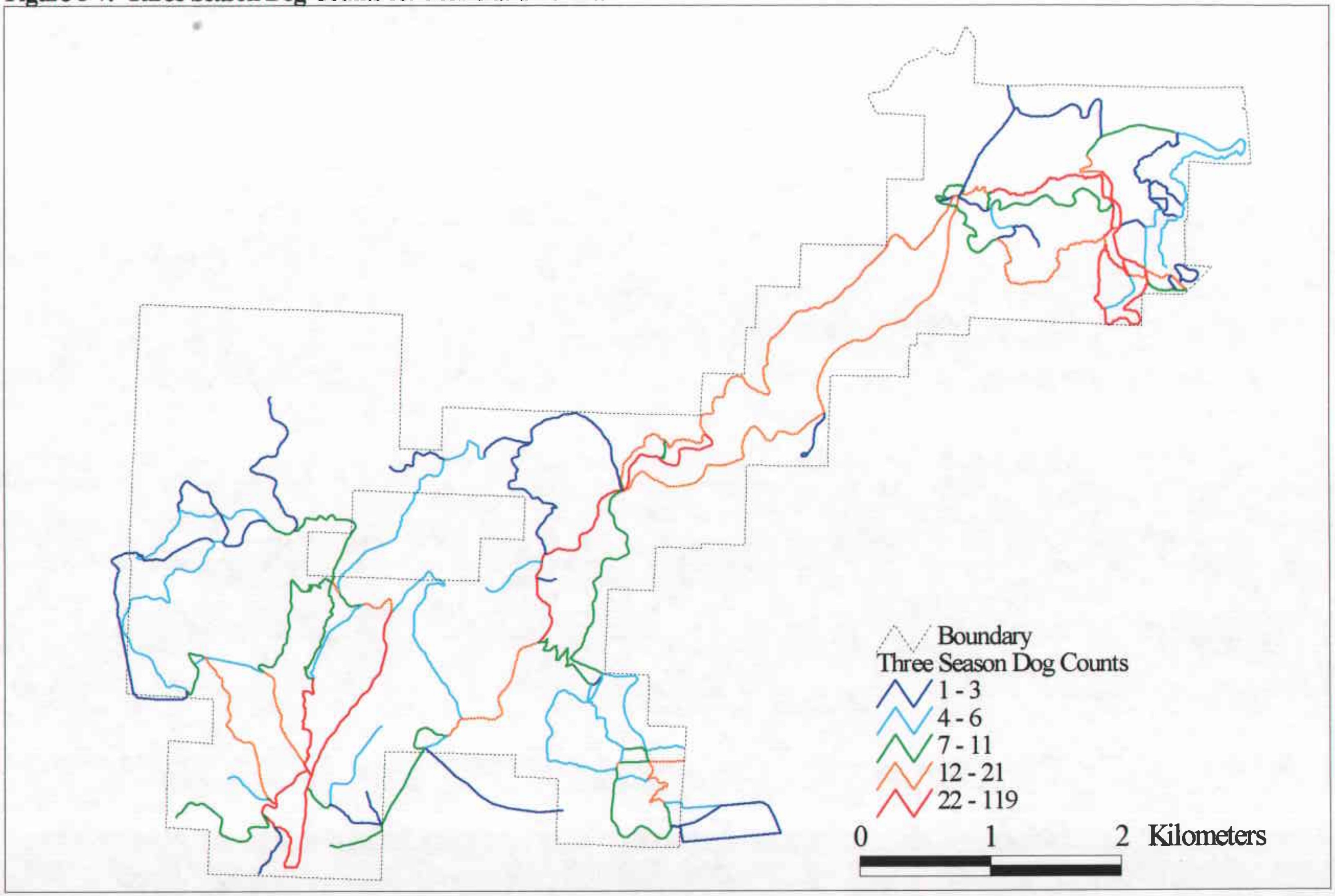


so, to what extent they believed it was a problem. One of the items was "uncontrolled dogs". While just over 40 percent of the respondents to this set of questions reported that they had noticed uncontrolled dogs, the mean response to this impact indicated that it was considered a "slight problem."

If dogs are considered to be a growing problem, forest staff could concentrate on educating visitors who bring their dogs to the forest. By installing signboards at areas of high dog density, dog owners might be instructed that their dogs must be under control at all times. Information might include the possibility of revoking the no-leash rule. In addition to user densities, data collection for this study included tracking the number of dogs that accompanied visitors to the forest. Assuming that dogs more or less accompanied their owners on the route that was indicated by each survey respondent, a dog density map can be constructed for the three survey seasons. Figure 5-7 presents the results of this analysis.

Similar to the density of users, the map in Figure 5-7 shows that three areas tend to feature the highest dog counts: Oak Creek, Lewisburg Saddle, and Peavy Arboretum. Forest staff could target the roads and trails in these areas as locations to post signboard information or places to post observers to monitor for potential conflicts. The map might also be helpful in locating dog clean-up stations where materials and receptacles for waste are distributed. If a leash rule is to be considered, forest staff could consult the use density and dog density maps to designate portions of the forest where leashes are required. Designating leash zones in areas of high-use and high dog density might alleviate potential conflicts.

Figure 5-7. Three Season Dog Counts for McDonald Forest.



Summary

This chapter provided some examples of how the use density database might be used to answer research questions concerning forest impacts on visitors. Applications were presented that demonstrated the versatility of the database in calculating the densities of affected parties. Harvesting, road closures, hunting, and dog presence are issues that are of current concern to the forest staff. These issues will likely remain important and contentious in the future. The use density database can assist in clarifying these issues by providing user statistics. The results can be used in planning and management efforts. For future considerations, the use density database lends itself to almost any spatial overlay process in McDonald Forest. As other issues emerge, it can serve as an information resource.

CHAPTER 6. DISCUSSION

Cole (1989, p. 146) examines the role of geographers in recreation ecology and writes:

> "One area of needed work is in developing the potential of geographic information systems (GIS) to aid recreation management. Most land management agencies are purchasing GIS hardware and software, but little consensus exists on what inventory data to collect, how to model linkages between inventory variables, or what types of output are useful. The potential is obvious; realizing that potential will be a challenge."

Cole's prophecy of challenge continues to hold true nearly a decade after writing this statement. While GIS applications to recreation have progressed since study descriptions first began appearing in literature ten years ago, there is a need for greater refinement in research efforts in this area. Demonstrating and documenting GIS methods in the field of recreation research will be fundamental in realizing the potential that Cole advocates.

This study presents a methodology for utilizing GIS to address impacts and standards often used in recreation research: use densities, conflicts, crowding, encounters, and percent of time in sight of others. It also demonstrates how forest managers might utilize density information to address harvesting, road closures, hunting, and concerns about dogs. The methodology is offered to illustrate how data collected in recreation research might be used to add a spatial component in recreation management. This approach has the potential to make information collected through surveys more specific to the resource and offers flexibility in the number of ways in which it can be employed.

While a handful of previous studies have directly addressed this issue (Confer et al. 1992, Harris et al. 1995, Gimblett et al. 1997), the need for additional spatial applications in analyzing recreation data has been recognized by many others (Stankey et al. 1976, Cole 1989, Manning and Lime 1996, Meighen and Volger 1997). The methodology offered here is in response to this need and is intended as a blueprint for others interested in this area. The following sections provide an overview on results of the survey, then discusses the successes, limitations, and possibilities of the GIS methodology. Recommendations for researchers wishing to conduct spatial analyses are provided.

Survey Results

The results of the survey questions suggest that during the 1993-1994 survey season, the impacts of recreation activities in McDonald Forest were acceptable to the majority of those who were surveyed.

About three percent (n = 49) of those surveyed reported a conflict during their experience. While this figure may appear to be low at face value, conflicts are often traumatic and can ruin an outdoor experience. The 16 percent of those who felt crowded was one of the lowest when compared to results from other studies that asked the same question. Statistically significant differences were detected between the crowding percentages reported between access points and between weekdays and weekends. These findings are in accord with previous research that suggests crowding scores will vary by location and by time of use (Shelby et al. 1989).

Survey respondents reported that on average, impacts for encounters and percent of time in sight of others did not exceed their reported standards. Significant differences were detected in responses to both impacts when analyzed by access point and weekday vs. weekend. These differences are to be expected since use levels were found to vary dramatically at the access points and during the week. Differences were detected in responses between the activity groups (hiker, biker, runner, horseback riders, and others) for percent of time of sight of others but not for number of encounters. This finding may be a reflection of the different natures of the activity types in the relatively low-density experience provided by McDonald Forest. One explanation may be that while bikers and hikers may meet the same number of other users, bikers travel at a faster pace and spend less time in sight of others. Reported standards were not found to be significantly different between activity groups, access points, or day of week. The stability of the standards in this study reinforces the saliency of using standards in recreation management. Studies have found that standards tend to be consistent for some types of experiences, particularly those in low-density settings (Shelby 1981, Shelby and Vaske 1991, Vaske et al. 1993).

While these results suggest that recreation conditions were acceptable to the majority of those surveyed, some considerations need to be taken into account. The GIS figures revealed that use density, conflicts, and reported impacts tended to increase in areas surrounding the access sites. This trend was not as clearly observable in the perceived crowding map, but the low number of observations for some road and trails sections may have influenced results. The Oak Creek, Peavy Arboretum, and the Lewisburg Saddle areas were receiving levels of use that sometimes challenged or exceeded user preferences, particularly on weekends. If use levels continue to rise, it is likely that conflicts, perceptions of crowding, and standards being exceeded will also increase. These increases will probably be the most pronounced in areas that already experience high use.

During the 1993-1994 survey year, it was estimated that McDonald Forest experienced 64,272 visits. Another user count was conducted at the Oak Creek access point in order to assess changes in use during the summer season of 1996. A systematic sampling scheme was designed and followed in accordance with the 1993-1994 data collection process. In comparison to the summer season data collected in 1993, use had increased about 25%. This represents an annual average of just over 8%. If this growth rate occurred uniformly throughout the forest and was applied to the 1993-1994 estimate of 64,274, a use figure of **80,582** could be estimated for the 1996-1997 (June-June) season.

This figure is conservative and only uses data collected at the high-use access points. It does not include the multitude of access points located around the perimeter of the forest that may be adding tens of thousands of visits per year and increasing in size.

Recommendations for Future Monitoring

With indications of increasing user density, it is important that McDonald Forest receive the monitoring attention set forth in the McDonald-Dunn Forest Plan (1993b). In addition to satisfying the requirements of this plan, a monitoring system would offer the opportunity for pro-active management of the forest regarding recreational use. While there are several strategies available for monitoring recreation conditions, the most accurate and reliable method would be to continue with periodic on-site surveying of forest visitors. Allowing a minimum of two to three years between surveys, so visitors are not overwhelmed, will be helpful in garnering useful results.

Although there are numerous entry and exit locations surrounding the forest, those areas and times that continue to serve as the focal points for use should continue to receive the bulk of attention during survey periods. Based on the results of this study, Oak Creek, Lewisburg Saddle, and the access gate at Peavy Arboretum are places that merit future monitoring. A site of secondary importance to those listed above would be the Jackson Creek access gate. These sites, even though they do not account for all of the recreational access of McDonald Forest, draw considerable usage and probably account for the majority. If monitoring is continued in these areas, usage totals and survey responses can be directly compared to the results of this study to determine if recreation conditions are changing.

The selection of sites for future monitoring should also attempt to take into account the anticipated increases in forest use and any other perceived recreation concerns that develop. Locations that show signs of periodic heavy use, such as the Walnut Hill and Chip Ross Park areas, may require monitoring. Related to this, it may also be advantageous or necessary to identify areas of high-use that occur inside the forest, away from the official and unofficial entry points. Monitoring at these sites may yield helpful data.

Study results also support the notion that weekends tend to be times of higher activity in the forest. The majority of research efforts should be allocated to weekends unless changes in this use pattern are detected.

Comparison of Regular and GIS Methodologies

Results of the GIS analyses were presented in the previous two chapters. In Chapter Four, GIS-produced figures accompanied tabular results of the same data. This provided a direct comparison between a traditional representation of recreation data and one involving a spatially explicit component. The GIS figures added to the tabular results by identifying the actual locations in the forest associated with response categories. This is an improvement from typical results that would state "the forest receives 65,000 visits per year" or "there were 49 conflicts reported by users."

The traditional methods of analysis are not without a spatial component. Results can be presented with reference to the survey point at which the information was collected. Table 4-1b presented use estimates for those entering at one of the five high-use access points. Although this is an acknowledgement of a spatial comparison, it still provides information for only five points of contact and does not provide a measure of spatial distribution throughout the forest. Figure 4-1 lists the activities by percentage of those who were surveyed. While this provides useful information regarding activities in the forest, it does not relate much information on where the activities are taking place. The GIS figures allow managers to go beyond these limitations and use the GIS information presented in this study to guide their efforts.

Figure 4-7 lists total use estimates for all roads and trails within the forest. This demonstrates the popularity of certain corridors and routes and provides a quick means for discerning forest density patterns. Figures 4-3 through 4-6 present density information for the four main user groups. The figures demonstrate that use is particularly heavy in the road and trail segments that surround the Oak Creek, Lewisburg Saddle, and Peavy Arboretum areas. Figures 4-10 and 4-17 demonstrate that conflicts occur and encounter standards are exceeded more often in these portions of the forest. If problems occur, these figures help to identify where they might be expected. The areas that exhibit unacceptable patterns of recreation impacts should receive continued monitoring to ensure that forest management is providing for acceptable recreation conditions. These figures show where these activities are most likely to occur and again provide a barometer for assessing density and activity patterns.

The density maps may be particularly helpful to forest management. High use areas pinpoint the roads and trails that should receive careful attention in monitoring and maintenance efforts. Additionally, forest operations should probably avoid these areas, when possible, if impacts to visitors are to be minimized. Operations that must occur in high use areas could be scheduled during low-density use periods such as weekdays and mornings or winter months. Additionally, the forest could make sure that closures or operations that occur in high use areas are well advertised at trailheads. Suggesting alternative routes may also be helpful. In general, these figures can assist in providing management direction and a justification for efforts.

The applications that were presented in Chapter Five provided some examples of how spatially referenced density information might be used to predict recreation impacts. The viewshed application estimated the number of forest visitors that would potentially be in sight of a hypothetically harvested stand. The stand unit was located southwest of the Lewisburg Saddle. Over the course of a survey year (a survey year excludes winter), it was estimated that nearly a fourth of the visitors could be in sight of the stand. A road closure analysis revealed that about 128 people would have their routes interrupted should the road be closed for a week's time during spring. A controlled deer hunt was predicted to impact about 200 people and 67 dogs per weekend day during the fall season. Included in this figure were 108 hikers, 54 bikers, 27 runners, and six horseback riders. A dog density analysis predicted that dog presence, like human presence, is most pronounced at the major access points. Should forest staff wish to inform dog owners of concerns or potential changes to the no-leash policy, many dog owners could be reached by targeting the areas around major access points.

These applications demonstrated the utility of having baseline data available. Forest managers faced with decisions regarding scenic values and operations that might detour or stop forest visitors from using resources should benefit from having information regarding the number of people impacted. Without this level of spatial detail managers are left with making or soliciting "best guesses" from others.

Other Potential Uses

Recent articles in the Corvallis newspaper have reported on conflicts between recreation and forestry experiments in McDonald Forest (Sanders 1997a, Sanders 1997b). A 1996 survey of Oregon State University researchers found that 48 percent reported experiments being vandalized (Torres et al. 1996). Researchers planning experiments in the forest might find the use density maps a useful tool in choosing study sites. If experiments are sensitive to human disturbance, they should be located away from the high-use areas to minimize interactions with forest visitors. Experiments that can't be confined to low density use areas should receive extra vigilance from researchers. Additional monitoring efforts may be required to ensure that unwanted perturbations are not introducing confounding influences on study results. A spatial representation of vandalism occurrence as reported by researchers could be a future effort that also might help guide researchers in selecting study sites.

One application that has already proved fruitful has been the creation of a road and trail map with use estimate totals superimposed on the roads and trails. The map was plotted out on a D-size (34 by 22 inch) sheet so that the entire forest road and trail network could be displayed while maintaining the legibility of the use numbers. Using this plot, forest managers can now quickly get an idea of how many visitors a proposed project or policy may impact. One recent project would have closed down a trail located along a high-density recreation route (Deagen 1997). The recreation forester presented the use density map to the project engineer. Based on the high-use estimates in this area, alternative plans were discussed. A potential solution was to leave enough space on the trail for recreationists to pass through.

Another potential application involves the justification of the selection of character trees. Character trees are defined in the McDonald Forest management plan as large, aesthetically appealing trees (Oregon State University 1993b). A forest-wide goal contained in the plan states that "large, old trees possessing unique characteristics significantly different from other mature trees on the Forest should be selected, branded as character trees, and protected during project planning" (Oregon State University 1993b, p. 15). These trees provide shade and aesthetic diversity and serve as landmarks for recreationists. The plan regulates the number of character trees to no more than one merchantable tree per 50 feet of road or trail.

The relevance of the character tree concept is reinforced by survey results reported in Chapter Four of this study. When on-site survey respondents were asked to list the scenic features that contributed most to their enjoyment, the category encapsulated as "trees" was the number one response. Descriptions provided by respondents in this category included "old growth," "large trees," and "forest."

The recreation forester is charged with the responsibility of selecting character trees. Character trees are to be excluded from harvest operations and are thus non-merchantable, representing a potential loss of income. The use figure plot can assist in the justification of character tree selection. Trees near roads and trails that receive high-density use have an increased status as potential character trees. A GIS-generated visibility analysis or buffer area could be created around roads and trails.

This theme used in conjunction with density results might help to identify the trees that are likely candidates for character tree status.

The delineation and representation of character trees could be accomplished within a GIS database. Locations could be captured using a Global Positioning System (GPS) and input into a GIS. The GIS could not only store and create a permanent record of locations but also help regulate the limit of one merchantable tree for every 50 feet of road or trail.

GIS Capabilities and Flexibility

Modern GIS packages offer tremendous power in manipulating and displaying spatial data. The price of these packages and the hardware required to run them are within the reach of most organizations. All GIS results presented in this study were created using ArcView GIS on a personal computer with a Pentium 90 MHz microprocessor and 64 megabytes of RAM. The software sells for about $1,000 and the personal computer would cost approximately $2,000 at current prices.

The mapping figures displayed in the text and appendices of this study underwent several revisions before a final copy was made. The physical size of the figures was limited by the 8.5 by 11 inch page format. This required that results be presented in categories rather than superimposing individual counts on each road and trail segment. If individual counts are desired, such as the exact number of users or average crowding score each road and trail segment received, it would be a routine operation to plot results on a larger media source and plot the actual figures on the network. Users could then view the individual counts for the entire forest.

Once templates were created in ArcView for these maps, changing the colors, line thickness, and the method used for legend classification (quantile, equal interval, or natural breaks) were accomplished quickly. While this flexibility presents advantages to the GIS cartographer, map creators and users should be cautious in their deployment of mapping results. As Monmonier (1996, p. 2) writes: "a single map is but one of an infinitely large number of maps that might be produced for the same situation of from the same data." This statement underscores the ability of GIS cartographers to represent the same data set in numerous portrayals.

Limitations

As discussed in Chapter Three, the dynamic segmentation approach was an accurate tool for portraying and manipulating the road and trail density information as reported by survey respondents. A limitation of this approach occurred during the representation of conflict, crowding, and encounter data. Responses to these survey questions were assigned to the entirety of a respondent's route and may not have delineated the specific road or trail section where an impact was experienced. This limitation was not due to the technical capabilities of the dynamic segmentation tool but resulted from shortcomings in the data collected from survey respondents. The inconsistent ability of survey respondents to accurately locate a specific impact in a previous McDonald Forest study and troubles with recalling routes in the present study were also discussed in Chapter Three.

Improving the accuracy of spatially representing user responses to survey questions will require additional efforts from researchers. Researchers wishing to meet this challenge might consider focusing studies on areas with smaller extents or using large-scale maps printed on large format paper. Smaller survey areas might pose fewer constraints on the recall ability of users. Large-scale maps have the potential to illustrate an area in greater detail. This could also assist the cognitive ability of users, but increases material costs for researchers. The 11 by 17 inch map format used for this study resulted in roads and trails in the Peavy Arboretum area (the densest area of roads and trails in the forest) appearing visually crowded in some places. The majority of respondents asking for assistance in locating their routes were those surveyed in the Peavy Arboretum.

Another, more obtrusive, measure might include providing resource users with mapping materials prior to their experience and encouraging them to record impacts and locations during their outing. This approach has the potential to yield useful results but might introduce some undesirable outcomes. Being asked to carry survey materials would likely be objectionable to some users and consequently, survey participation might suffer. Their record keeping might also influence the experiences of those participating in this approach. Primarily, the goal of recreation research has been to capture the experiences of users under normal resource conditions. Methodological questions might arise as to whether the experiences being reported differ from those that didn't include record keeping.

There was also a potential bias in collecting data only at trailheads. Use density information presented in the figures demonstrates that the roads and trails surrounding the major access points received the highest number of visits. This is probably attributable to the popularity of trailhead features such as parking lots and forest information contained on signboards but may also be explained by survey location bias. An investigation of this process might include positioning survey locations within the forest, away from the major access points, but at intersections that appear to draw heavy use.

Data Collection

Data collection costs are typically high for any study that involves collecting information directly from the public. This project was no exception. In addition to the costs associated with having a researcher on-site to record use information and administer surveys, the transformation of data into a GIS-compatible format required extra effort. In particular, comparing the GIS-representation of user routes against the original hard copies completed by users was a painstaking process. These costs might be lessened through collecting fewer surveys (1,641 in the present study) or focusing on smaller extents of resources. Unfortunately, these concessions may hinder the ability of the survey to address important issues.

Another problem encountered in this effort was the GIS representation of the trails within McDonald Forest. Although the roads appeared to be correctly located, several problems were detected with positional accuracy of trails. With the inexpensive availability of GPS tools now available, researchers may want to consider geo-referencing the linear networks if an existing spatial network theme is of questionable quality. If an existing spatial database is being used, determining its heritage and accuracy should be a priority before data collection occurs.

As areas develop, transportation networks may also change. Since the time of data collection, two trails have been expanded and modified in McDonald Forest (Dan's Trail and the Calloway Creek Loop). This change did not negatively impact the GIS database because modifications included adding switchbacks and a short connecting path. However, road and trail systems that undergo significant changes may reduce the effectiveness of the original database and may require updating the GIS route information.

Statistical Analysis of Network Patterns

The lack of statistical tools for analysis of linear features hindered statistical inference of the use data. Spatial data represented in a GIS format can be described using three categories: point, line, and polygon or area. Point locations are zero-dimensional entities that can be referenced by a single set of coordinates. Examples could include well locations or trees. Lines represent linear entities such as roads or streams. Polygons are used to capture two-dimensional objects such as study plots or land ownership patterns.

The statistical analysis of spatial data can be described according to three categories: geostatistical, lattice, and spatial point patterns. Geostatistical data are derived from measurements taken at fixed locations. Lattice data represent information associated with an area. These areas can be regularly or irregularly spaced. Point pattern data analysis is performed when the locations of variables are of interest. These techniques attempt to ascertain if relationships exist between pairs of points and whether point distributions are randomly or regularly spaced.

Spatial statistical analysis of natural resources has focused on point and area analysis. Statistical methods for geostatistical data include variograms (Legendre and Fortin 1989), correlograms (Rossi et al. 1992), spectral analysis (Turner et al. 1990), and Mantel tests (Fortin and Gurevitch 1993). Boots and Gettis (1978) discuss methods for point pattern analysis, which include quadrat analysis, nearest neighbor, second order, and Ripley's K. Statistical procedures for area analysis are nearest neighbor (Turner et al. 1989), and two types of correlation coefficients: Moran's I and Geary's c (Fortin et al. 1989). In general, geostatistical procedures can be applied to area data analysis.

Spatial analysis applications that address linear entities, such as roads or rivers, are referred to as network analysis techniques (Bailey and Gatrell 1995). Studies involving network analysis have centered on routing exercises that attempt to determine the shortest or most efficient path between two or more destinations. An example of this would be determining the route a delivery truck should take given that it must stop at a number of locations.

S-Plus (Kaluzny et al. 1996) is generally regarded at the leading spatial analysis software currently available to the public. It offers spatial statistical tools for point and area themes but does not address linear analysis. In general, there is no developed set of publicly available geostatistical tools for analyzing linear features. Although wavelet analysis can be used to identify spatial structure in transect data, it is suited for continuous linear entities (Bradshaw and Spies 1992). Applying this tool to a network pattern, one in which lines overlap and intersect each other frequently, would produce useless results.

Conclusion

This study presented a new methodology for the collection, display, and analysis of data related to recreation impacts. This was accomplished through the use of ARC/INFO's dynamic segmentation technology and the creation of mapped output. Maps have the potential to serve as powerful communicators of information. As some have observed, there is reluctance to question the information presented by maps (Monmonier 1995, Monmonier 1996). This places both tremendous power and responsibility in the hands of those whose decisions drive GIS operations.

With the spatial component provided by GIS, managers can get assistance in identifying resource areas that appear, or have the potential, to be problematic. This approach can help maximize available resources for managing recreation conditions by directing them where they are most needed. Although the examples in this study were presented in the context of data collected from a particular forest, other forest managers could use the methodologies in conducting GIS analyses in their own jurisdictions.

REFERENCES

Adelman, B. J., T. A. Heberlein, and T. M. Bonnicksen. 1982. Social psychological explanations for the persistence of a conflict between paddling canoeists and motorcraft users in the Boundary Waters Canoe Area. Leisure Sciences 5(1):45-61.

Agee, J. K., S. C. Stitt, M. Nyquist, and R. Root. 1989. A geographic analysis of historical grizzly bear sightings in the North Cascades. Photogrammetric Engineering and Remote Sensing 55(11):1637-1642.

Aitken, S. and S. Michel. 1994. Who contrives the "Real" in GIS?: Geographic Information, Planning and Critical Theory. Cartography and Geographic Information Systems 22(1):17-29.

Avery, T. E. and G. L. Berlin. 1992. Fundamentals of remote sensing and airphoto interpretation. Macmillan Publishing Company: New York.

Bailey, T. C. and A. C. Gatrell. 1995. Interactive spatial data analysis. John Wiley & Sons, Inc.: New York.

Balfour, R. 1997. Interactions between near-urban forest management and recreation: A pre- and post-harvest survey. MS Thesis, Oregon State University.

Balfour, R. 1993. McDonald-Dunn Research Forest. Personal Communication.

Ball, G. L. 1994. Ecosystem modeling with GIS. 1994. Environmental Management 18(3):345-349.

Barrett, L. R., J. Liebens, D. G. Brown, R. J. Schaetzl, P. Zuwerink, T. W. Cate, and D. S. Nolan. 1995. Relationships between soils and presettlement forests in Baranga County, Michigan. The American Midland Naturalist 134(2):264-286.

Bennet, J. 1993. Dynamic segmentation model of an underground electric distribution network. In: Proceedings of the Thirteenth Annual ESRI User Conference. Environmental Systems Research Institute, Palm Springs, California.

Berry, J. K. 1993. Beyond mapping: Concepts, algorithms, and issues in GIS. GIS World Publishers, Fort Collins, Colorado.

Betts, K. S. 1997. Mapping the future: With GIS, the proof is in the plotting. E 8(2):24-28.

Betz, C. J. and H. K. Cordell. 1988. Trends in recreation participation on public lands. In, Outdoor recreation benchmark: Proceedings of the national outdoor recreation forum. General Technical Report SE-52. USDA Forest Service, Southeastern Forest Experiment Station.

Blinn, C. R., D. J. Martodam, and L. P. Quenn. 1994. Enhancing access for natural resource professionals to geographic information systems: An example application. The Forestry Chronicle 70(1):75-79.

Bolstad, P. V. and J. L. Smith. 1992. Errors in GIS. Journal of Forestry 90(11):21-29.

Boots, B. and A. Getis. 1978. Point pattern analysis. Sage Publications: London.

Bradshaw, G. A. and T. A. Spies. 1992. Characterizing canopy gap structure in forests using wavelet analysis. Journal of Ecology 80:205-215.

Bristow, R. S. 1991. Greenway planning: An application of a geographic information system. In, Proceedings of the 1991 Northeastern Recreation Research Symposium. General Technical Report NE-160. USDA Forest Service, Northeastern Forest Experiment Station.

Bristow, R. S., S. P. Caron, and K. H. Green. 1993. Investigating spatial structure influences on recreation activity packages. In Proceedings of the 1993 Northeastern Recreation Research Symposium. General Technical Report NE-185. USDA Forest Service, Northeastern Forest Experiment Station.

Brown, J. F., Loveland, T. R., J. W. Merchant, B. C. Reed, and D. O. Ohlen. 1993. Using multisource data in global land-cover characterization: Concepts, requirements, and methods. Photogrammetric Engineering & Remote Sensing 59(6):977-987.

Brown, T. C., G. L. Peterson, and B. E. Tonn. 1995. The values jury to aid natural resource decisions. Land Economics 71(2):250-260.

Brunson, M. and B. Shelby. 1992. Assessing recreational and scenic quality: How does new forestry rate? Journal of Forestry 90(7):37-41.

Burke, K. and C. Tyler. 1993. Incorporating dispersed uses into geographic information systems (brochure). USDA Forest Service, Pacific Northwest Research Station.

Castle, G. 1997. Location, location, location – NOT! Business Geographics 5(6):18.

Chatfield, D., C. B. Deans Jr., and D. B. Freshwater. 1990. Computerizing parks and recreation. Parks and Recreation 25(6):54-59.

Cho, G. 1991. Taking computers into nature parks. Australian Parks & Recreation 27(2):30-31.

Chou, Y. H., R. A. Minnich, L. A. Salazar, J. D. Power, and R. J. Dezzani. 1990. Spatial autocorrelation of wildfire distribution in the idyllwild quadrangle, San Jacinto Mountain, California. Photogrammetric Engeeneering and Remote Sensing 56(11):1507-13.

Cody, R. P. and J. K. Smith. 1991. Applied statistics and the SAS programming language. North-Holland: New York.

Cole, D. N. 1989. Recreation ecology: What we know, what geographers can contribute. Professional Geographer 41(2):143-148.

Cole, D. N. 1996. Wilderness recreation use trends, 1964 through 1994. Research Paper INT-RP-488. USDA Forest Service, Intermountain Research Station.

Coley, D. 1997. Compliance for the right reasons. Business Geographics 5(6):30-32.

Confer, J. J., A. R. Graefe, and J. M. Falk. 1992. A geographic information systems approach to analysis of the spatial relationships between recreational boating uses and perceived impacts. In Proceedings of the 1992 Northeastern Recreation Research Symposium. General Technical Report NE-176. USDA Forest Service, Northeastern Forest Experiment Station.

Congalton, R.G. and K. Green. 1992. The ABCs of GIS. Journal of Forestry 90(11):13-20.

Corvallis Gazette-Times. 1995. Oregon, Benton County growth beginning to slow. Corvallis Gazette-Times, Corvallis, OR.

Croft, F. and B. Kessler. 1996. Remote sensing, image processing, and GIS. Journal of Forestry 94(6):31-35.

Dangermond, J. 1991. Where is the technology leading us? The Forestry Chronicle 67(6):599-603.

Deadman, P. and H. R. Gimblett. 1994. The role of goal-oriented autonomous agents in modeling people-environment interactions in forest recreation. Mathematical and Computer Modelling 20(8):121-133.

Deagen, D. 1997. McDonald-Dunn Research Forest. Personal Communication.

Devine, H. A. and R. C. Field. 1986. The gist of GIS. Journal of Forestry 84(8):17-22.

Dillman, D. A. 1978. Mail and telephone surveys: The total design method. Wiley & Sons: New York.

Dueker, K. and R. Vrana. 1992. Dynamic segmentation revisited: a milepoint linear data model. Journal of Urban and Regional Information Systems Association 4(2):94-105.

Entwisle, B., R. R. Rindfuss, S. J. Walsh, T. P. Evans, and S. R. Curran. 1997. Geographic information systems, spatial network analysis, and contraceptive choice. Demography 34(2):171-187.

Environmental Systems Research Institute, Inc. 1992. Dynamic Segmentation. Environmental Systems Research Institute Inc.: Redlands, CA.

Environmental Systems Research Institute, Inc. 1994. Arc Macro Language. Environmental Systems Research Institute Inc.: Redlands, CA.

Environmental Systems Research Institute, Inc. 1995. ArcView and transportation applications. Environmental Systems Research Institute Inc.: Redlands, CA.

Environmental Systems Research Institute, Inc. 1996. Using ArcView GIS. Environmental Systems Research Institute Inc.: Redlands, CA.

Finley, M. T. 1990. McDonald Forest: A case study in the use of the Recreation Opportunity Spectrum planning framework in a near-urban forest. M.S. Thesis, Oregon State University.

Fortin, M-J. and J. Gurevitch. 1993. Mantel tests: Spatial structure in field experiments. Pp. 342-359 in Scheiner, S. and J. Gurevitch, eds. Design and analysis of ecological experiments. Chapman & Hall: New York.

Fortin, M-J., P. Drapeau, and P. Legendre. 1989. Spatial autocorrelation and sampling design in plant ecology. Vegetatio 83:209-222.

Gericke, K. L. and J. Sullivan. 1994. Public participation and appeals of Forest Service plans – an empirical examination. Society and Natural Resources 7:125-135.

Gimblett, H. R., B. Durnota and R. M. Itami. 1997. Spatially-Explicit Autonomous Agents for Modelling Recreation Use in Wilderness. Complex International Journal 3:68-82.

Gobster, P. H., H. R. Gimblett, and B. B. Kelly. 1987. Modeling forest recreation policy alternatives: A geographic information systems approach. In: Proceedings of GIS '87. American Society for Photogrammetry and Remote Sensing, Falls Church, VA.

Grace, J. D. 1997. U.S. oil and gas meets ArcView GIS. ARC News 19(2):20.

Graefe, , A. R., F. R. Kuss, and J. J. Vaske. 1990. Visitor impact management: The planning framework. National Parks and Conservation Association, Washington, DC.

Graefe, A. R., F. R. Kuss, and L. Loomis. 1986. Visitor impact management in wildlife settings. In: Proceedings–National Wilderness Research Conference: Current Research. General Technical Report INT-212. USDA Forest Service, Intermountain Research Station.

Graefe, A. R., J. J. Vaske, and F. R. Kuss. 1984. Social carrying capacity: An integration and synthesis of twenty years of research. Leisure Sciences 6:395-431.

Gramann, J. H. and R. J. Burdge. 1981. The effects of recreation goals on conflcit perception: The case of water skiers and fishermen. Journal of Leisure Research 31(1):15-27.

Green, K. 1992. Spatial imagery and GIS. Journal of Forestry 90(1):32-36.

Green, K., M. Finney, J. Campbell, D. Weinstein, and V. Landrum. 1995. Using GIS to predict fire behavior. Journal of Forestry 93(5):21-25.

Green, K, S. Bernath, L. Lackey, M. Brunengo, and S. Smith. 1993. Analyzing the cumulative effects of forest practices: where do we start? Geo Info Systems 3(2):31-41.

Grove, M. and M. Hohmann. 1992. Social forestry and GIS. Journal of Forestry 90(12):10-15.

Haight, R. G. 1996. Wildlife models. Journal of Forestry 94(12):4-6.

Hamilton, M. P., L. A. Salazar, and K. E. Palmer. 1989. Geographic information systems: Providing information for wildland fire planning. Fire Technology 25(1):5-23.

Hammitt, W. E. and M. E. Patterson. 1991. Coping behavior to avoid encounters: Its relationship to wildland privacy. Journal of Leisure Research 23(3):225-237.

Hammitt, W. E., C. D. McDonald, and F. P. Noe. 1984. Use level and encounters: Important variables of perceived crowding among nonspecialized recreationists. Journal of Leisure Research 16(1):1-8.

Hargrove, W. W., R. F. Winterfield, and D. A. Levine. 1995. Dynamic segementation and Thiessen Polygons: A solution to the river mile problem. In: Proceedings of the Fifteenth Annual ESRI User Conference. Environmental Systems Research Institute, Palm Springs, California.

Harris, L. K., R. H. Gimblett, and W. W. Shaw. 1995. Multiple use management: Using a GIS model to understand conflicts between recreationists and sensitive wildlife. Society and Natural Resources 8:559-572.

Harris, T. M. and G. A. Elmes. 1993. The application of GIS in urban and regional planning: A review of the North American experience. Applied Geography 13:9-27.

Hart, J. A., B. B. Wherry, and S. Bai. 1985. An operational GIS for Flathead National Forest. In: Proceedings of Autocarto 7. American Society of Photogrammetry and American Congress of Surveying and Mapping, Washington D.C.

Heberlein, T. A. and B. Shelby. 1977. Carrying capacity, values, and the satisfaction model: A reply to Greist. Journal of Leisure Research 9(2):142-146.

Heberlein, T. A. and J. J. Vaske. 1977. Crowding and visitor conflict on the Bois Brule River. (report WISC WRC 77-04). University of Wisconsin Water Resources Center, Madison, Wisconsin.

Herrington, L. P. 1990. Geographic information systems: where do we stand? General Technical Report PNW-263. USDA Forest Service, Pacific Northwest Research Station.

Hull, R. B. 1988. Forest visual quality management and research. pp.485-498. In: Outdoor Recreation Benchmark 1988: Proceedings of the national outdoor recreation forum. General Technical Report SE-52. USDA Forest Service, Southeastern Forest Experiment Station.

Huppert, K. 1997. Managing Oregon's Aquatic Resources: A Dynamic Segmentation Application. M.S. Thesis, Portland State Univeristy, Oregon.

Ivy, M. I., W. P. Stewart, and C. C. Lue. 1992. Exploring the role of tolerance in recreational conflict. Journal of Leisure Research 24(4):348-360.

Jackson, E. L. and R. A. G. Wong. 1982. Perceived conflict between urban cross-country skiers and snowmobilers in Alberta. Journal of Leisure Research 14(1):47-62.

Jackson, J. M. 1965. Structural characteristics of norms. In, I. D. Steiner and M. F. Fishbein, (eds.), Current Studies in Psychology. Holt, Rinehart, and Winston, New York.

Jacob, G. and R. Schreyer. 1980. Conflict in outdoor recreation: A theoretical perspective. Journal of Leisure Research 12(4):368-380.

Jakubauskas, M. E., K. P. Lulla, and P. W. Mausel. 1990. Assessment of vegetation change in a fire-altered forest landscape. Photogrammetric Engineering & Remote Sensing 56(3):371-377.

Jambrosic, M. 1997. Mapping out an emergency. Business Geographics. 5(7):28-29.

Johnson, R. L., M. W. Brunson, and T. Kimura. 1994. Using image-capture technology to assess scenic value at the urban/forest interface: A case study. Journal of Environmental Management 40:183-195.

Johnston, J. J., D. R. Weigel, and J. C. Randolph. 1997. Satellite remote sensing: An inexpensive tool for pine plantation management. Journal of Forestry 95(6):16-20.

Kalunzy, S. P., S. C. Vega, T. P. Cardoso, and A. A. Shelly. 1996. S+SPATIALSTATS User's Manual, Version 1.0. MathSoft, Inc.:Seattle,Wa.

Kearsley, G.W. 1990. Tourism development and users' perceptions of wilderness in southern New Zealand. The Australian Geographer, 21(2):127-140.

Kessler, B. 1995. PC-based GIS grows on foresters. Journal of Forestry 93(5):28-29.

Kim, S. 1990. Introduction of using geographic information system (GIS) for forest recreation planning. Journal of the Korean Forest Society, 79(2):205-215.

Klar Jr., L. R., R. B. Warnick, G. Swett, and S. Johnson. 1991. In: Proceedings of the 1991 Northeastern Recreation Research Symposium. General Technical Report NE-160. USDA Forest Service, Northeastern Forest Experiment Station.

Kliskey, A. D. and G. W. Kearsley. 1993. Mapping multiple perceptions of wilderness I southern New Zealand. Applied Geography, 13:203-223.

Klock, G. O. 1991. Potential use of geographic information systems to enhance forest soil management. General Technical Report INT-280. USDA Forest Service, Intermountain Research Station.

Lachowski, H. M., T. Wirth, P. Maus, and P. Avers. 1994. Remote sensing and GIS: their role in ecosystem management. Journal of Forestry 92(8):39-40.

Lachowski, H., P. Hardwick, R. Griffith, A. Parsons, and R. Warbington. 1997. Faster, better data for burned watersheds needing emergency rehab. Journal of Forestry 95(6)4-8.

Lachowski, H., P. Maus, and B. Platt. 1992. Integrating remote sensing with GIS. Journal of Forestry 90(12):16-21.

Leckie, D. G. 1990. Advances in remote sensing technologies for forest surveys and management. Canadian Journal of Forest Research 20:464-483.

Legendre, P. and M-J. Fortin. 1989. Spatial pattern and ecological analysis. Vegetatio 80:107-138.

Levinsohn, A, G. Langford, M. Rayner, J. Rintoul, and R. Eccles. 1987. A micro-computer based GIS for assessing recreation suitability. In: Proceedings of GIS '87. American Society for Photogrammetry and Remote Sensing, Falls Church, VA.

Liu, R. and L. P. Herrington. 1996. The expected cost of uncertainty in geographic data. Journal of Forestry 94(12):27-31.

Loveland, T. R., J. W. Merchant, D. O. Ohlen, J. F. Brown. 1991. Development of a land-cover characteristics database for the conterminous U.S. Photogrammetric Engineering & Remote Sensing 57(11):1453-1463.

Lucas, R. C. 1983. Low and variable visitor compliance rates at voluntary trail registers. Research Note INT-326. USDA Forest Service, Intermountain Forest and Range Experiment Station.

Lucas, R. C. and G. H. Stankey. 1985. Role of research in applying the Limits of Acceptable Change system. In Proceedings: Southeastern Recreation Research Conference, 1985. Georgia Southern College, Statesboro, GA.

Lucas, R. C. and S. F. McCool. 1988. Trends in wilderness recreational use: Causes and implications. Western Wildlands Fall:15-20.

Macgill, S. M. 1990. GIS in the 1990s? Environment and Planning A 23:1087-90.

Maclean, A.L., D. D. Reed, G. D. Mroz, G. W. Lyon, and T. Edison. 1992. Using GIS to estimate forest resource changes. Journal of Forestry 90(12):22-25.

Manning, R. E. and D. W. Lime. 1996. Crowding and carrying capacity in the National Park System: Toward a social science research agenda. In, Crowding and Congestion in the National Park System: Guidelines for Management and Research. MAES Misc. Pub. 86-1996. Department of Forest Resources and Minnesota Agricultural Experiment Station, University of Minnesota, St. Paul, MN.

McCool, S. F., R. E. Benson, J. L. Ashor. 1986. How the public perceives the visual effects of timber harvesting: An evaluation of interest group preferences. Environmental Management 10(3):385-391.

McLean, H. E. 1995. Smart maps: forestry's newest frontier. American Forests 101(3-4):13-22.

McWilliams, W. H. and J. L. Faulkner. 1990. Spatial analysis using a systematic grid of forest inventory plots: Selected examples for the south central United States. General Technical Report PNW-263. USDA Forest Service, Pacific Northwest Research Station.

Meighen, E. and E. Volger. 1997. Spatial solutions to recreation use. In: Proceedings of the International Conference of Hydropower, Atlanta, Georgia. American Society of Civil Engineers, New York.

Microsoft Corporation. 1994. Microsoft Excel User's Guide. Microsoft Corporation: Redmond, WA.

Millette, T. L., J. D. Sullivan, and J. K. Henderson. 1997. Evaluating forestland uses: A GIS-based model. Journal of Forestry 95(9):27-32.

Monmonier, M. S. 1996. How to lie with maps. The University of Chicago Press: Chicago, Ill.

Monmonier, M. S. 1995. Drawing the line: Tales of maps and cartocontroversy. Henry Holt and Company, Inc.: New York.

Muller, M. 1997. Redlands, California Police use CrimeView to predict trouble spots. ARC News 19(2):28.

Oregon State University. 1993a. McDonald-Dunn Forest Plan: Presentation to the Dean. Second draft presented to the Dean of the College of Forestry, Oregon State University on Feb. 19, 1993, with minor revisions on May 24, 1993. McDonald-Dunn Research Forest Planning Team, College of Forestry.

Oregon State University. 1993b. Draft OSU College Forest standards, guidelines, and monitoring plan. Document accompanying McDonald-Dunn Forest Plan. Revision Mar. 29, 1993. McDonald-Dunn Research Forest Planning Team, College of Forestry.

Parsons, D. J., T. J. Stohlgren, and J. M. Kraushaar. 1982. Wilderness permit accuracy: Differences between reported and actual use. Environmental Management 6(4):329-335.

Patterson, M. E. and W. E. Hammitt. 1990. Backcountry encounter norm,s, actual reported encounters, and their relationship to wilderness solitude. Journal of Leisure Research 22(3):259-375.

Petersen, M. E. 1985. Improving voluntary registration through location and design of trail registration stations. Research Paper INT-336. USDA Forest Service, Intermountain Forest and Range Experiment Station.

Quigley, T. M. and H. B. Cole. 1997. Highlighted scientific findings of the Interior Columbia Basin Ecosystem Management Project. General Technical Report PNW-GTR-404. USDA Forest Service, Pacific Northwest Research Station; USDI Bureau of Land Management.

Rhind, D. 1991. Geographical information systems and environmental problems. International Social Science Journal 43:649-68.

Ribe, R. G. 1989. The aesthetics of forestry: What has empirical preference research taught us? Environmental Management 13(1):55-74.

Roggenbuck, J. W., D. R. Williams, and A. E. Watson. 1993. Defining acceptable conditions in wilderness. Environmental Management 17(2):187-197.

Roggenbuck, J. W., D. R. Williams, S. P. Bange, and D. J. Dean. 1991. River trip encounter norms: questioning the use of the social norms concept. Journal of Leisure Research 23(2):133-153.

Rossi, R. E., D. J. Mulla, A. G. Journel, and E. H. Franz. 1992. Geostatistical tools for modelling and interpreting ecological spatial dependence. Ecological Monographs 62(2):277-314.

Ruddel, E. J. and J. H. Gramann. 1991. Extending the goal/norm-interference model of recreation conflict: An analysis of the role of personal norms in noise-induced conflict. Paper presented at the Third Symposium on Social Science in Resource Management, May 1990. College Station, Texas.

Ruddel, E. J., J. H. Gramann, V. A. Rudis, and J. M. Westphal. 1989. The psychological utility of visual penetration in near-view forest scenic-beauty models. Environment and Behavior 21(4):393-412.

Sanders, R. 1997a. Recreation out of bounds. Corvallis Gazette-Times (October 19th), Corvallis, OR.

Sanders, R. 1997b. Campaign intended to educate forest users. Recreation out of bounds. Corvallis Gazette-Times (October 19th), Corvallis, OR.

SAS. 1990. Language and Procedures: Introduction, Version 6. SAS Institute Inc., Cary, N.C.

Shands, W. E. 1991. Problems and prospects at the urban-forest interface. Journal of Forestry 89(6):23-26.

Shannon, M. 1991. Resource managers as policy entrepreneurs. Journal of Forestry 89(6):27-30.

Shelby, B. 1981. Encounter norms in backcountry settings: Studies of three rivers. Journal of Leisure Research 13(2):129-138.

Shelby, B. 1980. Contrasting recreational experiences: Motors and oars in the Grand Canyon. Journal of Soil and Water Conservation 35(3):129-131.

Shelby, B. and J. J. Vaske. 1991. Using normative data to develop evaluative standards for resource management: A comment on three recent papers. Journal of Leisure Research 23(2):173-187.

Shelby, B. and T. Heberlein. 1986. Carrying capacity in recreation settings. Oregon State University: Corvallis, Oregon.

Shelby, B., J. J. Vaske, and M. P. Donnelly. 1996. Norms, standards, and natural resources. Leisure Sciences 18(2):103-123.

Shelby, B, J. J. Vaske, and T. A. Heberlein. 1989. Comparative Analysis of Crowding in Multiple Locations: Results from Fifteen Years of Research. Leisure Sciences, 11(4):269-291.

Shelby, B., R. Johnson, and N. Bregenzer. 1988. Displacement and product shift: Empirical evidence from Oregon rivers. Journal of Leisure Research 20(4):274-288.

Shelby, B., T. A. Heberlein, J. J. Vaske, and G. Alfano. 1983. Expectations, preferences, and feeling crowded in recreation activities. Leisure Sciences 6(1):1-14.

Shultis, J. and G. W. Kearsley. 1989. Environmental protection in protected areas. In: Proceedings of the Symposium on Environmental Monitoring in New Zealand. Department of Conservation, Wellington.

Skidmore, A. K., F. Watford, P. Luckananurug, and P. J. Ryan. 1996. An operational GIS expert system for mapping forest soils. Photogrammetric Engineering and Remote Sensing 62(5):501-511.

Stankey, G. H. and S. F. McCool. 1984. Carrying capcity in recreational settings: Evolution, appraisal, and application. Leisure Sciences 6(4):453-472.

Stankey, G. H. and R. Schreyer. 1987. Attitudes toward wilderness and factors affecting visitor behavior: a state-of-the-knowledge review. In: Proceedings--National Wilderness Conference: Issues, State-of-Knowledge, Future Directions. Genetal Technical Report INT-220. USDA Forest Service, Ogden, UT.

Stankey, G. H., D. N. Cole, R. C. Lucas, M. E. Petersen, and S. S. Frissell. 1985. The limits of acceptable change (LAC) system for wilderness planning. General Technical Report INT-176. USDA Forest Service, Intermountain Research Station.

Stankey, G. H., R. C. Lucas, and D. W. Lime. 1976. Crowding in parks and wilderness. Design and Environment 7(3):38-41.

Star, J. and J. Estes. 1990. Geographic information systems: An introduction. Prentice-Hall, New Jersey.

Stokols, D. 1972. On the distinction between density and crowding: Some implications for future research. Psychological Review 79(3):275-277.

Stone, K. D., G. A. Heidt, P. T. Caster, and M. L. Kennedy. 1997. Using geographic information systems to determine home range of the southern flying squirrel (Glaucomys volans). The American Midland Naturalist 137(1):106-112.

Suzio Jr, L. F. 1997. Does your bank have GIS? The Journal of Lending and Credit Risk Management 79(5):51-60.

Teply, J. T. and K. Green. 1991. Old growth forest: How much remains? Geo Info Systems 1(4):23-21.

Tomlinson, R. F. 1989. Presidential address: geographic information systems and geographers in the 1990s. The Canadian Geographer 22(4):290-298.
USDA Pacific Northwest Research Station. 1993. Incoporating dispersed uses into geographic information systems. USDA Pacific Northwest Research Station, Seattle, WA.

Torres, T., S. Ingraham, and D. Deagen. Summary of 1996 McDonald-Dunn Forests compatibility survey for research, teaching and demonstration. Unpublished report. McDonald-Dunn Research Forest, Corvallis, OR.

Turner, M. G., R. Costanza, and F. H. Sklar. 1989. Methods to evaluate the performance of spatial simulation models. Ecological Modeling 48:1-18.

Turner, S. J., R. V. O'Neill, W. Conley, M. Conley, and H. C. Humphries. 1990. Pattern and scale: statistics for landscape ecology. Pp. 17-49 in Turner, M. G. and R. H. Gardner. Quantitative methods in landscape ecology. Springer-Verlag, New York.

Vander Heyden, M. 1997. Female black bear habitat selection and home range ecology in the central Oregon Cascades. M.S. Thesis, Oregon State University.

Vaske, J. J., B. Shelby, A. Graefe, and T. A. Heberlein. 1986. Backcountry encounter norms: Theory, method, and empirical evidence. Journal of Leisure Research 18(2):137-153.

Vaske, J. J., M. P. Donnelly, and B. Shelby. 1993. Establishing management standards: Selected examples of the normative approach. Environmental Management 17(5):629-643).

Verbyla, D. L. 1991. Predicting forest changes associated with climate warming: potential uses of GIS technology. General Technical Report INT-280. USDA Forest Service, Intermountain Research Station.

Vining, J., H. W. Schroeder, and T. C. Daniel. 1984. Predicting scenic values in forested residential landscapes. Journal of Leisure Research 16(2):124-135.

Watson, A. E. 1990. Why is it imporatant to monitor social sonditions in wilderness? In: Managing America's Enduring Wilderness Resource: Proceedings of the Conference; 1989 September 11-17. Tourism Center, Minneapolis, MN.

Watson, A. E., M. J. Niccolucci, and D. R. Williams. 1993. Hikers and recreational stock users: Predicting and managing recreation conflicts in three wildernesses. Research Paper INT-468. USDA Forest Service, Intermountain Research Station.

Watson, A. E., D. R. Williams, and J. J. Daigle. 1991. Sources of conflict between hikers and mountain bike riders in the Rattlesnake NRA. Journal of Park and Recreation Administration 9(3):59-71.

Watson, A. E., M. J. Niccolucci, and D. R. Williams. 1994. The nature of conflict between hikers and recreational stock users in the John Muir Wilderness. Journal of Leisure Research 26(4):372-385.

Wheeler, D. J. 1993. Commentary: Linking environmental models with geographic information systems for global change research. Photogrammetric Engineering & Remote Sensing 59(10):1497-1501.

Whittaker, D. 1992. Selecting indicators: Which impacts matter more? General Technical Report PNW-305. USDA Forest Service, Pacific Northwest Region.

Whittaker, D. and B. Shelby. 1992. Developing good standards: Criteria, characteristics, and sources. General Technical Report PNW-305. USDA Forest service, Pacific Northwest Region.

Whittaker, D. and B. Shelby. 1988. Types of norms for recreation impacts: extending the social norms concept. Journal of Leisure Research 20(4):261-273.

Williams, D. R., J. W. Roggenbuck, and S. Bange. 1991. The effect of norm-encounter compatibility on crowding perceptions, experience and behavior in river recreation settings. Journal of Leisure Research 23(2):154-172.

Williams, D. R., J. W. Roggenbuck, M. E. Patterson, and A. E. Watson. 1992. The variability of user-based social impact standards for wilderness management. Forest Science 38(4):738-756.

Wing, M. 1996. Summary of the 1993-1994 McDonald Forest User Inventory. Oregon State University: Corvallis.

Zach, J. A. and R. A. Minnich. 1991. Integration of geographic information systems with a diagnostic wind field model for fire management. Forest Science 37(2):560-573.

Zhu, Z. and D. L. Evans. 1992. Mapping midsouth forest distributions. Journal of Forestry 90(12):27-30.

APPENDICES

APPENDIX A. SUMMER ON-SITE SURVEY.

McDonald Forest Recreation Survey

Please complete this short questionnaire. The McDonald Forest staff is interested in the experiences and opinions of those who visit the forest. Please ask if you have any questions.

1. What were your recreational activities on this visit? ______________________

2. About how much time did you spend in the forest on this trip?_____Hours_____Minutes

3. Did you feel crowded while you were in the forest today? (Circle a number.)

1	2	3	4	5	6	7	8	9
Not at all Crowded		Slightly Crowded		Moderately Crowded			Extremely Crowded	

4. Please list those scenic features that particularly **CONTRIBUTED** to your enjoyment (wildflowers, views, etc.) as well as any aspects of the area that **DETRACTED** from your enjoyment.

SCENIC FEATURES WHICH:

CONTRIBUTED	**DETRACTED**
A.________________	**1.**________________________
B.________________	**2.**________________________
C.________________	**3.**________________________
D.________________	**4.**________________________

5a. During today's visit to the forest, did you have any conflicts with others?_____Yes _____No
If no, go to #6.

5b. If you experienced a conflict, please identify who, besides yourself, was involved:

___ Hiker(s) ___ Mountain Biker(s) ___ Vehicle(s)
___ Forest Staff ___ Adjacent Property Owner(s) ___ Horseback Rider(s)
___ Dog(s) ___ Educational Groups(s) ___ OSU Faculty
___ Other, Identify:______________________________

5c. If you experienced a conflict, please describe the nature of the conflict.__________________
____
____

6. Using the attached map, please trace your trip route through McDonald Forest and use arrows to indicate your direction.

7. After the fall season, we would like to mail you a questionnaire which asks additional questions about McDonald Forest. Please print your name and address in the space below so that we can send the survey to you. It will take about ten minutes to fill out and will not require a stamp from you. Your responses to today's survey and the mail questionnaire will not be connected to your name.

Please print: Name_________________________
Address_______________________________
City_________ State_____ Zip

Thank you for your time and effort in completing this survey!
If you have any comments regarding recreation in the forest, please contact the recreation staff.

APPENDIX B. FALL AND SPRING ON-SITE SURVEY.

McDonald Forest Recreation Survey

Please complete this questionnaire. The McDonald Forest staff is interested in the experiences and opinions of those who visit the forest. Please ask if you have any questions.

1. What were your recreational activities on this visit? ____________________________

2. About how much time did you spend in the forest on this trip? Hours______ Minutes______

3. Please list those scenic features that particularly **CONTRIBUTED** to your enjoyment (wildflowers, views, etc.) as well as any aspects of the area that **DETRACTED** from your enjoyment.

SCENIC FEATURES WHICH:

CONTRIBUTED	**DETRACTED**
A.________________	**1.**______________
B.________________	**2.**______________
C.________________	**3.**______________

4. Did you feel crowded while you were in the forest today? (Circle a number.)

1	2	3	4	5	6	7	8	9
Not at all Crowded		Slightly Crowded		Moderately Crowded			Extremely Crowded	

5. During today's visit to the forest, did you have any conflicts with others?____Yes ___ No
If no, go to #6.

5a. If yes, briefly describe who was involved and the nature of the conflict.

6. How many times did you see people from other groups today? If you saw the same group more than once, count each occasion separately. I saw other groups about ___ times.

7. While in McDonald Forest, it would be O.K. to see other groups as many as...
____ times
____ it doesn't matter to me

8. About what percent of time were you in sight of people from other groups? (Circle a number.)

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

9. What would be an acceptable percentage of time to see people from other groups while you are in McDonald Forest? (Circle a number).

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

10. Using the attached map, please trace your trip route through McDonald Forest and use arrows to indicate your direction.

1. For each of the descriptive words or phrases below indicate how well you feel that it characterizes the route you took today. (Circle a number.)

	strongly disagree	disagree	neutral	agree	strongly agree
Abundant wildflowers	1	2	3	4	5
Good places to stop and rest	1	2	3	4	5
Multiple use recreation traffic	1	2	3	4	5
Colorful	1	2	3	4	5
Steep	1	2	3	4	5
Quiet	1	2	3	4	5
Good trail condition	1	2	3	4	5
Abundant wildlife	1	2	3	4	5
Timber harvesting	1	2	3	4	5
Damp	1	2	3	4	5
Presence of creeks	1	2	3	4	5
Foot traffic only	1	2	3	4	5
Open vistas	1	2	3	4	5
Monotonous	1	2	3	4	5
Challenging terrain	1	2	3	4	5
Presence of facilities (parking, restrooms, etc.)	1	2	3	4	5
Natural	1	2	3	4	5
Dead or dying trees	1	2	3	4	5
Cool	1	2	3	4	5
Presence of lake/ponds	1	2	3	4	5
Unusual	1	2	3	4	5
Good road condition	1	2	3	4	5
Abundant bird life	1	2	3	4	5
Pleasant-smelling	1	2	3	4	5
Timber management area	1	2	3	4	5
Other, specify:__________	1	2	3	4	5

2. About how many times in the past have you traveled along this route? Not counting today, I have taken today's route about ____ times.

3. Please list the most important reasons for the selection of your particular route today:

A.______________________________

B.______________________________

4. After the fall season, we would like to mail you a questionnaire which asks additional questions about McDonald Forest. Please print your name and address in the space below so that we can send the survey to you. It will take about ten minutes to fill out and will not require a stamp from you. Your responses to today's survey and the mail questionnaire will not be connected to your name.

Please print: Name______________________

Address______________________

City__________ State_____ Zip

Thank you for your time and effort in completing this survey!

Figure C-1. Summer Total Use Estimates for McDonald Forest.

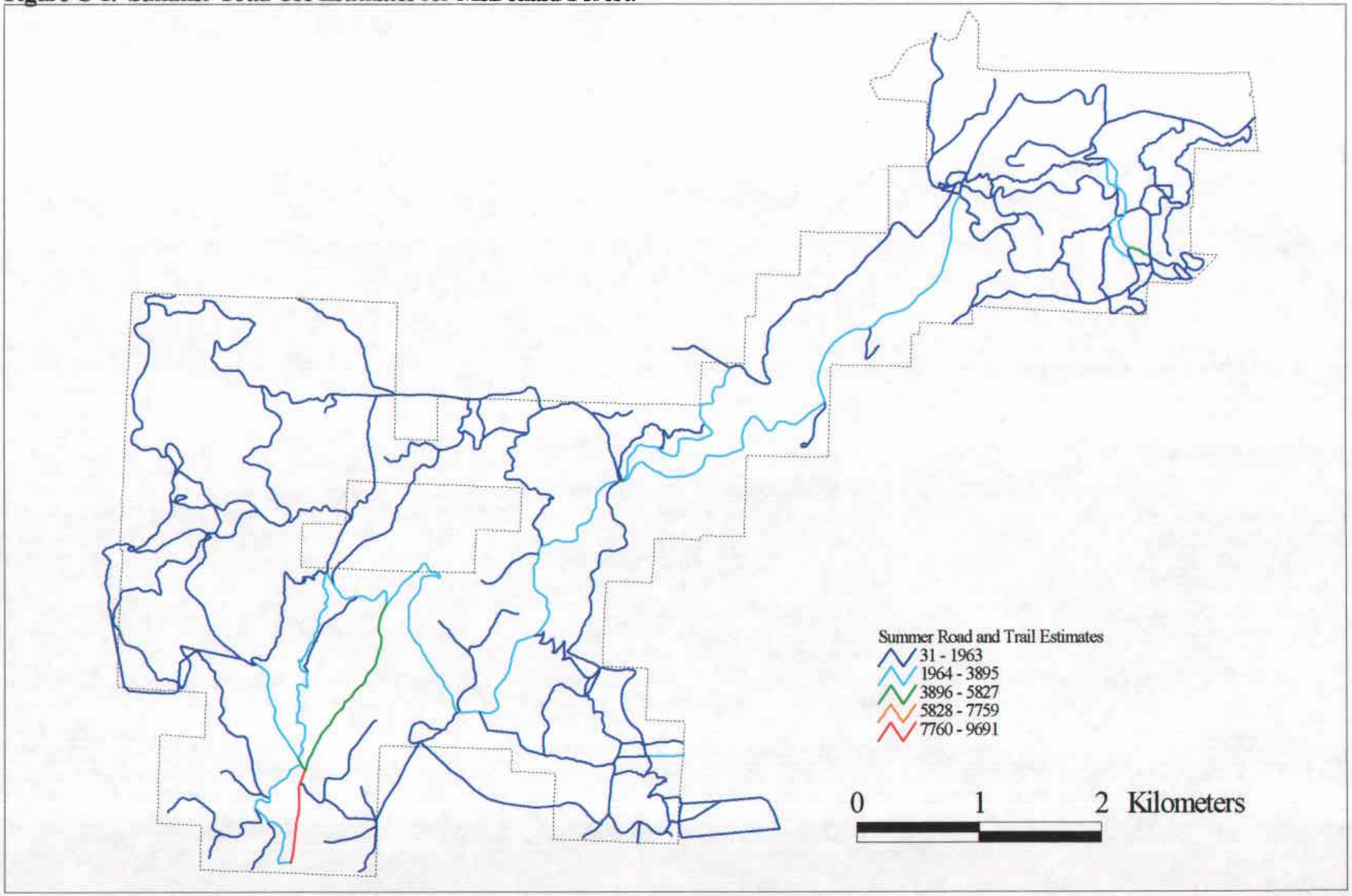


Figure C-2. Fall Total Use Estimates for McDonald Forest.

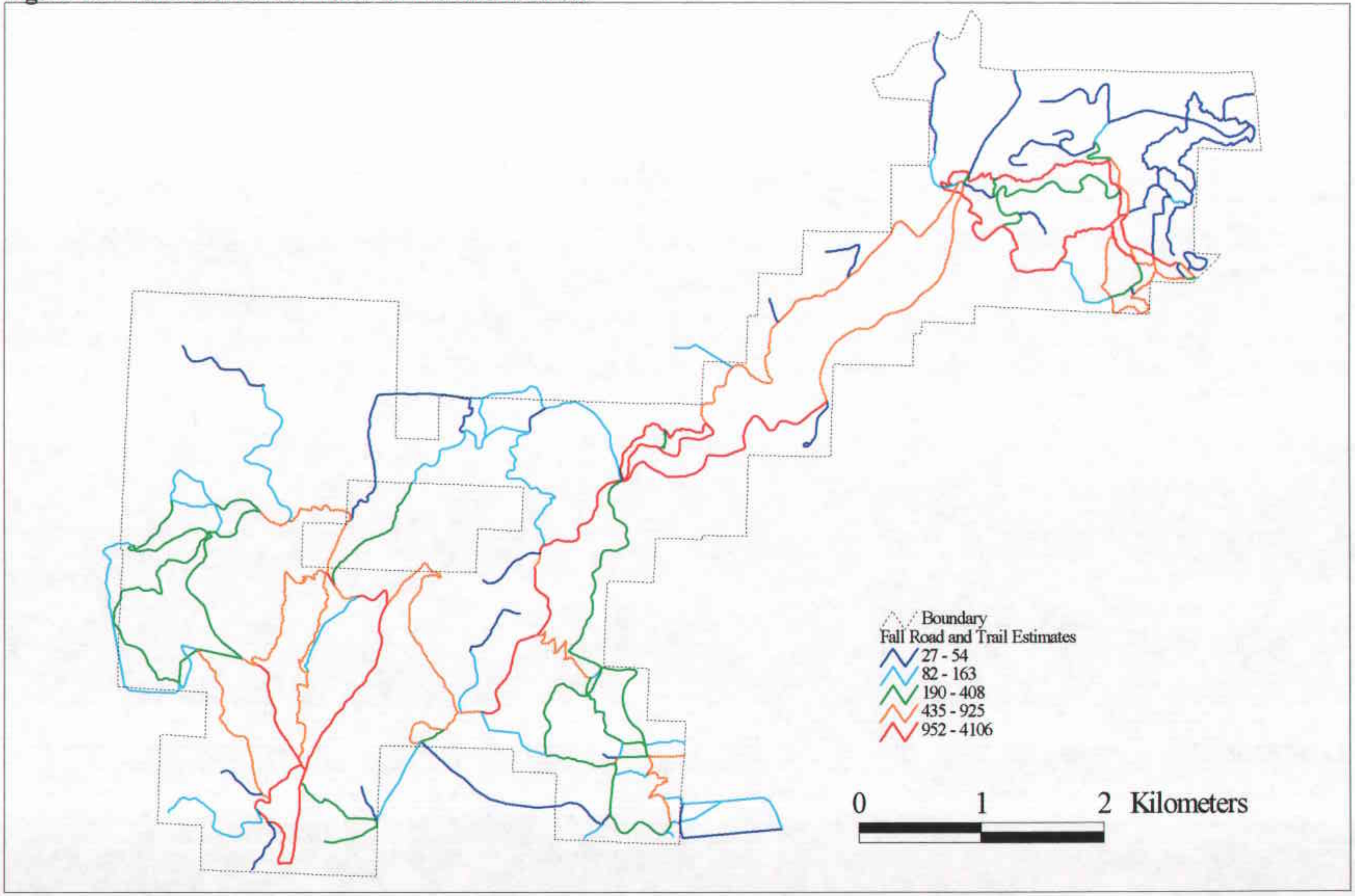


Figure C-3. Spring Total Use Estimates for McDonald Forest.

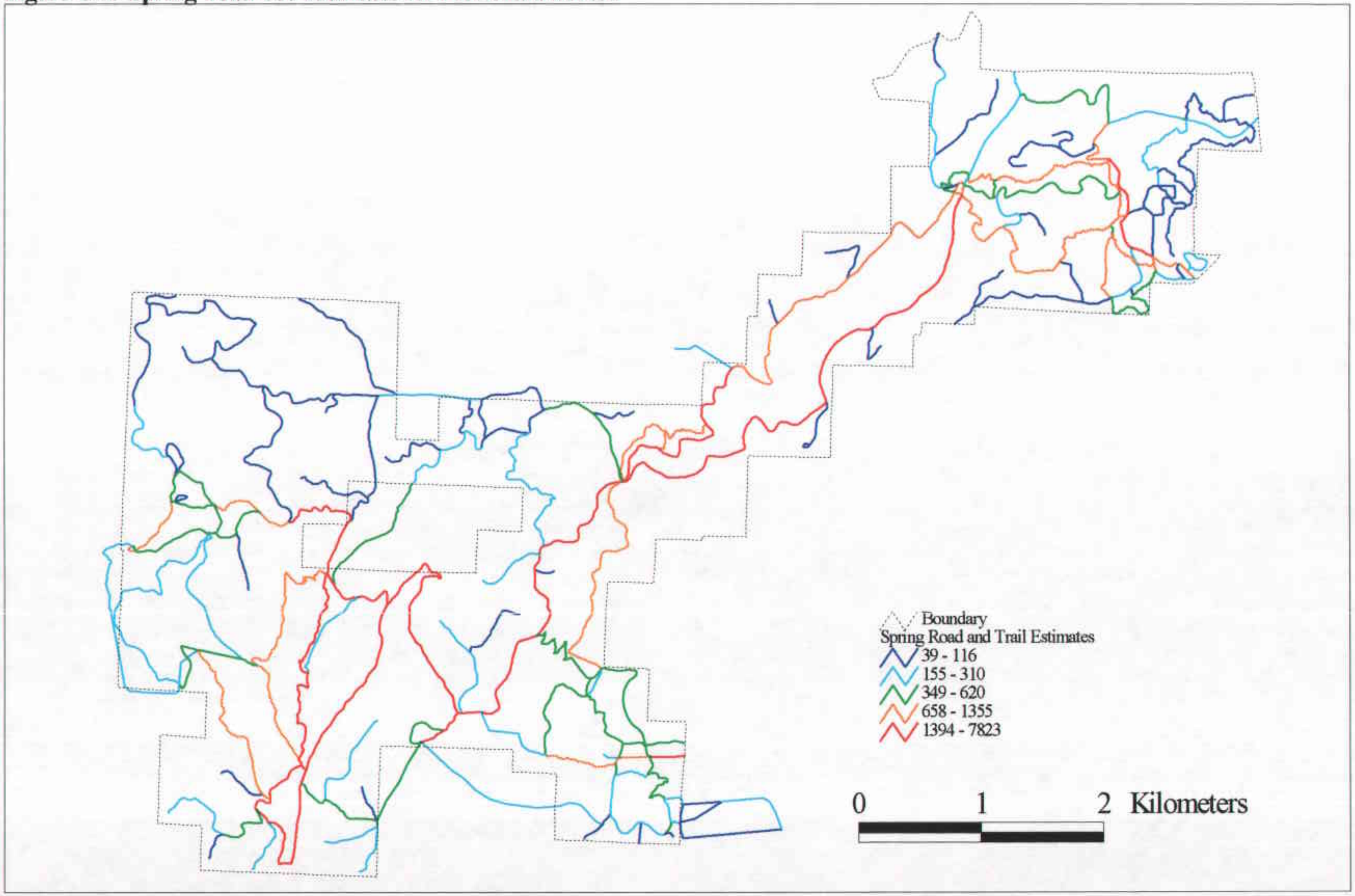


Figure D-1. Summer Conflict Totals in McDonald Forest.

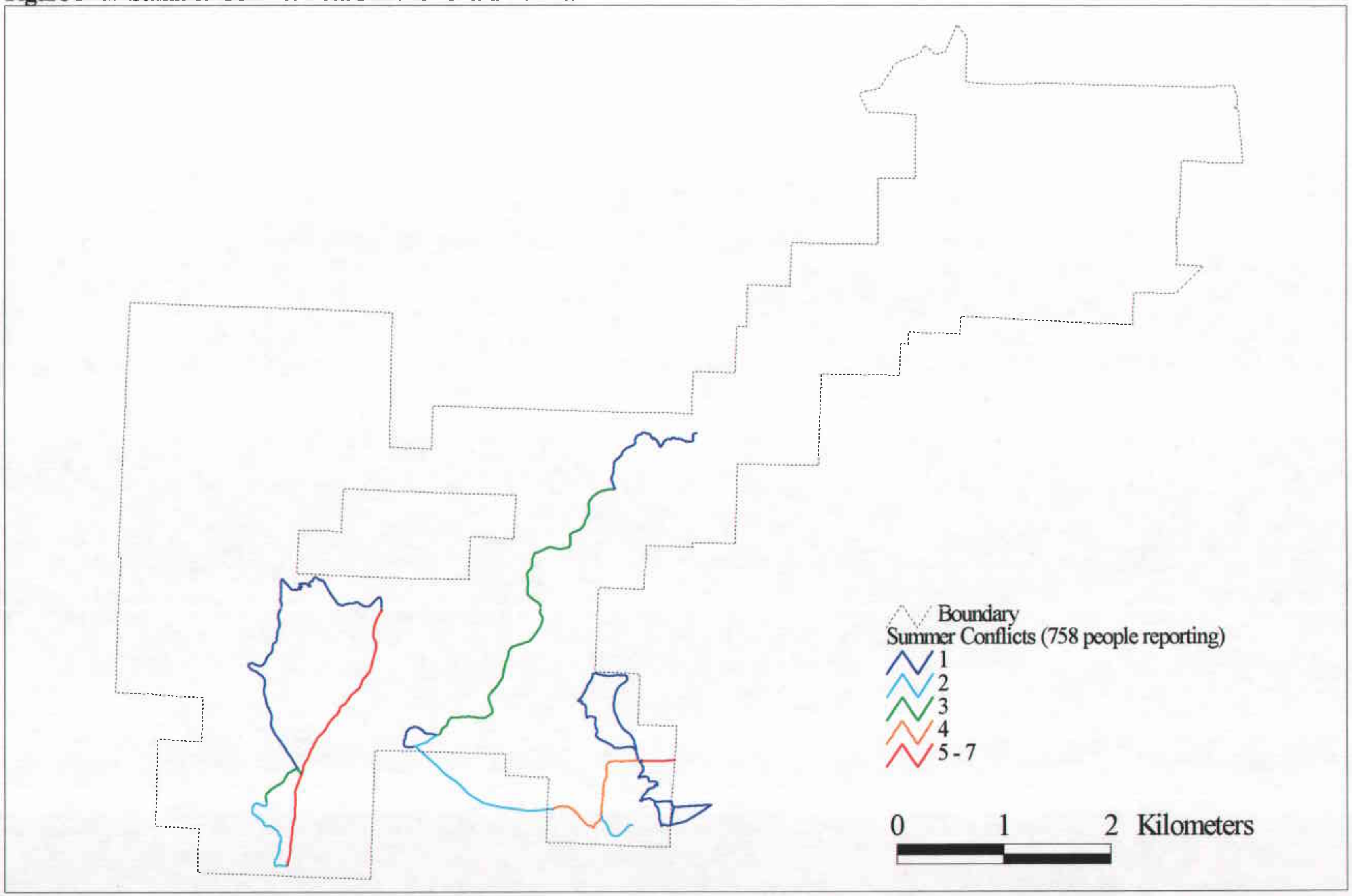


Figure D-2. Fall Conflict Totals in McDonald Forest.

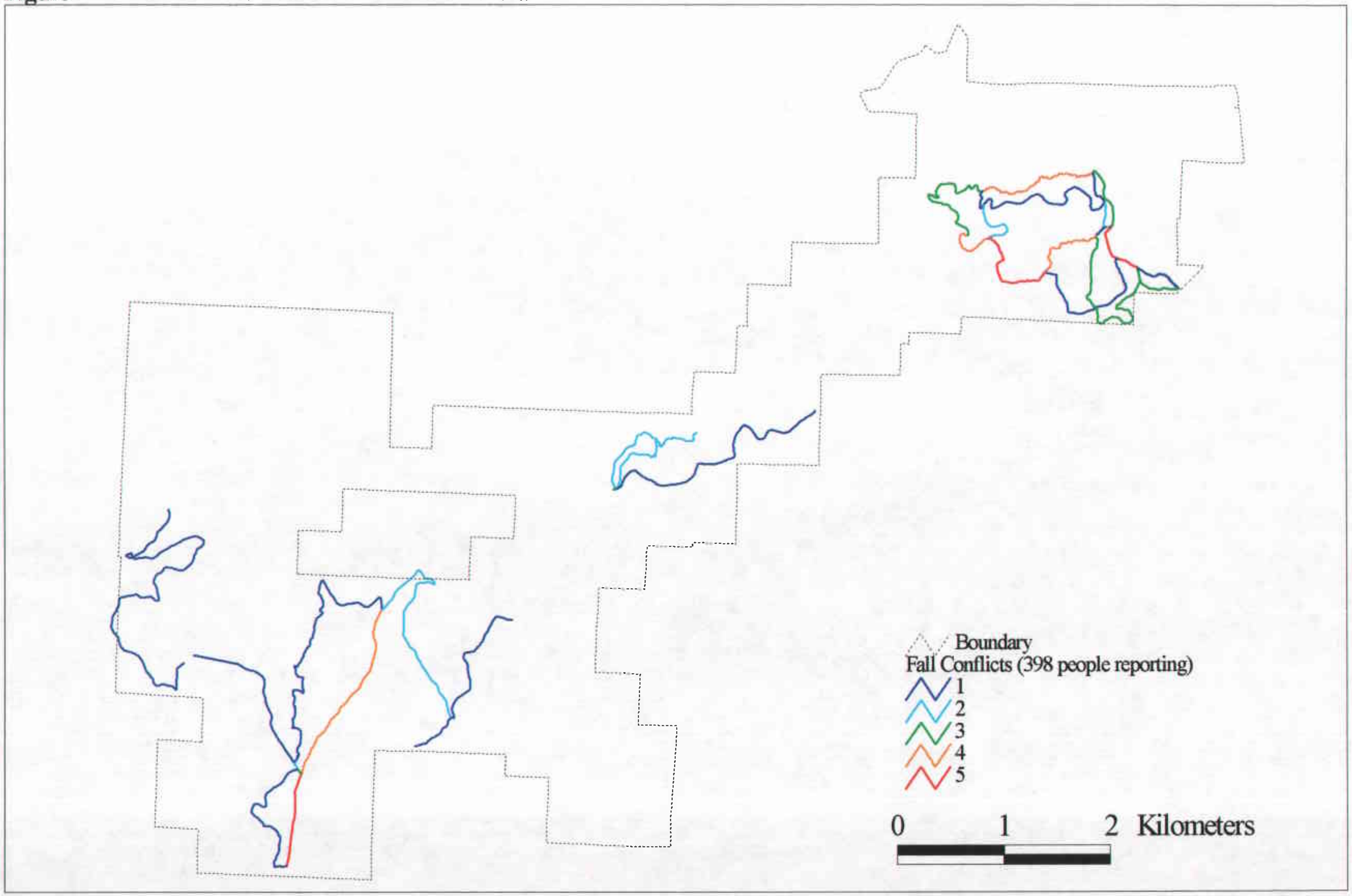


Figure D-3. Spring Conflict Totals in McDonald Forest.

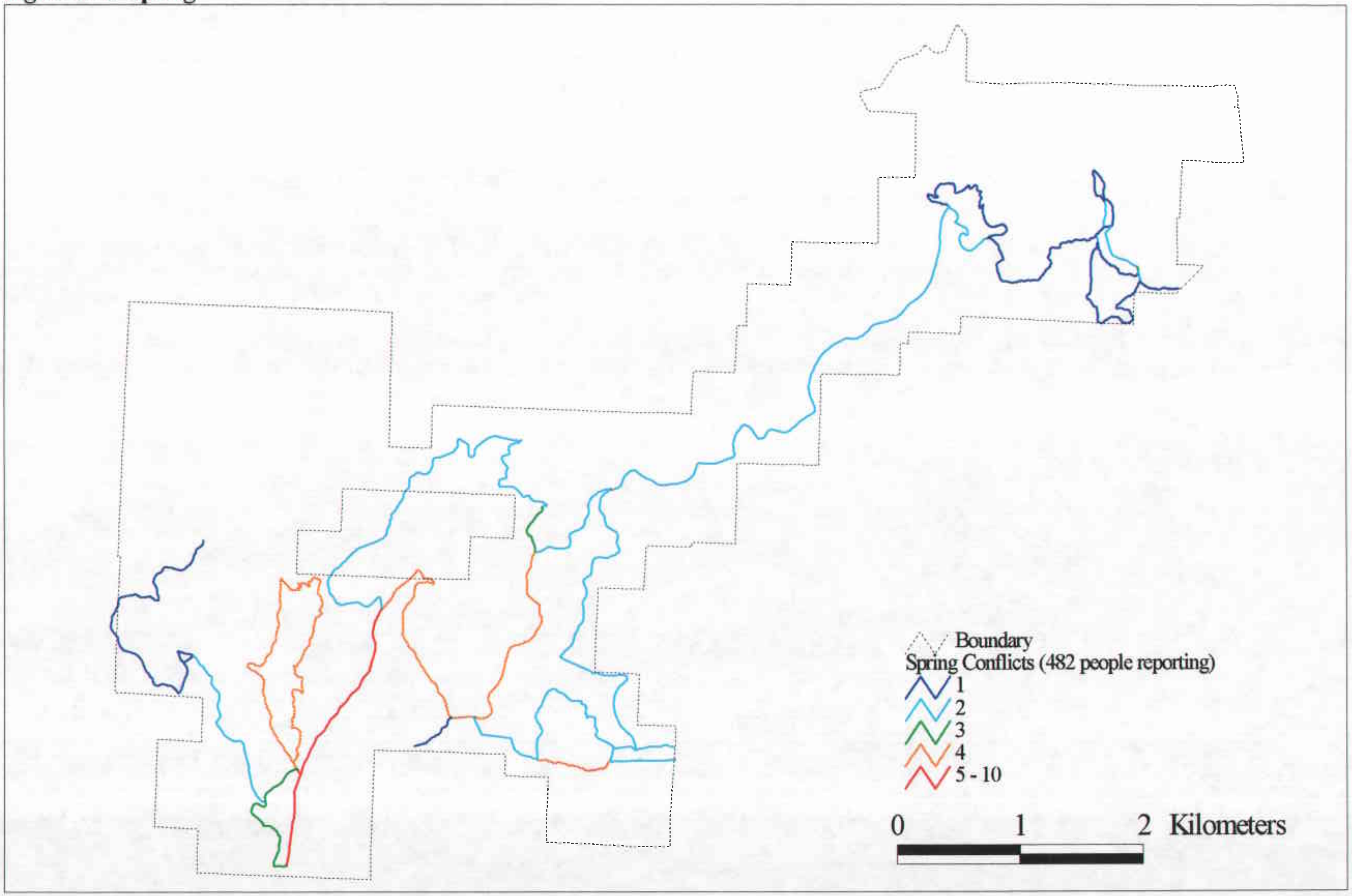


Figure E-1. Summer Crowding Percentage for McDonald Forest.

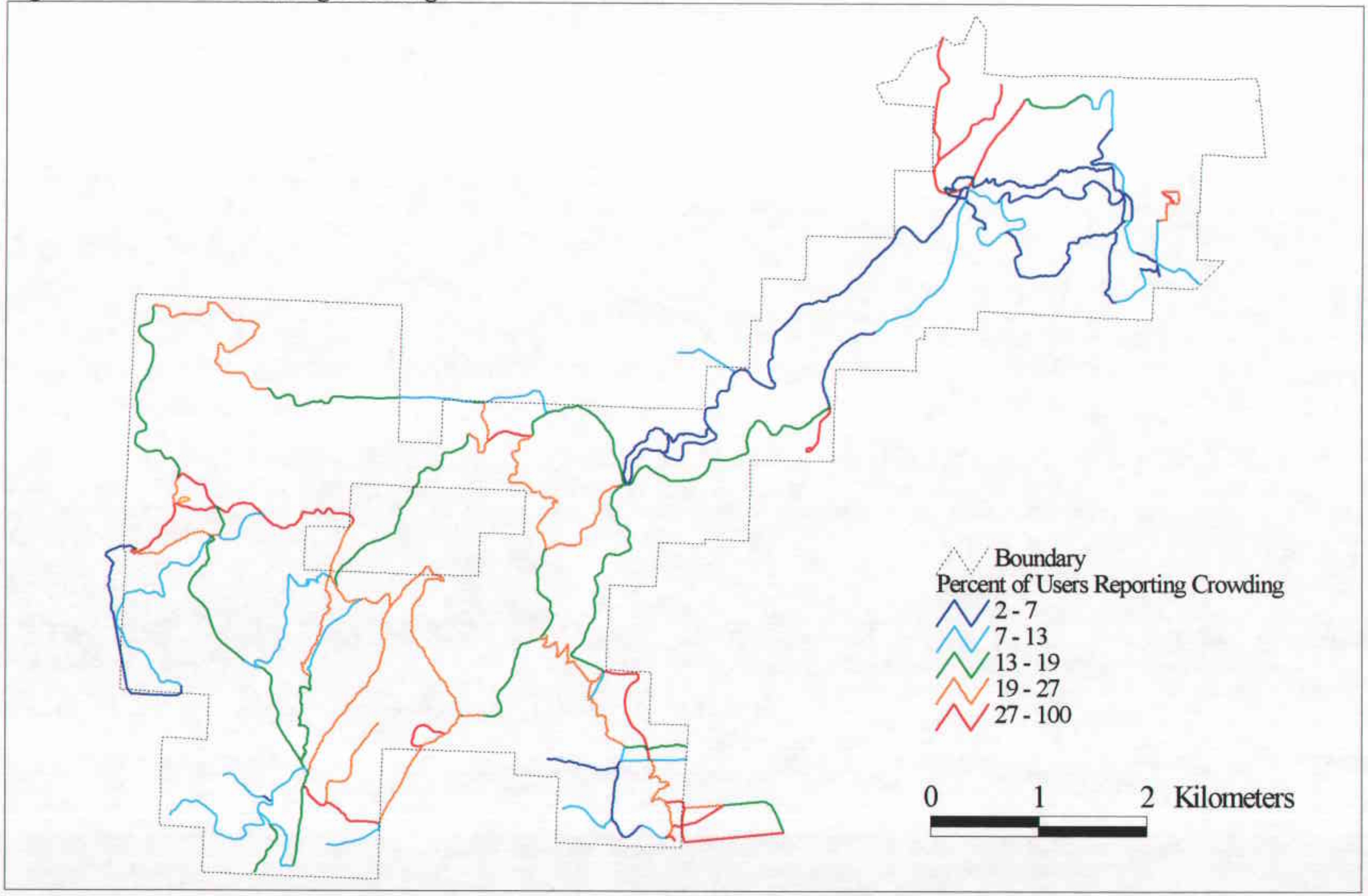


Figure E-2. Fall Crowding Percentage for McDonald Forest.

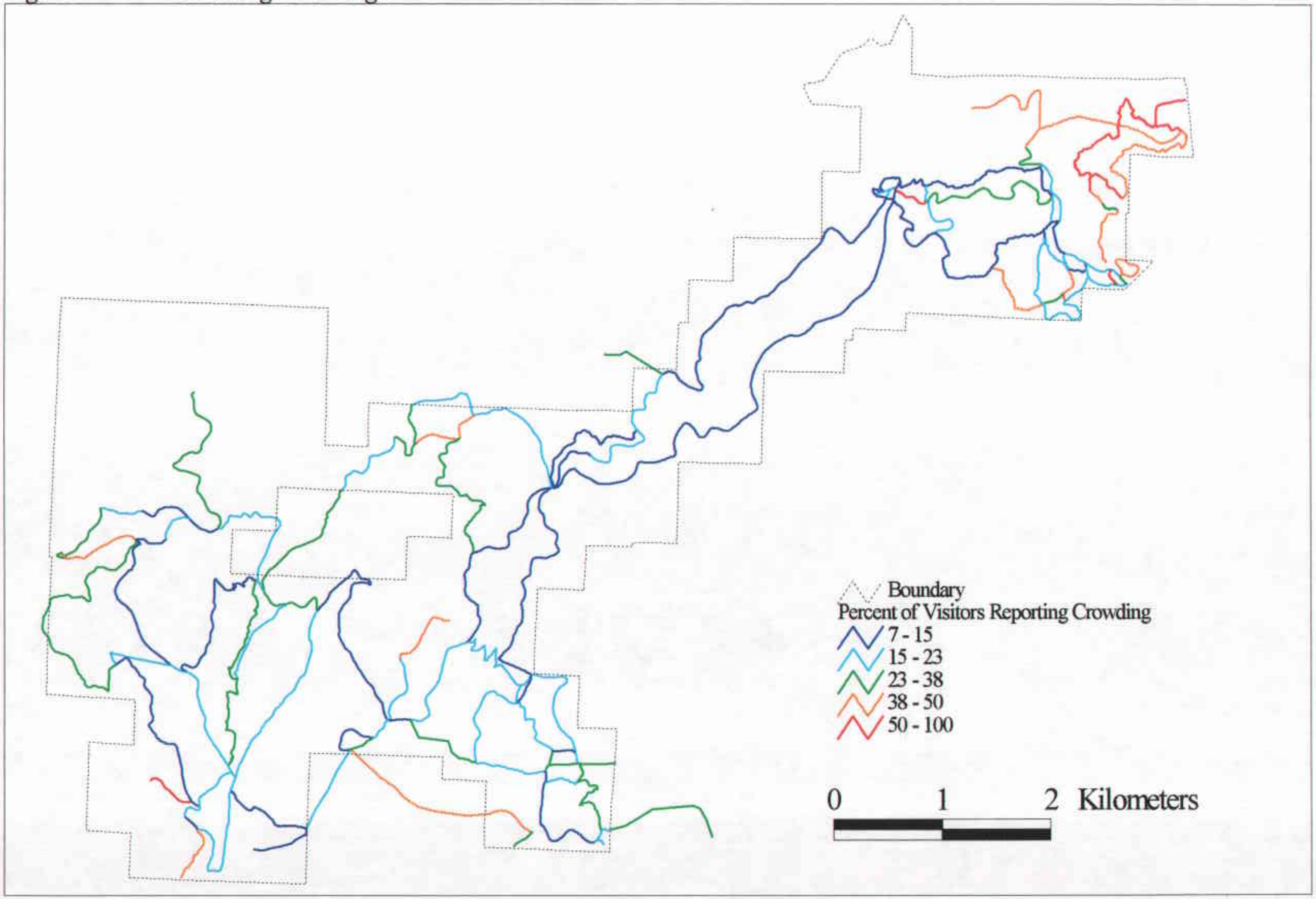


Figure E-3. Spring Crowding Percentage for McDonald Forest.

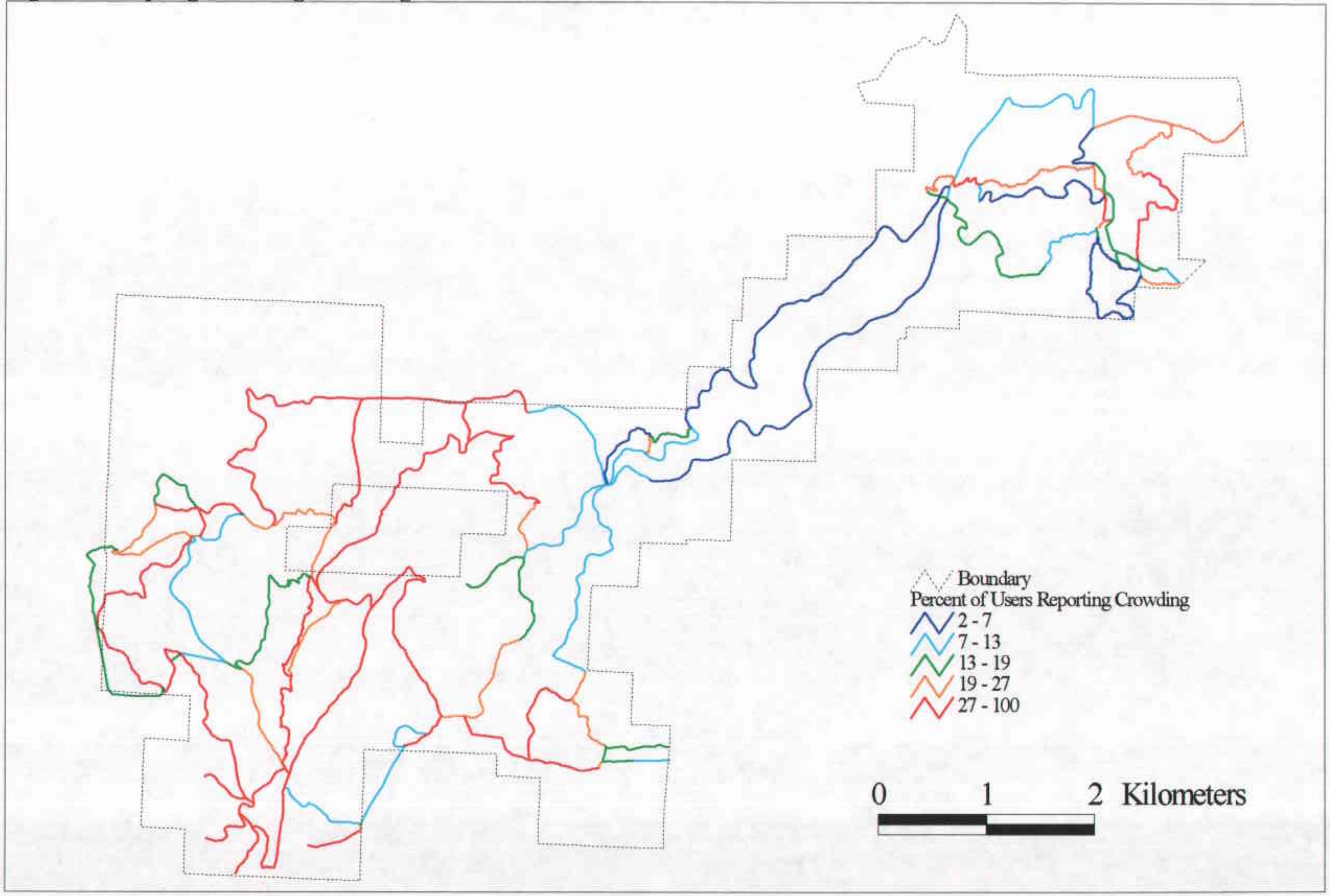


Figure F-1. Fall Locations of Encounter Standards being Exceeded.

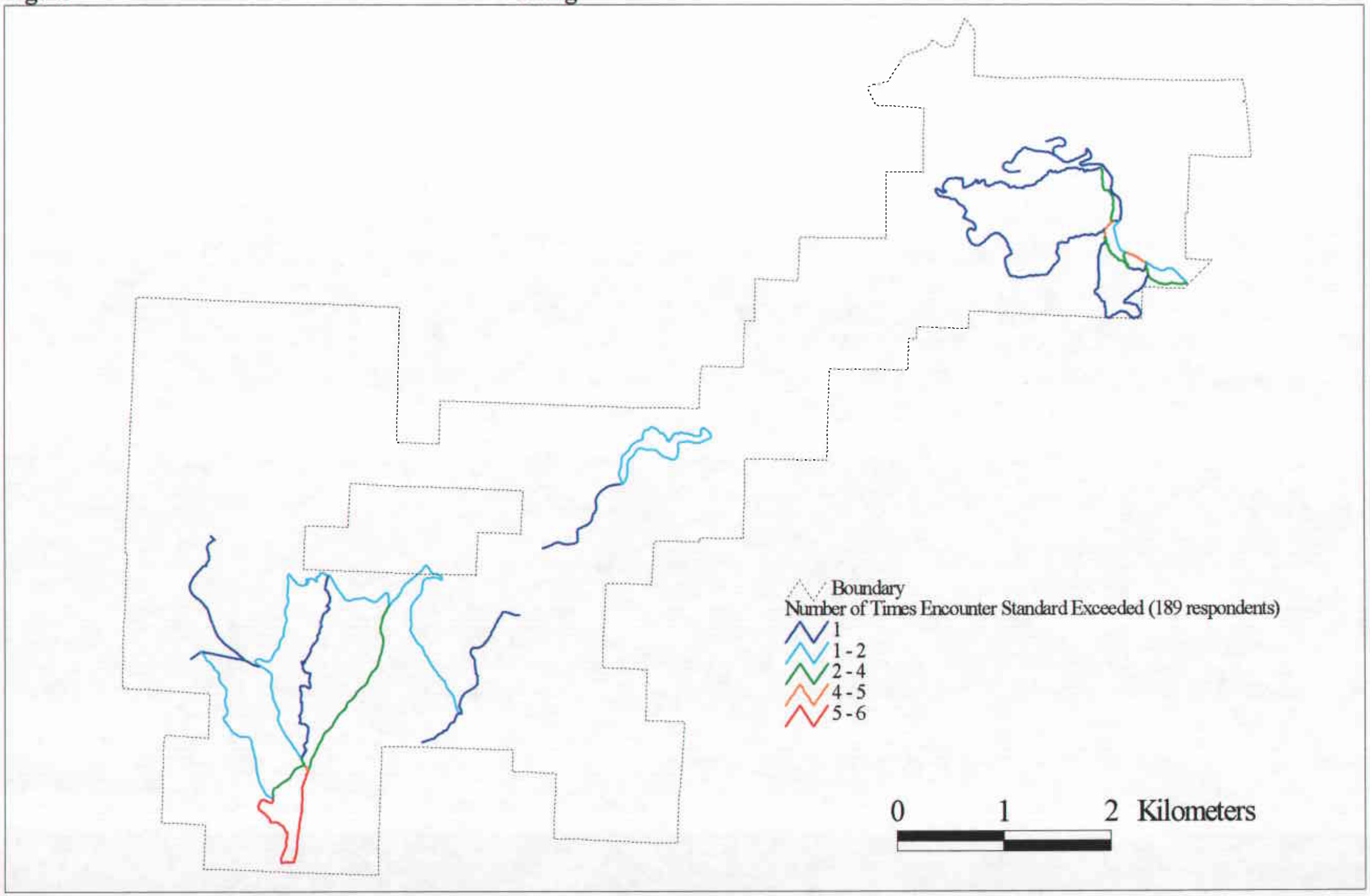


Figure F-2. Spring Locations of Encounter Standards being Exceeded.

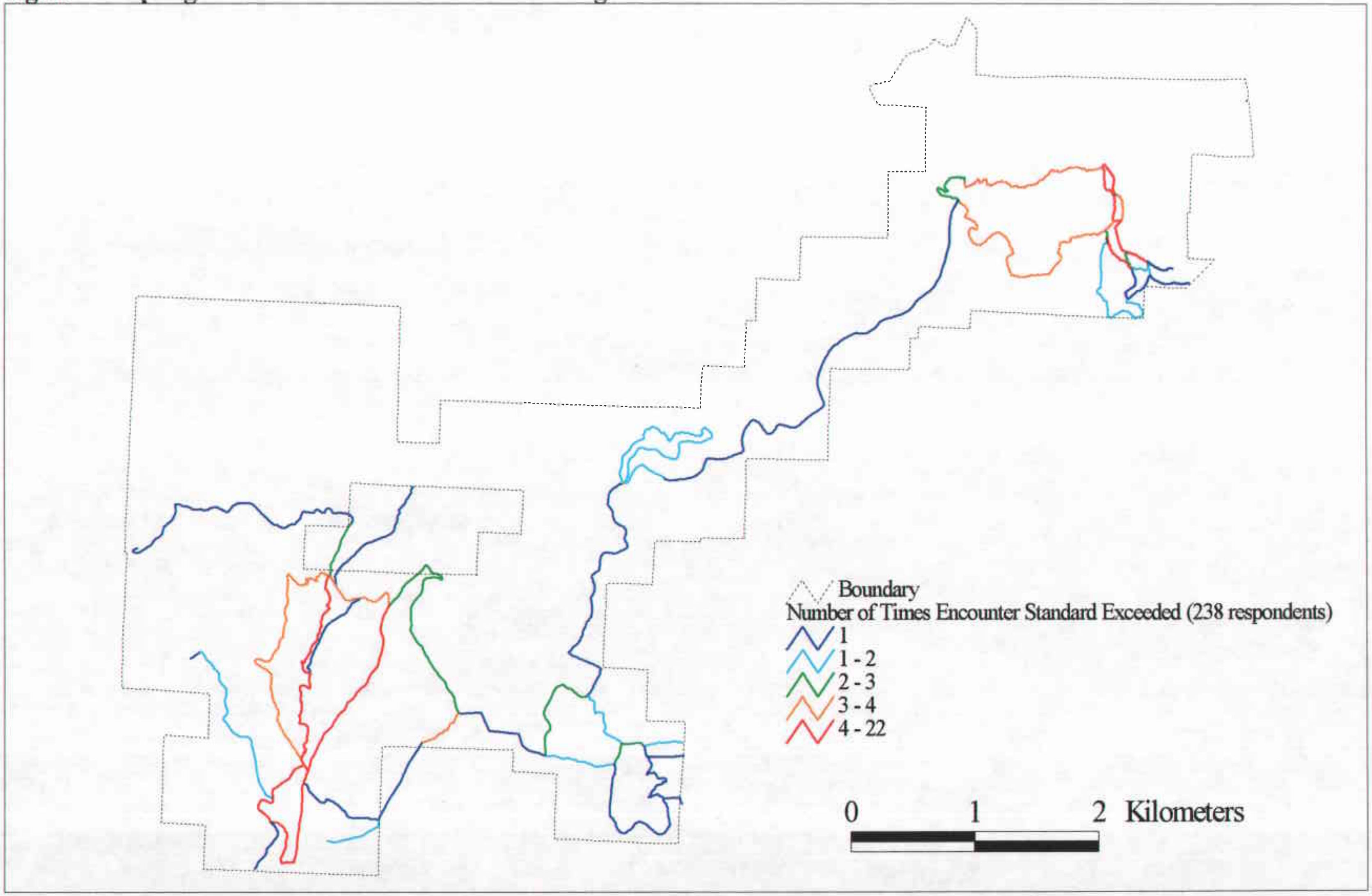


Figure G-1. Fall Locations of Percent of Time in Sight Standards being Exceeded.

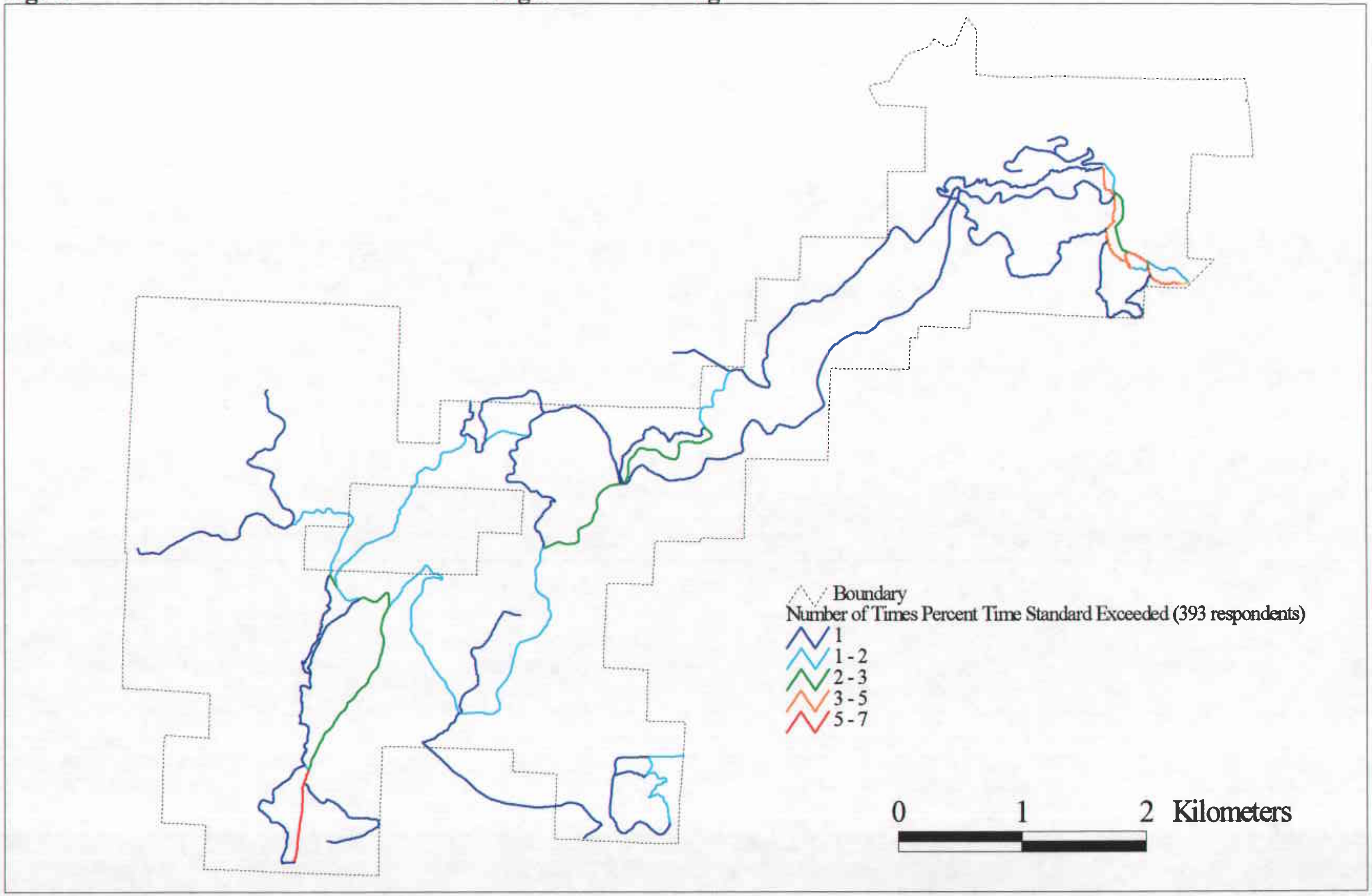


Figure G-2. Spring Locations of Percent of Time in Sight Standards being Exceeded.