# A BASELINE STUDY OF HUMAN IMPACTS IN THE WILDLAND-URBAN INTERFACE: RED ROCK RANGER DISTRICT

By Sarah E. Hankens

A Thesis

Submitted in Partial Fulfillment

of the Requirements for the Degree of

Master of Arts

in Rural Geography

Northern Arizona University

December 2007

Approved:

Pamela E. Foti, Ph.D., Chair

R. Dawn Hawley, Ph.D.

Christina Kennedy, Ph.D.

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ABSTRACT

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SARAH E. HANKENS

In recent decades, an increasing number of people have moved to areas rich in natural amenities and other recreational attractions (Johnson and Beale 2002). People's desire to live near forested landscapes and natural environments has led to an increase in the population of people living in the wildland-urban interface. The wildland-urban interface is the geographic location where private and residential development abuts a landscape dominated by wildland vegetation. Between 1990 and 2000, sixty-percent of new homes were located within the wildland-urban interface (Stewart 2007a). Recent studies show more than one-third of all housing units in the contiguous United States are located within the wildland-urban interface (Radeloff et al. 2005, Stewart et al. 2003). What is unknown is what types of human impacts occur within the wildland-urban interface as a result of private residences abutting open spaces, public lands, and natural wildlands. While people may move to areas within the wildland-urban interface because of its proximity to the natural environment and unhindered vistas, their presence and use patterns may be impacting and compromising those characteristics.

This research uses human impact monitoring to quantify the type, occurrence, and severity of impacts within the wildland-urban interface. Human impact monitoring, regularly used in wilderness and backcountry settings to assess, monitor and inventory human impacts, was modified to apply to the frontcountry setting of the wildland-urban interface in establishing a baseline study. Applying a multiparameter system, in conjunction with the rapid survey format, to assess a variety of human impacts, the researcher selected six one mile transects on the Coconino National Forest boundary and private lands located in Sedona, Arizona or the Village of Oak Creek, Arizona. The four categories of human impacts assessed were social trails, fence cutting, dumping, and other. All but social trails were assessed as a single point, even when they may be present with other impacts at the same locale. Social trails were assessed at the origin and walked to the end; with rapid data collection conducted every one-tenth mile. The following information was collected to adequately characterize the type and severity of the impact: vegetation type and damage, soil type and damage, level of erosion if present, presence of cryptobiotic soil and damage, litter, or vandalism. Social trail data collection also included trail length, depth, width, erosion, origin and terminus. A total of seventy-nine impacts were assessed and documented: thirty-seven social trails, twenty-one fence-cutting impacts, ten dumping impacts, and eleven other impacts.

Results indicate that human impacts were neither severe nor concentrated in occurrence and that human impact assessments within the wildland-urban interface may be useful in helping for land managers to use in order to learn more about the types of impacts communities they serve are having on resources. Human impact monitoring can be conducted by the responsible agency to learn what types of impacts are occurring and develop strategies to mitigate those impacts. Human impact assessments and monitoring can be time consuming and costly, but may provide a unique opportunity for land managing agencies to partner with local residents in joint stewardship of the wildlands.

ACKNOWLEDGMENTS

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I have been assisted by both friends and family throughout my return to school. Thanks to my family for keeping me in their thoughts, and checking in on me, though they are thousands of miles away. A thanks to many of my friends, who I am also lucky to have as coworkers for your patience, listening skills, and counseling.

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# CHAPTER 1: INTRODUCTION

An increasing number of people living in the wildland-urban interface has created a need for land managers and community members to have a better understanding of the extent and severity of human impacts within the wildland urban interface (Stewart, et al. 2003). Wildland-urban interface is (WUI) the term commonly used to identify the area where urban development presses against private and public wildlands (Theobald and Romme 2007). The WUI is estimated to contain between thirty-seven (Stewart et al. 2003) and thirty-nine (Radeloff et al. 2005) percent of all housing units in the continental United States and associated growth is a primary factor influencing the management of national forests. Hammer et al. (2007) states that housing growth adjacent to federal lands has been especially prominent in the West, but that growth in the WUI is largely undocumented.

Proximity to the wildland character and open vistas associated with public lands that people believe will never be developed or traded, is a major attraction. How residents live adjacent to these lands, however, may be detrimental to the wildland character of the lands themselves. By treating the adjacent public lands as their own private property, residents are not recognizing that public lands are intended for the greater good of the general populace and not the benefit of private individuals. Human impacts on adjacent lands, dumping of yard waste, creating private access points, cutting fences, and other impacts have the potential to degrade the wildland character of public lands.

Human impact monitoring systems have traditionally been a valued tool for land managers in backcountry and wilderness areas (Hammitt and Cole 1998, Cole and Spildie

1998, Weaver and Dale), and are most commonly referred to as recreation impact monitoring. The purpose of recreation impact monitoring is to provide land managers with empirical data regarding recreation impacts; their severity and spatial distribution, as well as possible social and ecological concerns (Cole 1989). Much of the existing recreation impact monitoring focuses on hiking, mountain biking, equestrian use, all-terrain vehicles, and campsite impacts.

The application of human impact assessment and monitoring systems within the WUI could provide federal land managers with both hard data about human use and impact patterns in the wildland-urban interface and often overlooked social data. Human impact monitoring is the process of conducting the same inventory over time that allows trends in use patterns and natural resource conditions to be recognized (Hammitt and Cole 1998). This study uses the term *human impact assessment* as it is a baseline exploratory study of impacts, and it is unknown if further impact assessments of the study area will be repeated by implementing a monitoring system. The term *human impact* is used, because while it is assumed that some of the impacts may be recreation-related, no one specific recreation activity is being assessed. Any type of human impact is assessed. This process, when applied to the WUI, provides public land managers with empirical data that enables them to make science-based decisions for future management of the area.

Just as recreation impact monitoring is conducted to assess and compile data regarding recreation related impacts, this study will apply human impact monitoring to assess and compile a baseline study of human impacts related to the wildland-urban interface. Human impact monitoring could then be used to evaluate the relationship between housing density and the presence of human impacts.

**Research Questions and Objectives**

This research will establish a baseline study of human impacts in the wildland-urban interface (WUI) near the city of Sedona and Village of Oak Creek. While conducting field research and collecting secondary data sources, the researcher will explore factors that may influence the presence of human impacts in the WUI.

The research questions are the following:

1. Will areas without adjacent housing have no visible signs of human impacts?
2. Is there a relationship between housing density and amount of visible human impacts?
3. Will presence of scrub and dense vegetation decrease the quantity of human impacts?
4. Will rugged or steep terrain decrease the quantity of human impacts?

In addition to answering the above research questions, the researcher hopes to provide a useful and applicable tool for land management agencies. A variety of objectives have been established to provide land managers with enough information to establish their own human impact assessment.

The objectives of this study are as follows:

1. To develop a human impact baseline study that will accurately assess human impacts in the wildland-urban interface

2. To conduct a baseline study of human impacts in the wildland-urban interface around Sedona, Arizona and the Village of Oak Creek, Arizona in the Coconino National Forest
3. To provide land managers with methodology and data for human impacts in the wildland-urban interface
4. To provide information to land managers to assist with policy and management decisions related to the wildland-urban interface

**Justification**

Between the establishment of the U.S. Forest Service in 1905 and the emergence of the automobile as the primary form of transport, it was the role of the district ranger to annually ride the district boundary by horseback. The study site, the wildland-urban interface that surrounding the communities of Sedona and Village of Oak Creek, has long since abandoned this practice. When the boundary was last ridden by the district ranger there probably was not the extent of wildland-urban interface that is now present (Stafford 2007). The District has not conducted any human impact monitoring, and Stafford agrees that it would be a useful tool in assessing the needs of the community as well as potential actions and adjustments needed by management.

There is a general understanding and acknowledgement within the Forest Service that residents who live adjacent to the forest have an impact on the natural resources, though the type, location, and extent is not always known. If given an unlimited budget to manage the wildland-urban interface the Recreation Staff Officer for the Red Rock Ranger District, Bill Stafford, stated he would put more money into education, engineering, and law enforcement for property infringement, vandalism, and natural resource damage (Stafford 2007). Human impact assessments and monitoring would be an objective method for the Forest Service to obtain information to assist the district in deciding what type of educational outreach would be appropriate for the community. Outreach efforts would reflect information gathered through assessments and monitoring to promote neighborly stewardship, indicate preferred access points and social trail patterns to assist in engineering more system neighborhood trailheads, and illustrate the variety and severity of impacts that may need attention from law enforcement officers.

The researcher is familiar with the Red Rock Ranger District and the communities of Sedona and the Village of Oak Creek. It was not anticipated that the human impacts would be ecologically or socially severe, although it was expected that there would be an abundance of user created trails and associated residential impacts. This baseline study quantifies, by assessing multiple boundary transects adjacent to the communities, the extent, type, frequency, and severity of human impacts by private residents on adjacent public lands.

# CHAPTER 2: LITERATURE REVIEW

The number of people living in the wildland-urban interface has increased significantly over the past several decades. During the same time period, recreation use on national forests lands has also increased. In fact it has been documented that recreation opportunities and easy access are some of the reasons people are moving to areas located within the wildland-urban interface (Johnson and Beale 2002). As the migration trend to areas within wildland-urban interface continue, environmental impacts and consequences are anticipated to increase as well (Stewart et al. 2003, Radeloff et al. 2005). The purposes of this review are to: 1.) explore the relationship of housing trends in the wildland-urban interface; 2.) discuss the evolution of the wildland-urban interface and its management; 3.) look at the history of recreation trends, management, and obtaining user information in the U.S. Forest Service; and 4.) discuss recreation impact monitoring techniques and how they may be applied to human impacts in the wildland urban interface.

## Housing Trends in the Wildland-Urban Interface

Since the 1970s, there has been a particularly high rural migration of Americans who want to live near open spaces, adjacent to forests and woodland, near recreational opportunities, and have access to open spaces and natural amenities (Davis 1990, Stewart et al. 2007, Johnson et al. 2002, Beyers and Nelson 2000, Radeloff et al. 2005, Radeloff et al. 2005a). This phenomenon has been especially prominent in the West, in forested areas, and in areas adjacent to federal lands. Wildland-urban interface (WUI) growth, however, remains largely undocumented (Hammer et al. 2007).

There are three categories of WUI, determined by housing density and pattern of development adjacent to wildlands: interface, intermix and occluded (USDA and USDI 2001, Radeloff et al. 2005, Hammer et al. 2007). Multiple definitions for each type exist, which is one of the reasons it is difficult to quantify the extent of WUI, and as a result the extent of consequences for nearby wildlands. Both the USDA and USDI published the following definitions in 2001 to identify WUI communities near federal lands. They are accepted as generic definitions and used for general purposes, but are somewhat abstract and too generic to quantify location and extent.

1.) Interface: There is a clear line of demarcation where development abuts wildland fuels, and contains three or more structures per acre, Wildland fuels do not generally continue into the developed area (Davis 1990, USDA and USDI 2001, Theobald and Romme 2007)

2.) Intermix: No clear demarcation, wildland fuels continue into the developed area, at least one structure per forty acres (Davis 1990, USDA and USDI 2001, Theobald and Romme 2007)

3.) Occluded: Occluded (or isolated)- there is a clear line of demarcation where isolated areas of wildland vegetation in the midst of urban areas (Theobald and Romme 2007, Davis 1990).

Identification of the WUI is important for multiple reasons. The WUI is a focal area for human-environment conflict, such as the destruction of home by wildfires, habitat fragmentation, introduction of exotic species, and biodiversity decline (Radeloff et al. 2005). The highest priority for federal land management agencies within the WUI is to protect life and property from wildfire. To meet that priority, and prevent potential loss, federal land managers have the enormous task of thinning and managing millions of acres of wildland vegetation from which the natural wildfire cycle has been removed. The number of homes and current housing trends within the WUI combined with a century of wildfire suppression tactics has created an environment where wildfire is the foremost managing concern within the WUI (Davis 1990). Correct identifications of areas identified as WUI may lead to greater funding for wildfire prevention efforts and other management needs.

Susan I. Stewart and Volker C. Radeloff have both extensively studied the wildland-urban interface types, location, and extent throughout the United States. In 2003, Stewart's presentation at the 2nd International Wildland Fire Ecology and Fire Management Congress discussed the need for clarification of the WUI definition to better characterize the WUI. Consistent between both Stewart and Radeloff's research is the need for clarification of the term "wildland" from the 2001 USDA and USDI definition. The USDA and USDI definition does not provide any examples of wildland vegetation. The language within the definition was created specifically for wildfire prevention and suppression within the WUI and cites wildland vegetation as a fuel type.

In separate studies, Stewart and Radeloff included and excluded the same types of vegetation from the wildland definition. Included wildland vegetation types were: deciduous and coniferous forests, native grasslands, shrubs, emergent herbaceous wetlands (Stewart et al. 2003), and shrublands (Radeloff et al. 2005). Excluded from wildland vegetation were orchards, pasture, arable lands, row crops (Stewart et al. 2003), urban/recreational grasses, small grains, fallow, and commercial/industrial areas (Radeloff et al 2005). Theobald and Romme include agricultural vegetation types in their 2007 study discussing expansion of the WUI (Theobald and Romme 2007).

In a series of articles published between 2003 and 2007, Stewart and Radeloff, along with other contributors, classify the WUI in the contiguous United States using a variety of vegetation levels. Their studies produced maps that identify WUI interface and intermix, and their housing density: high (>3 housing units/1acres) (HU/acres), medium (<3 HU/1 acres), and low 1HU/2.5acres) (Stewart et al 2003). Stewart's 2003 study classified WUI housing with U.S. Census data from 2000. Using a vegetation threshold for interface of less than fifty percent but within 1.5 miles of an area over 1,235.5 acres in size that is more than 75 percent vegetated, and intermix with a vegetation threshold of more than 50 percent wildland vegetation, Stewart's study resulted in 36.7 percent of all U.S. houses located in the interface and intermix (Stewart et al. 2003).

Stewart and Radeloff's articles published in 2005, 2006, and 2007 stated that 38.5 percent of all U.S. houses are located in the interface and intermix, 1.8% higher than their earlier 2003 study. As there were no differences in the classification of housing density levels or wildland vegetation between the 2003 publication and the latter studies, the increase in percentage is assumed to be a direct reflection of the increased migration to areas location within the wildland-urban interface.

Key findings from their studies and publications characterizing WUI distribution across the United States (Stewart et al. 2003, Radeloff et al. 2005, Stewart et al. 2006, Stewart et al. 2007) are as follows:

- WUI, interface and intermix, is present in every state, although percentage of land area, and housing units greatly varies
- A high percentage of land area in the WUI does not always result in a high number or percentage of housing units in the WUI, and likewise a low percentage of land area does not result in a low percentage of housing units in WUI. (Example: 2% of land area in New Mexico, 1.6 million acres, is classified as WUI, but 79% of homes are

located in the WUI (Stewart et al. 2003, Duryea and Vince 2005). See Table 2.1 for detailed interface and intermix samples by state.

- Intermix is much more extensive than interface, 82% of land area and 18% of land area, respectively. Yet:
  - As a result of higher average housing density in the interface, 1HU/1.47acres, versus an average intermix housing density of 1HU/7.06acres, 47% of WUI homes were located in interface and 53% in intermix (Stewart et al. 2003, Stewart et al. 2007).

**Table 2.1 State rank by area and housing units in interface, intermix, and total WUI**

| Rank | Interface | | Intermix | | WUI | |
|---|---|---|---|---|---|---|
| **Area (ha)** | | | | | | |
| 1 | PA | 1,048,577 | NC | 4,784,695 | NC | 5,527,830 |
| 2 | CA | 746,021 | GA | 3,328,527 | PA | 4,338,705 |
| 3 | NC | 743,134 | PA | 3,290,128 | GA | 3,957,293 |
| 4 | TX | 728,196 | VA | 2,911,236 | NY | 3,573,641 |
| 5 | NY | 707,604 | NY | 2,866,037 | VA | 3,504,168 |
| **Area (percent)** | | | | | | |
| 1 | DC | 19 | RI | 61 | CT | 72 |
| 2 | NJ | 15 | CT | 60 | RI | 70 |
| 3 | MA | 12 | MA | 53 | MA | 65 |
| 4 | CT | 12 | NH | 38 | NJ | 46 |
| 5 | RI | 9 | NC | 38 | NC | 44 |
| **Housing units (number)** | | | | | | |
| 1 | CA | 3,480,285 | CA | 1,607,624 | CA | 5,087,909 |
| 2 | FL | 1,636,248 | GA | 1,479,368 | FL | 2,587,074 |
| 3 | TX | 1,426,326 | NC | 1,451,811 | TX | 2,568,047 |
| 4 | PA | 1,395,140 | PA | 1,146,366 | PA | 2,541,506 |
| 5 | NY | 983,059 | TX | 1,141,721 | NC | 2,322,458 |
| **Housing units (percent)** | | | | | | |
| 1 | WY | 62 | ME | 50 | NH | 83 |
| 2 | NM | 41 | NH | 47 | WV | 82 |
| 3 | MT | 40 | GA | 45 | WY | 80 |
| 4 | UT | 40 | WV | 42 | ME | 79 |
| 5 | WV | 39 | NC | 41 | NM | 79 |

(Stewart et al. 2006)

In the American West, both interface and intermix exist, with communities and cities often bound on all sides by public and federal lands. In the West, thirty percent of WUI is federally owned, with the largest federal land manager being the Forest Service, managing thirty-nine percent of federal WUI, followed by the Bureau of Land Management (6.7%), and National Park Service (3.6%) (Theobald and Romme 2007). In western states a large percentage of land is federal. For example, forty-two percent of Arizona lands are publicly held, while Nevada has the highest percentage of public lands in the United States, at eighty-six percent (Department of Conservation and Natural Resources 2007). The high percentage of public lands in the West concentrates WUI into isolated areas rather than being widely dispersed over landscape, which is found in the East.

In Eastern states there is significantly more intermix than interface as a result of the overall higher population density, availability of buildable land, large areas of urban, suburban, and rural communities mingling with smaller parcels of privately held wildlands, and the occasional state or federal forest (See Table 2.1). The location of the study area, Arizona, is not included in Table 2.1 because it does not rank high enough in any of the included categories. This may change in future decades as a result of recent residential growth trends. By comparing Figure 2.1 and Figure 2.2, one can see that the WUI intermix and interface is denser is more pronounced in the Eastern states, coinciding with an overall higher population density. Much of the upper Midwest lacks WUI due to the dominance of agricultural crops as the vegetation type.

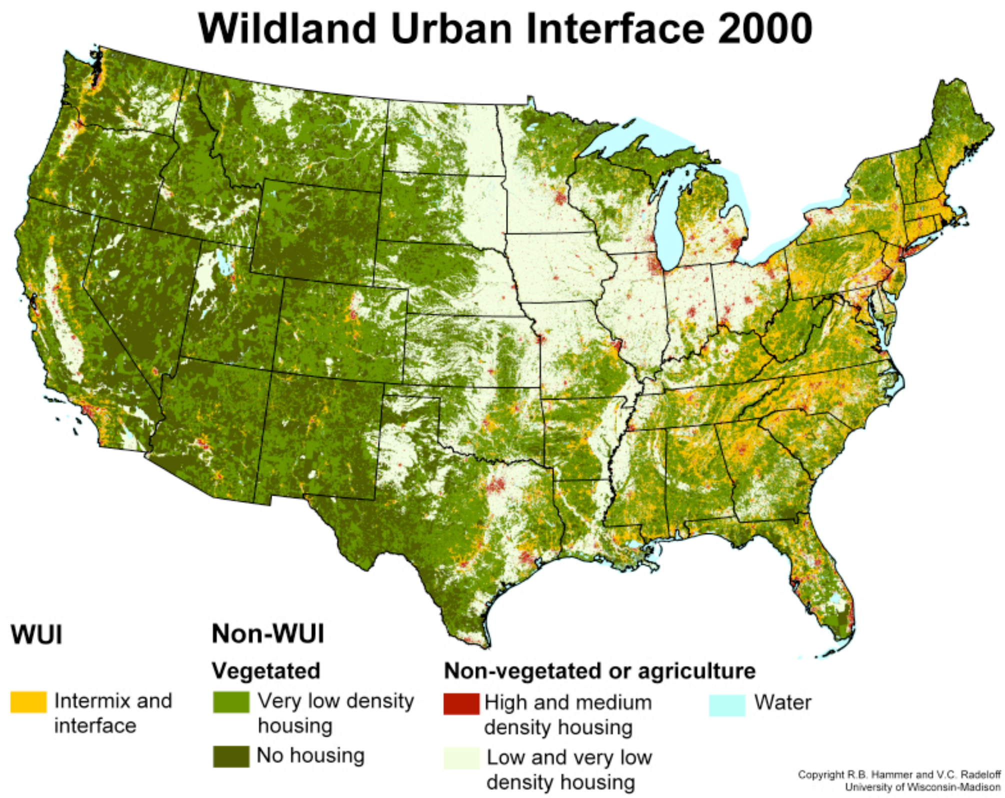



**Figure 2.1 Wildland-urban interface 2000**
(Radeloff et al. 2005)

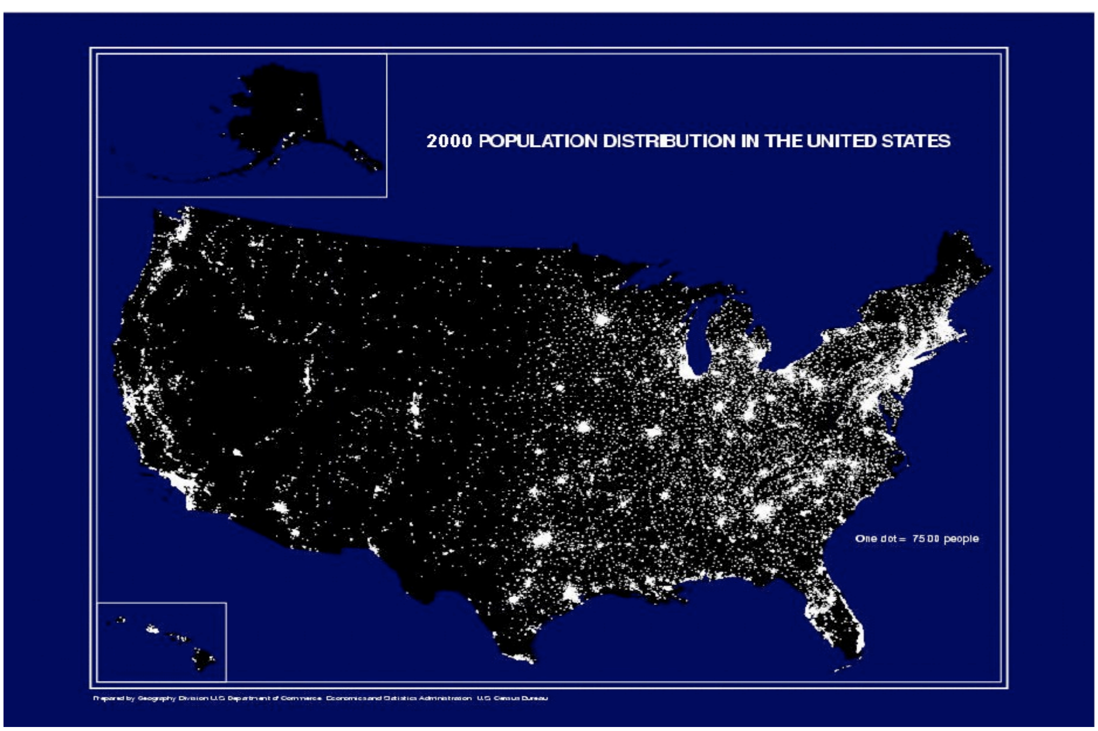



**Figure 2.2 Population Distribution in the United States**
(US Census Bureau 2000)

As a result of wildland fires, the WUI interface category is most often publicized because it has the densest development, thus the highest numbers of structures at risk. A large percentage of WUI in the West is located in areas of high fire severity, and it is those areas of WUI that are most heavily researched. The higher level of fire severity and federal management of WUI in the West creates a situation where public land management agencies shift roles from resource protection to protection of life and property. Theobald and Romme (2007) stated that eighty-three percent of the WUI is located in the eastern states, and only ten percent of WUI is in the high severity class, as compared with fifty percent high severity within the Western WUI areas.

Hammer et al. (2007) studied WUI growth patterns in California, Oregon, and Washington during the 1990s. Results showed the intermix WUI expanded at a rate more than five times that of the interface type, 14.5% and 2.5 % respectively, and that overall, sixty-one percent of new housing units were located in the WUI. The study looks at WUI growth and fire regime condition class, and does not incorporate other variables that may be impacted by WUI growth.

A comparison study of the effects of rural and suburban sprawl on forests by Radeloff et al. (2005a) concluded that the effects of rural sprawl are more significant, than suburban sprawl, from a conservation perspective. Paired with the findings of Hammer et al., WUI intermix development poses a significant threat to many rural, undeveloped landscapes. The rural sprawl pattern, which would be more associated with intermix WUI are scattered, and therefore may result in a larger area of disturbance, including important fragmentation impacts (Theobald and Romme 2007), higher levels of habitat loss (Radeloff et al. 2005a), increased exposure to exotic species and difficulty in maintaining forest health (Dwyer and Chavez 2005).

**Understanding and Managing the Wildland-Urban Interface**

Although the interfacing of wildlands and developed landscapes has been present for over two centuries (Ewert 1993), it is only in recent decades that it has been defined, discussed, and a clear need for further research has been identified. The rapid growth of areas within the wildland-urban interface (WUI) since the 1970s has brought the need for a better understanding of the WUI, wildfire risks, and its management to the forefront of public land and forest management.  Currently accepted WUI definitions are primarily comprised of three interacting components: social, ecological component, and geographic location.  The WUI is the geographic location where these components overlap and the potential for human-environment conflicts increases. (See Figure 2.3)

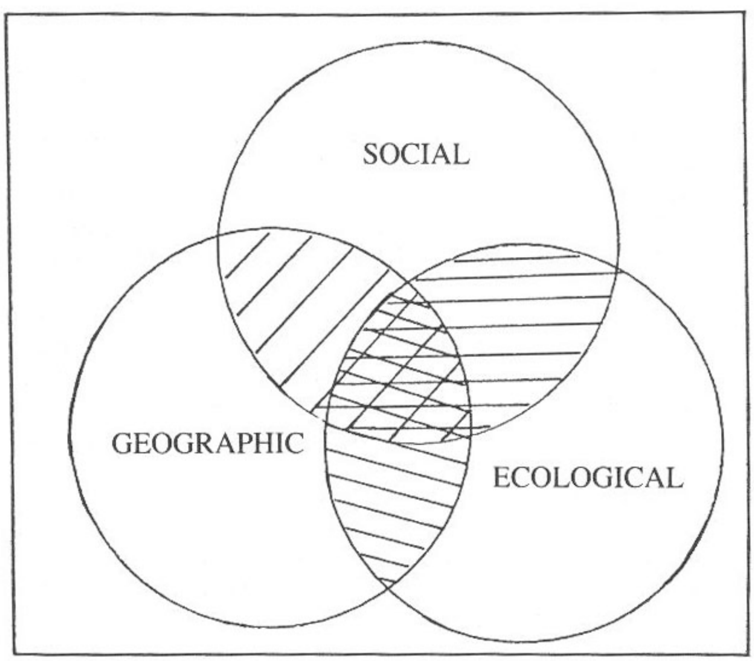



**Figure 2.3 Delineating the interface**
(Lee 1984)

The concept, understanding, and management of the wildland-urban interface has evolved and will continue to do so as a result of the changing nature of the social and ecological components. Housing trends within the WUI and management of wildland vegetation change throughout time. Early literature discussing the wildland-urban interface includes Vaux (1982) and Bradley (1984). Prior to the acceptance of the term wildland-urban interface, Bradley defined the urban/forest interface as two traditional land uses occurring near or adjacent to one another, forestry and land development. Early WUI management did not yet seem to be focused, but rather managers had come to the realization that its ecosystem management was made increasingly complex as a result of the dynamic social component. Soon after Bradley's publication, wildfire emerged as the focus of both WUI management and research. Davis (1990) identified wildland fire as being the primary threat and issue within the WUI, for both the public and land managers, stating that the nationwide scope of the problem could be overemphasized (Davis 1990). The term "wildland-urban interface" is now used almost exclusively in the context of wildland fire (Stewart et al. 2007).

The WUI has become the central focus of wildland fire policy in the United States (Stewart et al. 2007), and wildland fire has become the focus of WUI management. The emphasis on wildfire management and prevention is a direct result of the decades long trend of increases in residences adjacent to wildlands, and past fire management policies. Many cities, metropolitan areas, and rural communities throughout the West are surrounded by or adjacent to federal lands, primarily national forests. In 1987, then US Forest Service deputy chief for state and private forestry, Allan J. West, stated the following WUI management policy at a National Fire Protection Association conference:

> "The first priority of the Forest Service is to protect life and property. However, our legislative responsibility is to protect natural resources…However, under no circumstances will we walk away from a home and let it burn just because we have natural resources to protect." (Davis 1990: 27)

Since then, wildfire prevention and suppression has played an increasingly large role in the Forest Service's management of not only the WUI but also National Forest System lands as a whole. In 2003, the Healthy Forest Restoration Act (HFRA) became law, reiterating the need for resource managers to work with communities and homeowners in the WUI to reduce the risks associated with wildfire (Stewart et al. 2007). Also in 2003, then Forest Service Chief, Dale Bosworth, identified wildfire as one of the four threats to the National Forest System, furthering the focus of WUI management research, policy, and management on wildfire. Years of drought, expanding WUI and overgrown forests have created an environment in which the number of fires continues to increase, resulting in escalating costs of wildfire suppression; in 2006, the USDA Forest Service Fire & Aviation Management spent $1.5 billion to fight fires (USDA Forest Service 2007c). In comparison, the 2006 presidential budget request for the National Forest System, management, all 155 forests and 20 grasslands, was $1.6 billion (USDA Forest Service 2005).

Although wildfire prevention and management is the priority within the WUI, there are other management considerations as well. Ewert (1993) recognized that while the societal aspect of WUI management was acknowledged, it was an area where further research was needed. Research on land ethics, creating a more diverse user population, land ownership patterns, and conflict management within the WUI could all be further researched (Ewert 1993). Federal lands that contain WUI around both urban and rural communities create a unique opportunity for land managers to provide wildland and environmental education, and recreation opportunities to peoples that may not otherwise have the access or time to travel to a destination national forest or national park (Stein 2005). There was an early recognition that WUI management requires special knowledge, skills and abilities that do not always exist in public land management agencies, further complicating the creation of a successful WUI management strategy for both the human and ecological factors (Bradley 1984).

The accessibility of the WUI, adjacent to private property and residences, provides a challenge to land managers to both protect the integrity of the natural ecosystems and also provide recreation and forest use opportunities. The wildland-urban interface is unique in that there is continuous use, often on a twenty-four hour basis, a high density of uses, severe resource impacts, and a growing pressure from the cities (Ewert 1993). It is known that the WUI is an area where the influence of human development is manifest in many different ways: habitat fragmentation, interruption of hydrology, introduction of non-native plants, effects on air quality, and other ecosystem structures functions and services. There is an admitted need for further research in many areas (Bradley 1984, Ewert 1993, Stewart et al. 2007).

WUI In the Study Area

Available existing WUI research for the study area is limited, with much of the management policy focused on wildfire policy, prevention, and management. The study area is the WUI surrounding Sedona, Arizona and the Village of Oak Creek, Arizona. This confirmed the researcher’s belief that there is a need for further WUI research in other fields, as literature confirms that other less researched issues exist within the WUI.

Upon searching for a WUI map of the study area, the researcher found that there is no one definitive WUI map, but many variations, for a variety of wildfire and fuel management purposes.  The included WUI map (See Figure 2.4), classifications were produced by University of Wisconsin, headed by Volker C. Radeloff.  The classifications for housing density and vegetation types follow the guidelines for the Stewart and Radeloff studies.

Amendment 12 by the Coconino National Forest (USDA Forest Service 1998) identified management changes needed and addressed in the study area.  The management for the affected area, the Coconino National Forest surrounding Sedona, the Village of Oak Creek, and Oak Creek Canyon, was appended to the 1987 Coconino National Forest Management Plan in order to "substantially add to the protection of this treasured landscape, as well as to better meet social demands, residential development, and land use expectations."(USDA Forest Service 1998: introduction).

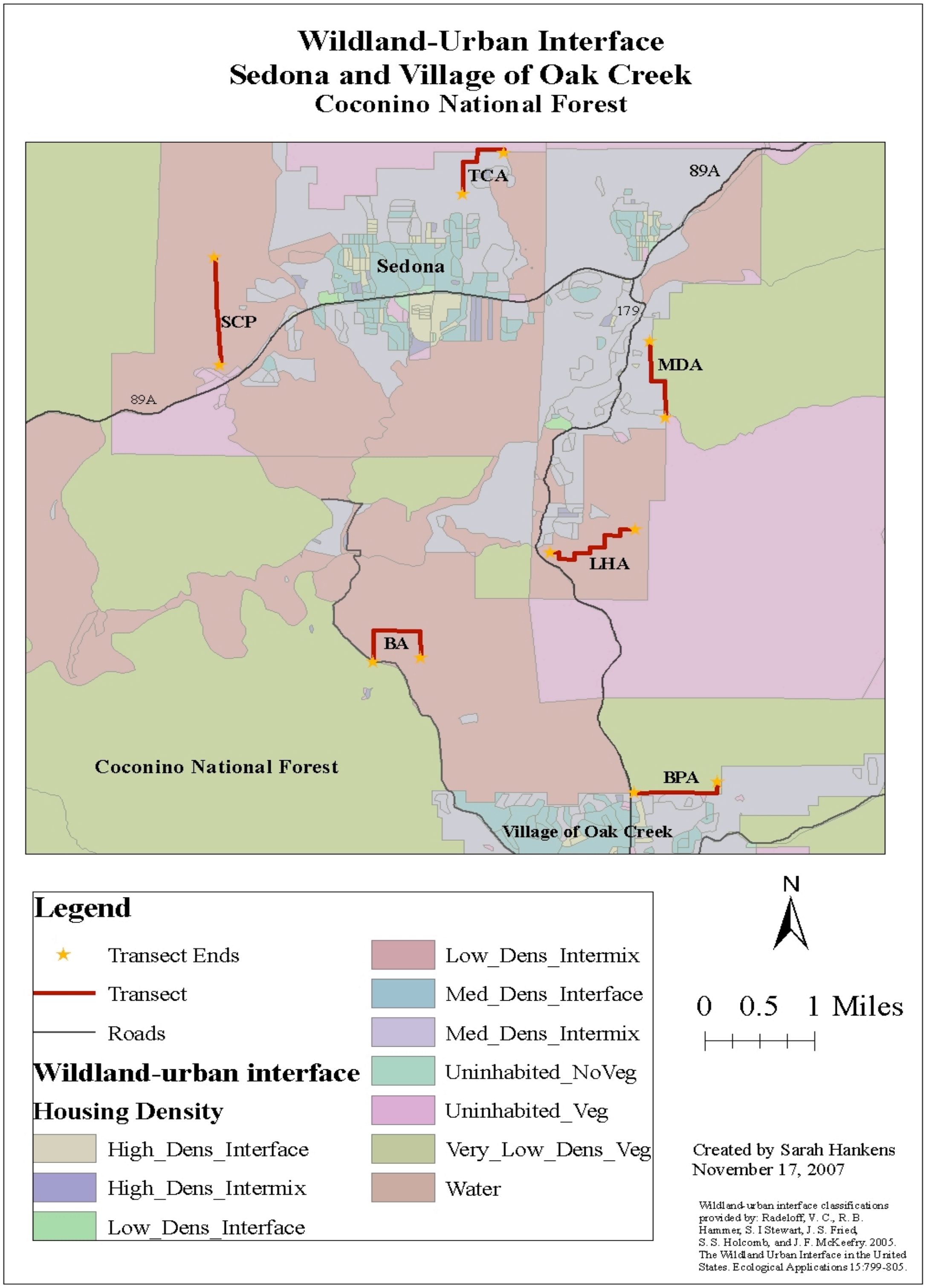



**Figure 2.4 WUI Classifications for Amendment 12 and the Study Area**

Amendment 12 land exchange policy places occluded WUI parcels, also known as private inholdings, as a high priority for acquisition due to the Forest Service's conclusion that, if not acquired or protected by land trust, parcels would be developed. The amendment also limits the potential for land exchange adjacent to present communities, which should further limiting WUI interface and intermix growth around Sedona and the Village of Oak Creek.

Amendment 12 creates a new management area, Neighborwoods Management Area 24 (MA 24) that is "Sedona's Backyard" and the WUI around the communities within the Amendment 12 area (See Figure 2.5). There are many objectives for MA 24, which fall into four categories: community, recreation, commercial, and interpretation and communication. The objectives of MA 24 address many of the concerns identified by researchers as needing more information. Community objectives include an effort by the Forest Service to provide information about noxious plants; intense fire management within the WUI, including identifying places of high fuel buildup; providing interpretation and information to residents regarding wildfire; and educating homeowners and builders on risk-reducing practices (USDA Forest Service 1998). Interpretation and communication objectives emphasize the importance of the Forest Service partnering with residents to encourage stewardship of the Coconino, and collaborating with Red Rock State Park on environmental education and stewardship.

**Recreation on National Forests**

Congress established the U.S. Forest Service in 1905 to ensure a continuous supply of water and timber for the nation's benefit. The Organic Act of 1897 stated:

> "No national forest shall be established, except to improve and protect the forest within the boundaries, or for the purpose of securing favorable

> conditions of water flows, and to furnish a continuous supply of timber for the use and necessities of citizens of the United States." (US Congress 1897)

Having greatly expanded upon Gifford Pinchot's original Forest Service vision, "to provide the greatest amount of good for the greatest amount of people in the long run", the U.S. Forest Service now provides much more than timber and water to the people of the United States (USDA Forest Service 2007d).

Since the 1950s there has been a steady growth trend of recreation on national forest lands (Cordell and Thompson 2003). The predominant public use of National Forest System lands today is recreation. In the 2005 National Visitor Use Survey for the Coconino National Forest, eighty-seven percent of participants responded that their visit to the forest was for recreation (USDA Forest Service 2006). The following is a review of recreation policy, trends, and user surveys on National Forest System lands.

Forest Service Recreation Policy

After the Great Depression and World War II, recreation became a major component of American life (Driver et al. 1999:18). In response to an increase in both mobility and affluence, a greater number of people were traveling and recreating on public lands. In 1958, Congress recognized a need for further evaluation of recreation infrastructure and supply, and the Outdoor Recreation Resource Review Commission (ORRRC) was created. Prior to the release of the ORRRC report stating their findings in 1962, Congress passed the Multiple-Use Sustained Yield Act (MUSYA) (See Table 2.2 for a timeline of federal efforts).

**Table 2.2 Federal efforts that have shaped current Forest Service recreation policy**

| Congressional Efforts | Year |
|---|---|
| Forest Service Organic Administration Act (Organic Act) | 1897 |
| Outdoor Recreation Resources Review Commission (ORRRC) | 1958 |
| Multiple Use Sustained Yield Act (MUSYA) | 1960 |
| Outdoor Recreation Act | 1963 |
| Wilderness Act | 1964 |
| National Wild and Scenic Rivers System Act | 1968 |
| National Trails System Act | 1968 |
| National Environmental Policy Act (NEPA) | 1969 |
| National Forest Management Act (NFMA) | 1976 |

The MUSYA, supplemental to the Organic Act, expanded Forest Service land management policy to include recreation, wildlife, range, and fish as of having equal importance as timber and watershed production. The 1962 ORRRC report, *Outdoor Recreation for America*, also formally recognized a massive federal movement to create more recreational opportunities in the United States, supporting the incorporation of recreation as one of the multiple-uses desired for Forest Service lands (Driver et al 1999). MUSYA created an important management shift to include natural resources as an important public amenity of public lands. While MUSYA was primarily intended for adoption by the Forest Service, the Bureau of Land Management also expanded their management policy to reflect the shift toward multiple-use.

Many other acts have passed since MUSYA and some of those have strongly shaped current recreation management policy on federal lands. The Outdoor Recreation Act of 1963 was enacted to assess and ensure adequate outdoor recreation resources, and created a Bureau of Outdoor Recreation (BOR) under the Department of Interior. In less than two decades, the BOR had been eliminated, in part due to interagency rivalry between land management agencies and also because it had accomplished many of the recommendations from the 1962 ORRC report (Driver et al. 1999). Upon elimination of the BOR, the remaining responsibilities of assessment of outdoor recreation services and the National Outdoor Recreation Plan became the responsibility of the Forest Service.

It did not go unrecognized that different types of recreation experiences were desired. The Wilderness Act provided the Forest Service, and other federal land management agency, with the means to protect designated areas to retain their primeval character and influence. The Wilderness Act also created policy to manage and provide for outstanding opportunities for solitude or a primitive and unconfined type of recreation. The Forest Service manages 418 wilderness units, approximately thirty-five million acres, or eighteen percent of the National Forest Lands system and thirty-three percent of all wilderness acres (wilderness.net 2007). The Red Rock Ranger District contains all or part of six wilderness areas, approximately 120,000 acres, comprising about 20% of the district lands.

The National Wild and Scenic Rivers System Act (WSR) and National Trails System Act (Trails Act) were both passed by Congress on October 2, 1968 (Betz et al. 1999). The WSR Act enabled Congress to designate rivers as wild, scenic, or recreational if they met a certain criteria of outstandingly remarkable values. The Forest Service manages more WSR miles than any other agency, a total of 4,327 miles, or forty-percent of the entire system (Betz et al. 1999). Arizona's only designated WSR is a portion of the Verde River, forming the southern boundary of the Red Rock Ranger District. The Verde River is the boundary for the Coconino and Prescott National Forest, thus management of the valued resource is shared. Designation as Wild and Scenic requires management to maintain the area as free-flowing waters. The Trails Act, similar to the WSR classes, classifies trails as historic, scenic, or recreational. In 1995 5,585 miles of National Recreation trails were located on federal lands, with an equal amount located on state, local, and other agency lands.

National Environmental Policy Act, and National Forest Management Act all enacted soon after MUSYA, continued to emphasize the role of the US Forest Service in restoring and maintaining environmental quality, despite the land's multiple-uses. The National Environmental Policy Act (1969) recognized:

> "the profound impact of man's activity on the interrelations of all components of the natural environment, particularly the profound influences of population growth, high-density urbanization, industrial expansion, resource exploitation, environmental quality to the overall welfare and development of man." (US Congress 1969)

Forest Service Recreation Use and Management

Visitation to Forest Service lands has far exceeded that of any other federal land management agency (See Table 2.1). One of the reasons these lands receive such heavy visitation is that numerous national forests border some of the nation's largest cities (Vince et al. 2005), as well as a large number of communities throughout the West.

**Table 2.3 Federal Agency Visitation**

| **Agency** | **Visits in 1996 (millions)** |
|---|---|
| Bureau of Land Management | 58.9 |
| Forest Service | 859.2 |
| Fish and Wildlife Service | 29.5 |
| National Park Service | 265.8 |
| Corps of Engineers | 375.7 |
| Bureau of Reclamation | 38.3 |
| Tennessee Valley Authority | 0.6 |
| Total | 1628.0 |

(Stein 2005:143)

The U.S. Forest Service has a dual mission when managing for recreation; natural resource protection by reducing impacts and providing high quality outdoor recreation opportunities (Dorwart 2004). Two methods that can be integrated to assist land managers in determining appropriate types and levels of use are the Recreation Opportunity Spectrum (ROS) and Limit of Acceptable Change (LAC). The ROS is a planning, management, and research concept intended to provide a variety of opportunities ranging from modern and developed to primitive, succinctly phrased "from the paved to the primeval." (USDA Forest Service 1979). The LAC process was originally developed to help land managers establish desired conditions to preserve wilderness attributes, that are monitored through ecological and social concerns, along with recreation opportunities (Brunson 1998). It has been found that LAC can also be applied to non-designated areas. It is the manager's job to manage both the visitor and the setting to ensure that changes do not exceed acceptable standards (Stein 2005).

The majority of Forest Service recreation management research, as well as visitor experiences, focus on wilderness areas. Much of the recreation research pertains to approaches to mitigating and managing recreational impacts in wilderness areas (Cole 1996). With the increase in recreational use of public lands, it is imperative that research of non-wilderness areas should also be conducted. This view is supported by Krumpe and Lucas (1986) in "The President's Commission on Americans Outdoors" as they note that there is a need for research on trails and trail users in non-wilderness areas.

In a 2005 speech, then U.S. Forest Service, Chief Dale Bosworth, stated that unmanaged recreation is as one of the four threats[1] to agency land (USDA Forest Service 2005a). The primary recreation activity threat included in unmanaged recreation is the increased use of off-highway vehicles, which has since been addressed through the Travel Management Rule. Not included in the threat of unmanaged recreation is the

[1] The four threats identified were fire and fuels, invasive species, loss of open space, and unmanaged recreation.

proliferation of non-motorized, user-created trails and other off-trail impacts. Neither Forest Service policy nor studies regarding non-motorized user-created trails and human impacts within the WUI could be found, although it is acknowledged by professionals that they occur on national forests, and that they are most likely increasing, coincidental with development rates in adjacent areas.

The presence of numerous communities within the Coconino National Forest, and the fact that the communities and the forest are popular recreation destinations, has created a complex management situation for the Forest Service. Recreation opportunities on the Coconino National Forest are created and maintained not only to serve the local communities, but also regional, national, and international visitors. Recreation opportunities on the Coconino National Forest include thousands of miles of motorized roads and trails, downhill and Nordic skiing, a variety of non-motorized trails, four heritage sites that are open to the public and hundreds that remain hidden, and ten designated wilderness areas.

The study area for this research is located on the Red Rock District, that comprises the southeastern quarter of the forest. A portion of the Red Rock District, around Sedona and the Village of Oak Creek, has been approved for special management guidelines under Amendment 12 (See Figure 2.5). This area, the Red Rock area, is also known as the Amendment 12 area. Amendment 12 also categorizes portions of this area as Management Area 24 Neighborwoods, coinciding with the WUI areas, creating management objectives that recognize the close proximity of residential neighborhoods and modify management policies to better serve the needs of the communities.

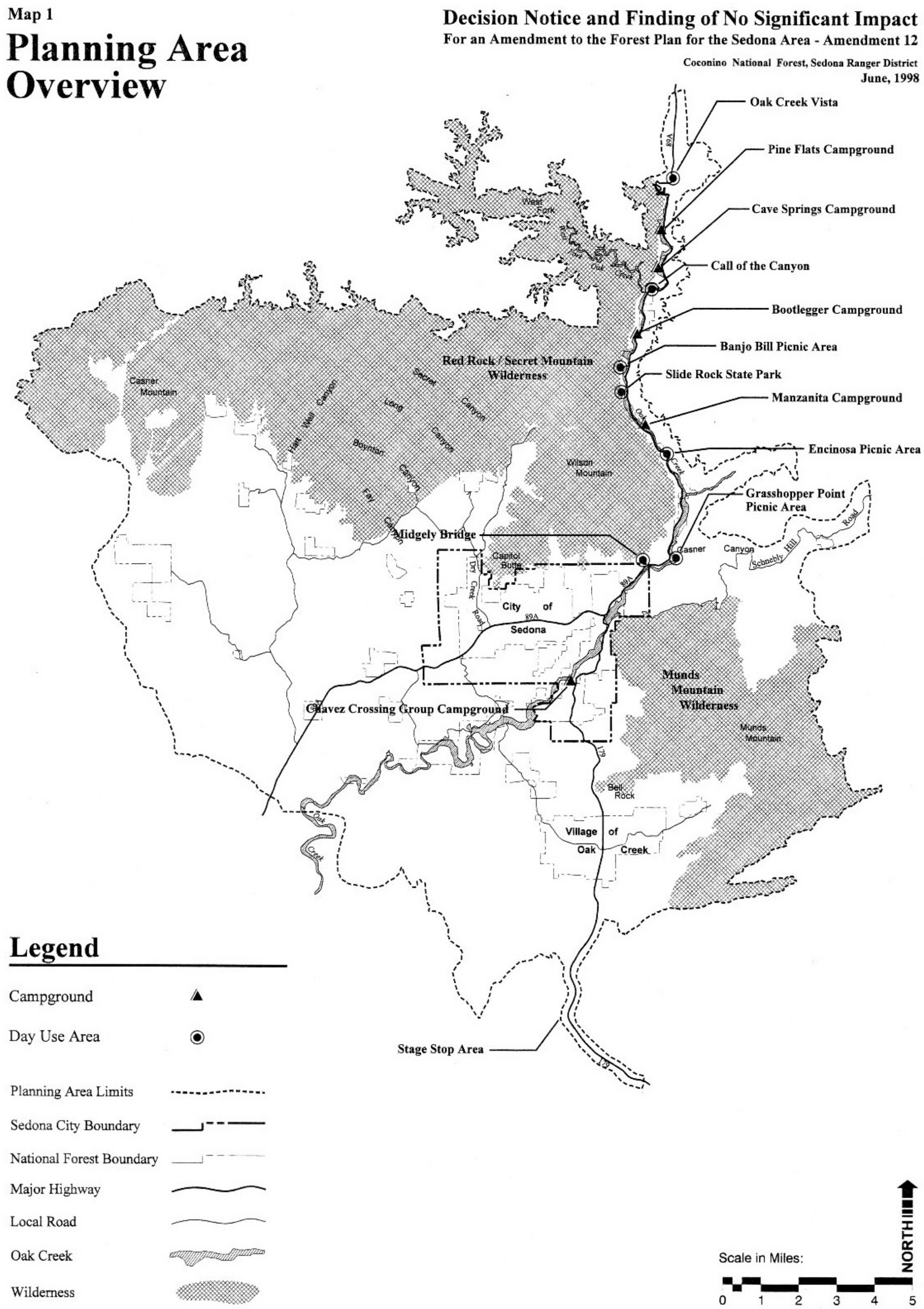



**Figure 2.5 Amendment 12 Planning Area Map**
(USDA Forest Service 1998)

The Coconino National Forest Amendment 12 Neighborwoods Recreation Objectives apply the Rural or Roaded Natural Recreation Opportunity Spectrum classes, with a pocket of semi-primitive designation, to the WUI areas surrounded Sedona and the Village of Oak Creek (USDA Forest Service 1998). By designating the WUI as such, it maintains the area for a system of trails and pathways, provides trail recreation opportunities and a means of nonmotorized travel off busy streets. The Forest Service states that their recreation objectives include providing convenient trail access for residents and visitors, preventing damage to vegetation and soils, and encouraging system trail use, while discouraging user-created paths. What is not stated is whether the Forest Service will enforce residential use of system trails or how it will formally discourage the use or creation of user created trails within the Neighborwoods areas. Prohibited activities within the Neighborwoods and other MAs within the Amendment 12 area include overnight camping, campfires, and cross-country motorized vehicle use.

Forest Service Surveys

Recreation use and visitation surveys are useful for collecting data that can be used to inform land managers of use levels and trends. The National Survey on Recreation and the Environment (NSRE) and National Visitor Use Monitoring project (NVUM) are two such surveys used by the Forest Service. NSRE is a nationwide in-home telephone survey, with the most recent (2000-2004) survey reaching over 80,000 people. NVUM is conducted by a comprehensive sampling of visitors at various sites throughout a forest. The Forest Service continues to fulfill its role of national outdoor recreation assessments, as inherited from the Bureau of Outdoor Recreation.

According to NSRE, results there is a rise in outdoor recreation (See Figures 2.6 and 2.7). Approximately 206 million, ninety-seven percent, of Americans participated at some level in at least one outdoor recreation activity within the last twelve months (Cordell 2003), up from seventy-two percent in 1980 (Boyle and Samson 1985).

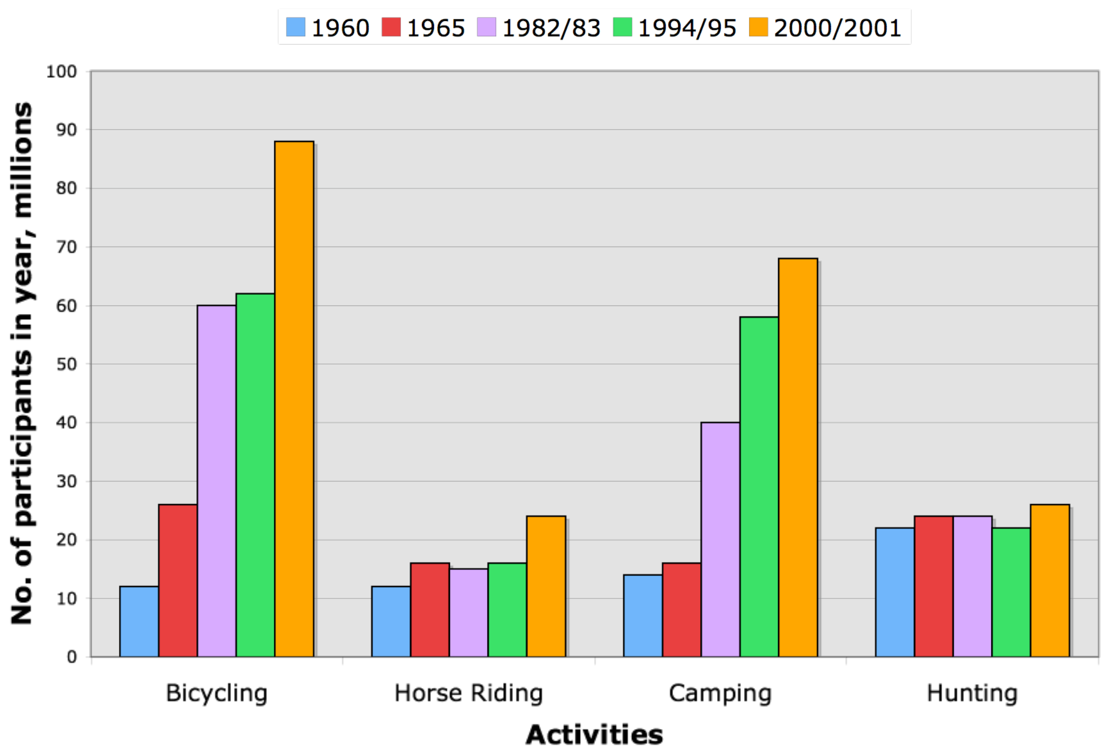



**Figure 2.6 Long-term trends in participation in land-based outdoor activities, USA, 1960-2001**
(Cordell et al. 2005)**This chart has been reconstructed due to poor quality of original*

According to NVUM data, the Coconino National Forest received 2.9 million visits during fiscal years 2005 (n=4024). The most frequently reported zip codes suggest that most visitors were from Flagstaff, Sedona, and the Phoenix metropolitan area (USDA Forest Service 2007b). Results from NVUM also indicate that the top five uses on the Coconino are viewing natural features, hiking or walking, viewing wildlife, general relaxation, and driving for pleasure (USDA Forest Service 2007b).

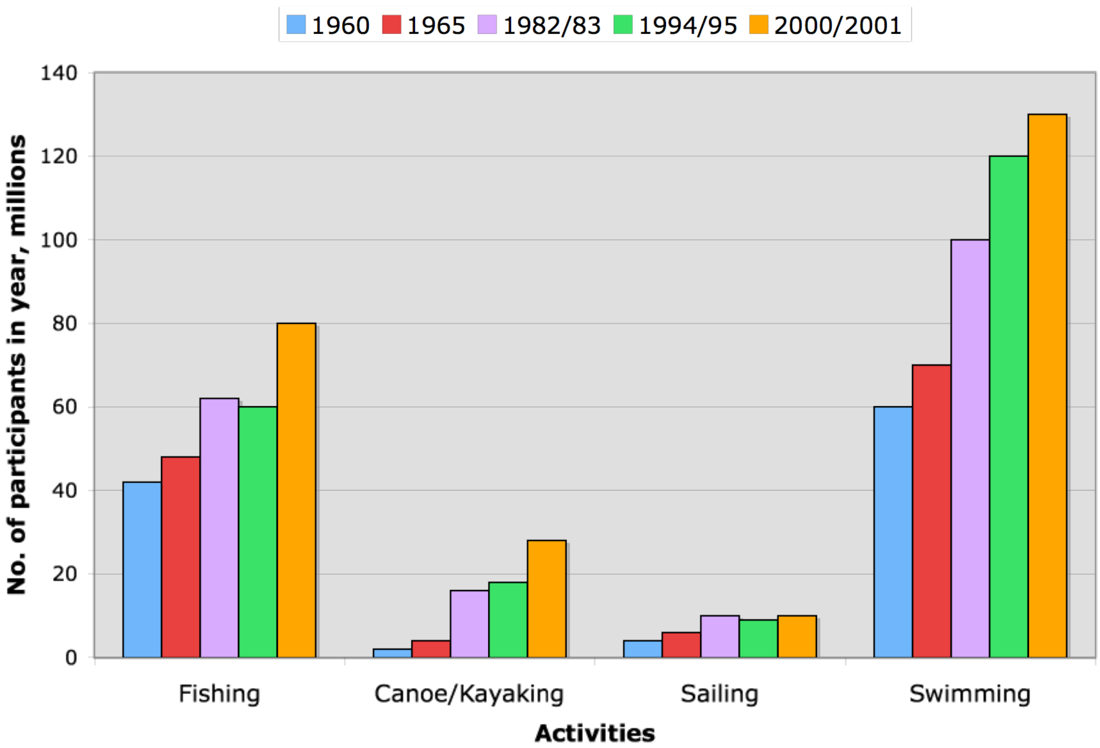



**Figure 2.7 Long-term trends in participation in water-based outdoor activities, USA, 1960-2001**
(Cordell et al. 2005)**This chart has been reconstructed due to poor quality of original*

While both of these surveys provide useful information regarding developed recreation opportunities, no studies have been carried out on the Coconino National Forest regarding residents' attitudes, beliefs, and perceived values of forest lands, or access to forest lands for residents. Questions included in the surveys primarily inquire about the use of developed facilities and trails. NVUM surveys participants at systems trailheads and collection points, resulting residents that may only access the forest from their backyard or neighborhood access points. Cordell (2003) identifies sustained forest access for both adjacent property owners and the public as being threatened due to high rates of WUI development.

**Human Impact Monitoring**

Human impact monitoring provides land managers with an empirical record of resource conditions. Through data collection, researchers quantify the nature and magnitude of recreational impacts, largely on vegetation and soil, and to a lesser degree on water and wildlife (Cole 2004). An assessment or inventory provides a snapshot of human impacts on the natural environment, whereas a monitoring program, or planned watching, is a repeated sampling of attributes of interest to detect changes in location and condition (Landres 1995). Human impact monitoring is " the systematic collection and analysis of resource data at regular intervals, in perpetuity, to predict, or detect natural and human induced changes, and to provide the basis for appropriate management response." (Marion 1991:3). There are a variety of human monitoring systems that have been applied, and are tailored to a wide range of research goals. This review will investigate the variety of human impact monitoring systems and their benefits and drawbacks, example of human impact monitoring studies, and how human impact monitoring can assist land managers.

Human Impact Monitoring Systems

There are three primary systems used in backcountry human impact monitoring, although with modifications they could be applied to a variety of frontcountry settings: photographic systems, condition class systems, and multiparameter systems, (Marion 1991). When selecting a system, the researcher has to consider which system will best meet their research needs. "The selected system should maximize accuracy and precision, the quality and amount of information for those impacts and information of most importance." (Cole 1989:2)

Photographic systems were used in early monitoring projects (Cole 1989). Photography provides multiple visual images of impact sites. While this method can provide a precise image of the impact, it provides no quantitative data regarding the impact. This method has many disadvantages: inconsistent photographic quality, difficult or impossible to obtain accurate quantitative measurements of impacts, and variability in staff experience with equipment (Marion 1991). An advantage to the photographic system is that it can be implemented at a fairly low cost, although that may compromise the quality of the equipment and training of the researchers.

Condition class systems involve assigning each impact site to a condition class based on defined levels and/or type of impact (Cole 1989). "Observers compare site conditions to these descriptive condition classes and simply record the class that most closely matches the conditions of the site being assessed." (Marion 1991:14). This system can provide a good summary of resource impacts, but can require a lot of personnel training to achieve consistent classification for each condition class.

"Multiparameter systems are based on independent assessments of several inventory and impact parameters." (Marion 1991:14) Assessments for multiple impact parameters are recorded independently, allowing accurate and precise information about each type of impact to be recorded. Benefits of the multiple parameter system are that moderately precise and accurate information can be collected in a relatively short amount of time (Cole 1989, Marion 1991). Integrating the photographic system into the multiparameter system is an easy way to maximize the amount of data in a minimal amount of time.

Human impact monitoring can be costly and time consuming. Within the multiparameter system, a rapid site survey has been developed (Cole 1989, Marion 1991). This involves estimating the amount of impact, rather than recording precise measurements. While the level of precision may be lower using the rapid site survey approach, it is still considered a valid method for monitoring impact sites.

Human Impact Studies

In the 1970s and 1980s, recreation impact monitoring studies looked at how different types of use determined impacts, such as hiking, equestrian use, llama packing, and camping on vegetation (Liddle 1975, Cole 1978, Weaver and Dale 1978, Cole and Spildie 1998). These studies expanded to include more recent popular recreation activities such as mountain biking and climbing impacts in the 1990s into the present (White et al. 2006, Walka 2004). Research pertaining to off-trail use is primarily limited to motorized recreation and wilderness areas (Cole 1996) and does not include the WUI area.

Trampling is the most prevalent observed recreation impact and occurs as a result of almost any land based recreational activity (Weaver and Dale 1978, Cole 1986, Cole 2004). Trampling is a direct, localized recreational impact resulting from hiking, bike riding or conducting any ground disturbing activity repeatedly in the same location, effectively damaging or killing vegetation and compacting soils. Repetitive trampling can result in localized, severe effects, altering the ecosystem structure and function. “All studies have found that impact increases rapidly as use increases from no use to low use levels. Above low use levels, however, further increases in use have less and less effect on amount of impact.”(Cole 1986:5) (See Figure 2.8) Multiple variables determine the magnitude of all user created impacts, including trampling: type of use, durability of environment, slope, amount of use, and season of use (See Figure 2.9). If there is an increase in one or multiple variables, an affected area has the potential to have increase, or decrease, in the intensity of the impact. Potential continued increases or decreases in the intensity of an impact are also highly variable between different impact sites.

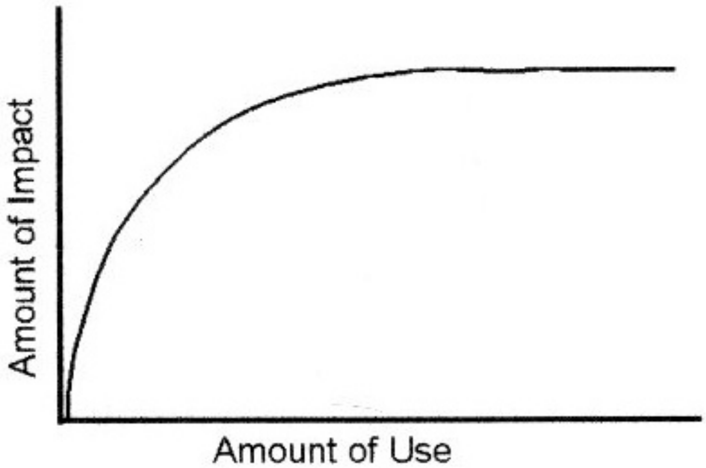



**Figure 2.8 The relationship between frequency of use and intensity of impact**
(Cole 2004a:12)

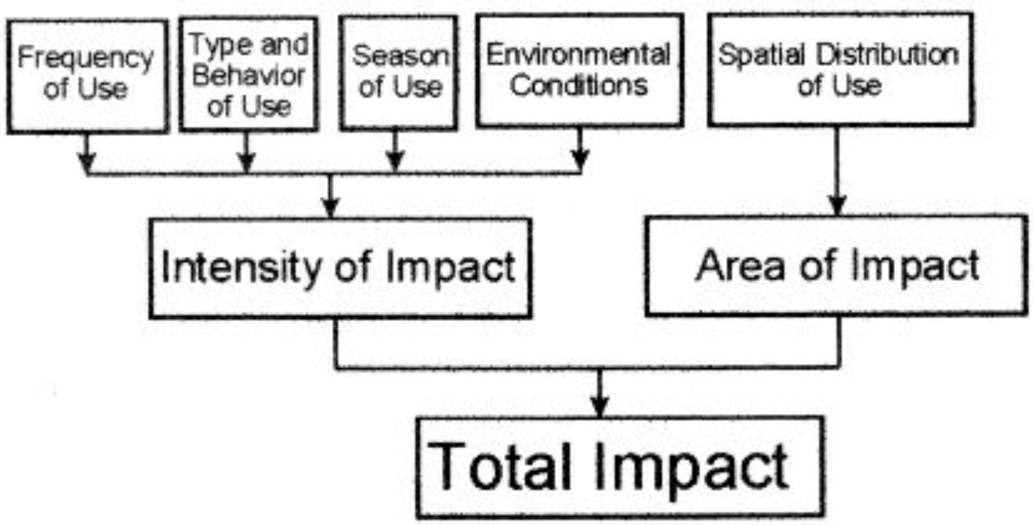



**Figure 2.9 A conceptual model of the primary factors that influence the magnitude of the impact from use**
(Cole 2004a:12)

Although often considered to be a nonconsumptive use, outdoor recreation and human use inevitably alters attributes of the environment in which it occurs: soil, vegetation, animals, and water bodies (Cole 2004). Nonconsumptive recreation includes, but is not limited to, activities such as hiking, horseback riding, boating, viewing, mountain climbing, and scientific research. Following the passage of MUSYA and NEPA, and seeing an increasing trend in nonconsumptive recreation, land management agencies were interested in developing a sound basis for managing recreational impacts (Boyle and Samson 1985).

Managerial Decisions and Human Impact Monitoring

Human impact monitoring provides resource managers with empirical data to support management decisions. Lack of data has forced managers to rely largely on their own personal experiences and judgment to draw conclusions about trends and even about whether or not recreation-related problems exits (Cole 2006). While the Forest Service, like other federal land management agencies, spends much of its time and money anticipating public use such as planning, managing and building facilities, trails and sites for public use, it often overlooks, or does not have the budget to incorporate a monitoring program to assess the success or failure of their management actions.

As a result of recent housing trends in the wildland-urban interface, and increasing recreational use of public lands, human impact monitoring and the field of recreation ecology can provide agencies with professional, empirical, hard data. Landres (1995) stated it well when he said, "Good management requires good information." Relationships between specific impacts and other controlling factors may suggest effective management actions. Monitoring data also permits an evaluation of the success or failure of implemented resource protection measures (Marion 1991).

Human impact monitoring, in addition to providing managers with a snapshot of on-the-ground impacts, also reveals social patterns of how users interact with the environment. Understanding the spatial distribution of impacts is critical for evaluating the significance of impact problems, knowing where it occurs, and having information about the severity of the occurrence (Cole 1989). While understanding the above will lead to knowledge of environmental needs, it will also reveal public needs and uses, enabling the agency to better serve the people. Cole (2006) urges agencies to utilize human impact monitoring, and suggests that its use will better enable agencies to make unbiased science-based decisions. Cole (2006) also states that by having access to empirical data, responsible management actions are more likely to be proactive rather than reactive.

**Conclusion**

This review shows that the upward trend in outdoor recreation and migration to residential areas within the wildland-urban interface is expected to continue. Through recreation monitoring systems, land management agencies, owners, and users have been shown the variety of ecological effects recreation can leave on the landscape. However, recreation impact monitoring systems have largely been relegated to backcountry and wilderness areas, focused on human impacts caused by recreational use. At the same time, literature states that residential development in the wildland-urban interface impacts adjacent wildlands. The specifics of the impacts, however, are unknown and largely unresearched. As the population in the United States continues to increase and people search for fresh air and quiet living, more people will seek to live adjacent to open spaces and public lands, resulting in further residential development in both the wildland-urban interface and intermix. This study seeks to provide a foundation for assessing human impacts on the wildlands resulting from residential development in the wildland-urban interface.

# CHAPTER 3: STUDY AREA & METHODOLOGY

## Study Area

The study area selected was the Red Rock Ranger District, Coconino National Forest, within which the communities of Sedona, Arizona and the Village of Oak Creek, Arizona, lie. This locale was selected based on the following criteria, as determined by the researcher: 1.) Sedona and the Village of Oak Creek are entirely surrounded by national forest, thus all city-forest boundaries are WUI areas; 2.) There are similarities in the setting, recent growth patterns, and population size compared with many other western towns, allowing the potential for methodology and data collection to be applied to other communities for future research; and 3.) These communities are close to Flagstaff, the residence of the researcher, which increased ease of access to collect field data.

### Coconino National Forest

Located just one-hundred and forty miles north of the Phoenix metropolitan area and surrounding the cities of Flagstaff and Sedona, Coconino National Forest (COF) is easily accessible to its residents and nearby visitors (See Figure 3.1). COF provides abundant recreation opportunities as well as scenic drives and wildlife viewing. The national trend of increased participation in outdoor recreation can be found on COF. In 2000 it was reported that COF received 1.89 million visits, and in 2005 received 2.96 million forest visits (USDA Forest Service 2006).

COF is a diverse landscape that encompasses 1.82 million acres and ranges in elevation from 2,600 feet at the Verde River to 12,633 feet at the summit of Humphreys Peak (Coconino National Forest 2007). As a result of the wide range in elevation, topography, and soils, the variety of ecosystems found within COF include: ponderosa pine forest, semi-desert grasslands, interior chaparral, spruce fir forest, desert communities, great basin grasslands, cottonwood willow riparian forest, piñon juniper woodlands, and Arizona's only alpine tundra ecosystem (USDA Forest Service 2007a). COF is comprised of four ranger districts: Mogollon Rim, Mormon Lake, Peaks, and Red Rock (See Figure 3.1).

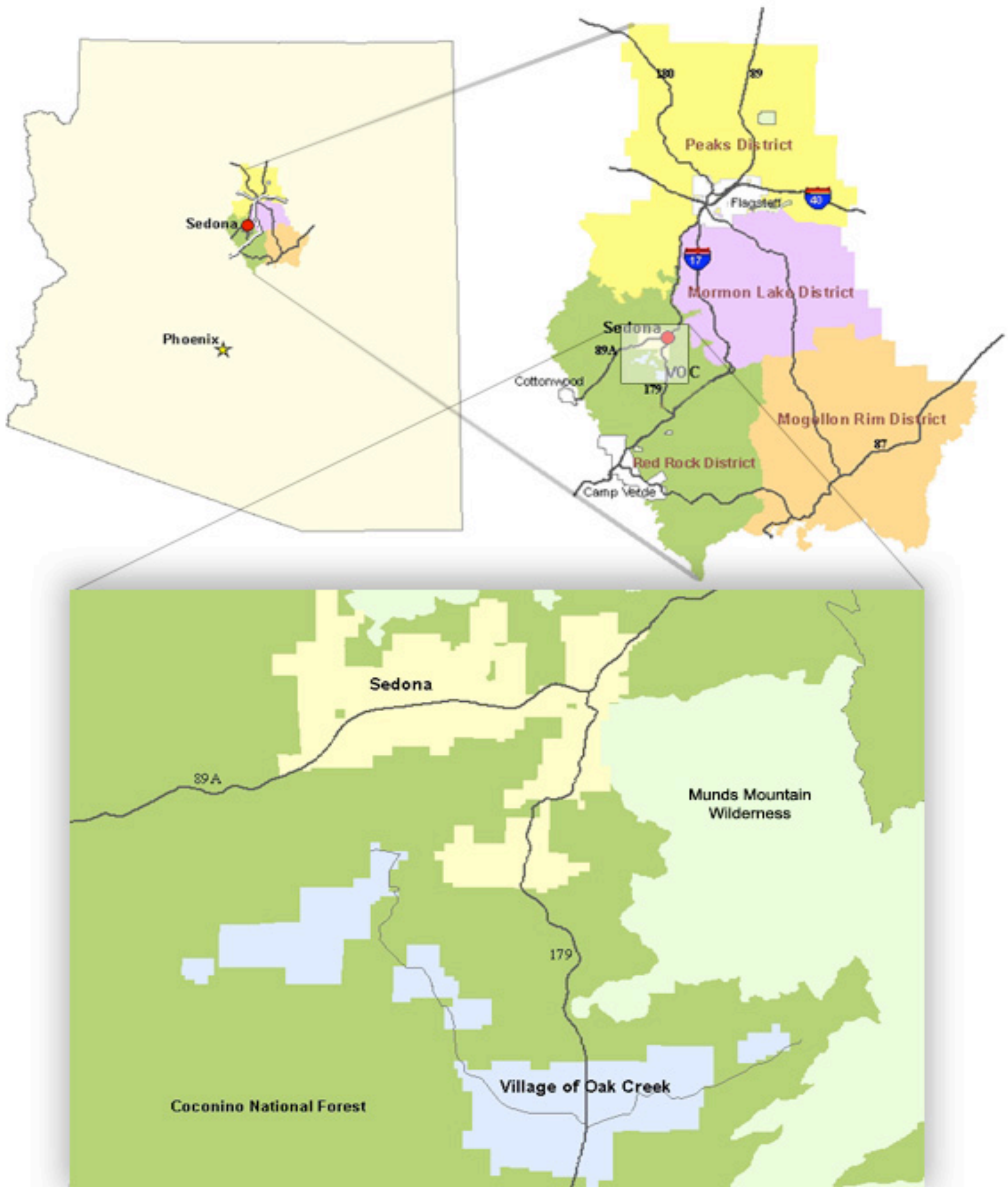



**Figure 3.1 Study Area, Sedona and Village of Oak Creek, Arizona**

Red Rock Ranger District

The study area, Red Rock Ranger District (Red Rock), is 560,000 acres and contains the lowest point on the forest, 2,600 feet elevation, at the Wild and Scenic Verde River. Most of Red Rock is located below five thousand feet elevation. Located between the searing desert heat found in the Sonoran desert and the cool climate found above the Mogollon Rim, human and wildlife communities enjoy mild winters and comparably temperate summers. The landscape is comprised of a variety of ecosystems, dependent on elevation, topography, and aspect. These ecosystems include piñon juniper woodlands, interior chaparral, desert shrub communities, semi-desert grasslands, and ribbons of cottonwood willow riparian forest. Wildlife that reside in the area include javelina, jackrabbit, Gambel's quail, coyote, mountain lion, and bald eagle. The geology surrounding Sedona and Village of Oak Creek are the cause for the name, Red Rock Ranger District. Red sandstone spires, striped with the occasional limestone layer reveal approximately three hundred million years of geological history.

Amendment 12, approved in 1998 for the Coconino National Forest Management Plan, created additional management guidelines and policy for the national forest surrounding Sedona and Village of Oak Creek. In addition to providing guidelines and objectives for Management Area 24, Neighborwoods (See Figure 2.5) prohibits further land trades thus limiting the future growth and expansion of Sedona as well as the Village of Oak Creek. With limited developable lands, the availability of both commercial and residential lands is quickly disappearing. As of 1990, fifty-three percent of available lands were developed within Sedona, and by 2006 that number had increased to seventy-three percent of all available lands being developed (City of Sedona 2007). Sedona does not expect available lands to be built out until the population reaches 15,826, or for another two decades (City of Sedona 2007).

*Red Rock Pass*

Three years after Amendment 12 was added to the Coconino National Forest Management Plan, an area within Amendment 12 area became a Fee Demonstration Project site. Through the Fee Demonstration Project the Red Rock Ranger District was allowed to charge a fee for vehicles parked and left unattended while in the pass area (See Figure 3.2). Although the initial legislation that the pass operated under expired in December 2004, the Pass continues be implemented by meeting the eligibility requirements for the Recreation Enhancement Act, as a High Impact Recreation Area (USDA Forest Service 2005b).

The Red Rock area, as the Red Rock Pass area is commonly referred to, contains over one-hundred miles of recreation trails, numerous campgrounds, picnic areas, and heritage sites. The Sedona area receives approximately three million visitors annually, and the Coconino National Forest bears many of their impacts (Sedona Chamber of Commerce 2007). In 2005, COF stated that the Red Rock Pass funds bring in an average of $800,000 annually (USDA Forest Service 2005c). Eighty percent of Red Rock Pass funds are applied in the 160,000-acre Red Rock area, with the remaining twenty percent used forest wide and sent to the Forest Service regional office. Use of Red Rock Pass funds provide much needed services to the community and visitors by helping fund management of their public lands. Table 3.1 shows accomplishments for the entire Red Rock Ranger District. The accomplishment table illustrates that the Red Rock Ranger District is aware of many human impacts occurring on the land and is taking action. A variety of infractions that occur on federal public lands, including the Coconino National Forest, are: methamphetamine labs, car and boat disposal, marijuana plantations, violent offenders, missing persons, homesteading on public lands, illegal woodcutting, and mining operations.

**Table 3.1 Red Rock Ranger District Accomplishments, 2004 through 2007**
(USDA Forest Service 2004, 2005d, 2006b, 2007e)

| | **2004** | **2005** | **2006** | **2007(Oct-May)** |
|---|---|---|---|---|
| Visitor center contacts | 423,198 | 455,513 | 445,355 | 174,422 |
| Field Contacts | 14,214 | 10,121 | 8,521 | 3,054 |
| "Leave No Trace" contacts | No data | No data | 614 | 58 |
| Miles of trail patrolled | No data | 759 | 860 | 449 |
| Fire rings dismantled | 485 | 300 | 214 | 112 |
| Social trails closed or obliterated | No data | 141 | 178 | 96 |
| Dump sites cleaned up | 178 | 162 | 132 | 39 |
| Transient camps cleaned up | 72 | 21 | No data | No data |
| Abandoned vehicles removed | 22 | 16 | No data | No data |
| Pounds of trash removed | 71137 | 45,743 | 49,542 | 17,537 |

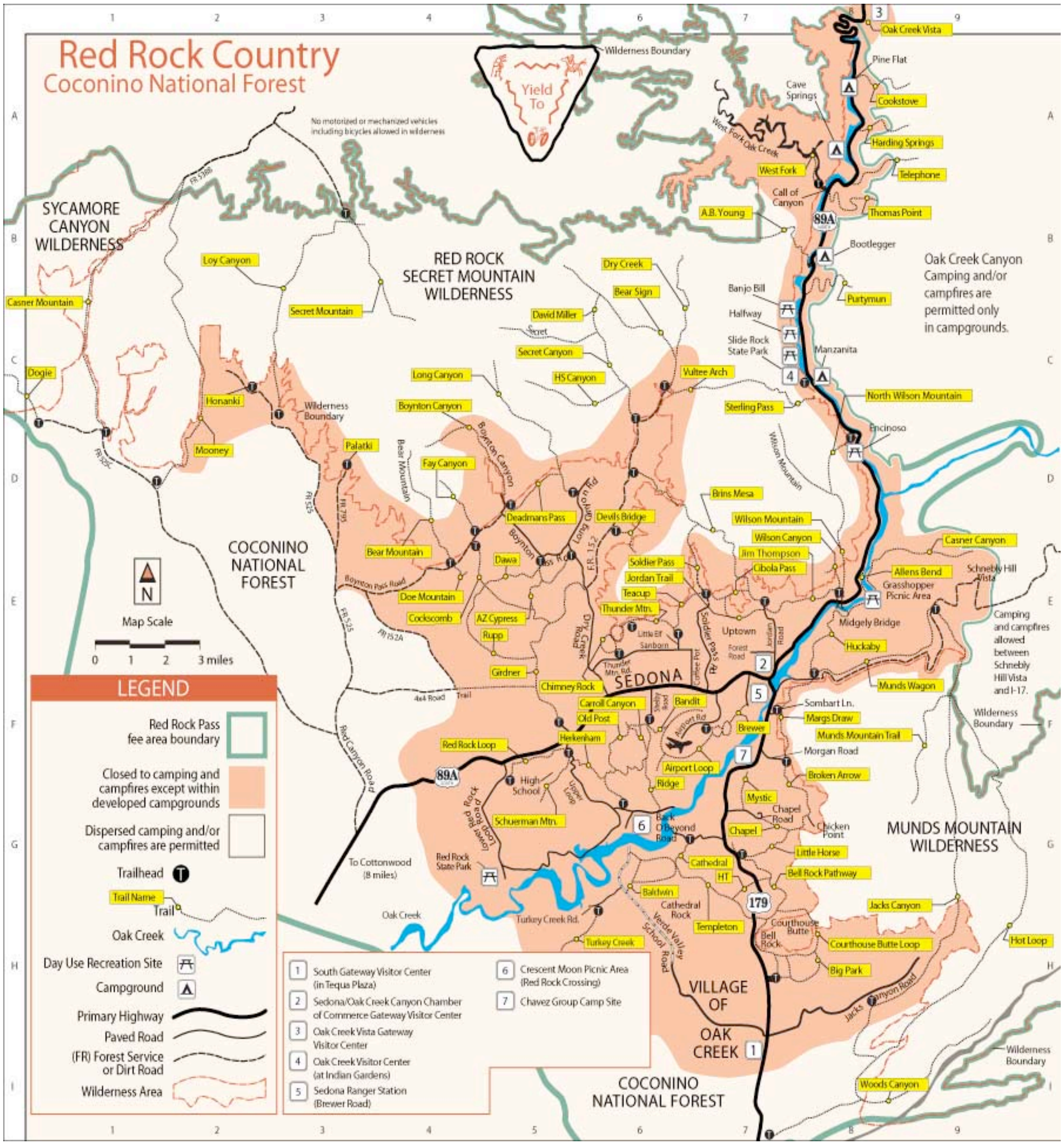



**Figure 3.2 Red Rock County Map, Red Rock Pass Area**
(USDA Forest Service 2007)

<u>Sedona and Village of Oak Creek</u>

Sedona and Village of Oak Creek are located in the Verde Valley, a mild-climate area, between Phoenix and Flagstaff, with milder winters and cooler summers than those of the Phoenix metropolitan area. Sedona is situated amongst scenic red rocks, at 4,500 feet elevation at the base of Oak Creek Canyon. The nineteen square-mile city is split between Coconino and Yavapai counties. Only fifty-one percent of its area is privately owned, the remainder belongs to COF (Sedona Chamber of Commerce 2007). With a growth surge in recent years, mirroring many western communities, the population of Sedona grew by thirty-two percent in a fifteen-year period, between 1990 and 2005 (www.census.gov). Sedona's growth trends in recent years mirror the high growth rates found in both Yavapai and Coconino counties between 2000 and 2006, 7.4 percent and 24.2 percent, respectively (www.census.gov). In 2007, the City of Sedona stated that its year round population is 10,400, while the Sedona Chamber of Commerce placed the community's population at 11,200 within incorporated city limits. The average age of residents is fifty years old (Sedona Chamber of Commerce 2007).

The Village of Oak Creek, situated seven miles south of Sedona, is an unincorporated community that had 5,245 residents in 2000 (www.census.gov). Similar to Sedona in growth rates and housing costs, all of the Village of Oak Creek lies in Yavapai County. The Village of Oak Creek is considered part of the greater Sedona area; and the two communities share educational facilities and other community services.

**Methodology**

To establish a baseline study of human impacts, a combination of multiparameter, rapid site survey and photographic systems were used (Cole 1989, Marion 1991, Hammitt and Cole 1998). The information collected had to meet the following needs of the researcher in order to establish a baseline study: 1.) accurately describe the existing impact, 2.) include multiple parameters to capture any type of impact at that location, 3.) incorporate photographs for additional documentation, and 4.) include information in order to relocate the impact site. In addition to the information requirements, the researcher had time and funding constraints, which led to the application of the rapid site survey method. This data collection format allowed the researcher to collect data for each site in an expedient manner, spending only ten to fifteen minutes at each impact (Cole 1989).

The multiparameter system allowed the researcher to collect a variety of data to create an overview of impacts for that transect. When a social trail was inventoried the rapid site survey provided a framework for recording data. Field research and data collection included the following: 1.) walking the boundary transects and recording data on the impact assessment forms, 2.) documentation with digital images, 3.) using a Global Positioning System, discussions with U.S. Forest Service staff, and 4.) compiling county zoning information about areas adjacent to the WUI.

Transect Selection

For this research project, six data collection sites were selected on the Red Rock Ranger District. The researcher limited collection to six sites for multiple reasons: available access, funding, and timeline. Available access played a large role in determining the location of the transect. Public access through neighborhoods, not from a system trailhead, was limited as a result of the high percentage of built lots in the Sedona area. In 2006, 68.1% of the city of Sedona's available residential lands had been developed. Between 1990 and 2006 available residential acreage decreased from 2,483 acres to 1,241 acres (City of Sedona 2007). The researcher used her own funds to pay for collection of field data. The research timeline was under an accelerated schedule due to the researcher's commitment to her employer.

Each transect was approximately one mile in length. All six sites were located adjacent to either the city of Sedona or the Village of Oak Creek (See Figure 3.2). All transect locations have system trails located within three-quarters of a mile from the Forest Service boundary. A system trail is a developed trail that has gone through the NEPA process, is recognized by the Red Rock Ranger District, and is managed by the District or a partner organization.

Four of the selected sites were located within the wildland-urban interface. The wildland-urban interface was defined as the areas adjacent to the COF boundary and privately held lands containing residences and building structures adjacent to the boundary. The selected WUI areas included Big Park Area (BPA), Teacup Area (TCA), Margs Draw Area (MDA), and Little Horse Area (LHA).

Two undeveloped boundary sites were also selected, the Sedona Cultural Park (SCP) and Baldwin Areas (BA). As a result of the high percentage of developed land in Sedona and in the Village of Oak Creek, only these two undeveloped WUI transects were assessed. SCP was not as undeveloped as it was initially thought to be, due to residential units along the northern half of the transect having been built recently. It was evident during the search for undeveloped boundary transects that build out of Sedona is inevitable. The SCP transect is more reflective of an undeveloped area transitioning to WUI than a true undeveloped transect. The Baldwin transect, however, is still undeveloped.

Data Collection

Field research for the baseline study of human impacts in the WUI was conducted between February and September 2007. Field research was conducted over the course of ten one-day trips: February 18th and 25th, April 18th, May 6th and 20th, August 4th, 12th, 25th, and 26th, and September 23rd. Six transects of approximately one mile each were assessed using the multiparameter, photographic, and rapid survey systems (See Figure 3.3). Both WUI and non-WUI transect data were collected and recorded using the same Impact Descriptor Form (See Table 3.2 or Appendix A for the entire form). Data collection was conducted by walking the select transect length and stopping to assess and document ever point with observable social impacts.

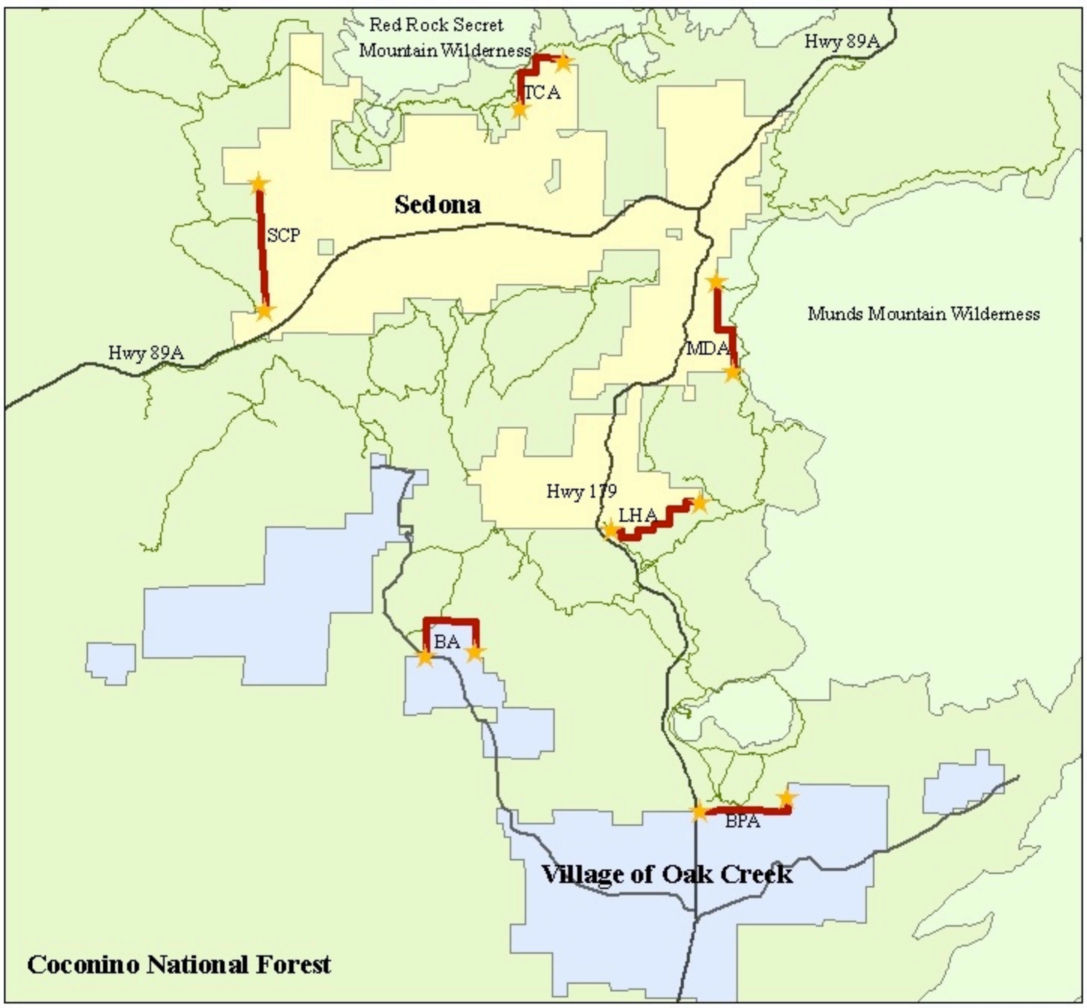



**Figure 3.3 Human Impact Study Transects, Sedona and Village of Oak Creek**

Two assessment forms were developed to thoroughly assess the type of impact, as well as associated ecological and social factors: Impact Descriptor Form (Appendix A,) and Trail Interval Form (Appendix B). The Impact Descriptor Form was used to document multiple variables during the initial impact assessment: name, type of impact, digital image, waypoint, dominant vegetation type, soil type, litter, and user type if discernible. The Impact Descriptor Form was also used to document the presence of environmental damage: erosion, cryptobiotic damage, root exposure, and vegetation trampling and breakage. Each impact location was identified using a Garmin eTrex 12 channel Global Positioning System (GPS) unit. GPS waypoints were collected at the same time as digital photographs were taken. This method allows for a site to be easily relocated in the future.

**Table 3.2 Sampling of impact parameters on Impact Descriptor Form**

| | |
|---|---|
| **Dominant Veg Type:** | **PJ Grass Shrub** |
| **Veg Damage:** | **Y N** |
| | **trampling** |
| | **root exposure** |
| | **pruning** |
| **Dominant Soil Type:** | **Sand Clay Loam** |
| **Erosion Present:** | **Y N** |
| **Cryptobiotic Soil:** | **Y N** |
| **Cryptobiotic Damage:** | **Y N** |
| **Litter Descriptor:** | |
| **Trail Origin Descriptor:** | |
| **Trail Depth:** | |
| **Trail Width:** | |
| **Type of Use:** | **Hikers Mountain Bikers Equestrians Other** |
| **Use level:** | **old infrequent frequent** |

The Trail Interval Form was used only in conjunction with social trail impacts. When a social trail was noted, the origin was identified, and the trail was walked in its entirety, thus the end was also documented. Social trails over one-tenth of a mile were also assessed using the Trail Interval Assessment, at which point the researcher stopped to document each tenth mile interval by taking a waypoint and digital photograph. The

Interval Assessment Form briefly documents trail mileage, depth, width, erosion, vegetation impacts, user type, and litter presence.

The researcher conducted data collection by walking each of the six transects and using the Impact Descriptor form (See Table 3.2). The Impact Descriptor Form was formatted for ease of completion in the field, with data formatted in column form, and basic category descriptors. Field entries were limited to yes/no answers, concise quantitative data, and circling provided categories. Provided categories included vegatation and soil types. Multiple impact parameters included documenting the type of impact, litter presence, vegetation damage, and erosion. The formatting of the form and method of collection allowed the researcher to complete an impact assessment in less than twenty-minutes. Photographs of each impact (See Figure 3.4) were taken to maximize the amount of data collected at each impact, while minimizing the amount of time for each impact.

a.

b.

**Figure 3.4 Examples of WUI Human Impacts on the Red Rock District**
a. Margs Draw Area Transect fence cutting. b. Big Park Area social trail.

Not included in the applied human impact monitoring systems, the researcher independently compiled detailed observations of the topography, vegetation types, and housing density. The purpose of these observations was to compare them with the documented impacts and determine if the observed variables may have limited, or facilitated, the presence of human impacts within the WUI. In addition to the researchers transect observations, city and county zoning was factored into the observations in order to assess the role of housing density on presence of human impacts.

Data Analysis

Field data from the six transects was divided into three software systems for safe storage and analysis: photographs were filed in iPhoto, all data from the Impact Descriptor and Trail Interval Forms were entered into Microsoft Excel, and GPS waypoints were entered into ArcView 9.1 GIS. Analysis was conducted to determine the following: 1.) the summary of each impact type, 2.) the number of impacts per transect, further impact comparisons within the WUI, 3.) transition, and undeveloped WUI, 4.) impact interactions, a summary of social trail user types, 6.) social trail origins and termini, and 7.) distribution of impacts. Individual transect evaluations were also conducted to record topography, vegetation, and housing density.

Each field from the Impact Descriptor Form and Trail Interval Form was entered into Microsoft Excel. Each form, and thus each impact, was kept track of by the impact name. An example of the naming system would be BPA_a, which represents the first (a) impact documented in the BPA (Big Park Area) transect. All points documented within a social trail were given the same name, but it was additionally documented if that point represented the beginning, an interval, or the end of the social trail. Raw field data was entered into Microsoft Excel, providing an inventory that maintained each individual impact parameter. Each impact parameter had a column; thus erosion was kept separate from trail width, and vegetation from soil, retaining the detailed information that was collected.

To provide a summary of each impact type, the data was compiled and sorted within Microsoft Excel. Further sorting and analysis was conducted to calculate the types and amount of impacts per transect. A variety of sorts and formulas were used, depending upon the desired outcome: such as a sort of impact types, in descending order. This would result in social trails being at the top of the sheet. Further sorting for trail origin and end provided a list of locations where all assessed social trails began and ended. Impact interactions were analyzed to investigate whether an impact was more likely to occur with another impact or to be an isolated impact. This was again done by sorting, but also was apparent in GIS.

GIS was used to spatially map the impacts. All data collected from both the Impact Descriptor and Trail Interval Forms was imported into GIS. Maps were produced to display the human impact type by different symbols. The following layers were included in the impact maps: Coconino National Forest, Red Rock Ranger District, topographic map, Munds Mountain Wilderness, system trails and trailheads, private property boundaries, major roads and highways, city of Sedona zoning, Yavapai County zoning and parcels layer for the Village of Oak Creek and Sedona, Coconino County parcel layer for the city of Sedona. Radeloff's WUI classification was included in the individual transect observation, but only to illustrate that the transect areas were classified WUI, and to potentially further depict housing density. The maps were created to visualize the human impacts relationship to: other human impacts, proximity to private property, system trails and trailheads, zoning (thus housing density), and topography. A statistical chi squared test of the data was attempted but proved not possible due to the limited sample size. Rather than use chi squared to prove relationships between impacts and variable, simple comparisons of variables were conducted to illustrate potential relationships.

# CHAPTER 4: RESULTS

An impact was defined as a point with an observable human impact. Human impacts were present in all assessed transects. A total of seventy-nine impacts were assessed (See Figure 4.1). The developed WUI transects average sixteen impacts per mile. Baldwin Area (BA), the undeveloped transect, had a markedly lower human impact occurrence with only one impact, an incident of fence cutting, for the entire transect. The SCP, transition transect, while a markedly greater number of impacts than BA, fourteen impacts, was still fifteen percent lower than the average WUI impact level of sixteen and a half impacts per mile. (See Figure 4.2).

Of the 79 inventoried impacts (See Figure 4.2 or Table 5.1 for transects and corresponding impacts), 46.8% were social trails (n=37), 26.6% were fence cutting (n=21), 13.9% were other (n=11), and 12.7% were dumping (n=10) (See Figure 4.3). The eleven "other impacts" consisted of: seven tree cutting or pruning impacts, three water features, and one miscellaneous garbage pile. The ten dumping impacts included yard waste, landscaping materials, and one large pile of dog waste. The miscellaneous garbage pile was classified as other, rather than dumping, because it consisted of only a few items left behind by a vagrant, and not an intentional dumping of human debris.

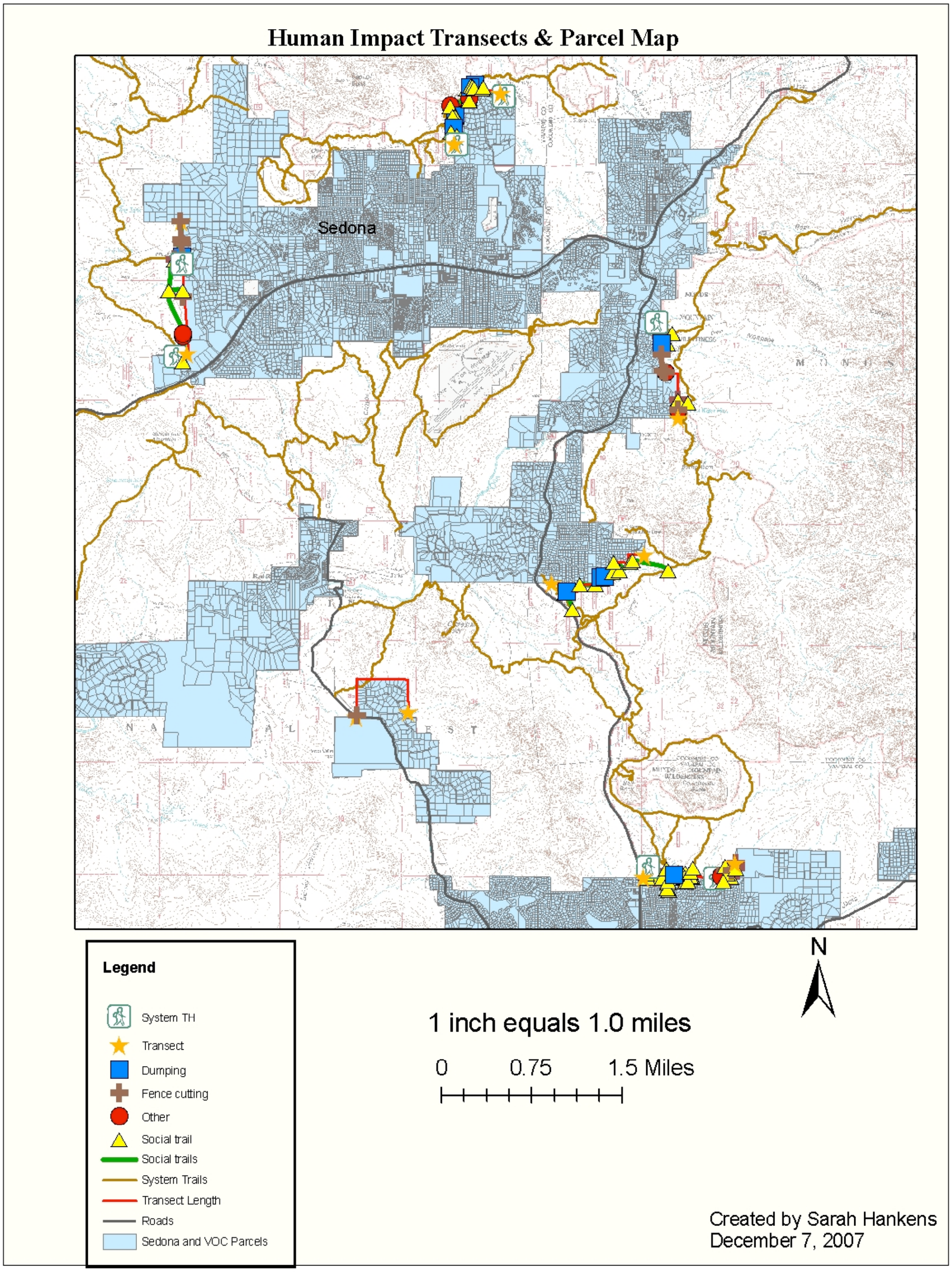



**Figure 4.1 Human Impact Overview**

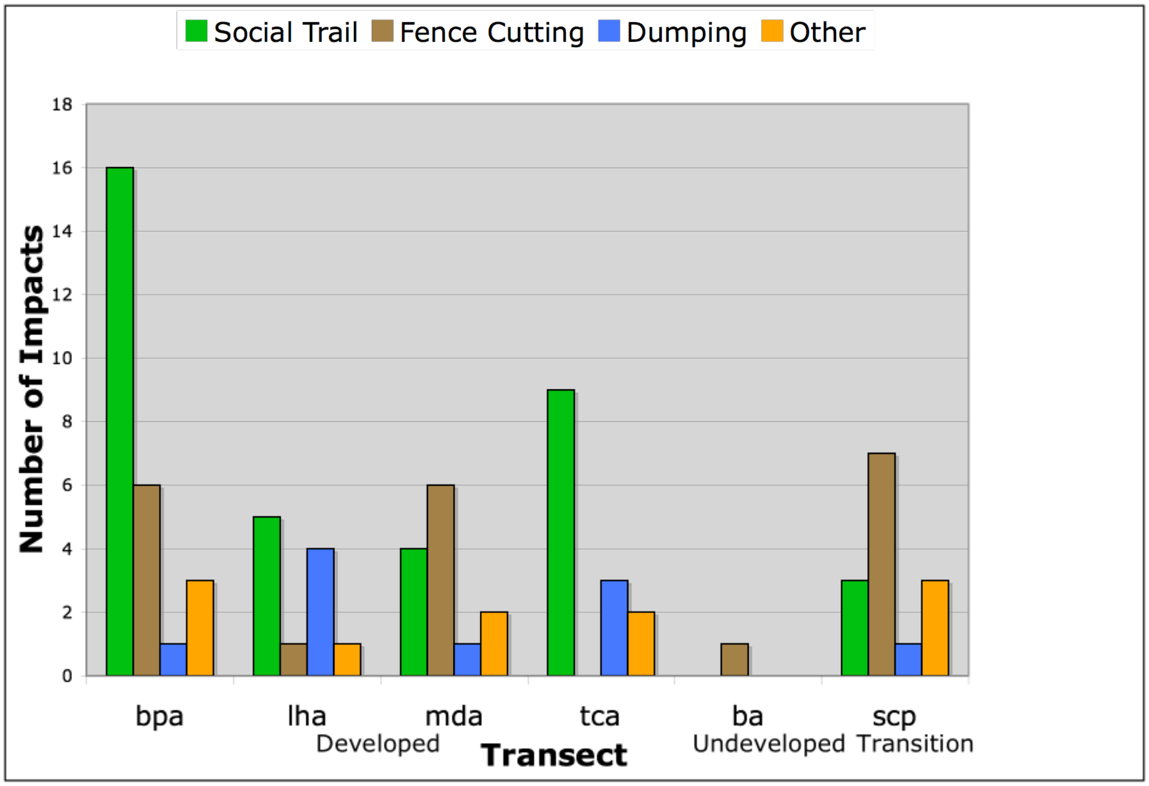



**Figure 4.2 Impact Totals By Transect**

Social trails far outnumbered other inventoried human impacts, but all social trails were relatively low in the severity of their impact on natural resources. Most had the expected trampling associated with social trails, however, only three social trails had short isolated occurrences of severe erosion and rutting over eight inches deep with gullying or root exposure. One severe erosion incident was located in a naturally eroded area on the LHA transect, with the erosion seemingly being exacerbated by hiker use. The remaining two severe erosion impacts were located on the BPA transect: BPA_M was a section of approximately 20 feet of heavily eroded, braided trail; and BPA_A was a very short section of severe erosion on a down slope into the pictured wash. (See Figure 4.4) BPA_M was more than 15 inches deep in areas within the photograph, with visible hoof prints. Studies show that horses cause substantially more erosion than hikers, (Cole and Spildie 1998) llamas, or mountain bikers (Cole 2004). (See Table 4.3).


a.


b.


c.


d.

**Figure 4.3 Impact Photos**
a. Little Horse Area: dumping, b. Margs Draw Area: fence cutting and social trail origin, c. Big Park Area: social trail origin, d. Big Park Area: social trail interval.

**Table 4.2 Where Social Trails Begin and End**

| **Where the social trails begin:** | | % of n |
|---|---|---|
| Private Residence | 12 | 32% |
| Neighborhood | 9 | 24% |
| Empty Lot | 6 | 16% |
| No information collected | 5 | 14% |
| Another Social Trail | 3 | 8% |
| System Trail | 1 | 3% |
| Water Tower | 1 | 3% |
| Social Trail Disappears | 0 | 0 |
| **n=** | **37** | 100% |

| **Where the social trails end:** | | % of n |
|---|---|---|
| Another Social Trail | 15 | 40% |
| System Trail | 10 | 27% |
| Social Trail Disappears | 6 | 16% |
| No information collected | 5 | 14% |
| Neighborhood | 1 | 3% |
| Empty Lot | 0 | 0 |
| Private Residence | 0 | 0 |
| Water Tower | 0 | 0 |
| **n=** | **37** | 100% |

a.

b.

**Figure 4.4 Severe Erosion Impacts**

a. BPA_A-.20 interval, mountain biking, b. BPA_M-.10 interval, equestrian

**Table 4.3 Summary of Erosion Levels for Entire Trails by User Type**

| **Type of Use** | **Erosion Levels** | | | |
|---|---|---|---|---|
| | None | Low 1"-3" | Moderate 4"-7" | Severe 8"+ |
| Hiking/Walking | 20 | 4 | | |
| Hiking & Mountain Biking | 3 | 1 | 3 | |
| Hiking & Equestrian | 2 | | 1 | |
| Equestrian | | 1 | 1 | |
| Mountain Biking | | 1 | | |
| TOTAL | 25 | 7 | 5 | 0 |
| % of n | 67% | 19% | 14% | 0% |

Type of use was classified as hiking, mountain biking or equestrian use and was determined by visual observation. Footprints, bike tracks, or hoof prints were largely visible throughout all transects with social trail impacts. A limitation to determining user type by visual observation is that tracks are temporal, thus the researcher was only observing only the most recent users, whose tracks were still visible. Hiking or walking was the dominant use of social trails, being the sole use on two-thirds (24 of 37) of the trails. (See Table 4.4) One quarter (10) of the assessed trails were multi-use: seven mountain biking and hiking trails, three hiking and equestrian trails. One mountain biking and two equestrian social trails were inventoried.

**Table 4.4 Social Trails: Type of Use**

| **Type of Use** | **Number of Trails** | **% of n** |
|---|---|---|
| Hiking | 24 | 65% |
| Hiking & Mountain Biking | 7 | 19% |
| Hiking & Equestrian | 3 | 8% |
| Equestrian | 2 | 5% |
| Mountain Biking | 1 | 3% |
| TOTAL | 37 | 100% |

Fence cutting was the second most common impact, with a total of twenty-one occurrences. Of those, eight occurred in relation to a social trail, six of which originated from a house or neighborhood. It is not Forest Service policy to fence the boundary of the forest. The fences that were present remain from former grazing allotments. Many of the fences were in disrepair, or whole sections had fallen down. Of the present boundary fences, where the fence was intact, three private gate installations were noted. Gate installations were not noted regularly in early transect assessments, so there may be more fence cutting for gate installations than the data reflects.

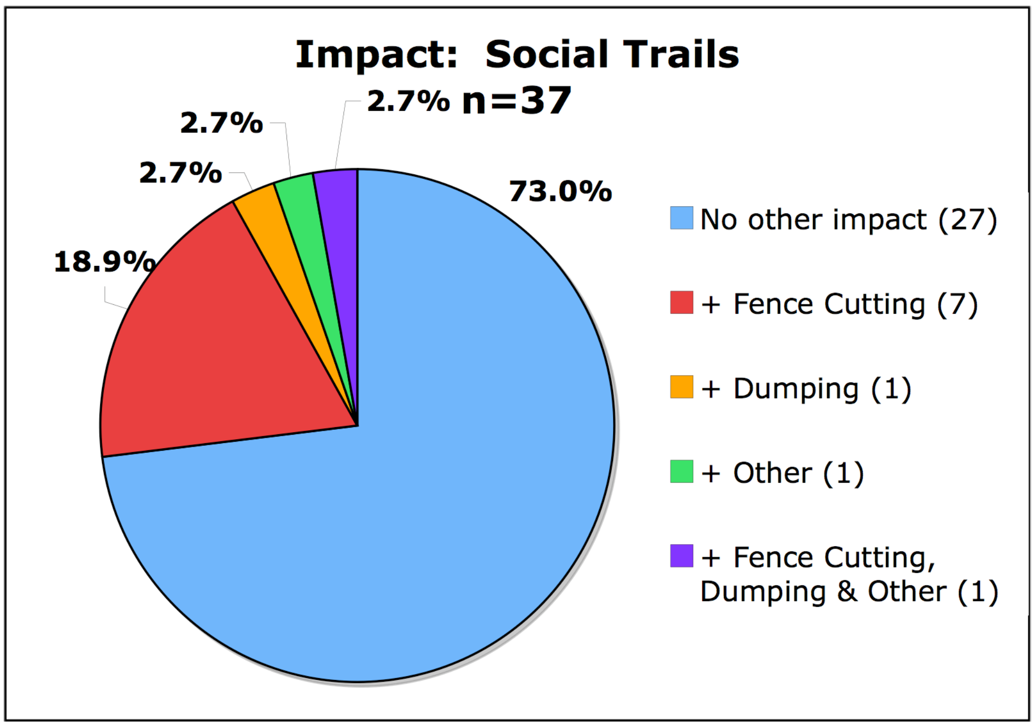



**Figure 4.5 Social Trail Impacts**

<u>Impact Interactions</u>

Almost three-quarters of social trails (73%) occurred with no other impacts present. The greatest amount of social trails (32%) started at a private residence and 40% of all social trails ended at another social trail. When combining social trail beginnings, ends, type of use (65% hiking), and levels of erosion (86 % had none to low levels), and a lack of other impacts, it appears that social trails serve individual users primarily as a private walking route out of their residence. The "other" impact that was located along a social trail was a miscellaneous garbage pile, consisting of tennis balls, old cans, and a variety of human trash. The one dumping impact along a social trail was almost immediately adjacent to the boundary, not appearing that the social trail was created for the purpose of dumping.

There was one social trail where all impacts, fence cutting, dumping, and other, were present. The social trail originated from a house, where the fence was cut, several trees had been pruned and there was a small dumping of yard waste. The trail received regular use and dog waste was present.

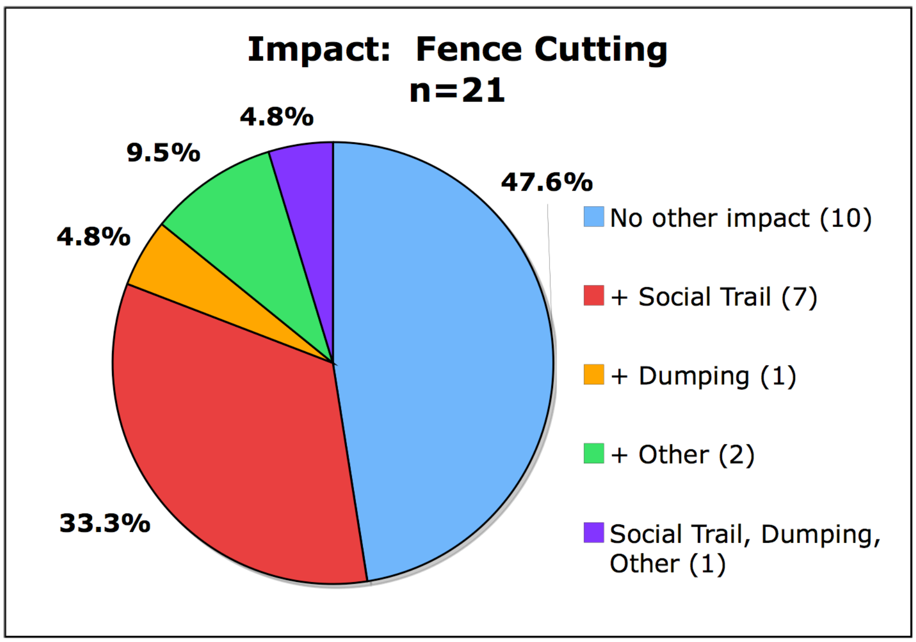



**Figure 4.6 Fence Cutting Impacts**

Almost one half of the fence cutting impacts (47.6%) occurred as isolated impacts. The isolated fence cuttings were locations along the boundary where the fence, always a three or four strand barb wire, had been cut one or more times. The dumping impact was directly adjacent to the fence cutting, on the other side of which was a private residence. Both fence cutting and other impacts occurred in the Margs Draw Area Transect directly adjacent to houses. One was a fence cutting with several shrubs cut to stumps and vegetation planted on the forest service side of the fence. The other "other" was a series of hoses laying in an area that had been cleared of shrubs.

Second only to isolated fence cuttings, were fence cuttings with social trails (33.3%). Three of the seven fence cutting-social trail impacts had gates present. The data suggests that people who are fence cutting may be doing so for forest access, not just dumping purposes, and creating social trails.

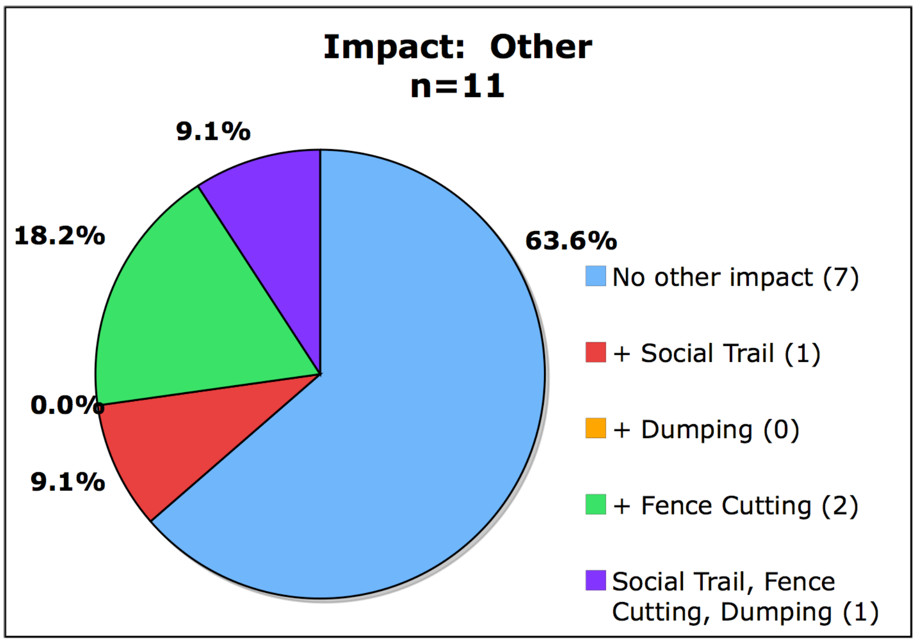



**Figure 4.7 Other Impacts**

Most of the "other" impacts had no other impact present. The "other" impacts were seven tree cutting or pruning impacts, three water features and one miscellaneous garbage pile. The miscellaneous garbage pile was located along a social trail, although contents suggested an old vagrant camp. With the exception of the miscellaneous garbage pile all "other" impacts were located directed on the forest boundary.

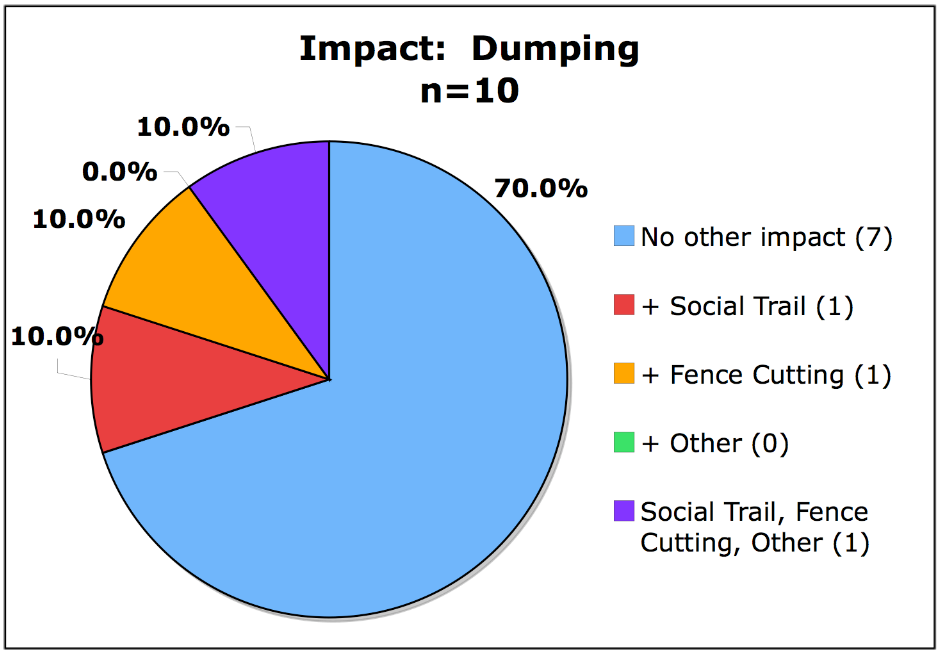


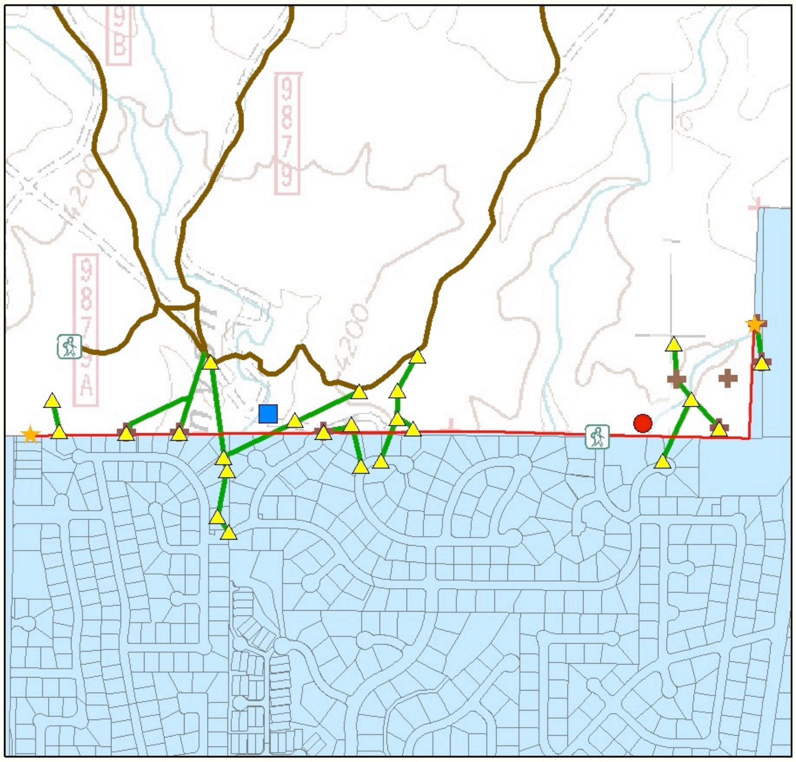

**Figure 4.8 Dumping Impacts**

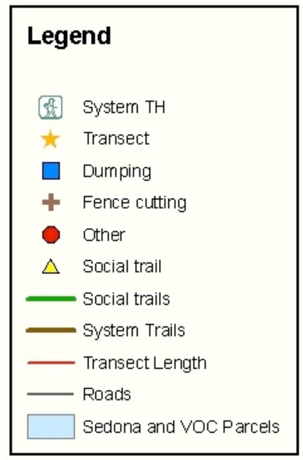
All dumping impacts occurred within one hundred feet of the forest boundary. Only yard and dog waste were included in the dumping. On the dumping-social trail impact, the dumping was very near the origin of the social trail. It did not appear that the social trail was created to lead to a dump site, but rather that the social trail had not received recent use and disappeared after 500 feet.

<u>Individual Transect Observations</u>

Seeking to answer the research questions of whether housing density, vegetation type and density, and topography influence the amount of impacts within a given transect, the follow evaluations have been made. Housing density information is base not just on personal observation, but includes zoning for the city of Sedona, Coconino County, and Yavapai County. While walking each transect the researcher observed and recorded the topography and vegetation type and density. All transects were approximately one mile. The included transect lengths were measured in GIS and do not take into account the variability of the terrain. All maps are oriented to the north.

*Big Park*
Length of transect: 4856 feet.




a. b.

| | Social Trail n=37 | Fence Cutting n=21 | Dumping n=10 | Other n=11 | Total # of Transect Impacts/n=79 |
|---|---|---|---|---|---|
| Big Park | 16 | 6 | 1 | 3 | 26 |
| % of n | 43% | 28% | 10% | 27% | 33% |

c.


d. e.

**Figure 4.9 Big Park Area Impacts**
a. Human Impact Map b. Human Impact Map Legend c. Big Park Impact Table
d. Flat open, grasslands with social trail e. Housing density with social trail

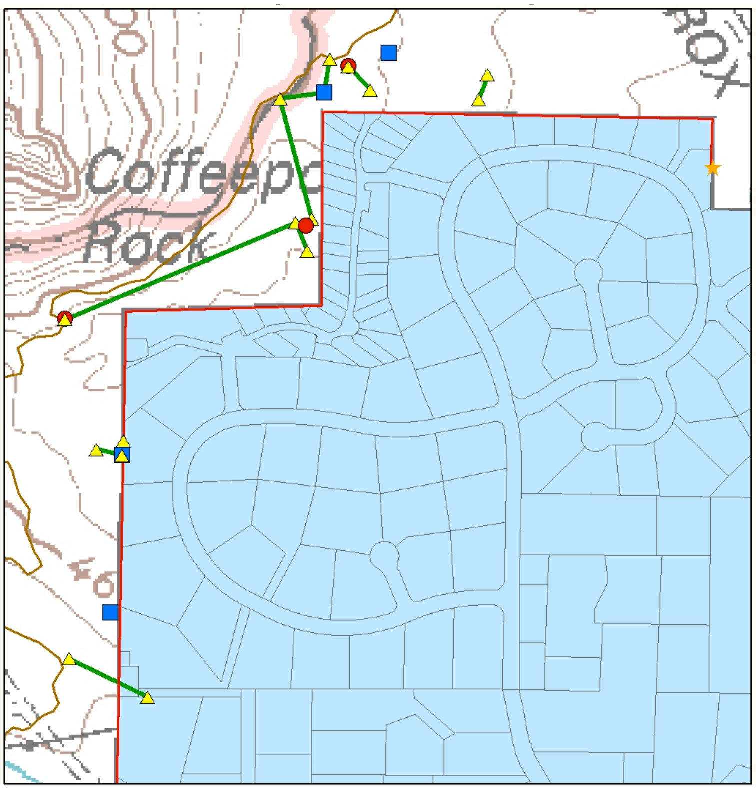
The vegetation at this locale was a mixture of piñon juniper woodlands and open grasslands. The terrain was rolling, broken by shallow washes, but otherwise lacking in difficult terrain that may curb cross-country travel.  According to Yavapai County GIS, the area is limited by zoning to four units per acre (Yavapai County GIS 2007). The adjacent private development was classified as medium density intermix.  The boundary can be difficult to discern, due to the variety of fences or complete lack of a fence.  Both Forest Service fences, seemingly to serve as older ranching boundaries, and a variety of private fences are present.

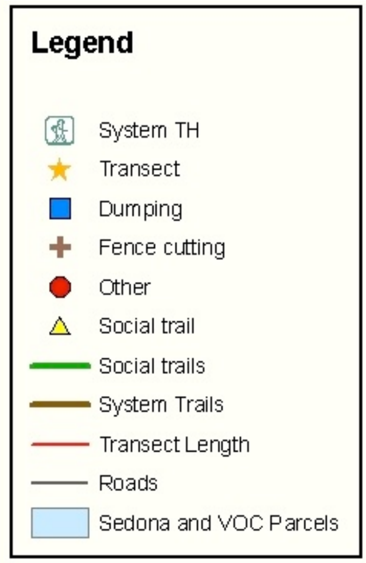
From the boundary, one could easily navigate to a system trail or meander the terrain with very little difficulty.  In some locations, the system trails were visible from the forest boundary.  Therefore it appears that topography and vegetation did not deter the establish and use of social trails.  Many of the housing units were older than other areas assessed, permitting more years for residents to access the forest.  Conversely, the exception was frequently used social trails originated from an empty lot that was under construction, which after completion residents would lose this access point.

*Teacup*
Length of transect: 4821 feet

a.

b.




c. d.

| | Social Trail n=37 | Fence Cutting n=21 | Dumping n=10 | Other n=11 | Total # of Transect Impacts/n=79 |
|---|---|---|---|---|---|
| Teacup | 9 | 0 | 3 | 2 | 14 |
| % of n | 24% | 0% | 30% | 18% | 18% |

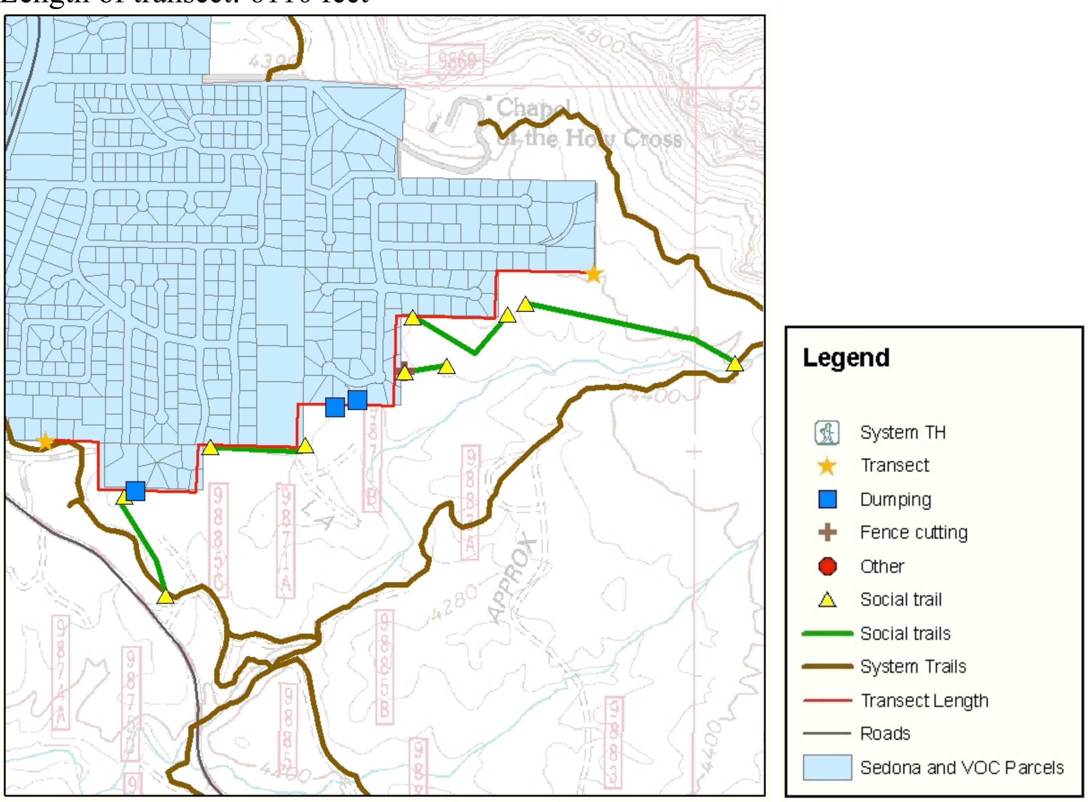
e.

**Figure 4.10 Teacup Area Impacts**
a. Dense scrub vegetation b. Social trail impact leading to private residences c. Human Impact Map d. Human Impact Map Legend e. Teacup Impact Table

The terrain in this transect was very hilly, with a significant rock ledge one-half mile in. Vegetation was dense, with patches of thick scrub and abundant piñon juniper trees. Housing was less dense than Big Park Area, with newer houses and large lots, many surrounded by private fences, including electric fences and security cameras. The majority of the transect was zoned RS-18a, permitting up to 2.5 housing units per acre, with a minimum lot size of 18,000 square feet (City of Sedona 2007a). A small section contained condominium type residences that were fairly dense, zoned as PRD (Private Residential Development). The adjacent private development was classified as medium density intermix. There were many older social trails, no longer in use, possibly due reduced access as a result of empty lots being built out in areas that were previously neighborhood access points.

There were no fence cutting impacts as there was no Forest Service fence on the transect. It appears that the rugged terrain and dense vegetation, combined with a lower housing density resulted in slightly lower than average WUI impacts for the Teacup transect (WUI average=16 impact, Teacup=14 impacts). Neighborhood access through empty lots is generally not present as the transect is well developed. It was assumed that few social trails would be present as a result of the dense vegetation, though there were approximately twice as many social trails as was found on the Little Horse and Margs Draw Areas.

*Little Horse*
Length of transect: 6110 feet



a. b.

| | Social Trail n=37 | Fence Cutting n=21 | Dumping n=10 | Other n=11 | Total # of Transect Impacts/n=79 |
|---|---|---|---|---|---|
| Little Horse | 5 | 1 | 4 | 1 | 11 |
| % of n | 14% | 5% | 40% | 9% | 14% |

c.

d.

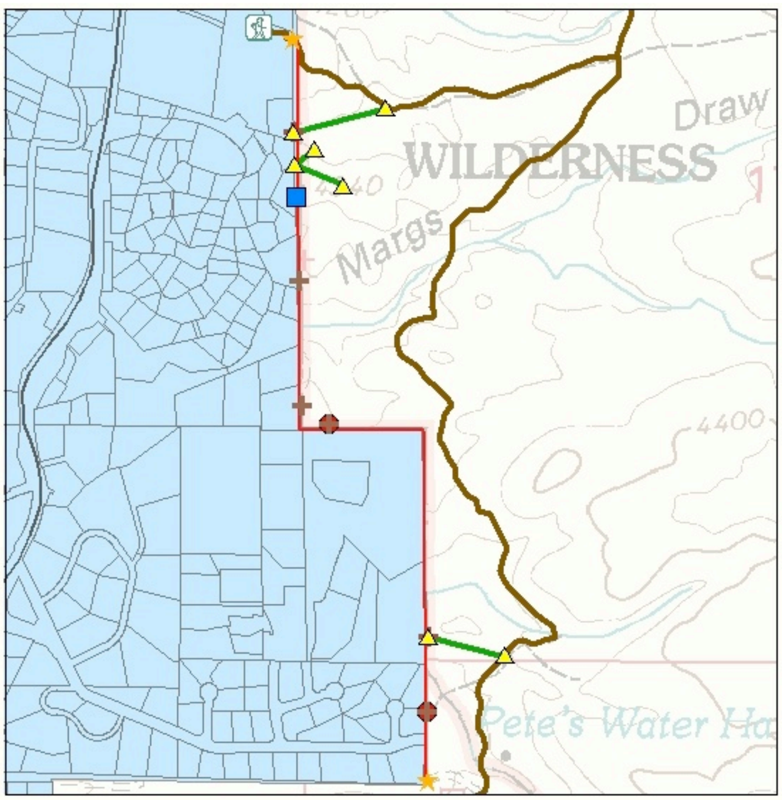
e.

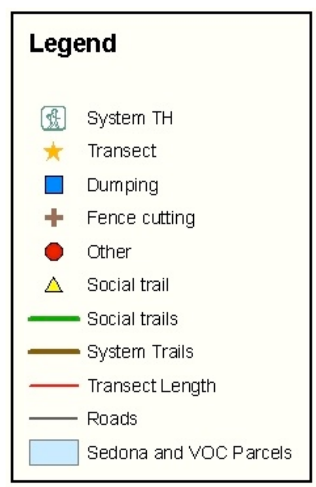
**Figure 4.11 Little Horse Area Impacts**
a. Human Impact Map b. Human Impact Legend c. Little Horse Area Impact Table
d. Dense vegetation with social trail leading to house e. Dumping of yard debris

The terrain in the Little Horse Area was level, broken by arroyos. Piñon juniper woodlands and oak scrub were the dominant vegetation. Similar to the Big Park Area Transect, housing was medium density, zoned as RS-10b, with up to four housing units per acre, with lots a minimum of 10,000 square feet (City of Sedona 2007a). This area was classified as low density intermix. There was not a continuous Forest Service fence, although pieces of an old allotment fence were visible throughout most of the transect. The majority of the properties were privately fenced, a mixture of barbed wire and chain link.

This transect had the highest number of dumpings. The variables of housing density, vegetation, and terrain, explored in this research were most likely not a factor in the amount of dumpings. This is assumed because all of the dumping occurred directly adjacent to the Forest Service boundary, thus terrain and vegetation would not have had influence. Housing density was the same as Big Park Area, but the Little Horse Area contained four times as many dumping impacts, thus it does not appear that housing density was a factor. The social trails that were present were difficult to discern due the lack of defined tread, as a result of the rocky terrain of the area. This transect had the same housing density as Big Park Area but 70% less social trails. It appears that a higher amount of trees and scrub, in combination with the variable terrain, resulted in fewer social trails. This is possibly due to the inconvenience of navigating the terrain cross-country.

*Margs Draw*
Length of transect: 5011 feet




a. b.

| | Social Trail n=37 | Fence Cutting n=21 | Dumping n=10 | Other n=11 | Total # of Transect Impacts/n=79 |
|---|---|---|---|---|---|
| Margs Draw | 4 | 6 | 1 | 2 | 13 |
| % of n | 1% | 60% | 10% | 18% | 16% |

c.


d.


e

**Figure 4.12 Margs Draw Area Impacts**
a. Human Impact Map  b. Human Impact Map Legend  c. Margs Draw Area Human Impact Table  d. Housing with other impact of vegetation cutting, social trail, and fence cutting  e. Very rugged terrain with scrub and piñon juniper woodlands

This area contained very hilly terrain and piñon juniper woodlands.  Housing was moderately dense, with several newer large houses on big lots.  Most of the area was zoned RS-10b, allowing up to four units per acre, with a lot minimum of 10,000 square feet (City of Sedona 2007a).  This area was classified as medium density intermix.  There was a Forest Serve fence along the entire transect.  A secondary private fence reinforced several sections of Forest Service fence.

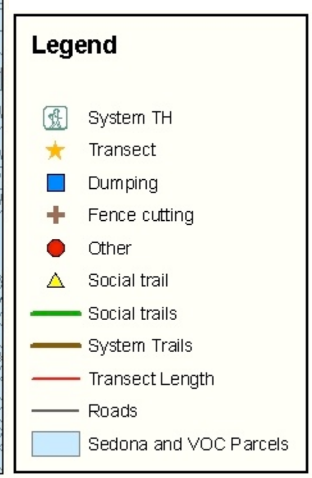
This transect had the lowest occurrence of social trails for the developed transects.  It appears that the hilly terrain and dense vegetation likely attributed to the low occurrence.  Only two of the six fence cutting impacts provided access for a social trail, and another two were cut for the installation of a private gate leading to a social trail.  The Margs Draw Area had the same housing density as Little Horse and Big Park Areas, but fewer impacts than Big Park Area and more than Little Horse Area.  The data suggests that the medium housing density did not result in a higher amount of impacts.

*Sedona Cultural Park, undeveloped transition*
Length of transect: 5834 feet

a.

b.


c.




d.

| | Social Trail n=37 | Fence Cutting n=21 | Dumping n=10 | Other n=11 | Total # of Transect Impacts/ n=79 |
|---|---|---|---|---|---|
| Sedona Cultural Park | 3 | 7 | 1 | 3 | 14 |
| % of n | 8% | 33% | 10% | 27% | 18% |

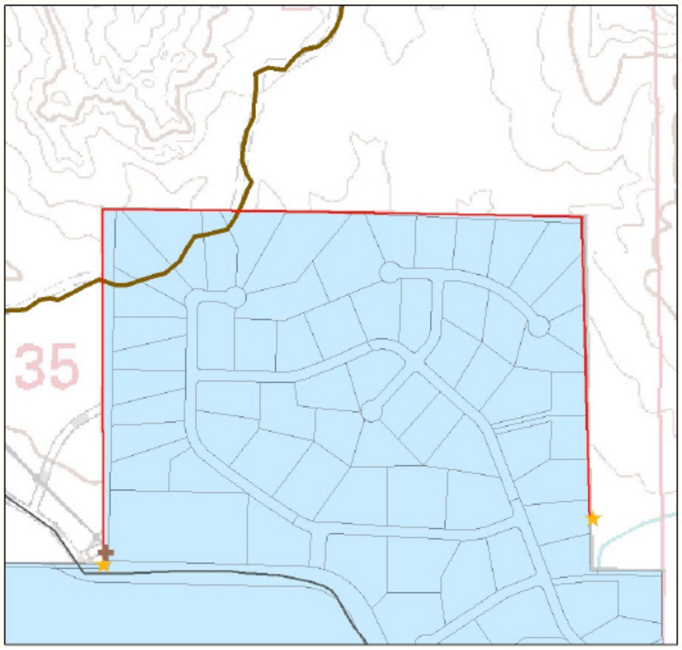
e.

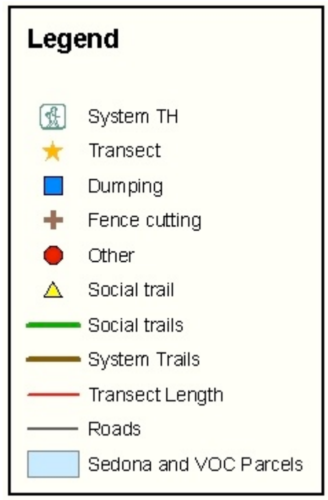
**Figure 4.13 Sedona Cultural Park Impacts**
a. Fence adjacent to new development b. Fence cutting impact, houses not adjacent to boundary c. Human Impact Map d. Human Impact Map Legend e. Sedona Cultural Park Impact Table

This transect contained generally flat terrain cut by several steep arroyos. The vegetation was piñon juniper woodlands with open grasslands intersperse. A barb wire Forest Service fence was present along the entire boundary, and in some locations two barb wire fences were in place and it could not be determined if the second fence was on Forest Service or on private land. The adjacent private land, in the very southern tenth mile of the transect, was just beginning to be developed with two apartment style buildings under construction. The area under construction is zoned as a Planned Development District. The remainder of the transect is zoned as RS-35, permitting one unit per acre, with a minimum lot size of 35,000 square feet (City of Sedona 2007a). Houses were present throughout the transect. Below the southernmost fence cutting impact (See Figure 4.13b) houses were not directly adjacent to the boundary, but set back approximately 100 yards, or the length of a football field. Above the southernmost fence cutting impact, there was development directly adjacent to the forest boundary. The development adjacent to the boundary, a combination of both RS-35 and RS-70, allowed maximum density of one or two units per acre, or a minimum lot size of 35,000 square feet or 70,000 square feet. The entire area was classified as low density intermix.

This transect had the lowest housing density; yet the number of impacts were greater than, or equal to, areas with higher housing density. The vegetation was not dense enough to deter residents from accessing the forest, although the presence of occasional steeply walled arroyos would most likely deter residents from continuing in that direction. The continuous presence of a Forest Service fence supports the high number of fence cutting impacts. The remainders of the impacts were relatively low. It was anticipated that this transect would be undeveloped. However private residences were sparsely present along the northern half. Five of the seven fence cutting impacts were present where there was development, suggesting a relationship between the development and fence cutting.

*Baldwin, undeveloped*
Length of transect: 5356 feet




a. b.

| | Social Trail n=37 | Fence Cutting n=21 | Dumping n=10 | Other n=11 | Total # of transect impacts /n=79 |
|---|---|---|---|---|---|
| Baldwin | 0 | 1 | 0 | 0 | 1 |
| % of n | 0 | 5% | 0% | 0% | 1% |

c.

d. e.

**Figure 4.14 Baldwin Area Impacts**
a. Human Impact Map b. Human Impact Map Legend c. Baldwin Area Impact Table
d. Open grasslands with fence cutting impact, no development e. Private fence that runs along length of transect

In this transect, wide-open grasslands quickly gave way to a small rolling plateau of rolling piñon juniper and scrubby oak woodland. In the open grasslands, the first one-tenth mile, a five-strand barbed wire fence easily identified the boundary. For the remainder of the transect, the boundary was easily identified by a new, rough lumber fence installed by the private landowner, as well as numerous benchmarks. There was no development until end of the transect where there were two newly constructed houses within sight of the boundary. It is believed that the land will soon be developed by CR Ranch. When developed, a maximum density of one unit per acre is dictated by Yavapai County zoning RS-35, a minimum permissible lot size of 35,000 square feet. This area is classified as low density intermix.

The Baldwin Area was the only transect that was truly undeveloped. In answering the research question number one, 'Will areas without adjacent housing have no visible signs of human impacts?' it appears that a lack of adjacent housing results in fewer human impacts. When the area is developed, the presence of the rough lumber fence will not be subject to fence cutting, nor is the scrub oak easy to navigate. The sole impact, fence cutting, occurred less approximately fifty feet from the main access road to the area. The lack of an associated social trail indicates that it may have been a single occurrence, not associated access to a private residence on the other side, as there was no development in the area.

# CHAPTER 5: CONCLUSION

The human impact baseline study conducted in the wildland-urban interface around Sedona and the Village of Oak Creek successfully met the thesis objectives. The first objective was to develop a human impact inventory system that can accurately assess human impacts in the wildland-urban interface. The developed inventory system was implemented such that any visible human impact was assessed. While four main impact categories (social trails, fence cutting, dumping, and other) emerged out of assessed impacts, the researcher believes that any visible human impact was accurately captured using the developed human impact inventory system.

The second objective was to conduct an inventory of human impacts within the wildland-urban interface around Sedona and the Village of Oak Creek. This objective was met as a result of the researcher conducting ten days of field research and recording the data to create the baseline study.

The third objective was to provide land managers with methodology and data for human impacts in the wildland-urban interface. This objective was met on November 30, 2007 when the researcher conducted a presentation of research results, data and methodology to the Coconino National Forest. This presentation also met final objective, to provide information to land managers to assist with policy and management decisions. Forest Service employees were very engaged in the presentation and the researcher has been invited to present the baseline study results to the Red Rock Ranger District staff in the near future.

**Synopsis of Findings**

In having conducted a baseline study of human impacts around Sedona and the Village of Oak Creek it can be acknowledged that while human impacts are occurring, nothing was found that should cause immediate alarm for either management or local residents. Although, if one subscribes to the “broken window” theory, the variety of seemingly minor impacts, such as cutting a signed Forest Service boundary fence and installing a private gate to their property signed “No Trespassing”, may lead to greater and potentially more severe impacts on adjacent public lands.

Four research questions provided focus for this thesis. All of the questions explored variables that may affect the quantity of human impacts in the wildland urban interface (See Table 5.1). The first research question, ‘Will areas without adjacent housing have no visible signs of human impacts?’ appears to be true. The Baldwin Area transect, entirely undeveloped, had only one fence cutting impact, with the next lowest transect impact count in the Little Horse Area with eleven total impacts. The second research question inquired whether or not there is a relationship between housing density and the amount of visible impact. The data collected suggests that there is no clear relationship between housing density and quantity of human impacts.

Vegetation type and density, and topography, were observed and recorded by the researcher to answer if theses factors affect the number of human impacts. It appears that rugged terrain and dense vegetation deter use from adjacent neighborhoods, thus decreasing the amount of human impacts in the area. Areas with like housing density, but denser vegetation and hillier terrain had fewer human impacts than Big Park Area, which had large areas of grassland vegetation and flat to rolling terrain.

Social trails were the most common impact encountered in the six inventoried transects. While none were causing severe natural resource damage, the abundance of social trails should call attention to the need for more system neighborhood trailheads. While fence cutting was also a regular occurrence, it is not recommended that the Forest Service take any management steps toward mitigating fence cutting, as most of the existing fences are no longer used for their original intent, nor is it Forest Service policy to maintain a boundary fence.

The assessed human impacts met the researcher's expectations, in type, magnitude, and occurrence. No activities or associated impacts from activities, such as campfires, overnight camping, or cross-country motorized vehicle use were found. Whether this is a reflection of the community demographics or compliance with Amendment 12 is unknown. A surprise was that the majority of social trails did not lead to system trails, but rather to other social trails, or simply disappeared. The amount of vegetation cutting and pruning was of concern to the researcher.

| Transect | Social Trail | Fence Cutting | Dumping | Other | Total impacts per transect | % of total impacts n=79 | Housing density | Vegetation | Topography |
|---|---|---|---|---|---|---|---|---|---|
| Big Park | 16 | 6 | 1 | 3 | 26 | 33% | </= 4HU/acre | grass | rolling |
| Teacup | 9 | 0 | 3 | 2 | 14 | 18% | </=2.5HU/ acre | dense scrub/Pinon Juniper | hilly |
| Little Horse | 5 | 1 | 4 | 1 | 11 | 14% | </= 4HU/acre | dense scrub/PJ | hilly |
| Margs Draw | 4 | 6 | 1 | 2 | 13 | 16% | </= 4HU/acre | Pinon Juniper | hilly |
| Sedona Cultural Park | 3 | 7 | 1 | 3 | 14 | 18% | </=1-2HU/ acre | grass/Pinon Juniper | flat/hilly |
| Baldwin | 0 | 1 | 0 | 0 | 1 | 1% | undeveloped | grass/scrub | rolling |
| | 37 | 21 | 10 | 11 | 79 | 100% | | | |

**Table 5.1 Transect Human Impacts and Variables**

## Management Implications

Human impact assessment and monitoring provides an excellent unbiased picture of use types, levels, and occurrences on the landscape. Human impact assessments and monitoring within the wildland-urban interface provide an important indicator to land managers not only about human use of the land, but may provide additional insight about local community use, access and potential needs to their public land managers. While walking boundary transects may be time consuming and costly, it is an activity that could also be carried out by volunteers, students, and partner organizations. A human impact study within the wildland-urban interface may provide a medium for public land managers to obtain an assessment of impacts, and also an opportunity for residents to have managers see potential community needs. The results of a human impact study may provide benefits to the public land managers and the community by creating an opportunity for residents to have a greater understanding of their stewardship roles as neighbors of public lands.

As a result of the shrinking amount of undeveloped land along the wildland-urban interface, future studies of Sedona and Village of Oak Creek may be limited to developed WUI. While there was benefit in inventorying the undeveloped WUI, further transect selection would need to be conducted based on the objectives of management.

Human impact monitoring within the wildland-urban interface can be used as a catalyst for management to interact with community members for reasons other than wildfire. While wildfire may be synonymous with wildland-urban interface, there are many other activities and management issues that occur in the wildland-urban interface, yet which lack the necessary research for management to base decisions upon. Human impact monitoring within the wildland-urban interface thoroughly supports the Forest Service motto of "caring for the land and serving people."

**Limitations of Research and Safety Issues**

Time and funding both contributed to the limitations of this research. Given more time, the researcher would have collected more data from additional transects. Given even more time, it is desirable that baseline data could have been collected from transects located in other communities, to compare types, magnitude, and levels of impacts. The amount of data collected limited the statistical analysis of this research.

Further refinement of the Trail Impact Forms and variables observed could have been done. It would have been beneficial and applicable to include dog walking as a user type. This type, while present in many areas, is difficult to document. An accurate record of dog presence can be difficult due to their small paw tracks and high amount of off-leash owner habits may result in no visual dog presence for observation. The variable of housing development establishment a factor that may increase the number of human impacts could be further explored. It would be interesting to note if the quantities of human impacts increased with longer established housing developments. All of the transects assessed had residential development. This may have limited the variety of impacts. For future assessments it is recommended to include a variety of structures and development in the transects.

Prior to conducting this baseline study of human impacts in the wildland-urban interface, the researcher's impact studies had been limited to backcountry and wilderness areas. If the researcher were conducting another frontcountry baseline study, she would be better concerned with and prepared for personal safety and emergency situations unique to the wildland urban interface.

Personal safety should be a concern when inventorying and monitoring within the wildland-urban interface. While studies in the backcountry and wilderness areas pose their own safety risks, the human element of the wildland-urban interface represents a significant unknown risk. From experience in this study, it is recommended that future research be conducted with two or more researchers, during daylight hours, and that those involved wear bright and obvious clothing. The bright clothing will allow the researchers to be visible from a distance and thus less likely to surprise a property owner. It is also suggested that if the researcher works for, or is contracted by a land management agency, that unless the agency has excellent relations with the local community, that research be conducted in civilian clothing. Due to the irregularity of boundary fences and the immediately adjacent private property it would also be advised that researchers carry some sort of defense item, such as pepper spray, to keep away loose dogs, other pets, or in a worst case scenario, a property owner. For an extra precaution a researcher may want to inform the local Home Owners Association of the research and its purpose, which may put some homeowners more at ease.

**Future Research Recommendations**

It is recommended that this baseline study be replicated in five years. The five year interval allows for more build out in the Sedona and Village of Oak Creek, while also allow sites that may go out of use to naturally rehabilitate. If the Red Rock Ranger District is able to obtain funding and personnel at an earlier date, it is recommended that the baseline study system be implemented in other transects around Sedona, the Village of Oak Creek, and other nearby communities.  In future baseline studies, in addition to considering housing density, it is recommended to also investigate how long the development has been there also be investigated.  The time variable would establish whether human impacts are more likely to occur in more recent communities or older developments.

In future human impact assessments it is recommended that all of the issues and concerns mentioned within the limitation section be addressed.  In addition to further development of the assessment forms and variables, opportunities for including demographics and housing size and types would also provide interesting social information.  Surveys or interviews of local residents would be useful to obtain information on how the WUI is relevant to the community.  Speaking with local residents would provide a unique opportunity to gather personal information regarding the residents wants and expectations from land management agencies.

This study provides a glimpse into human impacts that occur in the wildland-urban interface around Sedona and the Village of Oak Creek, potentially indicating human impacts that may be occurring in other similar communities. It should be acknowledged, however, that level, type, and occurrence of human impacts in the wildland-urban interface will probably vary greatly with each community's demographics.

It is recommended that future research be conducted with a computer laptop or personal digital assistant (PDA).  This would greatly reduce the time needed to transfer handwritten information to the computer and also reduce the potential for human error when transcribing.  This would not be cost effective if research was to be conducted by a group. Therefore a group's research should be completed with hard copies of the assessment forms. Data for this study was compiled and analyzed in Microsoft Excel due to technological limitations and computer access, though it is recommended for future research that Microsoft Access or a similar database system be used to increase the ease of data management and reduce the potential for human error.

**Conclusion**

While scientific studies of aquatic habitat, wildlife species, fire regime condition class, and timber stands are integral to the Forest Service mission, the agency's scientific studies do not as often explore the human element, which is increasingly present in, around, and on public lands. Human impact monitoring in the wildland-urban interface provides the Forest Service, and other land management agencies, the opportunity to apply existing human impact monitoring systems: to better learn about local people, communities and their needs; provide outreach regarding stewardship of their neighboring public lands; and thus help people help take care of public lands and maintain the integrity and character of the wildland-urban interface.

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APPENDIX

APPENDIX A: Impact Descriptor Form

**Impact Descriptor Form**

| | | | |
|---|---|---|---|
| **Date of Monitoring:** | | | |
| **Impact Name:** | | | |
| **Type of impact** | **Social Trail Dumping Fence Cutting Other** | | |
| | **Beginning** | | **End** |
| **Waypoint Number:** | | | |
| **GIS Coordinates:** | | | |
| | | | |
| **Digital Image:** | | | |
| **Dominant Veg Type:** | **PJ Grass Shrub** | | **PJ Grass Shrub** |
| **Veg Damage:** | **Y N** | | **Y N** |
| | **trampling** | | **trampling** |
| | **root exposure** | | **root exposure** |
| | **pruning** | | **pruning** |
| **Dominant Soil Type:** | **Sand** | | **Sand** |
| | **Clay** | | **Clay** |
| | **Loam** | | **Loam** |
| **Erosion Present:** | **Y N** | | **Y N** |
| **Cryptobiotic Soil:** | **Y N** | | **Y N** |
| **Cryptobiotic Damage:** | **Y N** | | **Y N** |
| **Litter Descriptor:** | | | |
| **Trail Origin/End Descriptor:** | | | |
| **Trail Depth:** | | | |
| **Trail Width:** | | | |
| **Type of Use:** | **Hikers Mountain Bikers** | | **Equestrians Other** |
| **Use level:** | **old infrequent frequent** | | |
| **Total Length:** | | | |
| **Impact Narrative:** | | | |

APPENDIX B: Trail Interval Form

| Trail Interval Form (Complete every 1/10 mile) | | |
|---|---|---|
| Date of Monitoring: | | |
| Trail Name: | | |
| Digital Image: | | |
| Waypoint: | | |
| GIS Coordinates: | | |
| Trail Mileage: | | |
| Trail Width (ft): | | |
| Trail Depth (in): | | |
| Trail Rutting: | | |
| Trail Erosion: | | |
| Cryptobiotic Soil Presence: Y / N Damage Y / N | | |
| Veg Impacts (# of incidents of breakage trampling): | | |
| Evidence of Recreation Activities: Hiking/Mtn Biking Horse/ Dumping/ Campfires/ Pets | | |
| Litter: | | |
| Descriptive Narrative: | | |