DISPERSED RIPARIAN CAMPSITE MANAGEMENT IN THE GREENWATER RIVER WATERSHED, WASHINGTON

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ABSTRACT

DISPERSED RIPARIAN CAMPSITE MANAGEMENT IN THE

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The objectives of the study were to evaluate effectiveness of inexpensive fences and signs in preventing vehicle access to riparian campsites; determine campers' campsite management preferences; and collect baseline biophysical data for long-term riparian campsite monitoring in the Greenwater River Watershed, Washington. Fences successfully prevented vehicle access to study area campsites in most cases, but when offered choices during the survey, campers preferred images of campsites blocked by countersunk boulders to any other option. The variable radial transect method utilized for baseline data collection in spring and fall 2006 proved time consuming and inconsistent, with confounding seasonal vegetative changes. The author recommends blocking vehicles from campsites with lightweight fences and signs as an interim measure until boulder treatments are funded, modified campsite monitoring, and increasing camper education and outreach efforts.

ACKNOWLEDGEMENTS

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CHAPTER I

INTRODUCTION

Problem Statement

Camping takes many forms, ranging from semi-permanent recreational vehicle sites to wilderness backpacking. Public land managers are often tasked with providing opportunities for recreation across the entire spectrum of recreation needs (Clark & Stankey, 1979). The range of public land camping includes a minimally managed form known as dispersed camping. Dispersed camping is undeveloped, relatively unmanaged, road-adjacent, and generally free of charge. Those who engage in dispersed camping tend to have stronger connections with their chosen location, and have more developed outdoor skills than those who frequent developed campgrounds (McFarlane, 2004). Dispersed camping is common on many U.S.D.A. Forest Service (Forest Service) lands, which presents a resource management dilemma because the Multiple Use—Sustained Yield Act of 1960 gives equal consideration to outdoor recreation, wildlife and fish habitat, range, timber, and watershed (i.e., water supply) uses. Dispersed camping has the potential to directly impact wildlife and fish habitat, timber, and watershed uses, in this case putting recreation at odds with the other resource mandates of the Forest Service.

Road-accessible areas, known within the Forest Service as "front-country," to differentiate them from trail-accessible "backcountry," are minimally managed to provide the public with primitive recreation opportunities for overnight and day use. In some areas, campers drive vehicles into streamside campsites, often driving and parking on, or very near, the streambank. Resource managers are concerned that these activities adversely affect fish and wildlife habitat by compacting soil and crushing vegetation, which reduces riparian shade, facilitates bank erosion and channel widening, and increases sedimentation of streambed gravels (T. Patterson, personal communication, June, 2005). While dispersed camping is not a primary cause or limiting factor of salmon recovery in the region, it represents low-hanging fruit for land managers without the budgets to address larger threats such as failing road networks, undersized culverts, and private land management shortcomings.

Forest Service resource managers in Mt. Baker-Snoqualmie and other National Forests have taken several approaches to preventing vehicle access to streambanks, including roadside guardrails, large cement blocks (known as ecology blocks), boulders, signs, wood rail fences, and lightweight wood snow fences. Most of these options are expensive, requiring heavy equipment, specialized labor, and large amounts of material. Some options, such as installing boulders near shorelines, trigger extensive processes mandated by the National Environmental Policy Act of 1969 (NEPA) because of significant environmental impacts caused by installation. Since primitive, unmanaged recreation does not generate funds for management or restoration, budgets for such activities are minimal. The Forest Service needs effective, low-cost, low-impact tools for preventing vehicular damage to riparian areas in front-country dispersed campsites.

The Greenwater River Watershed of Western Washington has been a popular destination for outdoor recreation for over three decades (Varness, 1976). Anglers, hunters, hikers, and campers access the watershed via a network of Forest Service roads that follow the Greenwater River and several tributaries. As the primary landowner in the watershed, the Forest Service is responsible for managing lands for multiple uses, including recreation and wildlife habitat.

Research Objectives

This project dealt specifically with front-country dispersed camping in close proximity to streams and rivers in the Greenwater River Watershed (Figure 1). The purposes of this project were threefold: (a) to demonstrate the short-term efficacy of low-cost, low-impact signage and fences in minimizing vehicle traffic in front-country dispersed riparian campsites in the Greenwater River Watershed; (b) determine users' reactions and preferences to management actions in signed, fenced campsites and untreated campsites; and (c) develop a baseline data set from which Forest Service staff or other

Figure 1. Greenwater River study site and area map.

researchers could measure changes to the biophysical campsite characteristics over time.

Significance

Anadromous fish habitat provided by the Greenwater River is considered critical to the recovery of White River spring Chinook (part of the Puget Sound population), Puget Sound steelhead, and bull trout (Pierce County, 2008), all listed as threatened under the Endangered Species Act of 1973 (64 FR 58909, 70 FR 37160, 72 FR 26722). The river is also home to coho salmon, coastal cutthroat trout, and pink salmon, all of which are important indicator species for Mt. Baker-Snoqualmie National Forest (Ketcheson, Leinenbach, Schuett-Hames, Whiley, & James, 2003). Spring Chinook adults, as well as coho, steelhead, and some Chinook juveniles are present in the river as adults through the summer months (Salo & Jagielo, 1983), when water temperatures are highest. Bull trout are presumed to be in the Greenwater River during summer months, but may seek refuge in cooler waters in the Norse Peak Wilderness, based on anecdotes from anglers interviewed during the project.

High temperatures and sediment loads have high modeled impacts on Chinook through most of the Greenwater River system (Ketcheson et al., 2003; Mobrand Biometrics Inc, 2001). These are largely legacy problems associated with timber harvest and road management in the watershed (Ketcheson et al., 2003; Mt. Baker-Snoqualmie National Forest, 2000). Unmanaged recreation in otherwise protected riparian areas exacerbates these problems, and in many cases delays natural vegetative recovery that would reduce stream temperatures and fine sediment loads. In order to promote recovery of riparian forests and their numerous benefits to aquatic life, recreation-related impacts to riparian areas such as soil compaction, vegetation damage, and rapid erosion must be addressed.

Forest Service land managers interested in restoring riparian areas need additional information to guide management decisions regarding dispersed campsites in riparian areas. Lessons learned from monitoring campsites and implementing management measures in the Greenwater Watershed could then be duplicated in other watersheds facing similar challenges.

The Mt. Baker-Snoqualmie National Forest encompasses over 1.7 million acres, only a small fraction of which is occupied by the Greenwater Watershed (Ketcheson et al., 2003). Outside of the Mt. Baker-Snoqualmie, Forest Service-managed watersheds harboring ESA-threatened salmon, trout, and char face similar challenges throughout Washington, Oregon, and northern California, and all could potentially benefit from advancement in knowledge regarding effective dispersed camping management.

CHAPTER II

SITE DESCRIPTION

Location

The study area includes four clusters of front-country, dispersed riparian campsites located in the Greenwater River Watershed northeast of Mt. Rainier in western Washington (Figure 1). The Greenwater River is a tributary to the Upper White River, which eventually joins the Puyallup River and flows into Puget Sound at the City of Tacoma, Washington. Much of the Greenwater Watershed is located in the Snoqualmie Ranger District, Mt. Baker-Snoqualmie National Forest, with the rest in private industrial timber ownership. The middle reaches of the Greenwater River are roughly paralleled by Forest Road (FR) 70, which branches north and then east from Highway 410 east of the town of Greenwater, and FR 7031, which branches from FR 70 and follows the Greenwater for about one mile toward the Norse Peak Wilderness.

The first cluster of study campsites are at an elevation of approximately 600 m adjacent to Midnight Creek, a second-order, right-bank tributary that flows south into the Greenwater at approximately River Mile (distance from the mouth of the river, abbreviated RM) 4.0, and is paralleled by FR 7010 (Figure 2). The lower half mile of Midnight Creek is privately owned and managed; the upper portions of the creek are located on Forest Service lands. The second cluster of campsites is at approximately 780 m elevation adjacent to the

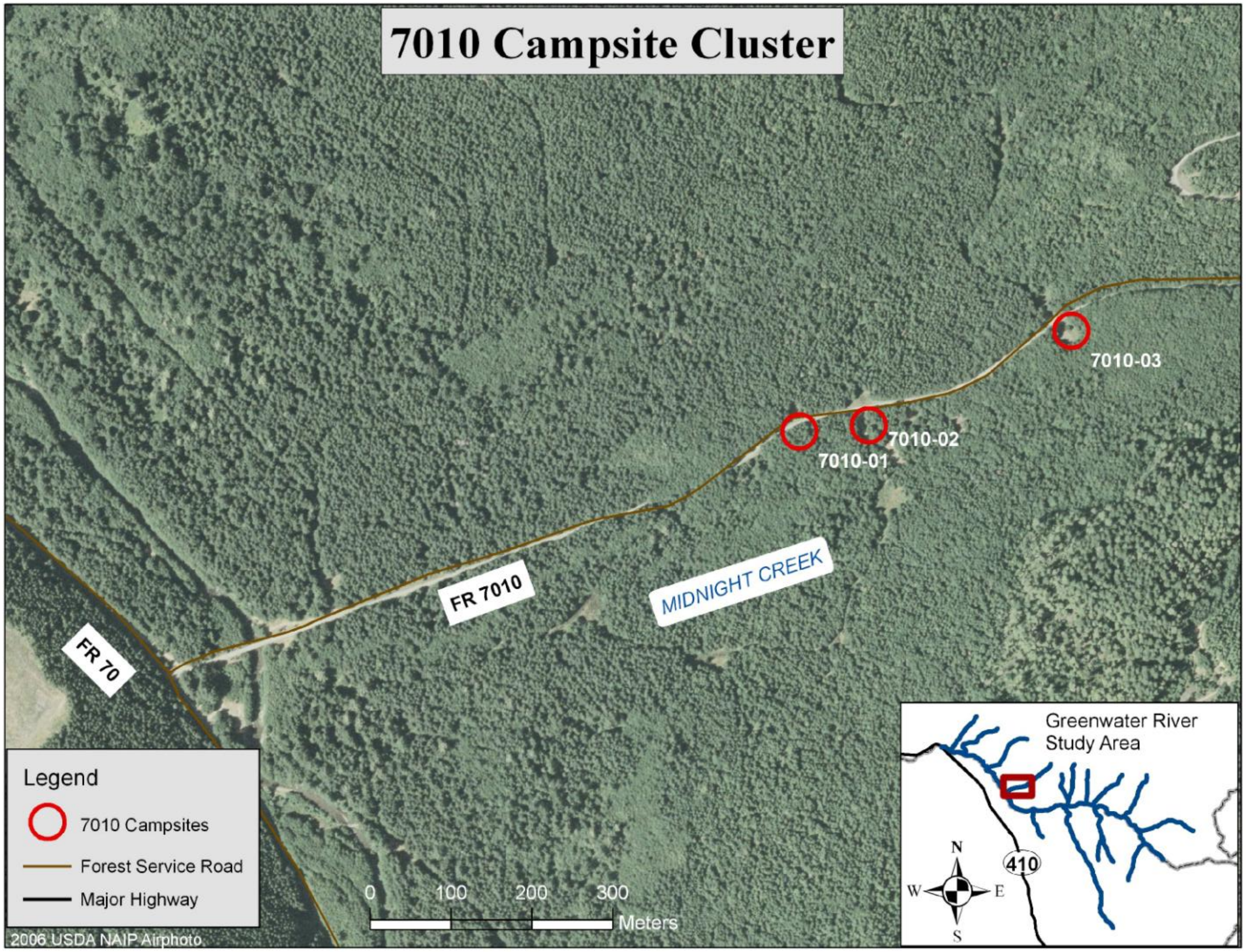

Figure 2. Map of 7010 campsite cluster (not treated).

Greenwater River at RM 10.3 is accessed via FR 7030 (Figure 3). The third cluster of campsites is at approximately 815 m elevation, adjacent to the Greenwater River at RM 11.2 (Figure 4). The campsites in the final cluster are approximately 830 m in elevation, accessed via FR 70, and are adjacent to Pyramid Creek, a second-order, right-bank tributary to the Greenwater River at approximately RM 11.0 (Figure 5).

Geology and Topography

Bedrock geology of the Greenwater basin is dominated by volcanic sequences dating to 20–24 million years ago. Three primary lithofacies of the Ohanapecosh formation are evident through much of the basin: lava/mud flow complexes, volcaniclastic rock accumulations, and ash flows and rhyolites. The Fife's Peak formation and some intrusive bedrock are also present, but over less area. The Osceola Mudflow, which flowed down the White River Valley from Mt. Rainier approximately 5,600 years ago, affected the lower Greenwater River Valley, but did not extend to the project area (Abbe, Beason, & Bunn, 2007; Crandell, 1969; Fiske, Hopson, & Waters, 1963).

The Greenwater River occupies a series of broad alluvial floodplains and narrow canyons through the project area. The topography is generally steep above valley floor and flood terraces, with elevations ranging from 508 m to 2,038 m (Ketcheson et al., 2003).

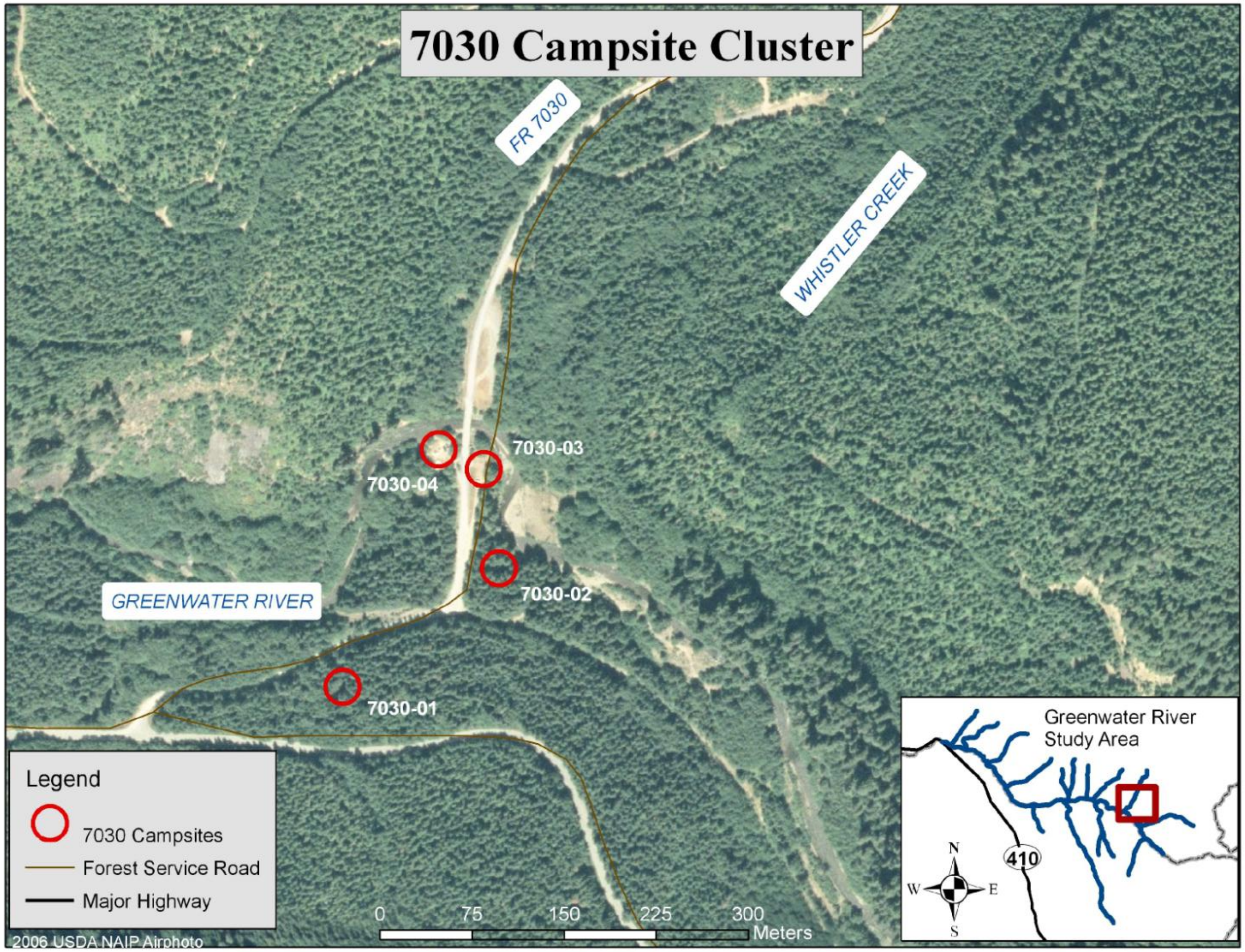

Figure 3. Map of 7030 campsite cluster (not treated).

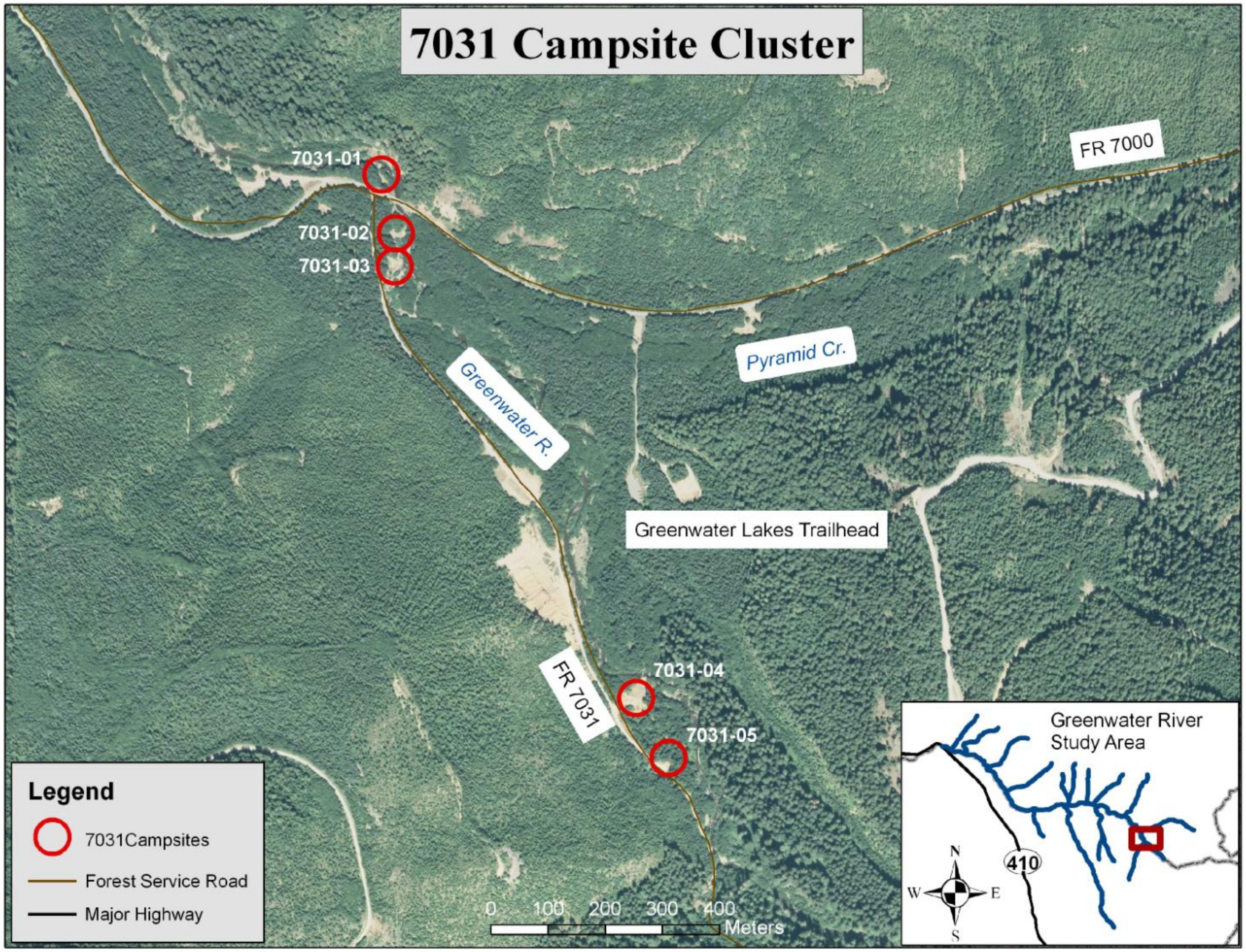

Figure 4. Map of 7031 campsite cluster (treated).

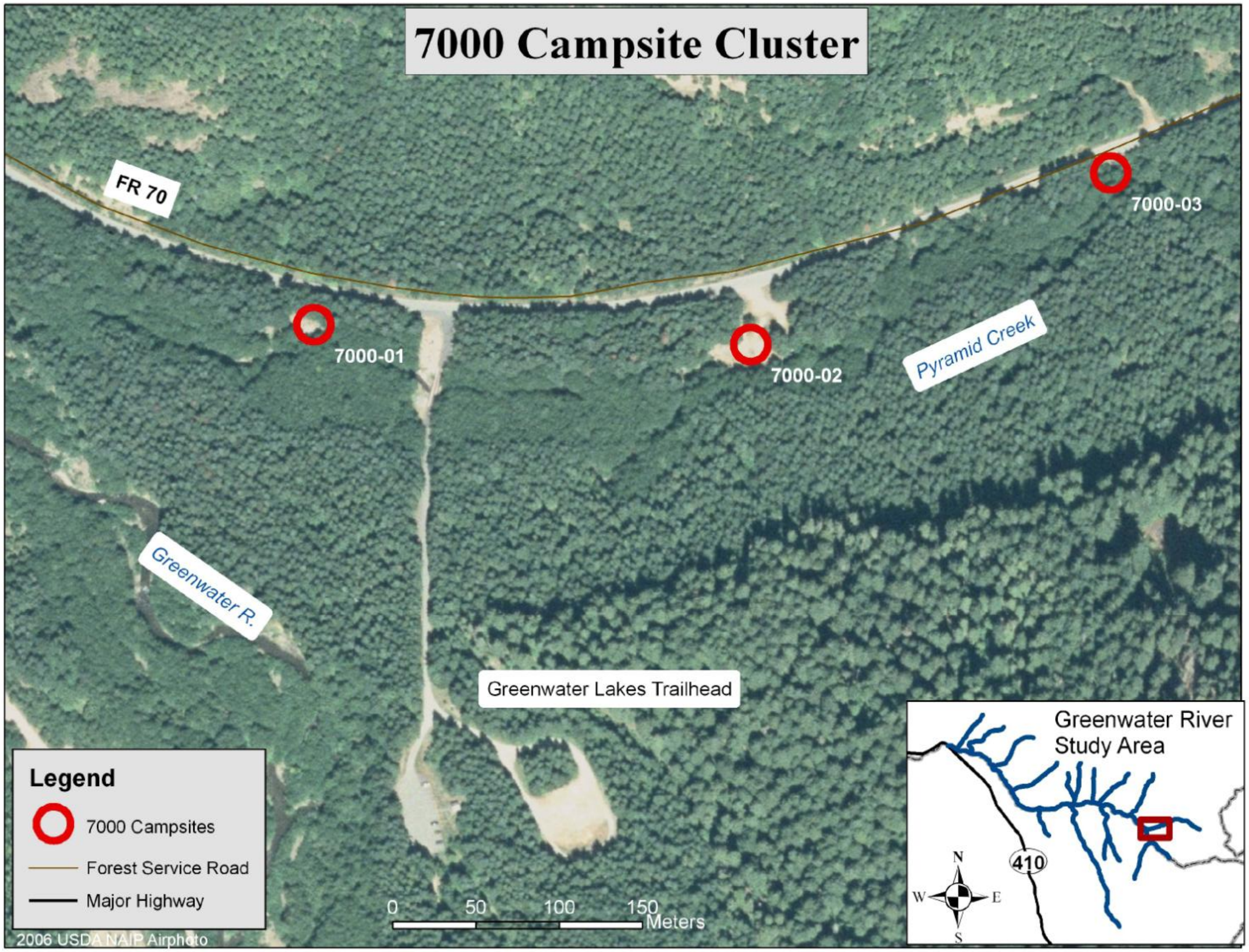

Figure 5. Map of 7000 campsite cluster (treated).

Climate

Summers in the Greenwater Watershed are typically warm and dry, and winters are generally cool and wet (Figure 6). Summer mean daily temperatures at the nearby town of Greenwater are approximately 14.0° C, and winter mean daily temperatures are approximately 1.5° C (Western Regional Climate Center, 2009).

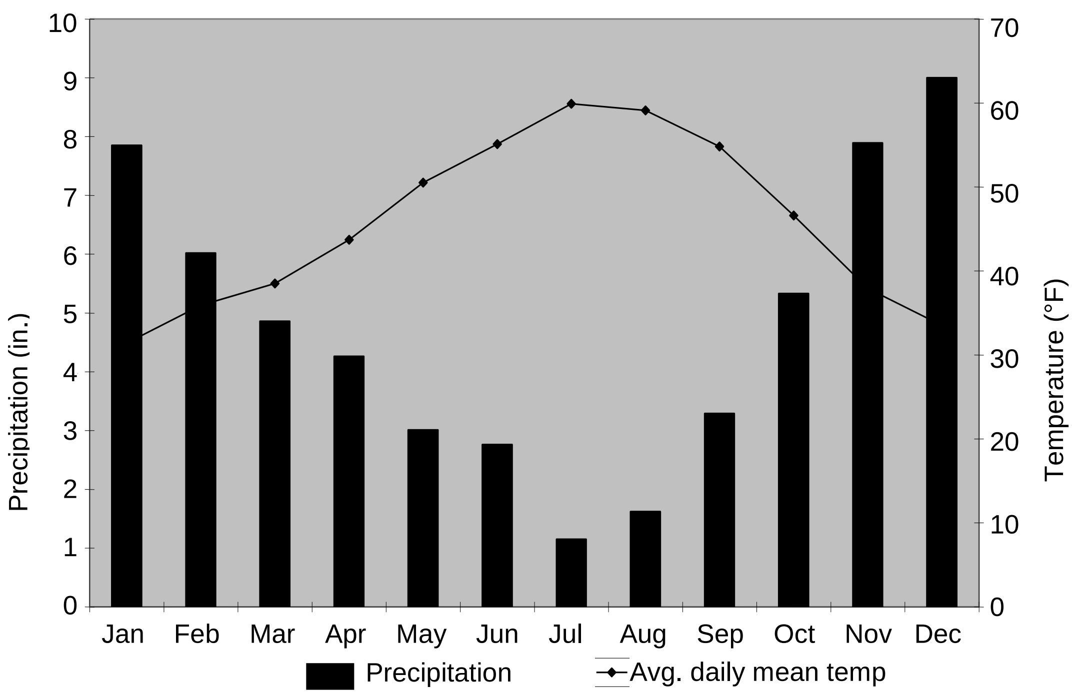

Figure 6. Climograph of Greenwater, WA. (Western Regional Climate Center, 2009).

The Greenwater Watershed is located northeast of Mount Rainier, which creates a rain shadow effect. Precipitation in the area is therefore generally lower than in other watersheds in the western Cascade Mountains. Most precipitation falls in the winter as snow, with an annual modeled average of

223 cm basin-wide (Ketcheson et al., 2003). The project campsites are located in the valley bottom, where precipitation is likely similar to the town of Greenwater, which receives an annual average of 145 cm (Western Regional Climate Center, 2009). Rain-on-snow events do influence flows in the Greenwater River, since a significant portion of watershed falls within the transitional snow zone, at elevations from 300 to 1,200m in the Pacific Northwest (Harr, 1986; Ketcheson et al., 2003; Washington Forest Practices Board, 1997).

Vegetation

The vegetation in the watershed is typical of low- to mid-elevation western Washington forests, with canopies dominated by Douglas fir (*Pseudotsuga menziesii*) and western hemlock (*Tsuga heterophylla*) at study area elevations. Disturbed riparian areas tend to have greater concentrations of deciduous trees such as red alder (*Alnus rubra*) and black cottonwood (*Populus trichocarpa*). Western red cedar (*Thuja plicata*), which originally drew loggers to the area, are now found primarily in the few unharvested areas of valley floor. Most forest stands are either early or late seral stages, with few mid-seral stands since most timber harvest occurred between 1970 and 1990; the last major natural disturbance was a large fire in 1920, with large, stand-replacement type fires approximately 200 and 400 years prior. The old growth that drew foresters until the 1980s also provided shade to the Greenwater River and its tributaries.

In 1956 aerial photos, canopy cover is estimated to be 70 - 90% over the Greenwater's streambed; estimated canopy cover in 1992 aerial photos is just 0 - 20% (Mt. Baker-Snoqualmie National Forest, 1996).

Study area campsites are within previously harvested areas and have canopies of mixed young evergreen and deciduous trees, or are in clearings surrounded by trees. Sites with coniferous tree cover tend to be in the stem-exclusion seral stage, characterized in the study area by young, even-age Douglas fir with a tightly closed canopy that limits undergrowth to a few shade-tolerant ferns and forbs (Oliver, 1981).

Soils

Natural Resources Conservation Service (NRCS) soil maps show soils in the campsite areas include arents and fluvents, with slopes from 0 to 8%. The NRCS advises that these soils are somewhat to very limited in usefulness for campgrounds, since arents are high in gravels and fluvents are prone to flooding (National Resources Conservation Service, 2007). Ground-truthing during site visits confirms these conditions; the campsites are situated on low flood terraces, and tend to be high in surface gravels and sand near the streambeds. The soils throughout the watershed are coarse and have low cohesion, which makes them especially prone to erosion and mass wasting events when clearcut or otherwise denuded (Mt. Baker-Snoqualmie National Forest, 2000).

Fish and Wildlife

The Greenwater River Watershed, including Pyramid and Midnight creeks, supports a self-sustaining population of coho salmon (*Oncorhynchus kisutch)*, thanks in part to habitat complexity provided by wood structures installed throughout the lower reaches and tributaries by the Forest Service and the South Puget Sound Salmon Enhancement Group in the early 1990s (T. Patterson, personal communication, June, 2005; T. Wright, personal communication, December, 2008). The Greenwater River also provides spawning and juvenile rearing habitat for Puget Sound spring Chinook salmon (*O. tshawytscha*), steelhead (*O. mykiss*), and bull trout (*Salvelinus confluentus*), all listed as threatened on the Endangered Species List (Mt. Baker-Snoqualmie National Forest, 2000). Numbers of bull trout in the river are not well known; their nocturnal habits and ambush feeding tactics do not lend themselves to counting by the snorkel surveys typically used to determine presence and relative abundance (David Evans and Associates, 1999). In recent years, large numbers of pink salmon (*O. gorbuscha*), have returned to the Greenwater River in odd-numbered years, surprising fishery biologists by their conspicuous presence in a watershed without high historic numbers (R. Ladley, personal communication, September, 2007). The Greenwater Watershed also supports populations of coastal cutthroat trout, (*O. clarki*), resident rainbow trout (*O. mykiss*), mountain whitefish (*Prosopium williamsoni*), various sculpin species

(*Cottus spp.*), and non-native Eastern brook trout (*S. fontinalis*) (Mt. Baker-Snoqualmie National Forest, 2000).

Approximately 288 species of wildlife (including mammals, birds, reptiles, mollusks, and amphibians) use the Greenwater Watershed, all of which are expected to use riparian areas for at least part of their life histories (Ketcheson et al., 2003). Notable macrofauna frequently discussed and/or sighted by area campers include blacktailed deer (*Odocoileus hemionus*), elk (*Cervus elaphus*), black bear (*Ursus americanus*), and cougar (*Felis concolor*).

Land Ownership and Use

The first road was built in the Greenwater Watershed in the 1940s to facilitate harvest of western red cedar for utility poles and pilings. General timber harvest started as early as the 1950s, but between 1970 and 1990 the watershed was heavily clearcut, leaving only scattered patches of old growth trees. The forest was logged to the stream banks, and most in-channel, large wood was salvaged for sale. Foresters tended to disregard soil stability or stream protection in construction of roads, with steep, unstable slopes logged bare, and some streambeds used as vehicle and skid roads (Mt. Baker-Snoqualmie National Forest, 1996).

The majority of the watershed is now divided between Forest Service and private industrial timber companies. Forest Service ownership starts at approximately RM 6.0 on the mainstem Greenwater, and extends upstream to the headwaters in the Norse Peak Wilderness. Midnight Creek, the downstream-most tributary in the study area, is privately owned from the mouth to RM 0.5, with Forest Service land upstream. The Huckleberry Land Exchange, completed in 1998, consolidated Forest Service ownership in the Watershed from its former checkerboard ownership with Weyerhaeuser.

Much of the riparian area within the Greenwater Watershed is heavily used for recreation. Dispersed camping has been common along FR 70 and its spurs since at least the mid-1970s (Varness, 1976). The Forest Service estimates that the Greenwater Watershed supports 121,000 annual recreation visits (Mt. Baker-Snoqualmie National Forest, 2000). Anglers target resident trout from July through October in the Greenwater River. Elk, deer, black bear, cougar, rabbits and grouse provide hunters with quarry from late summer through winter. Several hiking trails lure backcountry enthusiasts to the area, with the Greenwater Lakes Trail garnering the most attention. Mountain biking is available in limited supply in the Greenwater Watershed, but dual-sport and trail motorcycles are quite popular, both on- and off-road. The Naches Trail is a well used 4x4 trail in the drier summer months. Winter recreation, especially snowmobile riding, is popular in the area, with a snow-park adjacent to Pyramid Creek doubling as parking for summertime visitors.

CHAPTER III

LITERATURE REVIEW

Front Country Dispersed Camping

Recreation managers have long identified front country, dispersed camping as an important aspect of recreation on public lands, even identifying the Greenwater River Watershed as an important destination for campers seeking privacy and an undeveloped experience (Christensen & Davis, 1984; Clark, Koch, Hogans, Christensen, & Hendee, 1984). Front country, dispersed camping is characterized by direct vehicle access, lack of direct management by landowners, undeveloped campsites, and undefined camp area boundaries. Campers modify campsites according to their preferences, behavior generally disallowed in more formal campgrounds. Dispersed recreation, including front-country camping, is generally acceptable, and even supported by land managers (Downing & Moutsinas, 1978; Moutsinas, 1976), but environmental and social impacts of unmanaged camping have concerned resource managers for decades (Manning, 1979; Martin, McCool, & Lucas, 1989; Stohlgren & Parsons, 1986; Varness, 1976; Varness, Pacha, & Lapen, 1978). A vast majority of dispersed camping literature focuses on wilderness and backcountry campsites, and then typically focuses on vegetation cover loss. Very little academic literature focuses on front-country dispersed camping. This makes intuitive sense, since front-country campsites are found in areas already highly impacted by development and resource extraction.

Management Plans and Directives

The Forest Service is guided by a number of codes and regulations, including the National Forest Management Act of 1976 (Public Law 94-588), the Multiple-Use, Sustained Yield Act of 1960 (Public Law 86-527), the National Environmental Policy Act of 1969 (Public Law 91-190), Endangered Species Act of 1973 (Public Law 93-205), Clean Water Act of 1972 (Public Law 92-500), and others. As a result, National Forests develop individual forest land and resource management plans, analyze individual watersheds, and document records of decisions that significantly affect the quality of the human environment. In 1990, the Mt. Baker-Snoqualmie National Forest published their forest plan (Mt. Baker-Snoqualmie National Forest, 1990), which includes general direction for managing recreation, but the plan was soon significantly amended and superseded by the Northwest Forest Plan (USDA Forest Service, 1994).

In response to the Endangered Species Act listing of the northern spotted owl, the Forest Service issued the Northwest Forest Plan in 1994, thereby amending 19 separate Forest Service and 7 Bureau of Land Management plans within the owl's range. The Northwest Forest Plan (1994) includes three Standards and Guidelines (the finest level of management guidance in the plan) for recreation in riparian reserves, one of which specifically refers to dispersed recreation:

> Adjust dispersed and developed recreation practices that retard or prevent attainment of Aquatic Conservation Strategy objectives. Where adjustment measures such as education, use limitations, traffic control devices, increased maintenance, relocation of facilities, and/or specific site closures are not effective, eliminate the practice or occupancy. (p. C-34)

All campsites studied for this thesis fall within riparian reserves, since they are immediately adjacent to fish-bearing streams, and would therefore fall under this Standard and Guideline (USDA Forest Service, 1994).

At a smaller scale, the Forest Service conducts watershed analyses and watershed-specific plans to improve water quality and habitat conditions. In 2000, Forest Service staff completed the Upper White/Greenwater watershed analysis, which implies that dispersed recreation sites within riparian reserves are contributing to the decline of aquatic species' populations and habitats, but does not advise any specific action to remedy the situation (Mt. Baker-Snoqualmie National Forest, 2000).

More recently, Mt. Baker-Snoqualmie National Forest staff completed a plan in coordination with the Washington State Department of Ecology to reduce sediment and temperature impacts to water quality in the Upper White

River Watershed, including the Greenwater. The plan notes that dispersed recreation has intensified in the lower reaches of the Greenwater, and while the extent of the impacts is not known, the sites are likely contributing to water quality degradation through soil compaction, trampled stream banks, and loss of vegetative cover (Ketcheson et al., 2003).

Other documents from nearby watersheds recommend more specific actions to reduce impacts from dispersed recreation sites in riparian areas. For example, the Land and Resource Management Plan for the neighboring Gifford Pinchot National Forest stipulates that "dispersed recreation sites should be located at least 100 feet from the edges of lakes, streams, ponds, wet meadows, marshes, and springs" and that "[d]ispersed recreational activities which degrade the quality of riparian areas should be regulated or eliminated, e.g., the trampling of streambanks and lakeshores" (USDA Forest Service, 1995, p. 2-52).

Dispersed Camping Impacts

Direct impacts associated with dispersed camping include compacted soils, surface erosion, trampled lake and stream banks, damaged or destroyed vegetation, pollution from human waste, and garbage left by campers (Varness, 1976; Volker, 2008). Front and back country dispersed camping share these impacts, but front country dispersed camping impacts are magnified by the presence of passenger vehicles in the campsites (Volker, 2008). While the total area impacted by dispersed campsites is small in the watershed context, campsites are often located adjacent to stream and river banks already compromised by a legacy of aggressive timber harvest and stream cleaning (Ketcheson et al., 2003; Mt. Baker-Snoqualmie National Forest, 2000).

Soil compaction at dispersed campsites is a concern to resource managers because it tends to retard native plant establishment, increases erosion potential, inhibits hyporheic flow, and reduces infiltration rates. Soil compaction can range from mild to severe, with advanced soil compaction leading to campsites with denuded mineral soil (Kuss, 1986; Manning, 1979; Manning, Ballinger, Marion, & Roggenbuck, 1996). The degree to which soils become compacted depends on the soil and environment properties (i.e., soil type, climate, slope, vegetation, etc.) as well as the traffic that the soil receives. Moist soils with a range of grain sizes (such as loams) are the most prone to compaction that would cause long-lasting impacts to plant establishment (Kuss, 1986). Soils may become compacted through relatively light foot traffic, but are at greater risk of compaction when vehicles are involved because of the greater downward force they exert (Weaver & Dale, 1978).

Soil compaction caused by vehicles traveling off-road has been shown to cause myriad problems in agricultural applications, where even regular plowing fails to compensate for compaction (Hakansson & Voorhees, 1997). Military exercises utilizing tracked and wheeled vehicles have undergone extensive study to evaluate the level of disturbance they cause, including soil compaction (Althoff & Thien, 2005; Garten, Ashwood, & Dale, 2003). Recreational off-road vehicles, while generally lighter than military vehicles, also compact soils, and may even have a more detrimental effect than tracked vehicles because of the greater pressure exerted on tires (Prose & Wilshire, 2000). Once severely compacted, soils are less able to support re-vegetation by native plants and trees (Foil & Ralston, 1967; Kozlowski, 1999). In addition to compacting soil, vehicles are generally more likely to denude soils than foot traffic alone, and damage to vegetation increases as the weight and power of the vehicle increases (Yorks, West, Mueller, & Warren, 1997). Once denuded, streamside soils are more prone to erosion, which can increase fine sediment inputs, degrading spawning habitat for salmonids.

The importance of intact riparian vegetation for good water quality and proper ecosystem function has been well established in ecology literature (e.g., Hammitt & Cole, 1998; Liddle, 1997; Lowrance et al., 1984; Moring, 1982; Peterjohn & Correll, 1984). Much of the recent riparian and in-stream damage inflicted upon the riparian zones within the watershed has been attributed by recreation and ecosystem resource managers to motorized vehicle access to the stream banks (T. Patterson, personal communication, June, 2005). Recreational use of riparian areas in the Puyallup River Watershed, which includes the Greenwater River, likely degrades water quality through reduction in riparian shade, vegetation denudation, and soil compaction and subsequent erosion during high water periods (Upper Puyallup Watershed Committee, 2002).

Reducing Dispersed Camping Impacts

Researchers have found that even low levels of use cause significant resource damage, with impacts (typically measured by vegetation cover loss) having a curvilinear relationship with amount of use: most impact comes in the first few uses or seasons of use, and any use above a moderate level increases impacts only incrementally (Cole, 1989a, 1992, 1996; Cole & Monz, 2004; Leung & Marion, 1999). Most campsites in the Greenwater River study area have probably been in use for decades, and are unlikely to become much more impacted over time. This is not to say that high-use and low-use campsites are similarly impacted in all cases, nor do all vegetation types respond similarly. For example, Cole (1996) found that herbaceous meadow vegetation was more highly impacted by camping than subalpine forest with a *Vaccinium* understory in the short term. After 1 year of recovery time, however, the meadow had recovered at least partially, while the shrub-dominated groundcover of the subalpine forest had deteriorated further, suggesting that impacts to woody understory vegetation may be deferred and longer lasting than impacts to forbs growing in full sun.

When soils are completely denuded, campsites can become sources of fine sediment. Riparian camping denudes soils, exposes and damages tree roots, and exposes the soil to increased erosion potential (Dolan, Hayden, Howard, Hall, & Johnson, 1977; Green, 1998; Lockaby & Dunn, 1984; Volker, 2008). Compacted, denuded soils in riparian campsites tend to shed water faster than those with intact vegetation (Green, 1998; Vimmerstedt, Scoles, Brown, & Schmittgen, 1982), causing sediment-laden runoff to run directly into streams. Vegetation reduces splash erosion by intercepting and slowing raindrops, and roots and coarse woody debris slows or prevents rill and gully erosion (Gyssels & Poesen, 2003). Intact vegetation also provides surface roughness, slowing currents and promoting fine sediment deposition on floodplains (Fetherston, Naiman, & Bilby, 1995).

Concerns regarding soil erosion resulting from off-road vehicle use are not a recent phenomenon. Research finding high rates of erosion on off-road vehicle trails has spanned several decades. The rates of erosion found are variable, and are affected by vegetative (canopy and understory) cover, slope, soil type, and precipitation patterns, among other variables. Much of the literature addressing recreational off-road vehicle impacts focuses on desert soils (e.g., Eckert, Wood, Blackburn, & Peterson, 1979; Griggs & Walsh, 1981; Iverson, Hinckley, Webb, & Hallet, 1981). Central California ORV areas have undergone several studies, including one that found rates of erosion from ORV trails up to three metric tons per square meter in the oak woodland of Hollister Hills, California (Webb, Ragland, Godwin, & Jenkins, 1978). While these studies, on the whole, show that disturbed soils and vegetation tend to be more prone to erosion that undisturbed sites, they do not draw a conclusive link to stream sedimentation.

In an effort to determine long term impacts of ORV use on streams, researchers with the Forest Service's Southern Research Station compared two watersheds with established ORV trails to two watersheds without ORV trails. Preliminary findings indicated that fine sediment inputs were higher in watersheds with ORV trails, causing higher rates of embeddedness, shallower pools, and higher turbidity (Chin, Rohrer, Marion, & Clingenpeel, 2004). This finding expands on previous work that demonstrated that off-road fords locally increased fine sedimentation of river beds (Brown, 1994).

Campsite Measurement and Monitoring

Resource managers with the Forest Service monitor campsites as a method for identifying campsites that have exceeded the limits of acceptable change (LAC), a planning and implementation tool that has been in use for decades (Stankey, Cole, Lucas, Petersen, & Frissell, 1985). If a campsite has been found to be disproportionately affecting natural resources or impacting the recreation experience of users, managers take action to remedy the problem. After restoration activities have been initiated, the same protocols are used to monitor changes as a result of the restoration. Campsite characterization and monitoring has become an increasingly popular topic for research over the past three decades. As a result, researchers now have long-term monitoring data with which to hone monitoring techniques (Boyers, Fincher, & van Wagtendonk, 1999). Even though most research has focused on backcountry sites, the same methods (with some modification) can be applied to front-country sites such as those found in the Greenwater Watershed, since the variables measured are not changed by the mechanism of resource damage (i.e., foot traffic versus foot and vehicle traffic).

Time required for collecting monitoring data varies widely with the technique used, with some techniques taking as little as 3 minutes for a single researcher, while other, more precise techniques may demand several hours from a group of data collectors (Cole, 1989c). Cole and others suggest a technique that measures vegetation loss over the campsite by establishing a center point of the campsite, and then measuring the lengths of a number of radial transects to the edge of obviously disturbed vegetation to measure campsite area (e.g., Cole, 1989a, 1989b, 1989c, 2000; Marion, 1995). Cole (1989c) advocates for a variable radial transect method, in which a central point is staked, and wire flags are installed where the campsite boundary changes direction. Azimuth and length of transects from the center point and each flag are recorded, and mapped later on radial graph paper. Other researchers (e.g., Marion, 1995), have employed a fixed radial transect method, in which a central point is staked and transect lengths are measured at 16 fixed azimuths, regardless of campsite boundary shape.

Delineating campsite boundaries has been identified as a challenge, even with trained surveyors (Cole, 1989c), and no definitive method exists for eliminating bias and other inaccuracy. Cole (1989c) explains that sites in areas with fragile, dense groundcovers are relatively easy to measure, since trampled vegetation will form a site boundary. He also notes that sites without vegetative groundcover (e.g., bare soil or rock) can be very difficult to measure accurately or precisely, since boundaries are not as clearly defined. While he notes that campsite boundary delineation is typically completed by eye, he suggests that the boundary between vegetated and non-vegetated ground could be established by "at least 15 percent cover in a 1.09 x 3.28 ft (0.33 x l m) quadrat oriented perpendicular to and bisected by the tape" (Cole, 1989c, p. 14). This is a rather unwieldy decision instrument in the field, though, and still leaves room substantial error, especially in sites with little vegetative cover.

Cole (1989c) attempted to address the issue of surveyor inconsistency and methodological gaps by conducting a small-scale power analysis with a group of recreation management graduate students trained in campsite monitoring protocols. The objective of the power analysis was to establish the level of change that a campsite must encounter in order to be identified positively with the techniques he suggests. By his estimates, campsites areas must change up to 25% to reliably avoid a type-1 error (identifying a change when in fact no significant change occurred) when using interval-level data, such as those collected through radial transect methods. He concludes that coarser methods, such as the Frissell (1978) classification are more reliable than methods that collect interval-level data, but do not provide the precision desired by many recreation managers.

In addition to monitoring campsite impacts, Cole also has been involved in modeling campsite impacts, experimenting with low-level (foot trampling) stress applied to otherwise pristine sites, various spatial measurements of campsite impacts, and campsite restoration studies. Cole (1992) explained that empirical campsite impact studies have been hampered by a combination factors, including highly site-specific campsite characteristics and a lack of theoretical framework with which observed relationships may be explained. In response to this gap in research, he suggested a theoretical site modeling approach incorporating amount of use, vegetation fragility, vegetation density, and degree to which trampling is concentrated in the site. In theoretical and empirical studies, Cole and his co-researchers characterized campsites as being more highly impacted in the center of a campsite than in the periphery, which they attributed to concentrated activity near a centrally-located camp stove and/or campfire (Cole, 1989a, 1992; Cole & Monz, 2004; McEwen, Cole, & Simon, 1996; Smith & Newsome, 2002).

In recent years, the Respect the River program has developed a detailed inventory form for dispersed campsites. The form is suitable for volunteer use, and some ranger districts have organized events during which campsites are inventoried for future monitoring or management (USDA Forest Service, N.D.-a). The form does not, however, include a scaled measurement method to quantify campsite area change over time.

In an attempt to quantify dispersed camping impacts in the Cooper River Bridge area of the Cle Elum River, Washington, Volker (2008) mapped campsite perimeters and recorded impact observations for ten campsites on each of three levels of river terrace. She mapped perimeters with various GPS units for future monitoring use. She measured soil compaction, roads and social network trails, canopy cover, and root exposure and analyzed data to determine differences between values on the three terraces and control reference sites. In some cases, the results of the inter-terrace analysis were significant (e.g., vegetation canopy cover), but Volker notes that differences in vegetation species assemblages on the three terraces may not have been comparable with the spherical densitometer technique used in the research. Soil compaction at campfire rings was also significantly different between terraces, but this result may have been affected by different soil grain sizes on the three terraces. On all three terraces, soil compaction was several times higher at campsites and social trails than at control sites, indicating that front-country dispersed camping significantly compacts soils.

Recreation Site Restoration

Wilderness areas are managed to preserve natural conditions while providing recreation opportunities for visitors (Hendee, Stankey, & Lucas, 1990). Similarly, front-country areas used for recreation are managed for multiple uses and maintained in a semi-natural state (Clark & Stankey, 1979). Unfortunately, natural conditions and visitor usage are often at odds, since even minimal human use can impact natural areas. This apparent conundrum in management priorities has led land managers to attempt to restore recreation-impacted sites to natural conditions. Restoration is implemented by managers when impacts to areas are deemed excessive or inappropriate. Restoration may be relatively passive, consisting of closing an area to use to allow it to return to a more natural state, or more active, involving labor and materials to accelerate the restoration process (Cole & Spildie, 1999). In addition to resource concerns, incentives to restore impacted sites come from visitors themselves: forest users' opinions of heavily impacted areas tend to be less favorable than in more pristine conditions (Flood & McAvoy, 1999).

Using exit surveys, Flood and McAvoy (1999) found that restoration efforts are positively viewed by visitors, with 67% responding that observing restoration efforts increased or greatly increased the quality of their recreation experience, and 74% of respondents reporting positive to extremely positive opinions of land managers who implemented the restoration projects. Other researchers, however, have found that visitors have different views of resource damage than resource managers. Features such as denuded earth and trees spiked with nails, considered damage by wilderness managers, are perceived as amenities by campers (White, Hall, & Farrell, 2001).

In addition to measuring public opinion of restoration, researchers have also tested a variety of restoration techniques for use in recreation-impacted areas. Recognizing the social impacts of dusty (in dry weather)/muddy (in wet weather), compacted recreation areas, the Forest Service attempted to restore vegetation in two front-county areas in Tennessee and Georgia by planting, mulching, watering, and fertilizing a selection of grasses in fall, 1966 (Cordell & Talhelm, 1969). Without protection from trampling, the grass was eradicated from all unfenced and unprotected sites by September 1967, suggesting that revegetation may not be an effective method of restoration in areas subject to continued use, unless protected by travel barriers. Other restoration research has tended to focus on wilderness recreation, where the sites slated for restoration are not intended for continued use.

In areas with relatively high moisture and long growing seasons, vegetation recovery can take effect in relatively short time periods and with little or no direct management other than protection from trampling (Cole &

Spildie, 1999; Godefroid, Massant, Weyembergh, & Koedam, 2003; Roovers, Bossuyt, Gulinck, & Hermy, 2005). For example, in two western European studies conducted in temperate deciduous forest, Roovers et al. (2005) and Godefroid et al. (2003) found that terrestrial flora in previously denuded areas naturally recovered to conditions similar to surrounding forest within 6 year study timelines when protected from trampling.

In contrast to these rapid recoveries, higher elevation wilderness examples in the western United States tend to require more intensive management to achieve rapid recovery (Cole & Spildie, 1999; Zabinski, DeLuca, Cole, & Moynahan, 2002).

Recreation Management Strategies

Resource damage is an inevitable result of recreational use (Leung & Marion, 1999), but impacts may be reduced through a variety of management strategies, including passive education (e.g., newspaper or television advertisements, signs, flyers, and informational kiosks), in-person education (e.g., campsite visits, law enforcement patrols, backcountry rangers), regulatory actions (e.g., temporary legal orders, camping duration and group size limits, and area closure), access limits (e.g., closing areas to vehicles or stock), and physical closure of sensitive sites (e.g., fences, boulders, and road decommissioning). Appropriate choices for management at damaged sites depend, at least in part, on the causes or mechanisms of damage.

Resource damage occurs in five general categories of harmful behavior: careless, unskilled, uninformed, unavoidable, and intentionally illegal (Hendee et al., 1990). Careless behavior, such as littering, is typically addressed through a combination of education and enforcement (e.g., "Pack-it-in, Pack-it-out" campaigns, in combination with citations issued by law enforcement personnel). Unskilled behavior, such as allowing campfires to escape containment, can be somewhat effectively addressed by education and outreach programs, or by proper site development (e.g., installing steel fire rings). Uninformed behavior, such as leaving hitching lines or clotheslines tied around tree trunks for future use, is a direct result of lack of knowledge and can be avoided with effective information distribution. Examples of unavoidable impacts provided by researchers have included trampled campsite vegetation and disposal of human waste (Manning, 2003), but the degree of these impacts may be reduced through several approaches, depending on the individual impact. Campsite trampling, for example, can be effectively reduced in overall area by limiting group size, limiting vehicle access (in front-country sites), or by locating campsite amenities closer together (Kangas et al., 2007). Intentionally illegal behaviors, such as violating posted fire prohibitions, will only be effectively addressed through law enforcement action and/or physical area closure.

Resource management agencies are fond of educational programs as tools for promoting responsible behavior by user groups because they do not limit freedom and access for visitors (Christensen & Cole, 1999), but can reduce impacts caused by unskilled and uninformed actions (Hendee et al., 1990; Roggenbuck, 1992). Educational programs may also be helpful in reducing impacts caused by careless and illegal behaviors by explaining the rationale for rules and regulations (Reid & Marion, 2003). Agencies have employed a range of educational campaigns over the last several decades. For example, Smokey Bear remains a popular icon more than six decades after his introduction; his signature line, "only you can prevent forest fires," is a household phrase. Similarly, the Pack-It-Out and Leave No Trace campaigns have been widely used in an attempt to reduce anthropogenic impacts to natural areas. Many educational campaigns, however, are undertaken without standards or benchmarks for effectiveness. This gap in knowledge has prompted a handful of researchers to design studies with which to test the efficacy of environmental education programs.

Prior to the current dominant wilderness management paradigm of containment, in which wilderness visitors are encouraged to limit camping and other high-impact activities to already-degraded areas, wilderness managers attempted to reduce impacts by dispersing visitors over a wide area (Leung & Marion, 1999; Reid & Marion, 2003). Representing one of the first efforts at managing visitor impact to wilderness areas, the dispersion strategy was promoted largely through educational programs.

Several researchers evaluated the effectiveness of educational campaigns to disperse visitors into less-frequently used locales and published mixed results. One study found that pamphlets distributed to backcountry campers were ineffective in changing behavior, but the researchers attributed the failure to limited scope and distribution, as well as distribution late in the decision process (Lucas, 1981). Published during the same time frame, another study demonstrated that not only were pamphlets effective in redistributing wilderness campers to more lightly used sites, they were as effective as pamphlets in combination with an in-person ranger visit (Roggenbuck & Berrier, 1981, 1982). Other studies have found that less traditional communication techniques, including computers and trail charts, were also effective in redistributing wilderness visitors (Huffman & Williams, 1985; Krumpe & Brown, 1982).

Trailhead signs are an often-employed technique employed to disseminate information (Reid & Marion, 2003). Effectiveness of trailhead signs has been evaluated on a number of levels, ranging from short-term knowledge gain to behavior modification. Researchers have also evaluated the relative effectiveness of various types of trailhead signs. In general, researchers found signs to be effective in transmitting information. A relatively early study found that signs were less effective than contact with an agency representative, but performed better than brochures, which were found to be minimally effective (Fazio, 1979). In contrast, signs about complex Leave-No-Trace low-impact camping practices were found to be only minimally effective in altering backcountry visitors' knowledge, intent to change behavior, and actual behavioral change (Stubbs, 1991). Signs that warned visitors of sanctions for leaving the trail in Paradise Meadows, Mount Rainier National Park were found to be more effective than signs with humorous, ethical, or symbolic appeals, suggesting that regulatory signs may carry more weight with visitors (Johnson & Swearingen, 1988). Supporting this theory, a study at Mount St. Helens showed that, while all tested signs were effective in preventing visitors from removing pumice from the protected area, signs with regulatory messages were the most effective (Martin, 1992).

Adding an in-person component to education and outreach efforts can increase the effectiveness of the message being delivered. Results of a study at a front-country developed U.S. Army Corps of Engineers campground showed that distributing a flyer in person at campsites decreased vandalism and litter in the campground by 80%, versus 50% when the flyer was distributed at the gate (Oliver, Roggenbuck, & Watson, 1985). Other studies showed that the mere presence of uniformed agency personnel increased compliance with rules and regulations (Christensen & Davis, 1984; Swearingen & Johnson, 1995).

Overall, educational programs have been shown to be effective in increasing visitor knowledge, and in most cases, effective in changing behavior. Signs were generally effective, with regulatory messages being more effective than other types of messages. Most researchers found brochures to be somewhat to very effective in increasing knowledge, if not behavior. In-person contact with an agency employee or representative was also found to be effective. This sample of research suggests that a combined strategy of signage, brochures, and in-person contact would likely be effective in changing campers' behavior in the Greenwater Watershed to lower-impact practices.

Several National Forests in the western U.S. have, as a component of the Respect the River program, employed a combination of signage and light-duty barriers to establish parking areas away from stream banks while allowing access to dispersed camp sites by foot (USDA Forest Service, N.D.-b). The Respect the River program includes education and outreach to campers, replanting and fencing sensitive riparian areas, and selectively closing or modifying campsites. Barriers used range from wood and wire snow fences similar to those used in this project to large, countersunk boulders installed with heavy equipment. Snow fences have been most commonly used to deter high-marking and hill-climbing by ORVs, and have been locally successful. Success of the campsite barriers installed in the Cle Elum Ranger District of the Wenatchee National Forest has been variable, with more robust structures (e.g., countersunk boulders) faring the best over several years. Smaller boulders tend to be wrapped with chain or cable by campers or off-road vehicle users and dragged out of place to restore vehicle access (R. Wassell, personal communication, July, 2005). The treated campsites have not, however, been systematically monitored to evaluate effectiveness of the barriers or gauge campers' opinions of the measures (USDA Forest Service, N.D.-b; R. Wassell, personal communication, August 2006).

CHAPTER IV

METHODS

Overview

The action plan for this project had four parts: (a) site selection; (b) installation of low-impact barriers and signs; (c) camper survey; and (d) biophysical baseline data collection as part of an ongoing, multi-year monitoring protocol carried forward by the Forest Service.

Site Selection

Tyler Patterson, a Forest Service fish biologist with 12 years of experience in the Greenwater Watershed, and I toured the Greenwater River Watershed in mid-May 2006. We drove each forest road and spur that accessed the main stem Greenwater and the lower sections of tributaries from the junction of Forest Road 70 and State Highway 410 to the highest water access site at the Pyramid Creek culvert on FR 70. We used the following criteria for site selection: (a) site must be located on Forest Service property; (b) site must be immediately adjacent to a streambank, or must have an established motorized-use path leading into or across a nearby stream; (c) site must be usable for customary camping practices after treatment, i.e., installed vehicle barriers must not preclude campsite use; and (d) site must be in a relatively high-use area.

I developed the criteria with input from Snoqualmie Ranger District recreation management staff, road engineering staff, and ecosystems staff to maximize benefits to natural resources without eliminating use of popular campsites. Some campsites in the watershed are located on private timber land, which I excluded from the study. Coincidentally, the landowner (Hancock Timber Resource Group) blocked most of the sites on private land with large boulders during spring 2006, and posted signs prohibiting camping and campfires, among other uses. I observed two groups using the blocked sites over the summer season, a dramatic decline from the previous year's use when the campsites were open. I eliminated other sites on National Forest land (three) from consideration because blocking vehicle access would eliminate safe vehicle parking.

From the entire watershed's population of 18 open, water-adjacent sites, the final study sample included 15 sites, which Mr. Patterson and I divided into four groups by geographic area (Figure 1):

- 7010 cluster: three sites adjacent to Midnight Creek accessed by FR 7010 (Figure 2);
- 7030 cluster: four sites (three adjacent to the Greenwater River and one site adjacent to an unnamed tributary to the Greenwater River, just upstream of the confluence) accessed by FR 7030 (Figure 3);
- 7031 cluster: five sites adjacent to the Greenwater River (four accessed by FR 7031 and one accessed by FR 70) (Figure 4);

- 7000 cluster: three sites adjacent to Pyramid Creek accessed by FR 70 (Figure 5).

These four groups were divided into two groups of two: tributary sites (Pyramid and Midnight Creeks) and main stem Greenwater River sites to ensure that at least one tributary group and one main stem group would be treated as part of the project. Two coin flips determined which two groups (one tributary cluster (7000), and one main stem cluster (7031)) received barriers and signage. The other two clusters, 7030 (mainstem) and 7010 (tributary), remained untreated as controls.

This study included the entire population of campsites that met the campsite selection criteria, but they were not representative of all campsites in the watershed, nor did they constitute a representative sample of all dispersed, front-country campsites. In order to develop a representative sample, campsites outside of the riparian buffer would have been included, as well as less-frequently used campsites that were of minimal concern to Forest Service land managers. A representative sample of dispersed campsites on a region-wide or statewide basis would have required sampling many more watersheds than possible with available resources.

Barriers and Signage

Following the signage and fencing example implemented as part of the Respect the River program (USDA Forest Service, N.D.-b), I installed 4-foot-high wood snow fences to block larger "driveways" into sites while allowing foot travel and conveyance of large items such as coolers (Figures 7 and 8). I installed the fences and signs over the course of 2 weeks in early May 2006, after the spur roads opened from their annual wildlife protection closure, but before the high-use Memorial Day to Labor Day summer season. The fences consisted of vertical redwood-stained wood lath strips $^3/_8$ inch thick by 1½ inch wide, spaced 2½ inches apart, woven together by five galvanized single-strand wires. The fences were purchased by the Forest Service in 50 foot rolls, cut to length, and fastened with baling wire to 6-foot T-posts driven by hand with a steel post driver. Fence positioning varied from site to site as constrained by topography and existing trees.

I posted signs in sites selected for treatment stating that motor vehicles were not allowed, but walk-in camping was permitted (Figure 9). The signs included applicable federal codes (36 CFR 261.58(g) and/or 36 CFR 261.56) and potential penalties for violation. An image of the American Flag was included next to the text, which anecdotal evidence from other Forest Service land managers had shown to reduce vandalism of the signs. The signs were printed on a color laser printer and laminated to protect the paper from moisture. I also installed 6-foot Carsonite® boundary markers (similar to highway mile-

Figure 7. Carsonite® post, fence, and sign in site 7031-05, which was inundated by a seasonal side channel in spring 2006.

Figure 8. Fence and sign blocking vehicle access to site 7000-03.

Figure 9. Sign posted at treated campsites.

marker posts) with stickers that read “Foot Travel Welcome” in some sites to discourage cross-country vehicle travel around the campsite.

Forest Service employees or I visited the study campsites at least once prior to each weekend through the high-use recreation season from Memorial Day weekend through Labor Day weekend, 2006. This visit, during mid- to late-week, guaranteed that barriers and signs were intact; if the barriers or signs were missing or damaged, I repaired the fence or sign to its original condition prior to campers’ arrival on the weekend. Repair of a removed or damaged fence was only required twice, one instance of which did not affect the fence’s function.

I also visited treated and control campsites on 14 Saturdays between mid-May and Labor Day (Sunday on Labor Day weekend) in 2006. Two weekends were excluded: June 17 for a pre-existing commitment, and August 19 because a personal injury prevented me from safely visiting the area. No in-person surveys were conducted on June 17 or August 19. During these weekly visits, I recorded the occupancy of each site, and noted any damage to the fence and any vehicles parked beyond the fence. If the fences were in their original position, and no vehicles were parked beyond the fences, I deemed the barriers successful in (at a minimum) reducing vehicle parking beyond the fence, if not vehicle travel. Conversely, if the barriers and signs were missing or moved from their original position, or if vehicles were parked beyond the barriers and signs, I deemed them unsuccessful. If the site was occupied, I requested an adult's participation in the in-person survey (see In-Person Survey, below) to collect additional information about the group.

To analyze the effectiveness of the barriers and signs, I compiled vehicle occupancy frequency counts in treated and untreated sites in tabular form, and employed a 2x2 chi-square analysis (Thompson, 1979; McGrew & Monroe, 2000) to determine significance and Cramer's *V* to determine the strength of the relationship (if any) between barriers and signs and parking patterns. I used the VassarStats website (Lowry, 2010) for both of these calculations. Using the above tests, I compared counts of vehicles parked in non-treated sites in areas that would have been blocked by fences, vehicles parked outside of non-treated sites, vehicles parked outside of treated sites, and vehicles parked beyond the fences in treated sites.

In-Person Survey

I designed an in-person survey in collaboration with Central Washington University (CWU) Resource Management faculty and Forest Service staff to gather information from campers in study sites during the summer of 2006. I submitted the survey and associated materials for review by the CWU Human Subjects Review Committee. Since the survey did not include information that could be used to identify the interviewees, CWU staff deemed this research exempt from further institutional review under federal regulations (45 CFR 46.101).

I chose the in-person survey as a method for four reasons: (a) the survey provided a structured avenue for user feedback on the vehicle barriers; (b) the survey allowed comparisons between treated and control sites to determine any differences in levels of concern or satisfaction expressed by the respondents; (c) the summarized results of the survey would be useful to the Forest Service for demographic information to target public-information campaigns and preferred management strategies for the future; and (d) an in-person, researcher-administered survey minimized coding errors, ensured consistency from group to group, and ensured a high response rate (Shafer Jr. & Hamilton Jr., 1967).

The survey included a variety of demographic information and use patterns, as well as open-ended questions regarding the respondents' concerns about the watershed and preferences for future management. The survey instrument, the introductory statement read to campers, and a take-home contact sheet for respondents are attached as Appendix A.

Survey Instrument Design

I limited the survey instrument to two typed pages printed back-to-back to eliminate the possibility of separated pages and confused data. This resulted in an interview that ran approximately 10 minutes in length during tests, which was short enough to keep the campers' interest while attaining sufficient detail for the project. The survey was tested on classmates and colleagues prior to pilot testing in the field, after which I made minor changes to wording to clarify questions.

General, demographic questions were placed at the beginning of the survey to put the interviewees at ease while more in-depth questions were placed in the middle of the interview to take advantage of the interviewees' newly-gained attention, and simple, yes-or-no questions were placed at the end of the interview to provide an easy conclusion (Creswell, 2003; Fink, 2003; Oishi, 2003).

Survey Administration

I conducted all surveys during the weekend visit schedule described in the barrier and signage methods section. I conducted six surveys as a pilot in mid-May, 2006, and made one minor wording change as a result. Prior to each site visit, I prepared a survey sheet with the date, site number, weather condition, and time of survey. I noted unoccupied sites. Sites with gear but with no people present were noted, and then visited again later in the day to attempt to contact the occupants.

I wore unofficial clothing (shorts or jeans and a polo-style shirt), and identified myself as a graduate student conducting thesis research. On approaching each campsite, I waved, and if invited by an occupant who was obviously over 18 years old, entered the campsite area and recited the following statement from memory:

> Hi, my name is Eli Asher; I'm a graduate student in the Resource Management Program at Central Washington University. I'm interviewing campers in this area as part of my master's thesis research, and I'd really appreciate ten minutes of your time to tell me about your camping experience here by answering a handful of questions. Participation is completely voluntary, and you can stop the interview at any time for any reason. I won't be asking you for any personal information, and you will not be identifiable or linked to your answers.

If the initial contact was obviously under or close to 18 years old, I asked if he or she was 18 or older, and if not, if someone over 18 was present. If no adults were present, and the youth did not offer information on when they would return, I said goodbye and left the campsite area.

After identifying an adult who was willing to take the survey, I read the survey questions and recorded the respondent's answers. I asked the campers to defer all questions until after the survey was complete, at which time I offered to answer questions or supply any other helpful information.

Survey Questions

What is your home zip code?

This question was used to determine the origin of visitors to the watershed. In addition to providing some geographical insight to the user groups in the area, this question would help guide education and outreach efforts conducted by the Forest Service or non-profit partners interested in influencing campsite user behaviors in the watershed.

The question was originally drafted as "What is your home zip code and the zip codes of members of your group?" but was revised during the pilot to avoid the time spent locating all individuals in the campsite during the interview process.

Did your group bring any vehicles that are not here at the site right now?

The number and type of vehicles present at the campsites is an important factor when the Forest Service is considering management actions for a campsite. One of the criteria for selecting the sites for this project was the availability of parking for vehicles along the road if access were restricted.

This question was originally phrased as a list-type question:

> I am going to read you a list of types of vehicles. As I read each one, please tell me how many of that type of vehicle your group brought on this trip: passenger car, pickup truck, SUV, van, pickup camper, tent

trailer, camper trailer, motor home, other trailer, trail motorcycle, 4-wheeler/quad, other.

After administering the question during a pilot period, however, I determined that coding inconsistencies and time spent reading and explaining each category were problematic. As a result, I asked about vehicles not currently at the site, and added them to the categorized tallies that I conducted immediately after the interview.

How many people in your group fall into each of the following age categories: male, 0-5 years, 6-17 years, 18-29 years, 30-54 years, or 55 and over; female, 0-5 years, 6-17 years, 18-29 years, 30-54 years, or 55 and over?

This question provides information on the age of campsite users, and could be used to tailor future education and outreach efforts by the Forest Service or non-profit partners. It also provides some basic information about the general groups that use the campsites.

How many nights (if any) will your group occupy this site on this trip?

This question provides basic information on how long the campsites are typically occupied, and whether the users are camping or using the site for the day only. This question was included at the request of Forest Service employees who wanted additional information on the length of stay of campers at dispersed campsites.

Have you personally visited this watershed before? The watershed includes lands accessed by Forest Road 70 and spurs, such as Forest Road 7010. [If yes]: During what year was your first recreation visit to the Greenwater Watershed? How many times, total, have you visited this watershed?

This series of questions was used to describe the level of ownership and sense of place that users had with the watershed. Forest Service staff and I suspected that most users were repeat visitors, and that many of those visited the watershed frequently. This information could be used by the Forest Service to tailor outreach efforts in the watershed through signage or in-person contacts. If most users were frequent visitors, in-person contact would be the most efficient method of transferring information and modifying behavior.

On the following scale, how do you rate this campsite: very good, good, fair, poor, very poor?

This question was crafted to determine the general satisfaction of users for each selected campsite, which could eventually lead to better decisions for managing the campsites. For example, if a campsite was generally viewed as fair or poor, and it was determined to be impacting sensitive areas such as streambanks, it could be selected for closure, while other campsites would be improved for continued use. This question was also included to detect differences in user satisfaction between treated and untreated campsites.

I am going to read you a list of reasons that might have played a role in your choice of this campsite. After each item, please say "yes" if it was a reason you chose the site, or "no" if it was not a reason you chose the site: near water, shade, sun, near fishing, near swimming, near paved roadway, privacy, natural setting, availability of firewood, preferred sites were full, or tradition. Are there any other reasons that you chose this campsite?

This question was designed to develop a general list of campsite amenities sought by campsite users to inform a responsive campsite management plan.

I am going to read you a list of activities that may or may not have been reasons for your decision to camp in the Greenwater Watershed. After each item, please say "yes" if it was a reason for camping here, or "no" if it was not: camping, picnicking, swimming, wading, sunbathing, fishing, hunting, orienteering or map and compass work, gathering berries, mushrooms, or other forest products, sitting around a fire, relaxing. Are there any other reasons you camped in the Greenwater Watershed?

This question was developed to give land managers an idea of the activities campers tend to engage in during camping trips. This list originally included "drinking" as an option, but in order to avoid potential legal and human subject review issues related to respondents between ages 18 (the minimum age of respondents) and 21 (the minimum legal drinking age), the option was dropped from the list. Since this was the second list-type question, highly likely activities (e.g., relaxing) were included with less likely activities (e.g., orienteering) to ensure that respondents remained focused on the presented options (Fink, 2003).

Would you still camp here if you were required to bring your own firewood?

Collecting firewood has been identified by many land managers as a serious impact related to campfires (Reid & Marion, 2005). Collecting firewood is considered by many an integral part of the camping experience, but it can have detrimental effects on already challenged watersheds. Recreation managers have taken measures for many years to mitigated impacts involved with campfires (Price, 1985). For example, visitors to the nearby Alpine Lakes Wilderness Area are prohibited from building campfires above 4,000′ elevation. This policy is intended to alleviate impacts to downed woody debris in the slower-growing subalpine and alpine environments and prevent unsightly campfire scars. Woody debris provides habitat benefits on forest floors, as standing snags, and as in-stream structure, all of which tend to be used for fire wood in areas near campsites. One potential solution to these impacts that still allows campfires is to require that campers bring their own firewood. Forest Service employees involved with the project were interested in determining if firewood collecting was an essential element of campers' experience, so this question was included on the survey.

On the following scale, how concerned are you about the condition of areas used for recreation in the Greenwater Watershed: very concerned, slightly concerned, or not concerned. [If concerned]: What concerns you about recreation areas in the Greenwater Watershed?

This question was designed to indicate whether the signage placed in the treated campsites heightened awareness of the degraded conditions of the campsites. It was also included to determine whether a relationship existed between the number of years or visits to the watershed and the campers' level of concern for the recreation areas in the watershed.

In which of the following ways would you like to see this area changed: more informational signs, informational flyers at base of the Forest Road, garbage cans/dumpsters, toilets/outhouses, picnic tables, permanent fire rings, increased fishing opportunities, designated parking, cleaner campsites, grassier campsites? Are there any other ways that you would like to see this area changed?

This question was designed to determine which added amenities were most desirable to campers. As with other list-type questions, I mixed likely answers with less likely answers to keep interviewees engaged with the question. This question also prepared respondents to answer the following question, which related directly to changing the campsites.

In an effort to improve water quality in this watershed, the Forest Service is considering a variety of options to protect sensitive shorelines from vehicle damage.

Looking at the sheets of photographs I have given you, what are your two favorite options? What two options are your least favorites? What did you like and dislike about these options?

These questions, together with the six photographs depicting management options for campsites (Figures 10, 11, and 12), were designed to determine users' preference of management techniques. The top-two, bottom-two approach was utilized to force respondents to choose a preferred management action, and a least favorite management action, even though their favorite or least favorite option could have been be the no-action alternative. This would provide the Forest Service with a ranked list of management options, even if the users' favorite option overall was the no-action alternative.

I am going to read you a list of forest-related topics about which forest rangers could inform you during a campsite visit. After each topic, please say "yes" if you would like to learn about the topic from forest rangers, or "no" if you are not interested in learning about the topic from forest rangers: rules/regulations, fire levels/burn bans, water quality, potential threats, area hiking trails, off-road vehicle recreation areas, local fishing, local hunting, natural history, plants, animals, ecosystems, low-impact camping practices, catch-and-release fishing practices, job opportunities. Are there any other things you would like to hear about from a forest ranger during a visit?

Option A: Regulatory closure of campsites.

Option B: Cement blocks to prevent vehicle access to stream, walk-in camping allowed.

Figure 10. Management options A and B presented to campers.

Option C: Guardrails to prevent vehicle access to stream, walk-in camping allowed.

Option D: Boulders to prevent vehicle access to stream, walk-in camping allowed.

Figure 11. Management options C and D presented to campers.

Option E: Lightweight wood fences and signs to prevent vehicle access to stream, walk-in camping allowed.

Option F: No action. Vehicles are allowed to drive and park on stream bank.

Figure 12. Management options E and F presented to campers.

This question was designed to inform the Snoqualmie Ranger District's Watershed Steward Program, which was based upon the Respect the River program implemented in several National Forests (USDA Forest Service, N.D.-b). Specifically, the program manager was interested in providing desirable information to campers in addition to the ecosystem conservation information that was the basis of the program.

Which of the following do you use to learn about forest rules and regulations: signs, rangers, Ranger Stations, radio, television, newspaper, internet? Are there any other ways you learn about forest rules and regulations?

Forest Service law enforcement personnel provided input during the development of the survey, and expressed a desire for this question to be included. The resulting information could be used by the Forest Service to more effectively disseminate regulatory information to the public to reduce confusion over prohibited activities in the watershed.

Survey Response Analysis

Survey response analysis focused on providing management information to Forest Service recreation and ecosystem managers to inform decisions regarding dispersed campsite management. Many of the questions were designed to gather information regarding campers' preferences in campsite amenities and opinions on various campsite management techniques.

This information would be used by recreation and ecosystem management staff to support selective campsite closures, access restriction, or campsite improvements.

To give a broad impression of campers' preferences and opinions, I compiled frequency counts of responses and displayed them in tables and graphically in histograms and pie charts. I reported many responses in percentages of surveyed campers, as appropriate. In many cases, descriptive statistics provide the information necessary to make informed campsite management decisions.

In addition to descriptive statistics, I conducted simple chi-square contingency analyses to determine if the presence of signs and fences significantly influenced survey response. To manage and analyze the dataset, I manually entered survey responses into Microsoft Excel® 2003 spreadsheets by date, and then imported them as needed into Statistix® 8.0 quantitative analysis software, produced by Analytical Software. I chose the chi-square test because it is the most powerful test available for nominal data sets, and the data collected fit the requirements of the test: random sample, nominal (or ordinal) data, and raw frequency counts (McGrew & Monroe, 2000). The single significant (at $\rho = .05$) result was analyzed with Cramer's *V* statistic to determine the strength of the relationships. Cramer's *V* was performed using analytical tools provided by the VassarStats website (Lowry, 2010).

I also mapped campers' zip codes to graphically demonstrate their origins using ESRI ArcGIS® 9.1 (ESRI, 2005) and a public Washington State county boundary layer.

Biophysical Baseline Data Collection

As the initial stage of a continuing Forest Service-funded monitoring plan, I collected baseline biophysical data from 14 of the 15 study campsites in the Greenwater River Watershed in early spring 2006. Campsite 7031-05 was occupied by an active river side channel during spring 2006 (Figure 7). I also collected data again for all 15 sites after the end of the high use summer season in September, 2006. The literature does not give a clear indication of the season that is best suited for campsite biophysical data; most researchers report collecting data during the vegetative peak of summer (e.g., Godefroid et al. 2003; Marion & Cole, 1996; Marion & Farrell 2002; Monz, 1998). In contrast, Bristow (1998) recommends collecting monitoring data between fall and spring to take advantage of bare deciduous trees, but recommends avoiding muddy spring conditions.

Each site was provided a unique identifier that included the four-digit Forest Service road number followed by a two-digit campsite number. I marked the center of each site with a Magellan® 310 handheld GPS receiver unless canopy cover prevented satellite reception, in which case the site was marked at its access point on the nearest roadway. I collected all site data while the sites were unoccupied by campers or camping gear.

Site Form

I developed a site form and instruction sheet and laser printed them on Rite-in-the-Rain all-weather printer paper. In addition to the data fields described below, the form included fields for site number, date, and surveyor's name, and notes. The site form, attached as Appendix B, includes the following data fields:

Site area

Site area is the most basic measurement of campsite impact, but one whose measurement is easily (if not accurately) replicable and indicative of overall impact to riparian areas (Cole 1989c). If a campsite expands in area over time, it would likely have an increased impact to riparian vegetation and therefore impact effective stream shade and erosion. Site area was chosen as a monitoring variable to demonstrate the effectiveness of blocking vehicle traffic to a site if the Forest Service chose to retain the temporary fences beyond the period of this project, and to provide a baseline condition for future monitoring in unmanaged sites.

Site area measurements were collected with a variable radial transect method (Cole, 1989a, 1989b, 1989c, 2000). A central point was visually established and temporarily staked, and transects were measured from the central point to points at the edge of the campsite where the border changes direction (Cole, 2000; Schreiner & Moorhead, 1978). The center point was described in relation to two or more prominent trees or other remarkable campsite features to facilitate relocation for re-surveying. To determine the length of each transect, a 100 meter measuring tape was fastened to the central stake and stretched to the edge of the campsite, and recorded to the nearest 0.1 meter. The edge of the campsite was determined by a vegetation break (Figure 13), which includes, for example, trampled vegetation transitioning to vigorous, un-trampled vegetation, or bare soil transitioning to un-trampled vegetation. In the case of fully shaded sites, the boundary was delineated at the edge of obviously altered forest duff (Cole 1989c), where mostly whole leaves or evergreen needles transitioned to crushed or pulverized duff or bare soil. The azimuth of each transect was determined using a Silva® Ranger compass. The length and azimuth of each transect were recorded in the field. The number of transects measured varied by campsite from eight to twenty four, depending on size and complexity.

Campsite area has been computed by other researchers using radial graph paper, or by summing areas of triangles formed by transects using trigonometric equations (Cole, 1989c). For this project, I plotted transect length and azimuth on ESRI ArcGIS® 9.1 mapping software, using the Direction/Length sketch tool. I then created a polygon by connecting the outside endpoints of each transect, from which the software calculated site area. This technique proved expeditious in calculating site area and provided the

Figure 13. Example of campsite boundary with a survey flag inserted between obviously trampled vegetation and relatively un-trampled vegetation.

additional benefit of forming the basis for an accurately scaled map for each camp site.

Trees

Anthropogenic damage to living trees is common in dispersed recreation sites (Figure 14), and can facilitate disease establishment in trees that provide root cohesion and shade to streams (Vasiliauskas, 2001). Tracking damage to trees over time may inform management decisions in these areas. In addition, location of trees can help orient future surveyors, and provide a check for mapping accuracy.

Figure 14. Damaged riparian trees in dispersed campsites.

Location and general condition of trees within the site area or within two meters of the boundary were recorded on site forms. Only relatively mature trees were counted (greater than 20 cm diameter at breast height). Tree location was recorded in the same manner as site boundaries: a measuring tape was stretched from the center stake to the center of the bole (estimated from the side of the tree), and length and azimuth were recorded in the field. Trees were not identified by species or size, other than meeting the minimum diameter for documentation. Trees, classified by the amount of damage observed, were plotted on the base map for each site using the same method described for site area.

Damage to each tree, such as axe marks and nails embedded in the trunk, was recorded in five classes: no or little damage (0), bark-deep damage (1), including nails, chop marks, superficial saw marks, and knife marks that did not extend significantly beyond the bark into hard wood; damage into or beyond cambium (2), which included moderate damage that extended into hard wood, but did not exceed 25% of the circumference of the trunk; extensive damage to cambium, (3), which included shotgun blasts, and serious saw or axe damage, and any damage that exceeded 25% of the circumference of the trunk; and dead or obviously dying (4), which was judged by condition (or lack of) foliage.

Fire rings

Campfires are an integral part of many campers' outdoor experience (Figure 15), but campfires can adversely impact natural resources. Policy solutions, such as banning fires or controlling fire sites, have been formulated to limit these impacts, with little success overall (Reid & Marion, 2005). If vehicles are prohibited from entering dispersed sites, however, fire sites may become more centralized, more closely mimicking traditional wilderness campsites (Cole, 1989a, 1992; Cole & Monz, 2004; McEwen et al., 1996; Smith & Newsome, 2002), thereby limiting scope of the fires' direct impact on soils and vegetation.

Figure 15. A carefully constructed fire ring in campsite 7000-03.

Location and size (diameter in meters) of fire rings was recorded. Fire rings were identified by a recognizably intact circle or oval of rocks with burned material contained within the ring. Blackened areas, piles of ash, and discarded briquettes, all of which could have indicated past use as a fire ring, were not included. Location was recorded in the same manner as the site boundary, measured from the center of the fire ring. Size of the fire ring was measured at the outside edges of the widest point of the rock ring.

Social trails and access roads

Social trails, or user-built trails, are common in front country campsites. Trails lead to water, latrine areas, other campsites, or other destinations. Like other maintained trails, social trails can cause soil erosion and contribute to vegetation impacts, but since they are not professionally designed, monitored, and maintained, social trail impacts may be disproportionately high (Marion, Leung, & Nepal, 2006). Soil compaction on social trails tends to be less pronounced than on access roads or in campsites, but is much higher than on untraveled forest floor (Volker, 2008). Social trails were included in the site forms to determine if blocking vehicle traffic would eventually lead to passive restoration of social trails, especially those used for vehicle travel, if barriers would simply be ignored, or if barriers would promote the initiation of new trails.

Location and class (footpath, ORV trail, or access road) of social trails leading to and from the campsite were recorded. The junction of footpaths and ORV trails with the campsite perimeter were recorded in the same manner as campfire rings. Paths that showed relatively intact organic layers and no tire tracks or ruts were classified as foot paths. Paths that were denuded to mineral soil, were over one meter wide, or had noticeable tire tracks and/or wheel ruts, but did not directly access Forest Roads, were classified as ORV trails. Access roads were those trails that connected Forest Roads with campsites and were wide enough to allow passenger vehicle clearance. Access road width was recorded by two points on the perimeter of the campsite.

Non-Vegetated Streambank

Vehicles are often parked immediately adjacent to stream banks. When impacts from vehicles are eliminated from a site, stream bank vegetation is expected to eventually reestablish, reducing overall non-vegetated stream bank length. Erosion is more likely on non-vegetated streambanks and repeated foot and vehicle trampling will inhibit growth of riparian trees that serve a multitude of ecosystem functions (Madej, Weaver, & Hagans, 1994).

Non-vegetated streambank was measured and recorded in straight-line length to the nearest 0.1 meter (Figure 16). Vegetation was classified as any leafed-out understory plant, including grasses, forbs, ferns and shrubs. Tree trunks located near the river bank were not considered vegetation unless undisturbed vegetation was present at the trunk's base.

Canopy and Groundcover

Campsite canopy and groundcover may be used as a metric of successful riparian restoration, or conversely, could be the measure of degradation of a relatively intact riparian campsite (Cole 1989c).

I recorded a description of canopy composition and rough estimate of canopy cover (<25%, 26-50%, 51-75%, or >75%) over the site area. This figure was estimated by eye. I noted the campsite surface, including type of vegetation, general description of duff layer, or of exposed soil (organic, mineral, cobble, etc.), but did not measure a percentage of groundcover for the sites.

Figure 16. Non-vegetated streambank measurement in campsite 7031-03.

Garbage

Garbage discarded by campers is not usually considered a severe impact upon natural resources, but is an important measure of campsite quality by users (White et al., 2001). Some garbage is directly harmful to fish or wildlife by entanglement or poisoning. Food-related garbage encourages habituation of scavengers such as bears, raccoons, and skunks, which become nuisance animals and may be killed as a result. Human waste from dispersed camping contributes to water pollution, and serves as a disease vector (Varness, 1976; Varness et al., 1978).

I recorded a qualitative description of human-created garbage at each of the sites. Descriptions included the general quantity and quality of garbage, including human waste, toilet paper, food wrappers, beverage containers, household garbage, abandoned appliances, diapers, etc.

Photo point monitoring

Photo point monitoring is well established as an inexpensive, effective landscape monitoring technique, especially for monitoring vegetation over time (Hall, 2001). Cole (1989c) notes that photo monitoring is a precise, yet inaccurate method for measuring campsite changes over time because it captures few overall campsite impact types. If vegetation encroaches upon campsites over the course of several years, photo monitoring may be hampered by leaves (Hall, 2001). Hall (2001) also notes that seasonality can greatly affect the apparent results of photo monitoring. Hall therefore suggests establishing, at a minimum, a consistent date or date range in which to conduct photo monitoring activities, and better, to establish several dates throughout the year to capture seasonal variations in vegetation.

Photographs were taken with a Sony PowerShot® digital camera at 5 feet (1.5 m) above ground without a flash during baseline data collection in spring 2006 (mid-May to early June) and again in fall 2006 (early September). I recorded the location and direction of each photograph in relation to the center point as well as a description of nearby landmarks, such as large stumps or unique trees. I took photographs from at least two locations at each site in order to record the entire site.

Site Maps

I created scale digital maps of each site with ESRI ArcGIS 9.1 software to familiarize future surveyors with the site in general and to assist in locating fixed locations for radial transect area measurement and photo monitoring. The maps included a polygon forming the perimeter of the site, the relative location of fire rings, trees (color-coded by damage class), access trails, and photo monitoring locations and photo azimuths.

CHAPTER V

RESULTS AND DISCUSSION

Barriers and Signs

Table 1 shows the weekly tally of motorized vehicles and trailers parked outside of untreated sites, in untreated campsites in areas that would have been blocked by fences if the sites had been treated, vehicles parked outside of fences at treated campsites, and vehicles parked beyond the fences in treated campsites.

Table 1.
Parked Vehicle Frequency Counts at Study Area Campsites Outside or Inside of Fences, or in Untreated Sites, Where Barriers Would Have Been Placed

Date (2006)	Vehicles parked			
	Treated sites		Untreated sites	
	Inside	Outside	Inside	Outside
5/27	0	43	26	0
6/3	0	15	0	0
6/10	0	10	3	0
6/24	0	13	4	0
7/1	0	10[a]	8	0
7/8	0	17	14	0
7/15	0	12	9	0
7/22	0	3	7	0
7/29	0	8	6	0
8/5	0	11	5	0
8/12	0	0	4	0
8/26	0	7	10	0
9/3	0	25	19	0
Total	0	174	115	0

[a]One camper reported driving beyond the fence in a treated site (7031-01), and then removing his vehicle and replacing the fence after being issued a citation by a Forest Service law enforcement officer.

The 2x2 chi-square analysis showed a significant relationship between parking location and the presence of barriers and signs ($\chi^2 = 284.4$, $\rho = <.0001$). The Cramer's *V* statistic, which is displayed in values of 0-1, was a perfect 1, showing a very strong relationship. My field observations and analysis indicate the barriers and signs were very effective at preventing campers from parking their vehicles in sensitive riparian areas. While vehicles could have been driven or parked behind the barriers while I was not able to observe them, I did not note any tire tracks or other signs of vehicles beyond the barriers and signs. Soils in most of the campsites seemed very compacted, however, and would have been unlikely to yield easy evidence of recent vehicle travel.

During the course of the summer of 2006, I recorded four cases of vandalism to the signs and fences: in mid-May, the fence was removed from the ground in campsite 7000-03, neatly rolled, and left to the side of the site's driveway. Since the fence was intact when I interviewed the site's occupants just 3 days prior, and they did not respond negatively to the fence at that time, I speculate that the occupants removed the fence to facilitate driving a vehicle out of the parking area, in which they had parked head-in and downhill instead of parallel, as intended. The second case was the removal of two lath slats from the fence at campsite 7031-05 (which was unoccupied) in mid-July; they were easily replaced that week. The third case was a sign in campsite 7031-04 that was shot with a paintball gun, and then dutifully cleaned by the subsequent site occupants (they reported the damage to me during the interview). The fourth case was a site occupant that moved the fence in campsite 7031-01 in order to park within the campsite. During the in-person interview, he reported that he received a citation from the Forest Service law enforcement officer within 15 minutes of his arrival. The occupant removed his vehicle and repaired the fence. In total, these cases required reinstallation of one fence, replacement of two lath slats into another, and eventual replacement of the laminated paper sign that had been shot with paintballs, for a materials cost of about $3.00 and 20 minutes of labor.

The study design incorporated extra site visits (one per week) to check for fence damage and maintenance needs; in retrospect, this was not required for successful operation of the fences. The fences' longevity makes intuitive sense, in that upon arrival at the site, occupants would be unlikely to damage fences in a site they would be occupying through the weekend. Upon leaving, damaging the fence would not provide significant benefits to them, and after my visit their desire to damage or remove the fences would likely have been diminished.

During fall site monitoring activities, I carefully examined all of the fences for damage. In several cases, the fences had been repurposed by site occupants; some fences were used as clotheslines, utensil racks, or covered with towels to serve as privacy screens. These uses eventually must have stretched the wire in the fences, for some of them had been pulled tighter and re-fastened to the posts. Two fences were fastened to fence posts with materials other than those originally used, indicating that the fences had been removed and then reinstalled shortly thereafter, or that occupants (or passers-by) had found fences in disrepair and had fixed them. No survey respondents mentioned fixing the fences during their stay, but the survey did not specifically ask about fence maintenance.

Since the fences are relatively easy to remove and reinstall, this process could have occurred repeatedly during the summer season. If site occupants removed the fences in order to unload camping gear, they must have removed their vehicle(s) and replaced the fence prior to my visit on Saturday. This seems an unlikely norm, however, and probably did not occur frequently. I observed vehicles beyond the fences just once in the course of the summer: a pair of trail-motorcyclists riding through the streambed and riparian vegetation. I was unable, however, to monitor each campsite continuously for the duration of the summer, so determining what happened between visits was impossible.

In-Person Survey

Survey Administration

A total of 88 surveys were completed. Four groups declined to take the survey: one group was using the site for day-use only, one group declined because they feared their aggressive dogs would attack me, and two groups declined without a reason volunteered. One of the two groups that declined without volunteering a reason occupied the site on back-to-back weekends, declining both weekends. I chose to forgo re-surveying campers that had been surveyed in previous weekends, which occurred 10 times. On 16 occurrences, sites were in use (camping gear present) but the occupants were absent. One group was not interviewed in order to preserve their privacy during an intimate encounter. This amounts to a sample of at least 80.7% of groups using the campsites selected for the study on surveyed weekends, since some of the 16 groups not contacted may have been repeat visitors previously interviewed. Not all campsites were occupied on all weekends, and some campsites were more commonly occupied than others. A larger sample would have been helpful in determining statistically significant results from the survey, but to increase the sample would have required either including another major watershed or including sites that did not fit the original criteria. Time and resources were inadequate to include another watershed. Surveying sites that were not immediately adjacent to the water was inappropriate since riparian areas are the focus of the thesis and of greatest concern to the Forest Service. Conducting surveys during mid-week would have been futile, based on my mid-week checks, which revealed very little camping use.

The survey typically took between 10 and 12 minutes, with the shortest clocking under 7 minutes (respondents were expressly eager to set a new time record), and the longest taking more than 45 minutes (respondents were very intoxicated, loquacious, and unfocused). Interviewing one individual from each group proved difficult, if not impossible, because other members of the group tended to be very interested in the process, and eager to share their opinions. The group often completed the survey in a semi-consensus fashion, in which one person (the initial volunteer) answered each question, but received input from the rest of the group. Some groups insisted on agreeing upon every answer, while others insisted that I record opposing views (the groups were obliged, but the initial volunteer's answers are used in the summary statistics for consistency). Respondent questions, unless specifically related to a survey question, were deferred until survey completion to avoid influencing survey responses.

Campers were generally enthusiastic about participating in the survey. Many groups were initially cautious, and required assurance that I was neither an official nor a salesperson. After initial skepticism, most groups were very welcoming, inviting me to join them around the campfire (regardless of hot summer weather). I was often offered food, and the first daily offer of beer seldom came after 10:00 a.m. Saturday proved to be the ideal day to survey campers: By Saturday, most groups had settled into their campsites and were somewhat bored with immediately available recreation opportunities. The human population of the watershed swelled considerably on Friday afternoon and evening, and shrank quickly on Sunday morning.

Survey Responses

Campers' Origins

All campers interviewed reported living in Western Washington, with the majority from King and Pierce Counties (Figure 17). The highest concentration of campers reported living in the nearby communities of Bonney Lake and Auburn, Washington.

Respondents' Campsite Selection and Satisfaction

Respondents' ratings of the campsites were generally favorable (Table 2), with 89.7% judging their campsites as good or very good, and only two respondents (2.3%) rating their campsites as poor (no respondents rated their site as very poor). No significant difference existed between ratings of fenced and unfenced sites ($\chi^2 = 2.71$, $\rho = 0.44$), suggesting that fences neither significantly hindered nor improved overall site suitability. This also indicates that the barriers and signs were effective in preventing travel without adversely affecting users' experience, although their responses may have been influenced by the desire to avoid offending me. Some respondents, when questioned about possible management actions at sites, reported that fences did not look natural. This sentiment, however, did not appear in responses to the question

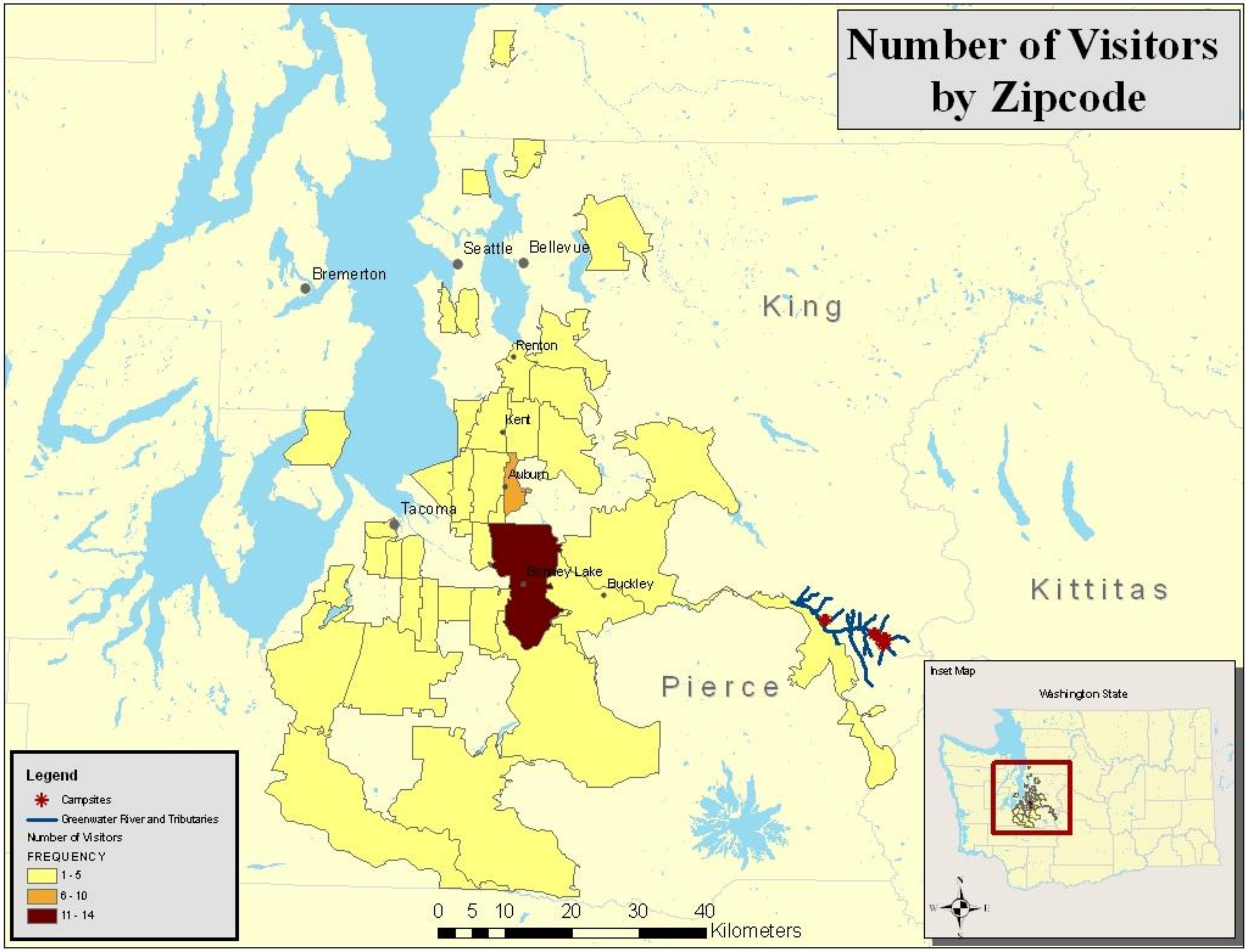

Figure 17. Map of reported camper origin by zip code.

on site selection: in fenced sites, 93.5% of respondents reported that "natural setting" was a reason they chose the site, versus 95.7% in unfenced sites, a difference of only one respondent.

Table 2.
Respondents' Rating of Campsites

	Very good	Good	Fair	Poor
Fenced sites	25	15	2	0
Unfenced sites	23	16	5	2
Total	48	31	7	2

Direct access to water was cited as an important aspect to the camping experiences of most respondents, with all but two (97.7%) responding that proximity to water was a reason for choosing the site (Table 3), and many reporting that wading, swimming, and fishing (78.4%, 40.9%, and 33.0%, respectively) were activities that brought them to the watershed (Table 4). During late summer 2006, the Forest Service implemented a temporary ban on campfires, which likely influenced campers reporting of sitting around a fire. Without this ban, the percentage of campers reporting that sitting around a fire was one of their activities would likely have been higher.

Table 3.
Respondents' Reported Reasons for Site Selection

Reason for site selection	Affirmative responses (percent)
Near water	97.7

Table 3 (continued)

Natural setting	94.3
Privacy	81.8
Sun	76.1
Near shade	73.9
Tradition	55.7
Near swimming	40.9
Preferred sites were full	36.4
Availability of firewood	31.8
Near paved roadway	28.4
Near fishing	27.3

Table 4.
Respondents' Reported Activities in the Watershed

Activity	Affirmative responses (percent)
Relaxing	100.0
Sitting around a fire	92.0
Tent camping	88.6
Wading	78.4
Sunbathing	48.9
Swimming	40.9
RV camping	38.6
Fishing	33.0
Gathering berries, mushrooms, or other forest products	13.6
Hunting	10.2
Orienteering	5.7

Motor Vehicles

Motor vehicles appeared several times in survey data. Each group's vehicles were tallied into various categories (Table 5). Totals include vehicles present at the site during my visit that I counted, and those they reported were elsewhere, but would be at the site later. Many groups (34.1%) had recreational vehicles (RVs), including truck campers (slide-on campers), travel trailers (including fifth-wheel trailers), tent trailers (folding camping trailers), and motor homes (Class A, B, or C motor homes), and even more (38.6%) reported that RV camping was a reason for visiting the watershed. This discrepancy could be attributed to several factors, including differing views of RVs. Several groups cited RV access as a primary reason for choosing their specific campsite, in spite of being required to walk from the campsite to their vehicle in treated sites.

Table 5.
Categories and Total Numbers of Vehicles in Surveyed Sites

Vehicle type	Total observed	Mean per site
Car/Van	106	1.2
Pickup Truck/ Sport Utility Vehicle	155	1.8
Off-Road Vehicle/Trail Bike	19	0.2
Recreational Vehicle (RV)	43	0.5
Total	323	3.7

I observed many off-road vehicles (ORVs), especially dual-sport motorcycles, in use during the course of the survey season. Many of these, however, apparently belonged to day-use visitors to the watershed, since the vast majority of groups (89.8%) did not possess ORVs at their campsites, and few non-surveyed campsites appeared to have trailers or ORVs. Off-road vehicle use is a divisive issue with campers: when asked about issues that concern them in the watershed, 13.2% of respondents volunteered concern about ORV use and ecological damage caused by ORVs. Others reported displeasure with the lack of ORV opportunities, and over half (51.1%) of respondents replied that they would like to learn about local ORV areas from forest rangers during a campsite visit.

Respondents' Concerns about Recreation Areas

Most respondents (83.0%) were repeat visitors to the watershed; many reported having visited the watershed for decades; the median year of first visit was 1990, with the earliest visit reported in 1954 (this is a suspect response in light of historic use and road construction in the area) and the rest of responses spread from the early 1970s to 2006 (Figure 18). The median number of visits reported was 25, the highest number of visits reported was 1,000, and 14 (15.9%) respondents reporting that they had visited just one to three times prior to being surveyed. Many visitors, especially those with lengthy histories of watershed use, expressed strong opinions on the condition of the watershed and possible management activities in the area.

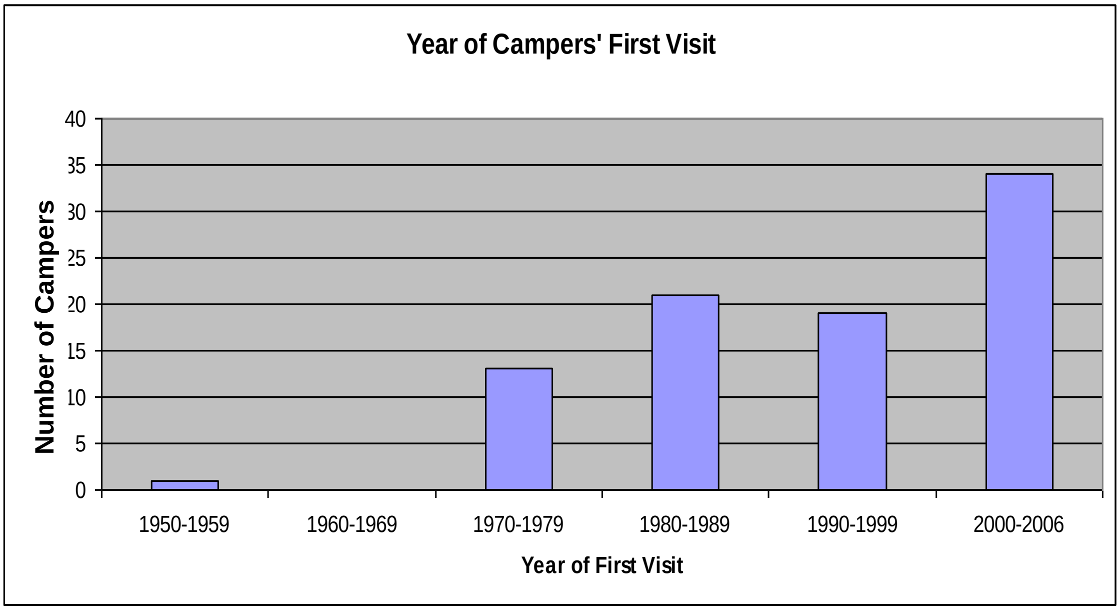

Figure 18. Year of campers' first visit to the Greenwater Watershed.

When asked how concerned they were about the condition of areas used for recreation in the Greenwater Watershed, 84.1% responded that they were either very concerned (52.3%) or slightly concerned (31.8%) (Table 6). Instead of presenting possible topics of concern, I asked respondents to explain their concerns. I coded these concerns into major categories, with less frequently cited concerns falling into an "other" category. No significant differences existed between responses from fenced campsites and unfenced campsites, but respondents in fenced campsites tended to cite a greater number of concerns than those in non-fenced sites (50 separate concerns coded in non-fenced sites, 75 coded in fenced sites). The concerns were similar, however, in fenced and unfenced sites, yielding an insignificant chi-square score (overall $\chi^2 = 7.44$, $\rho = 0.19$) when compared.

Table 6.
Campers' Reported Concerns about Areas Used for Recreation in the Greenwater Watershed

Reported Concern	Campers reporting concern (percent)
Garbage	81.6
Campsite closure	18.4
Personal issues with other campers	18.4
Damage to trees	13.2
ORV use	11.4
Other concerns	19.3

The most commonly cited concern was garbage (also coded as garbage: litter, trash, trashed campsites, glass, etc.), with 81.6%, followed by concern about campsite closure and personal issues (general complaints such as "disrespectful people"), both with 18.4%.

Concern about campsite closure was probably heightened during the summer of 2006 by the closure of several popular, highly visible campsites on private timber land in the lower Greenwater River Watershed. Campers seemed to believe (erroneously) that these sites were on Forest Service land, or had been on Forest Service land that was purchased recently by the timber company. In reality, the land had been private for years, and camping had been overlooked by the landowners (Weyerhaeuser, and then Hancock Timber). Many of the post-survey questions from campers, especially in the early summer, focused on campsite closure and the likelihood that their preferred site would be closed. Several respondents commented that campsite closure was a trend in the watershed, with "more campsites closed every year." This assertion, however, is somewhat dubious, especially in the Greenwater Watershed, where the only direct campsite closures in the past 20 years have occurred on private land. Several Forest Service roads have been decommissioned in the area in recent years, however, rendering some campsites unusable for vehicle-based camping. These closures were enacted to lower road densities in accordance with the Forest Plan, not to reduce dispersed camping opportunities (T. Patterson, personal communication, June 2005), but the net result is that fewer established campsites are available to users.

A more valid concern expressed by one respondent was that of campsite fees being instituted for dispersed campsites in the area. Respondents most often expressed this concern when a list of possible changes to the area was presented. While some respondents favored changes such as outhouses and picnic tables, they insisted that fees not be levied for such improvements. The Forest Service, like other public land-management agencies, has begun to look at "user-pays" arrangements as vital to continuing public access. For example, the Northwest Forest Pass program, initiated under the Congressional Recreation Fee Demonstration program in 1996, requires visitors parking at developed trailheads to display a daily or annual parking pass. Other National Forests have begun charging nominal fees under the Recreation Enhancement Act of 2004 for dispersed camping, such as the French Cabin Creek area in the Cle Elum River Watershed in the Wenatchee National Forest. Campers at French Cabin Creek are required to pay a daily fee, but campsites are not designated (as they would be in a traditional Forest Service campground), and on-site services are limited to portable outhouses, law enforcement patrols, informational signs, and message boards (T. Mayo, personal communication, June, 2006).

Very few respondents expressed concern about ecological damage (other than garbage), with only 10 (13.2%) citing concern for vegetation or tree damage. Of those 10 respondents, however, eight were surveyed in fenced sites. While suggestive, this result was not significant ($\chi^2 = 3.81$, $\rho = .0511$) when analyzed with the chi-square test. Almost every campsite surveyed included within its boundaries several trees that had been severely damaged by humans, and many campsites showed evidence of recently felled, live trees, usually along the river bank. The only sites without damaged trees were those without trees in the mapped area; trees immediately outside the mapped area generally showed damage. These results suggest that most campers did not view vegetation damage as a serious concern unless they were prompted, in this case by an informational/regulatory sign attached to the fence in their campsite.

Off-road vehicle (ORV) use factored into the concerns, with 11 campers (11.4%) reporting that they were concerned with the areas used, or the manner in which the ORV operators used their vehicles. Some campers referenced mud holes and stream crossings, while others complained that ORV riders were riding on the roads, making noise, and causing a traffic hazard.

The less frequently cited concerns lumped into the "other" category ranged widely, from "not enough liquor stores" to "meth[amphetamine] labs." Less frequently cited concerns included open latrine areas, street racing, road noise, forest fire protection, shooting, and infrequency of law enforcement patrols.

Campfire Wood

In the Greenwater Watershed, downed wood, standing dead wood, and standing live trees are all collected for firewood by campers. Tools used for wood collecting tend to be used even when not actively collecting firewood; I observed campers throwing an axe into a living tree, campers chopping live trees on stream banks, and live trees that had been felled adjacent to campsites. Live trees felled near streambanks reduce shade, increasing water temperatures. Streambanks stabilized by tree roots are less prone to erosion, reducing sediment loading in the stream. Even downed wood collection is problematic; during low summer flows, campers collect large wood from below the high-water line, removing wood that is essential for habitat and river morphology function during high flows.

The vast majority (96.6%) of respondents in the Greenwater Watershed reported that they would still camp in the watershed if they were required to bring their own firewood, and only 31.8% reported that availability of firewood factored into their campsite decision, suggesting a willingness to forgo the firewood gathering tradition in favor of more environmentally sensitive alternatives.

Amenity Changes Desired by Respondents

Respondents did not express high levels of support for most amenities offered as future possibilities (Table 7). The most popular amenity suggested was a garbage can or dumpster, with 78.4% of respondents supporting this option. A majority (63.6%) of respondents also supported the idea of cleaner campsites, an option originally included in the survey as a universally supportable option. Informational signs and designated parking were the least supported options, with 23.9% and 12.5% of respondents supporting them, respectively. Other options included: informational flyers available at the base of the forest road (36.4% in support), toilets/outhouses (52.3% in support), picnic tables (43.2% in support), permanent fire rings (59.1% in support), increased fishing opportunities (44.3% in support), and grassier campsites (46.6% in support).

Table 7.
Reported Level of Support for Desired Amenities

Desired amenities	Percentage of respondents
Garbage cans or dumpsters	78.4
Cleaner campsites	63.6
Permanent fire rings	59.1
Toilets or outhouses	52.3
Grassier campsites	46.6
Increased fishing	44.3
Picnic tables	43.2
Flyers at base of forest road	36.4
More informational signs	23.9
Designated parking	12.5

When asked if they would like to see any other changes in the area, respondents' answers varied widely. Some said they wanted less Forest Service intervention, while others wished for more law enforcement patrols. Some wanted more ORV opportunities, while others wanted ORVs restricted. Some suggestions reflected the respondents' state of mind during the survey: Wal-Mart, naked girls, personal chronic [marijuana] plants, and liquor stores all got the nod as desirable improvements to the camping experience.

Respondents' Travel-Management Preferences

Respondents expressed preferences for management activity in campsites after viewing photographs depicting six possible management options for campsites in the Greenwater River Watershed. The photographs, displayed on three 8.5"x11" laminated sheets, are shown in Figures 8-10. Respondents indicated their favorite, second favorite, least favorite, and second-least favorite option, and in most cases, explained what they liked and disliked about the options. This survey question was designed to elicit responses on a variety of options; Forest Service employees, colleagues and I all expected the "no action" option to be the most desirable to respondents, so the second-favorite choice would allow resource managers to determine which options would be most acceptable to campers.

The opinions expressed by the respondents did not, however, match the responses expected during survey design (Figure 19): 40.2% of respondents identified a barrier created from large, countersunk boulders as their favorite option. A smaller proportion (30.5%) favored no action; all barrier options combined comprised 69.5% of responses, clearly indicating that campers in the Greenwater River watershed support management actions that provide environmental protection while continuing to allow camping and other recreational access.

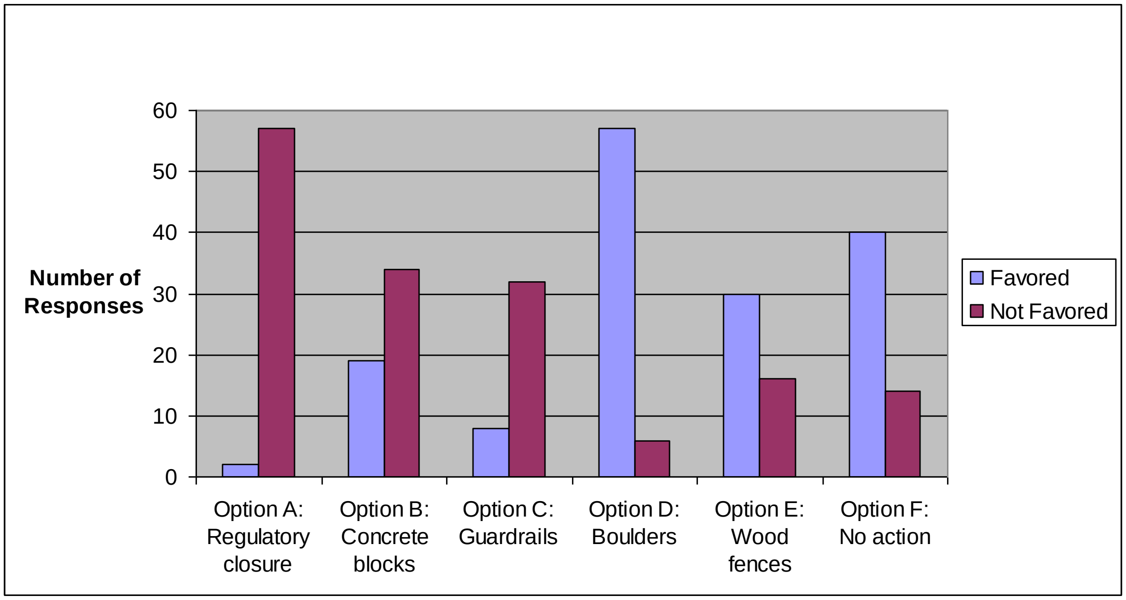

Figure 19. Reported level of support for campsite travel management actions.

A complication in analyzing favorite and second favorite options arose when eight respondents insisted that only one option was acceptable, refusing to choose a second favorite option. Six of those respondents chose the no-action option, one chose boulders, and one chose fences.

While most survey answers did not differ significantly between fenced and unfenced sites, preferences for vehicle barriers were markedly different. A chi-square test comparing combined favorite and second favorite options in fenced and unfenced sites showed a significant difference (overall $\chi^2 = 10.31$, $\rho =$ .036,) between the groups of preferences. While significant, this result showed only a weak relationship between the presence of barriers and signs and campers' management preferences (Cramer's $V = 0.257$). The biggest difference in preferences, not surprisingly, was that of the fences. In fenced sites, 23 respondents indicated that the wood snow fences were either their favorite or second favorite option, while just seven respondents in unfenced sites chose the fences as their favorite or second favorite option. This result could have been attributable to several influences. First, occupants of fenced sites may have accepted the fences as a minimally invasive measure to limit damage to their favorite campsites, and therefore found them more acceptable than other options. As one respondent stated, "boulders and blocks say 'no camping,'" while the fences (and associated signs) welcome campers. The familiarity with the fences probably swayed respondents away from other options with which they had less experience. The second likely reason that fences were more popular in fenced sites is that occupants observed the fences functioning as designed. Occupants in unfenced sites frequently cited concerns about the fences' longevity and effectiveness, including: "fences won't work," "fences will burn," and "fences won't last." The final obvious possibility is that respondents identified the link between the fences and the survey, and either consciously or subconsciously responded more favorably to the fences to please the surveyor (Oishi, 2003). This type of bias is, unfortunately, difficult to control in this type of study without surveying campers in campsites equipped with other vehicle barriers in the same watershed. In this study, increasing the sample to include other barrier types would have necessitated expanding into other watersheds in which those barriers were in use, exponentially increasing materials cost and labor.

Respondents' reasons for choosing one option over another (and for choosing least and second-least favorites) ranged widely, from aesthetic (e.g., "boulders look natural, fences and blocks [detract] from experience"), to functional (e.g., "guardrails and boulders are a permanent solution"), to financial (e.g., "boulders are cheap, guardrails and blocks are expensive"). The most frequently cited reason for a choice, however, was aesthetic, with nearly all groups mentioning the appearance of barriers, either positive or negative. Some respondents insisted that the no-action option adequately protected natural resources as long as campers were responsible (said one inebriated camper: "death to disrespectful people!"), even though many of these same groups had vehicles parked within 1 meter of the wetted stream channel.

Biophysical Baseline Data Collection

Azimuths marking campsite boundaries, trees, fire rings, roads, ORV trails, and photo points were entered into ESRI ArcGIS® (ESRI, 2005) to develop scale maps of each campsite as of May 2006, and September 2006. The resulting maps and data may aid Forest Service staff or other researchers in long term monitoring of the riparian campsites in the Greenwater Watershed. Since staffing levels may vary in future years, surveyors may choose to use spring or fall maps as their study baseline, increasing flexibility without sacrificing comparability of newly collected data with baseline data.

Campsite Descriptions

Campsite number 7010-01 (Figures 20 and 21) is the first campsite upstream from the private land/Forest Service boundary on Forest Road (FR) 7010. The campsite accesses Midnight Creek, and shows signs of long term use, including damaged trees and barren stream banks. The campsite has a relatively closed canopy, and no grass. RV-based campers did not tend to occupy the site, probably because scattered trees preclude a safe through-parking. Since adjacent, privately-owned campsites were closed in May 2006, some campers may have been deterred before reaching the site, depressing visitor numbers.

Campsite 7010-02 (Figures 22 and 23) is close to site 7010-01, but trees provide privacy. The site is immediately adjacent to Midnight Creek, with campers sometimes parking vehicles overhanging the creek. The site is accessed by two dirt tracks from FR 7010, and has an open canopy. The site is popular with squatters and RV users, and is heavily used during the summer.

Campsite 7010-03 (Figures 24 and 25) is a small, lightly used site with an ORV trail accessing Midnight Creek. The site is grassy and private, and in 2006 seemed to have a greater amount of garbage from week to week than most sites. The site is most suitable for tent camping.

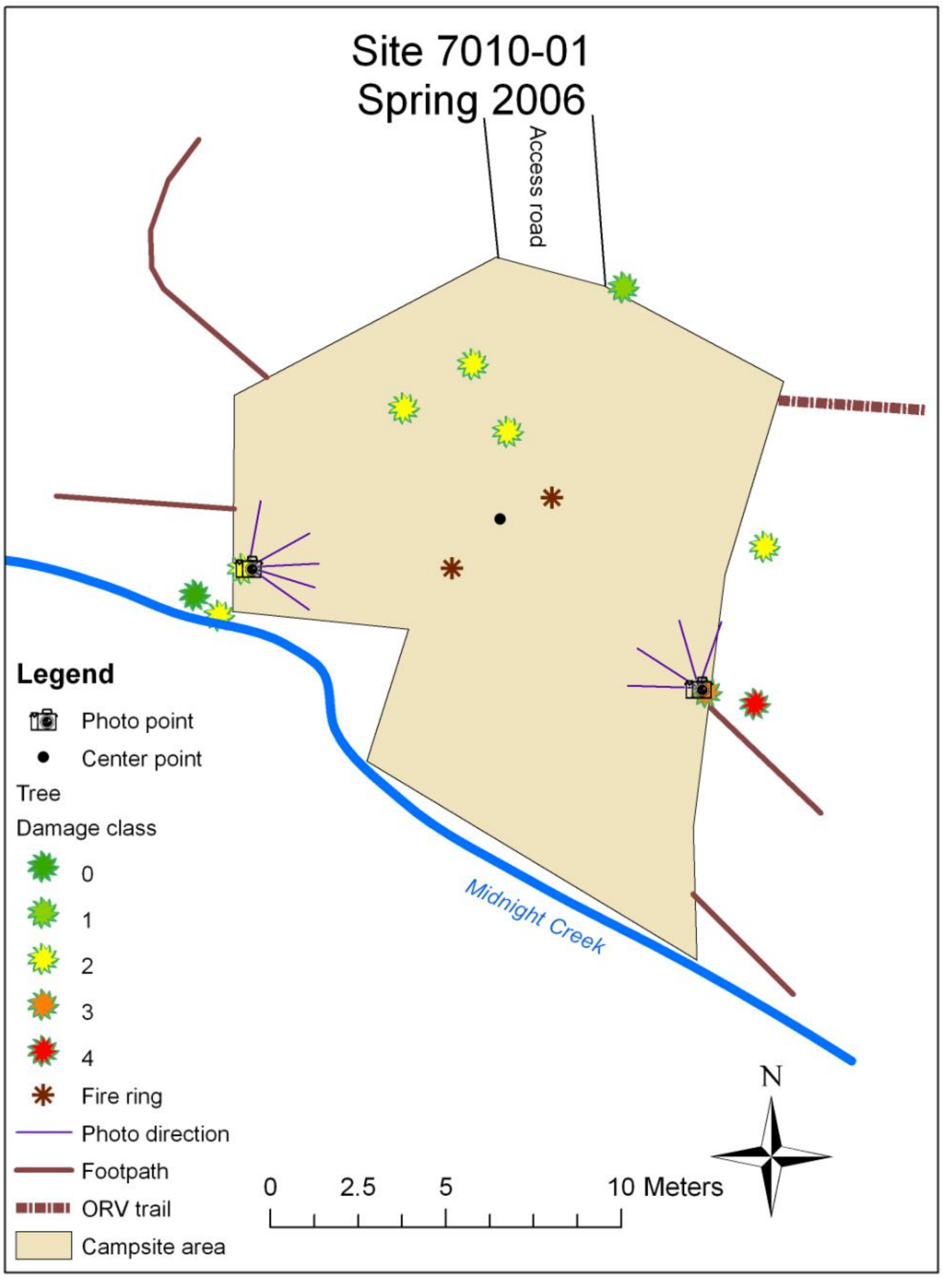

Figure 20. Map of campsite #7010-01, spring 2006.

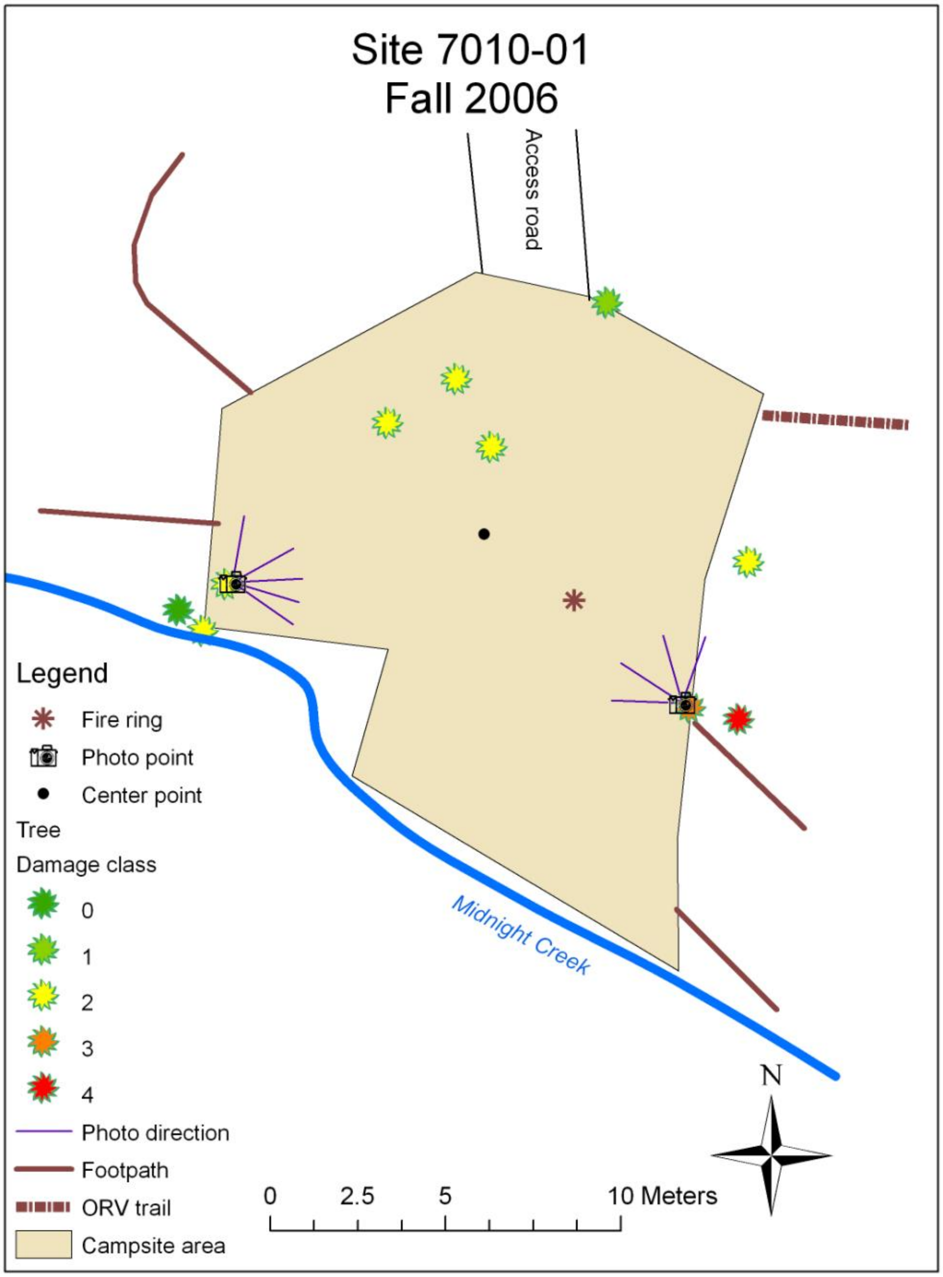

Figure 21. Map of campsite #7010-01, fall 2006.

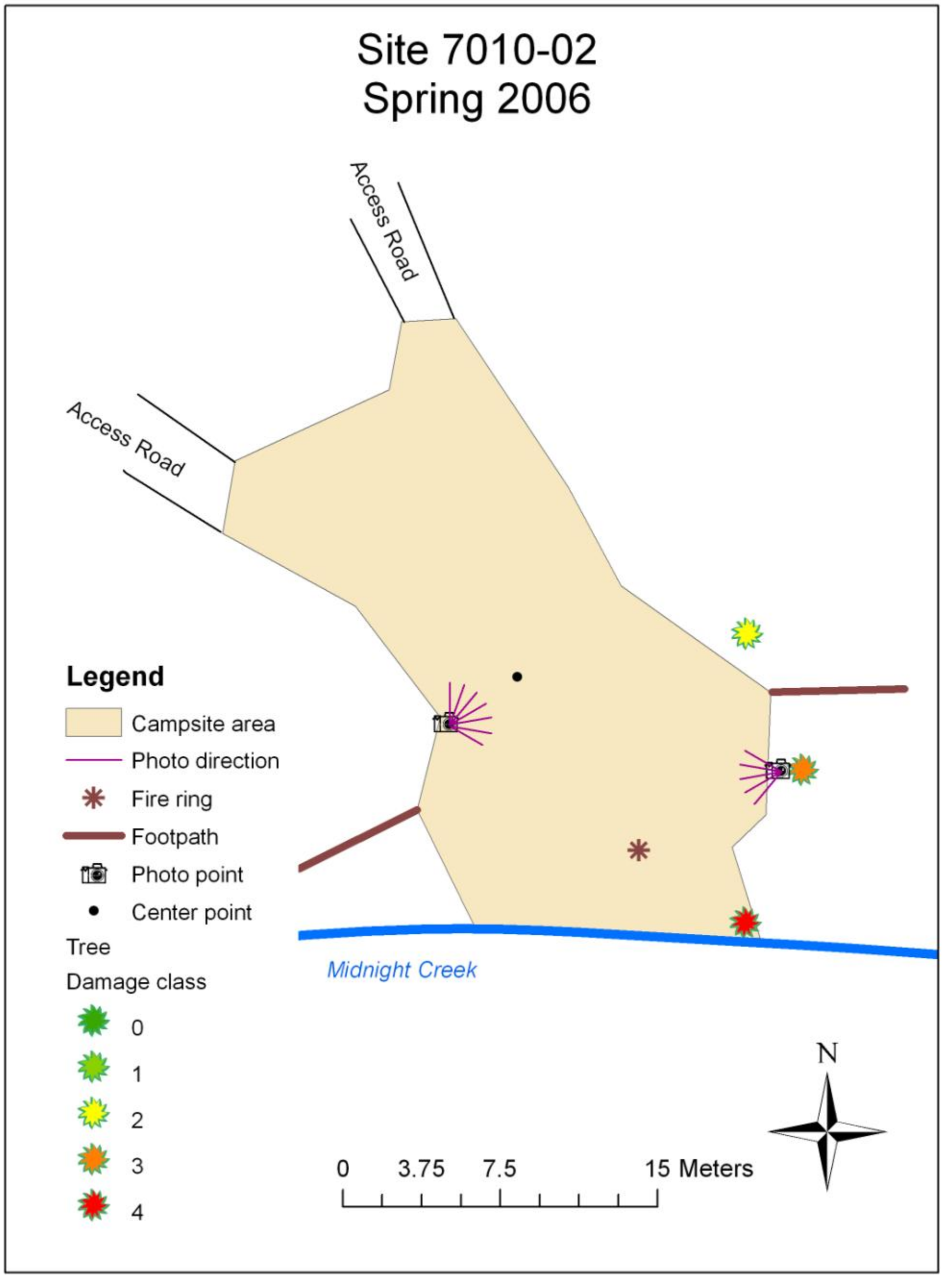

Figure 22. Map of campsite #7010-02, spring 2006.

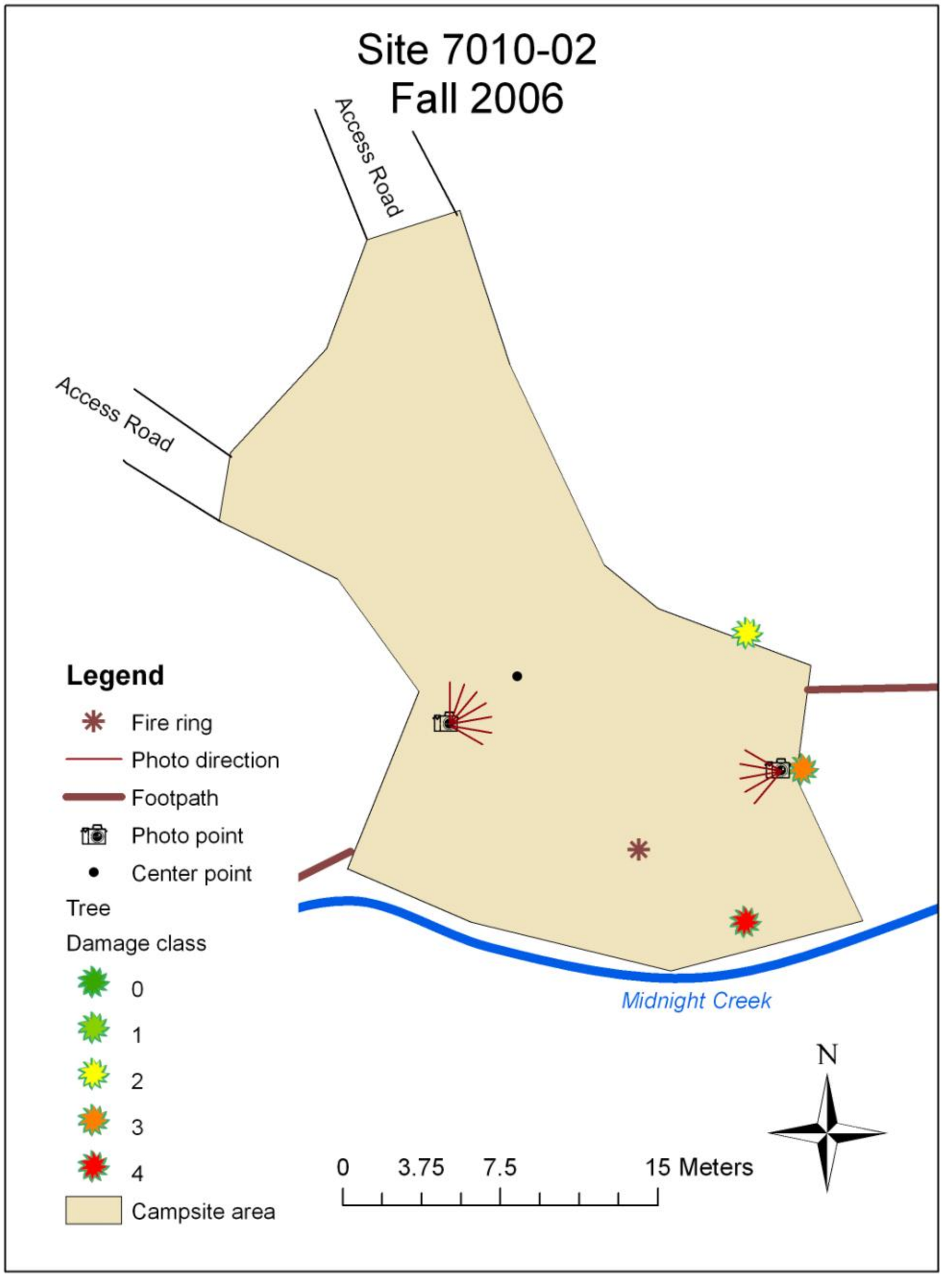

Figure 23. Map of campsite #7010-02, fall 2006.

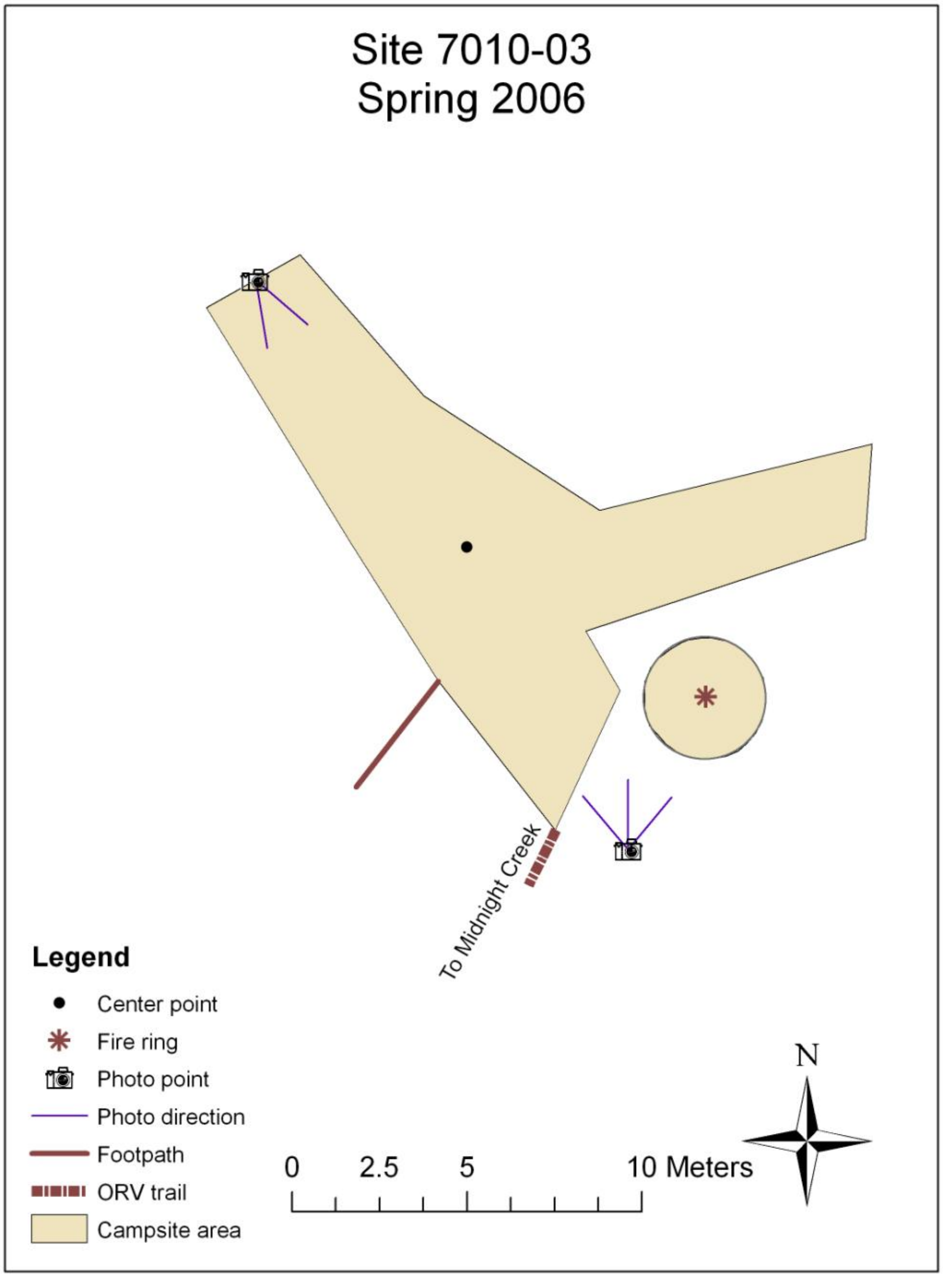

Figure 24. Map of campsite #7010-03, spring 2006.

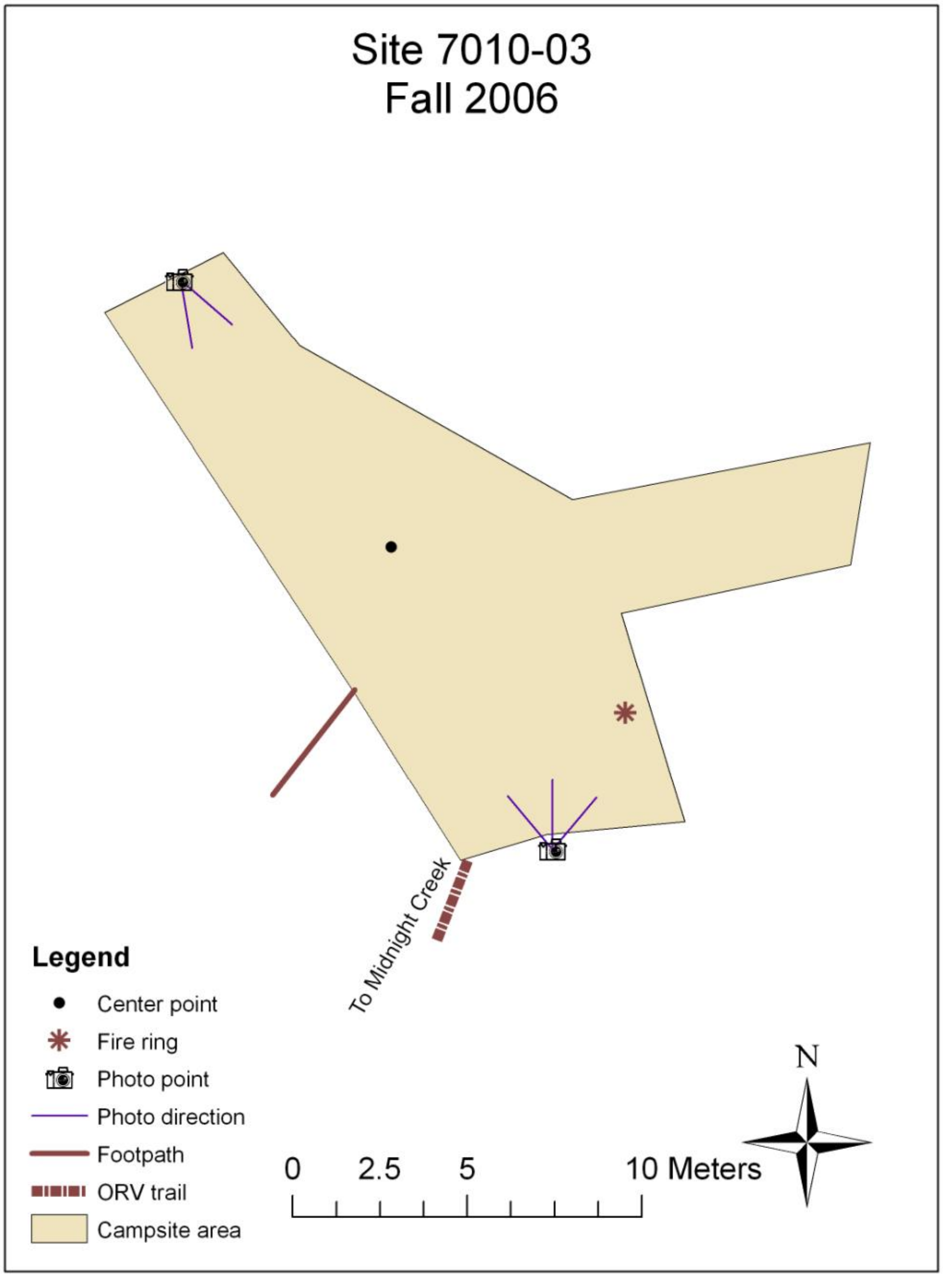

Figure 25. Map of campsite #7010-03, fall 2006.

Campsite 7030-01 (Figures 26 and 27) is located on a small, unnamed tributary to the Greenwater River, and is accessed by a decommissioned road spur from FR 7030. The site appears to be located on one side of a removed culvert crossing. The site is moderately used, private, and probably because of its steep approach, not typically used by RV campers.

Campsite 7030-02 (Figures 28 and 29) is a heavily used, wooded campsite near an illicit ORV riding area in the Greenwater River floodplain. Easy access to the site and ORV trails is gained from a decommissioned road segment or directly off FR 7030. The site is immediately adjacent to the Greenwater River, which is actively eroding the bank. A well-worn ORV path leads from the site directly into the river. Numerous trees prevent easy RV access, so the site is primarily used by tent campers. The Forest Service attempted to block access by vehicles along the eroding bank by dumping a small load of modestly sized boulders in the access road, but several routes into the site remain.

Campsite 7030-03 (Figures 30 and 31) is a flat pad of gravel immediately adjacent to the FR 7030 bridge approach over the Greenwater River. It is popular with RV campers, and is often occupied as overflow from campsite 7030-04. Differentiating the access road from the actual campsite is nearly impossible, since the site is a continuous strip of gravel.

Campsite 7030-04 (Figures 32 and 33) is a large, flat patch of denuded Greenwater River floodplain immediately downstream of the FR 7030 bridge.

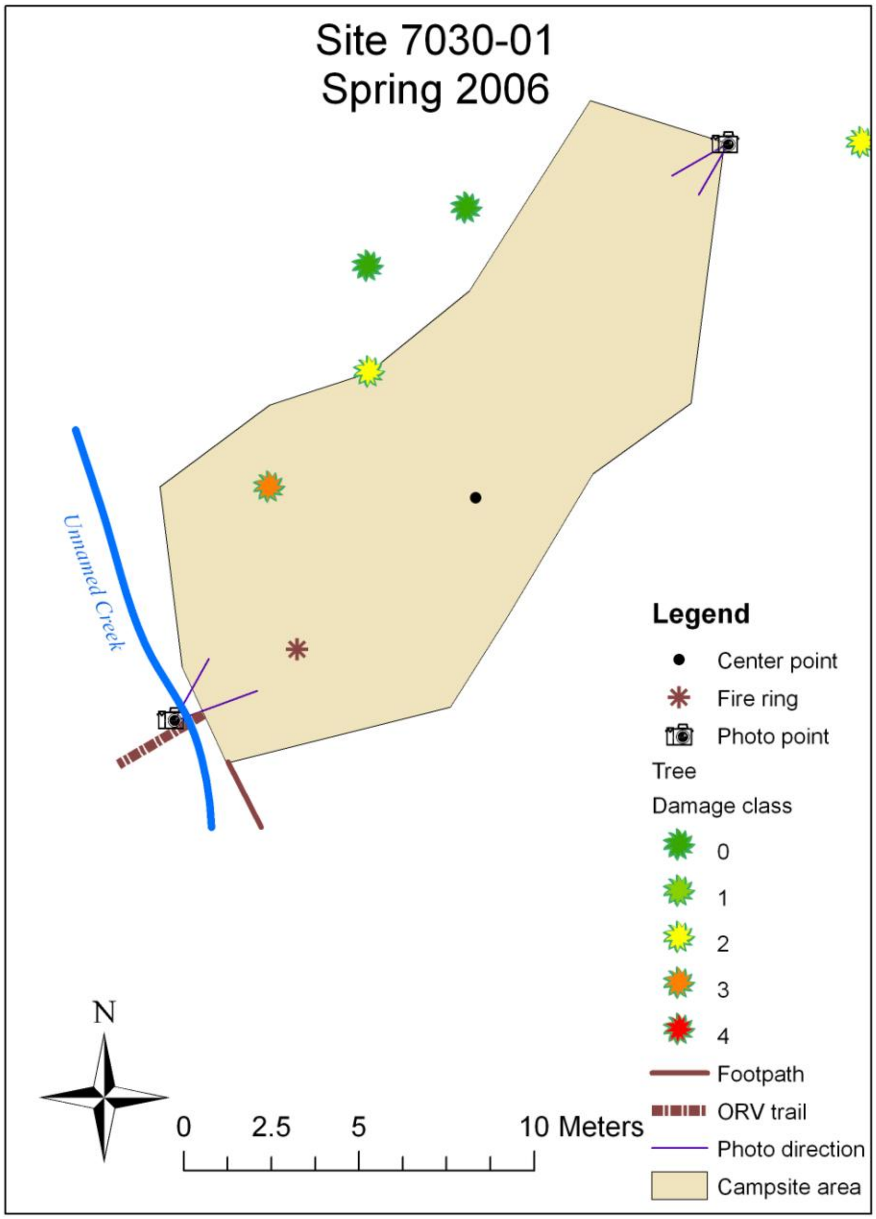

Figure 26. Map of campsite #7030-01, spring 2006.

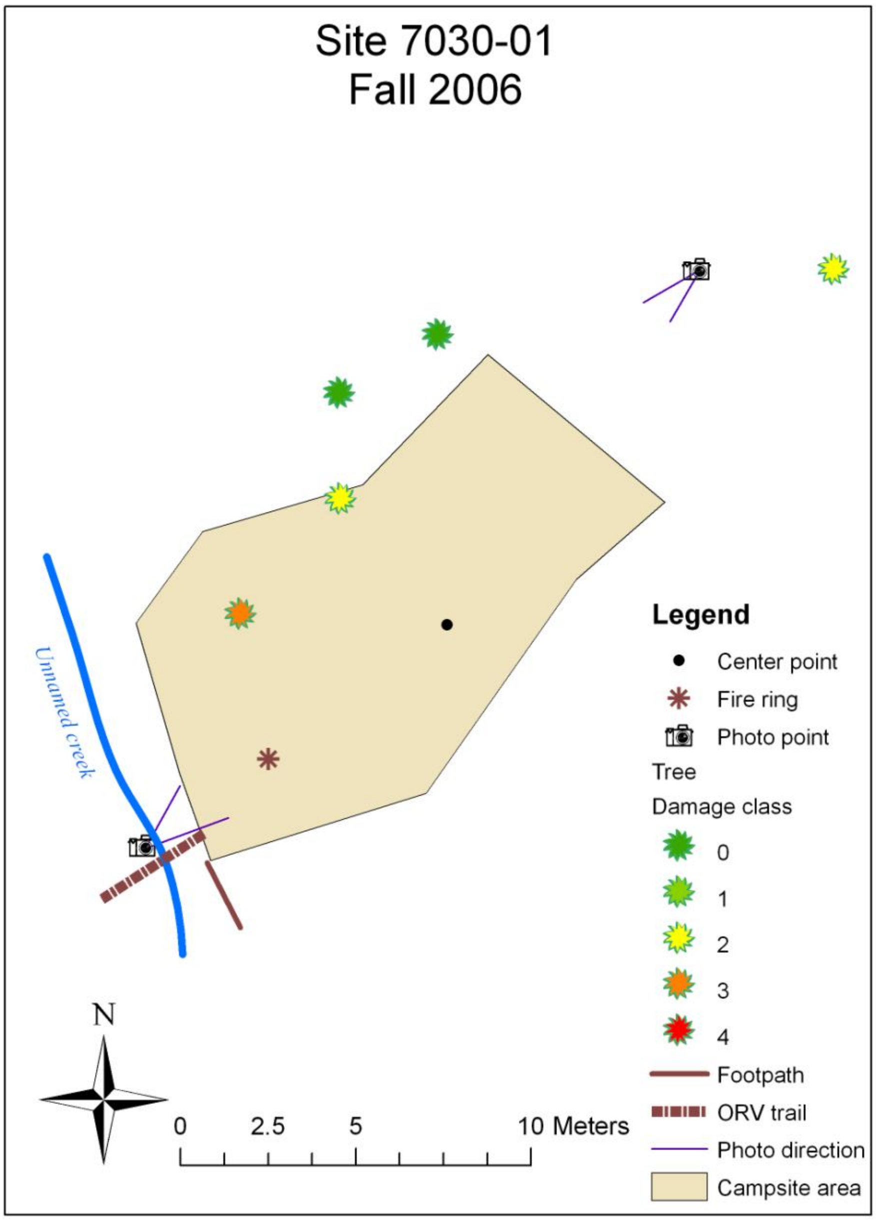

Figure 27. Map of campsite #7030-01, fall 2006.

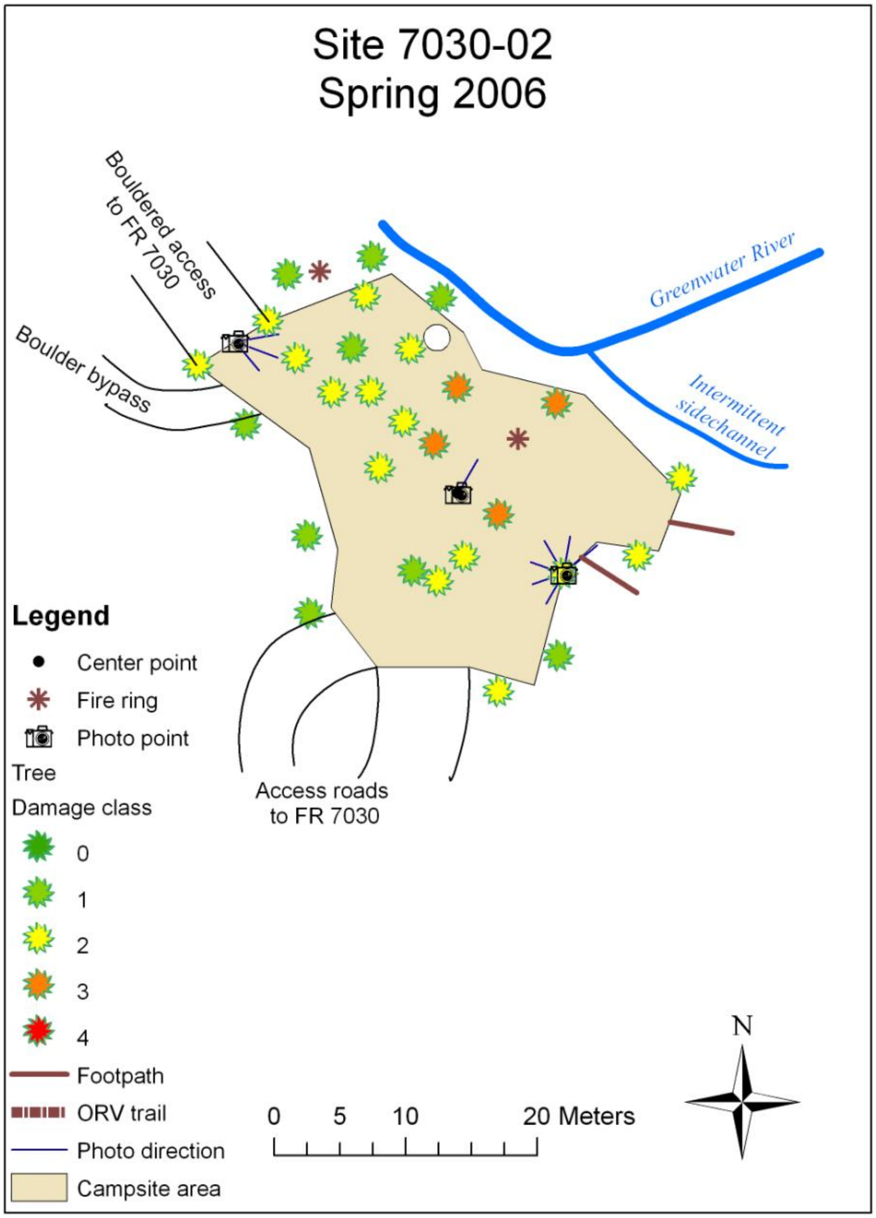

Figure 28. Map of campsite #7030-02, spring 2006.

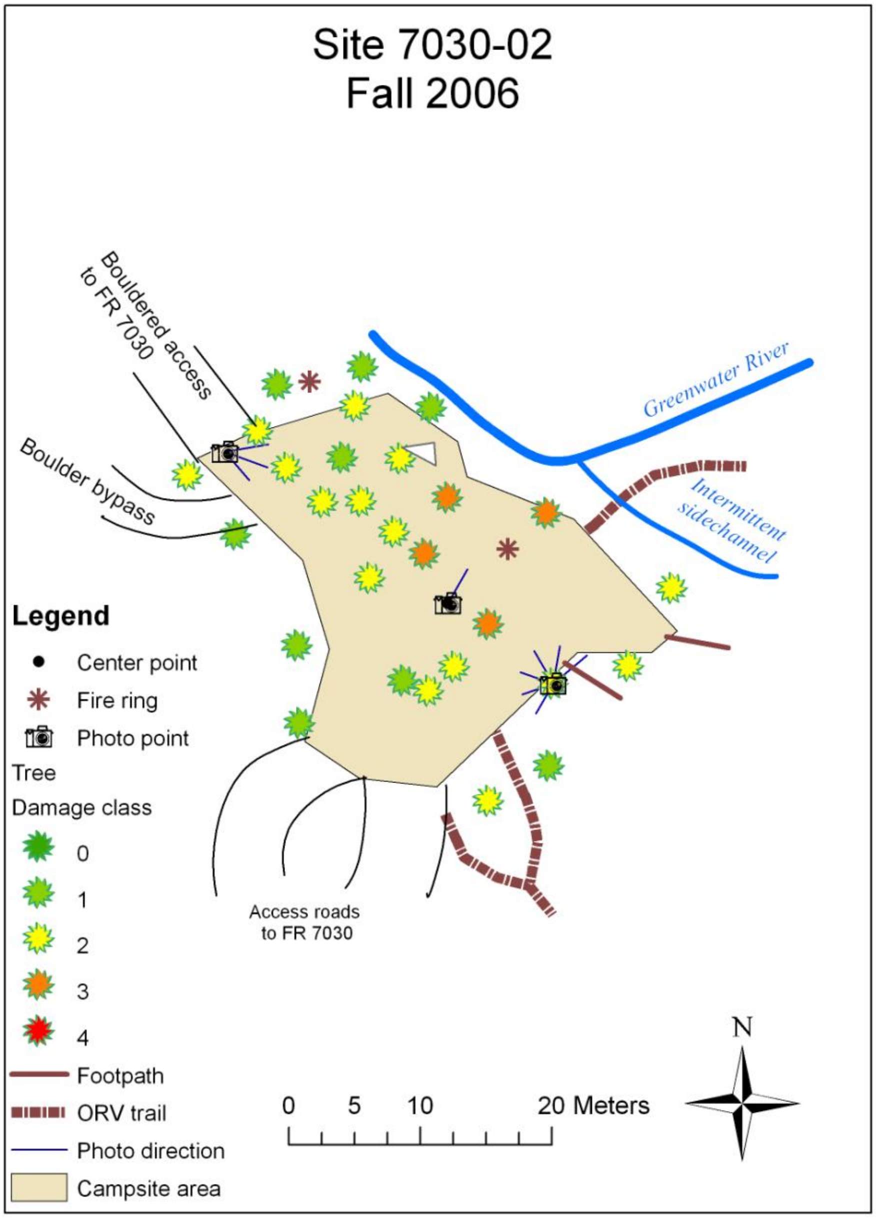

Figure 29. Map of campsite #7030-02, fall 2006.

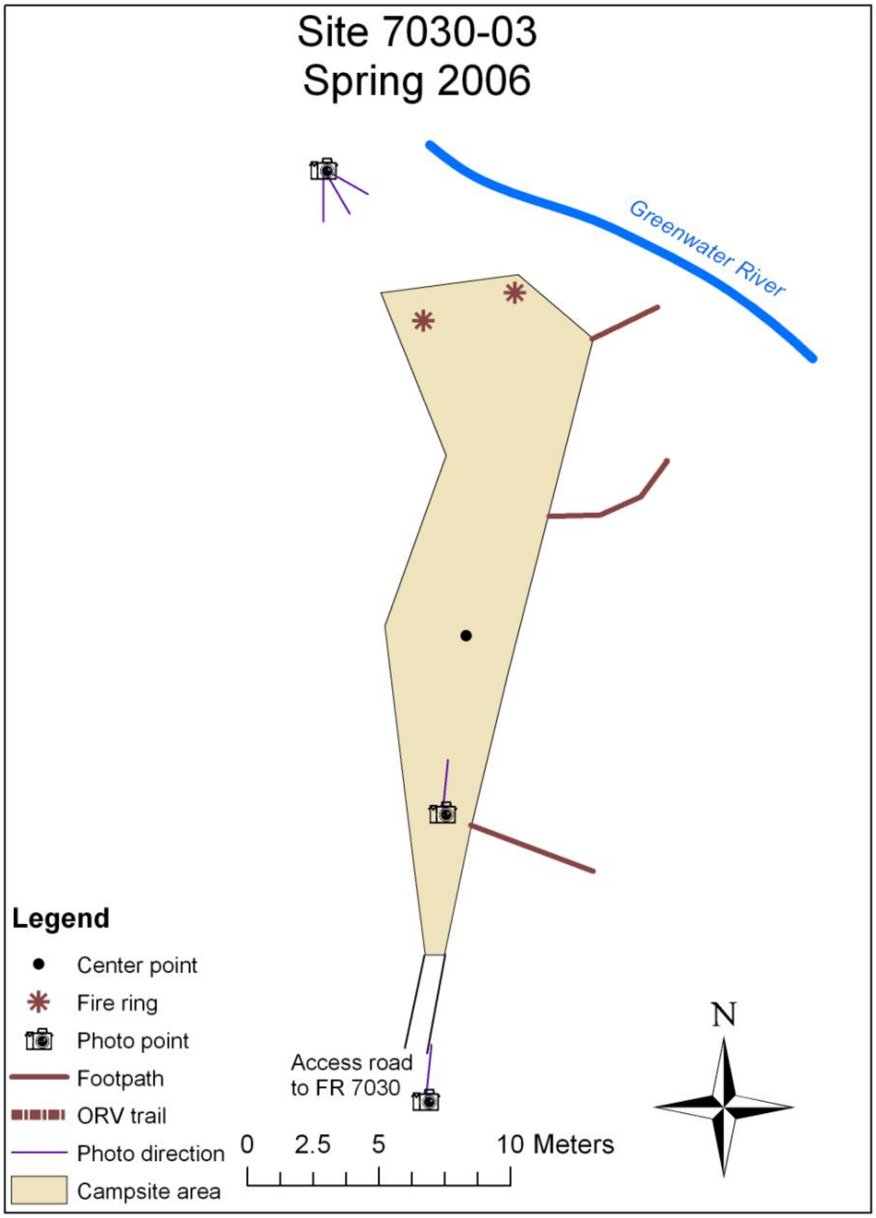

Figure 30. Map of campsite #7030-03, spring 2006.

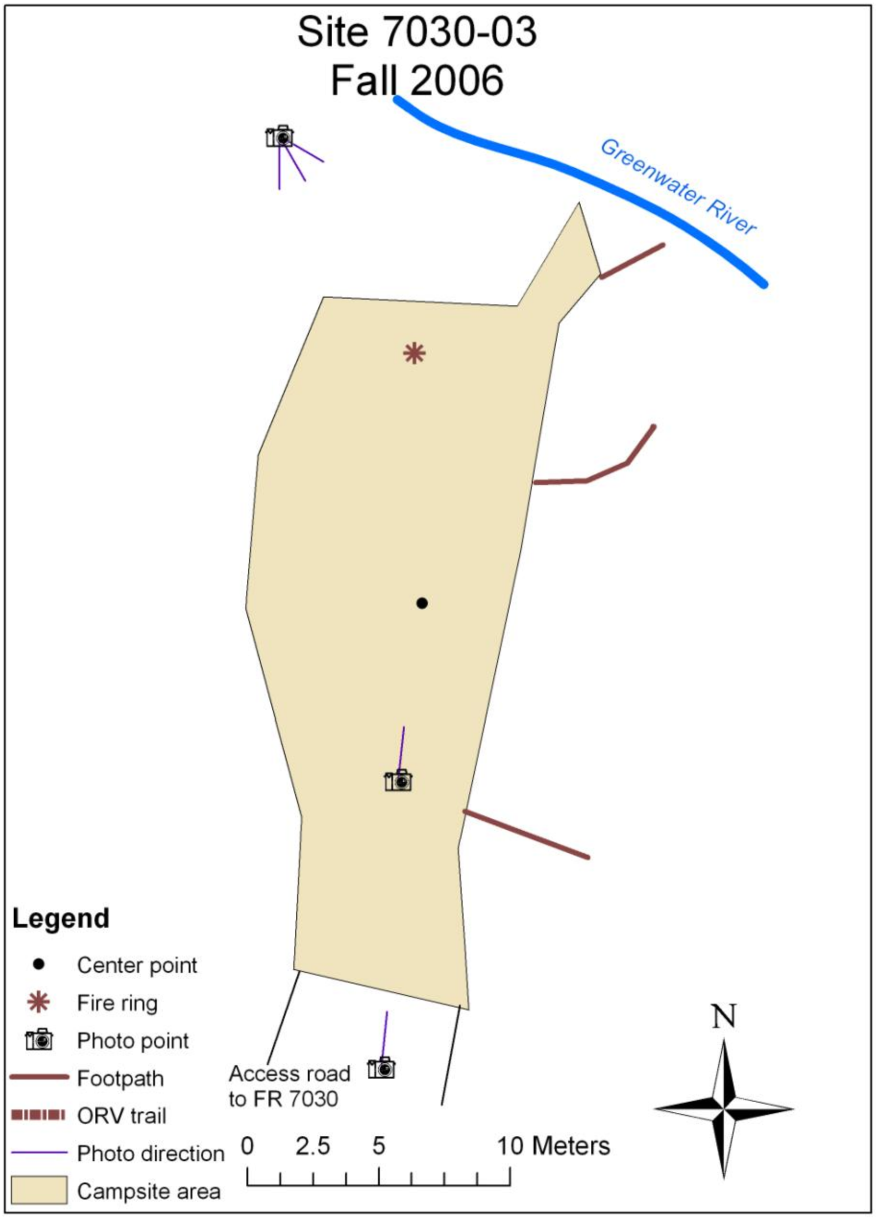

Figure 31. Map of campsite #7030-03, fall 2006.

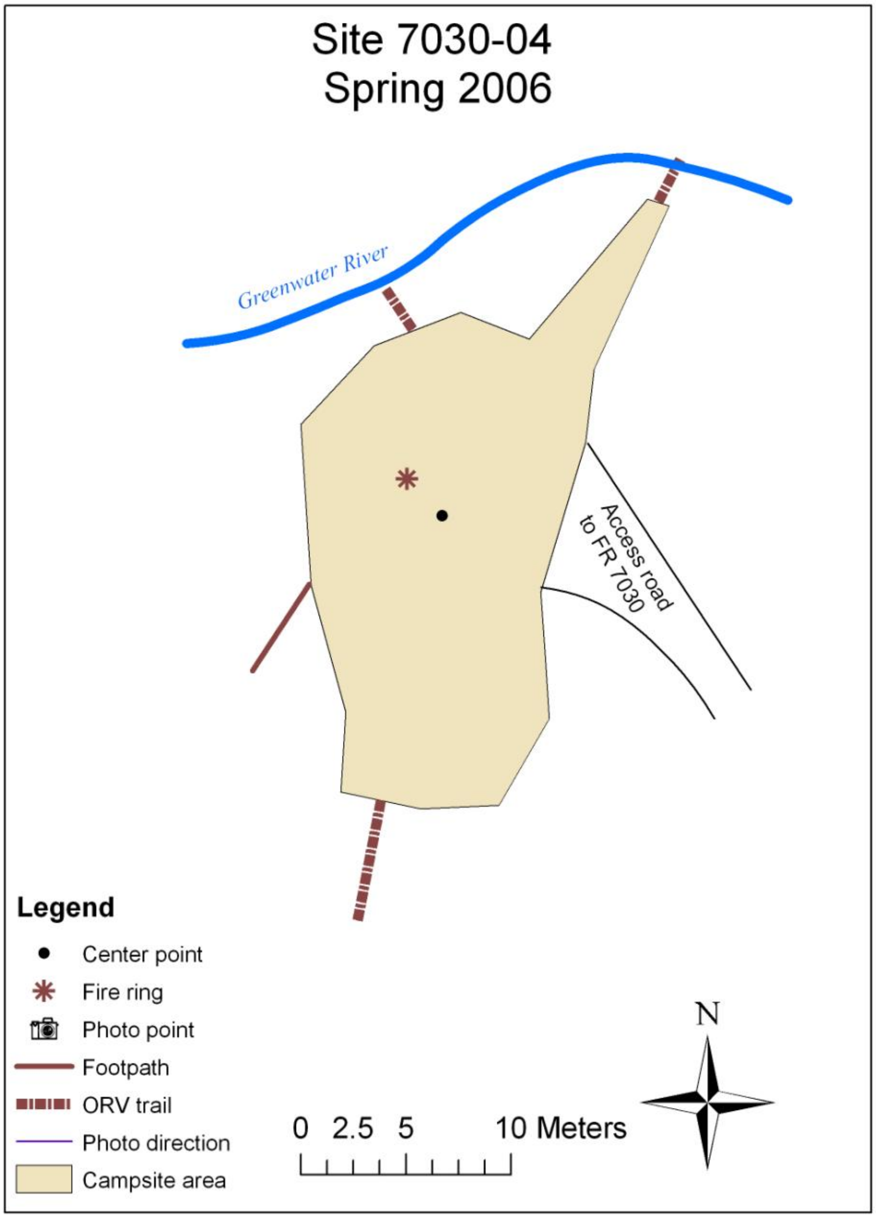

Figure 32. Map of campsite #7030-04, spring 2006.

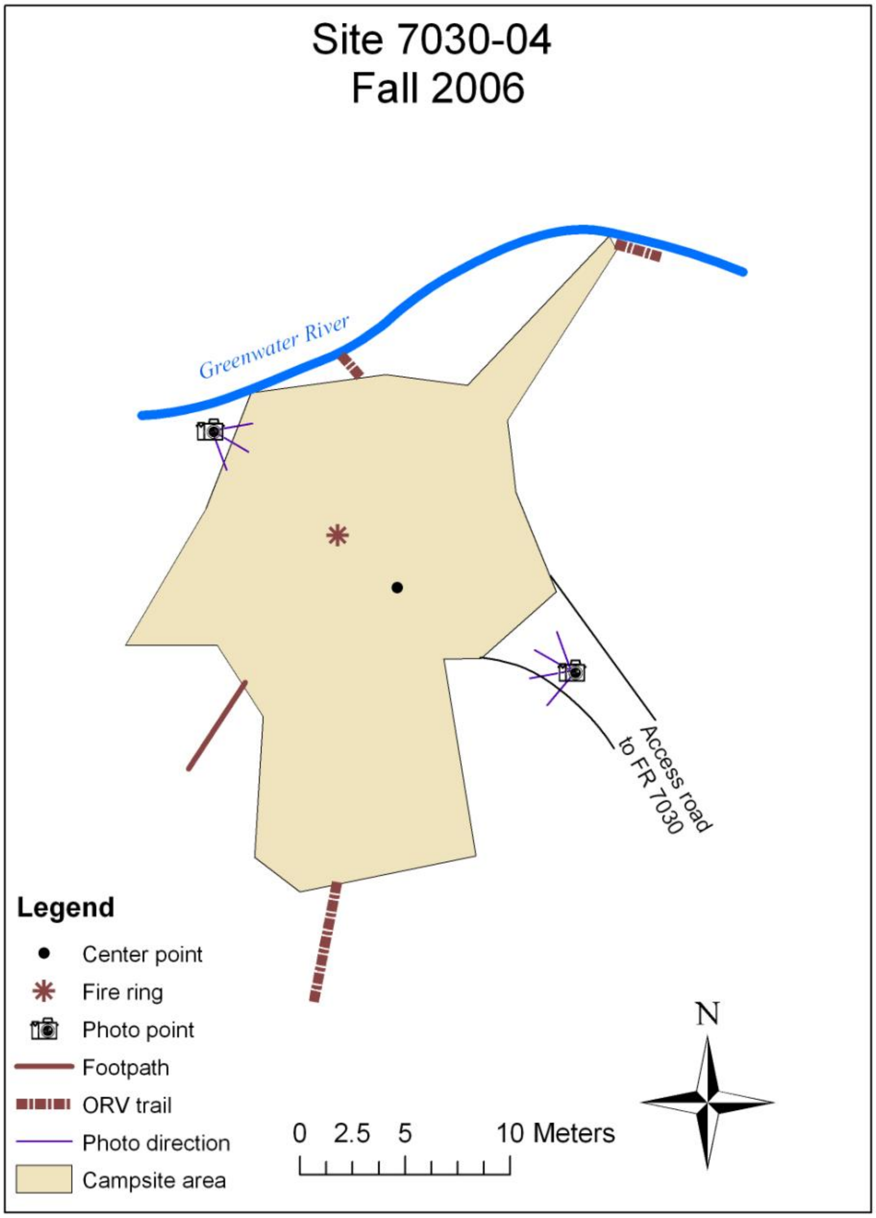

Figure 33. Map of campsite #7030-04, fall 2006.

The campsite was occupied nearly every weekend during the 2006 season, and is popular with RV campers despite its treacherously steep access road. An abandoned truck marks what was likely an old campsite, or satellite area.

Campsite 7031-01 (Figures 34 and 35) is accessed by a very steep trail from FR 70 opposite the end of FR 7031. The site is inaccessible to RVs, but was commonly used by compact cars and trucks in 2005. The site was only occasionally used in 2006 after being fenced and signed. The site rests on a steep bank, with direct Greenwater River access at one point. A camper visiting the site prior to July 1 removed the fence and sign, parked in the site, and was promptly issued a ticket by a Forest Service law enforcement officer. The camper removed his vehicle, replaced the fence and sign, and continued his camping weekend.

Campsite 7031-02 (Figures 36 and 37) is the first campsite accessed by FR 7031. It is a medium sized site, and is heavily used by RV and tent campers. The site is immediately adjacent to the Greenwater River, and is bordered by willows on the floodplain. An ORV trail leads from the site to campsite 7031-03. A previous attempt at blocking vehicle access is evidenced by small (< .5 m diameter) boulders arranged in a broken straight line across the access road.

Campsite 7031-03 (Figures 38 and 39) is near campsite 7031-02, but is perched above the Greenwater River on what appears to be a floodplain terrace. The bank is actively eroding, and is treeless along most of the campsite's length.

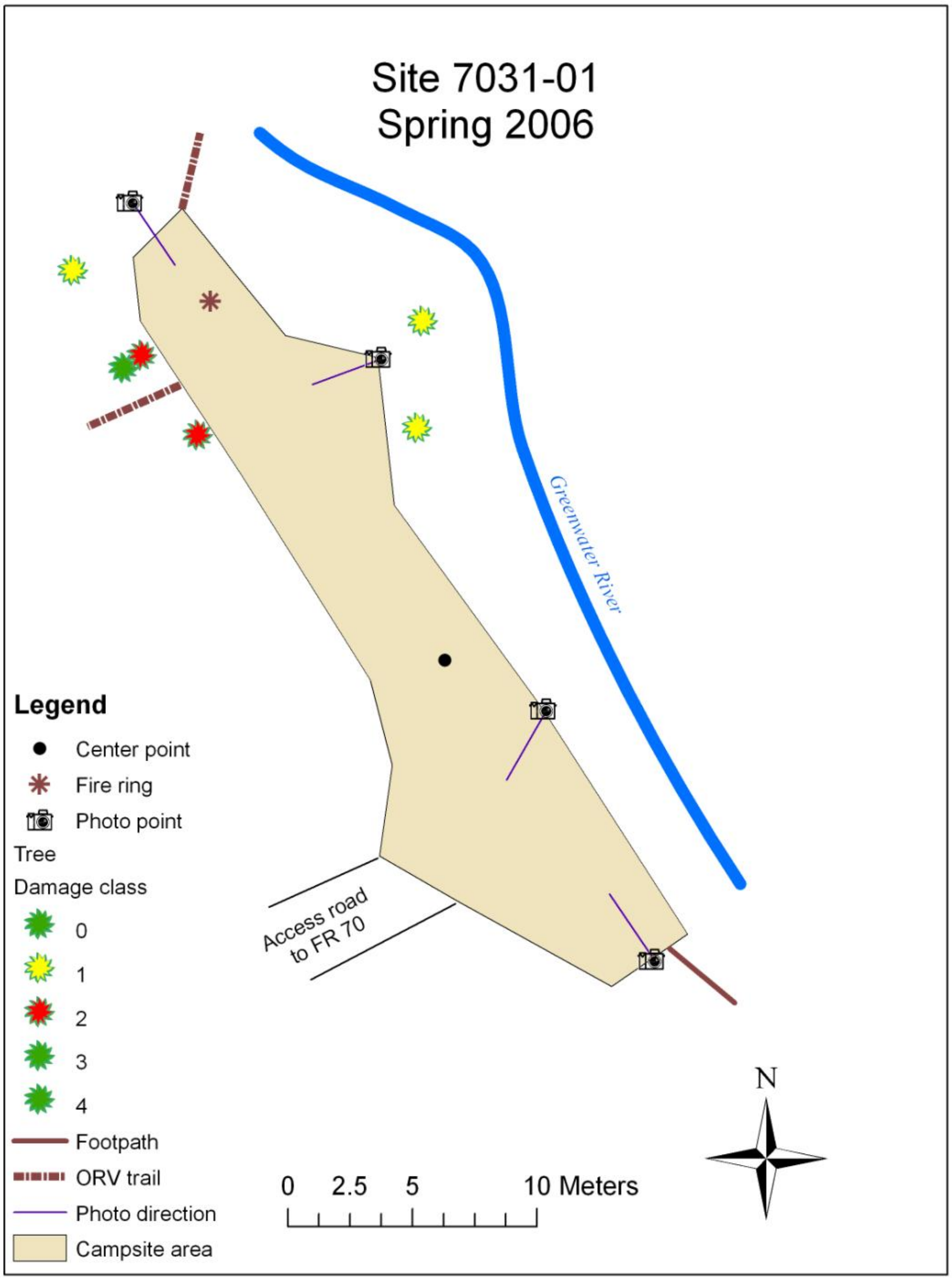

Figure 34. Map of campsite #7031-01, spring 2006.

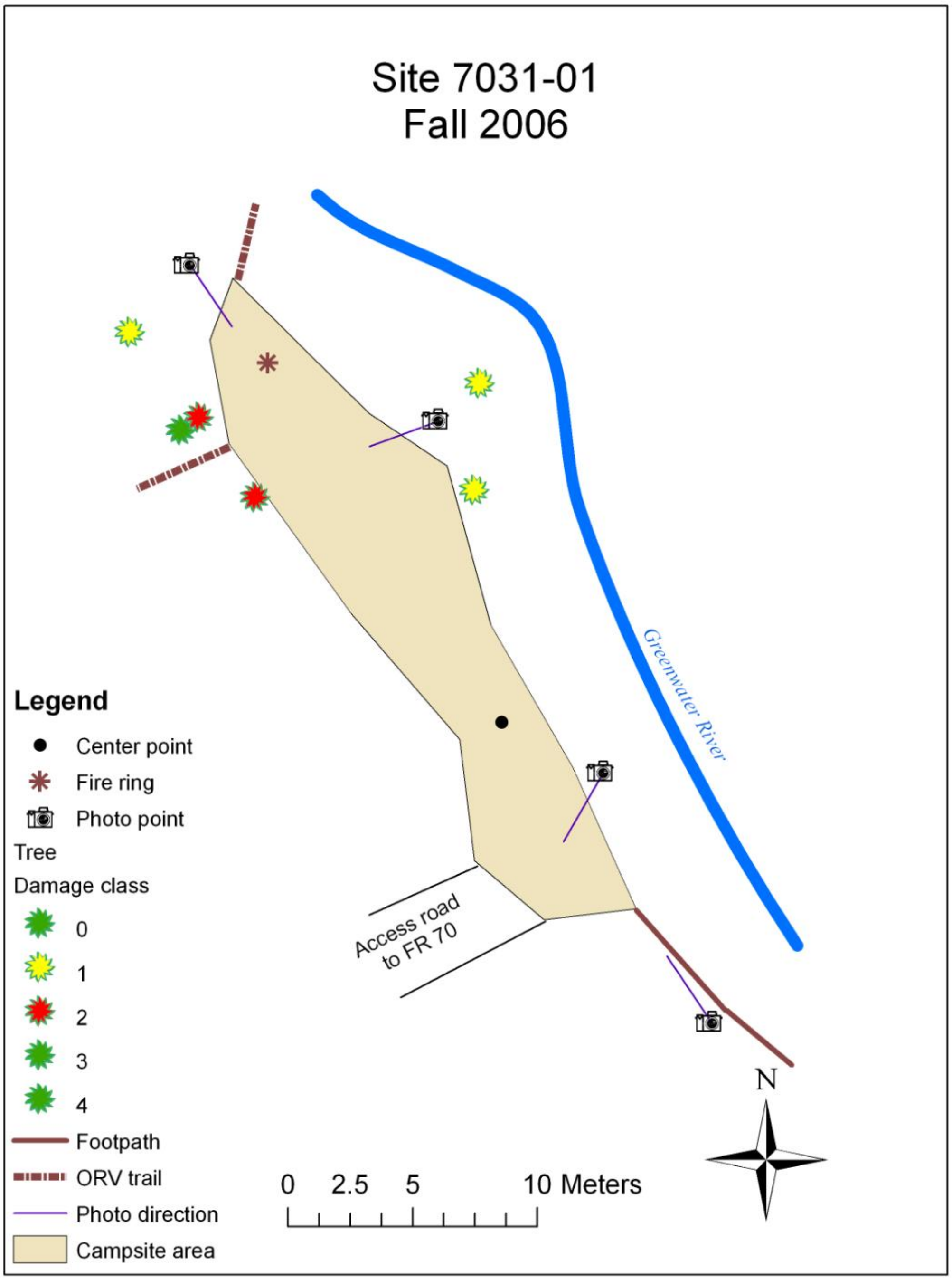

Figure 35. Map of campsite #7031-01, fall 2006.

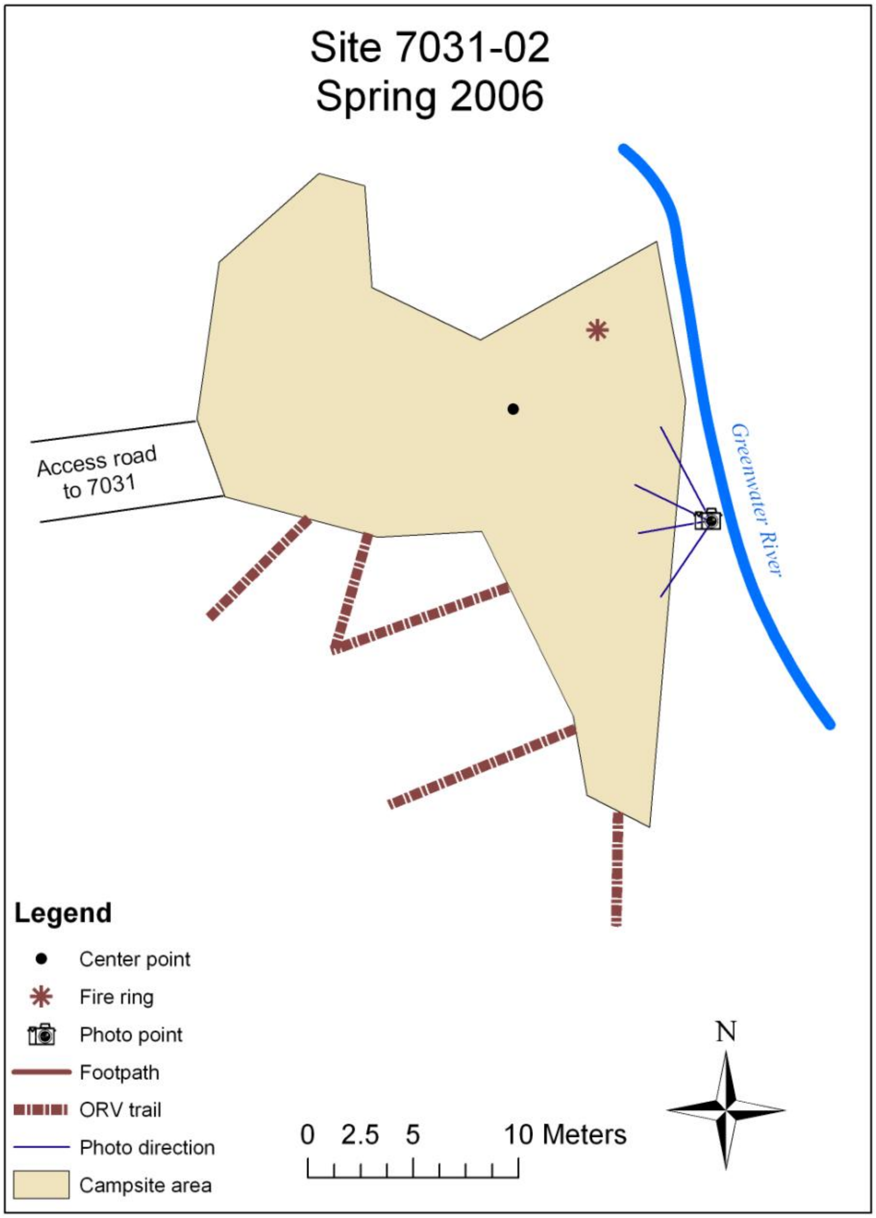

Figure 36. Map of campsite #7031-02, spring 2006.

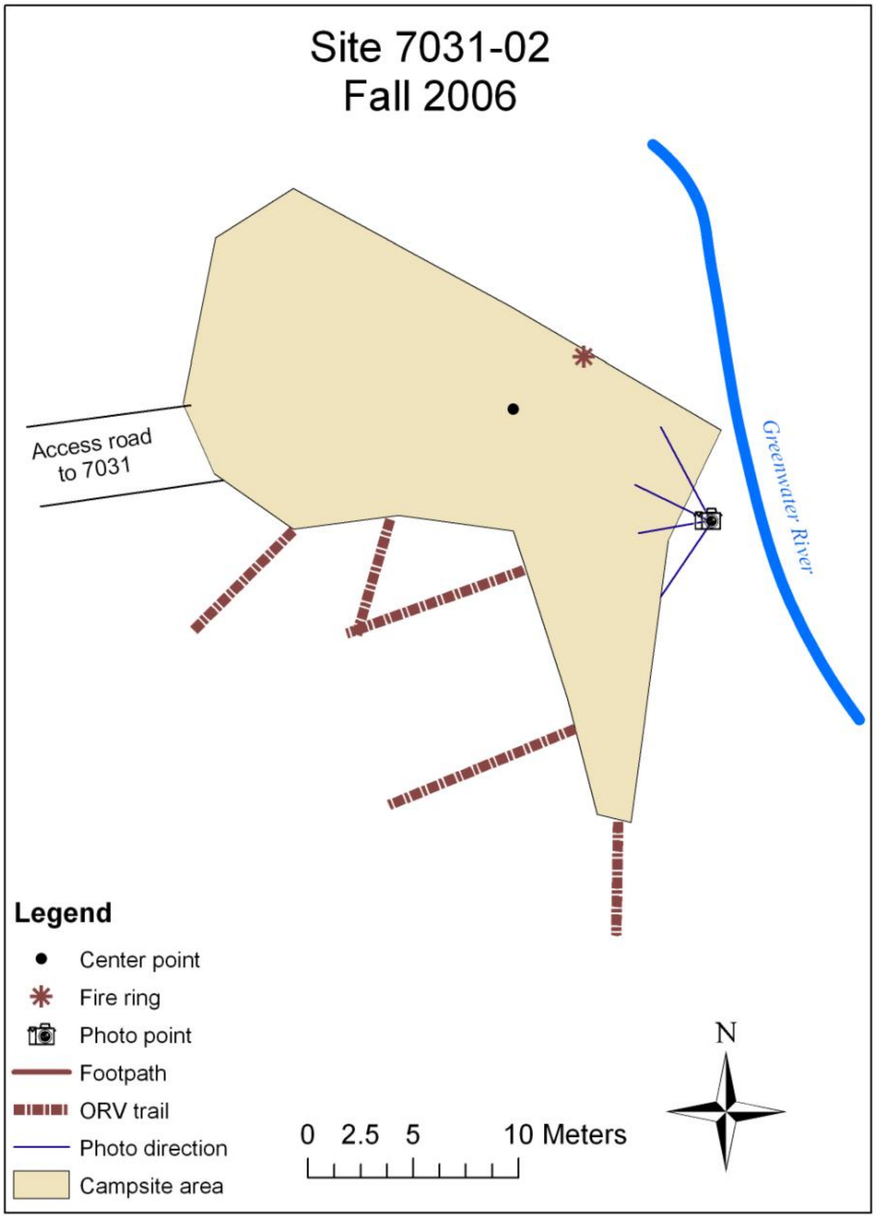

Figure 37. Map of campsite #7031-02, fall 2006.

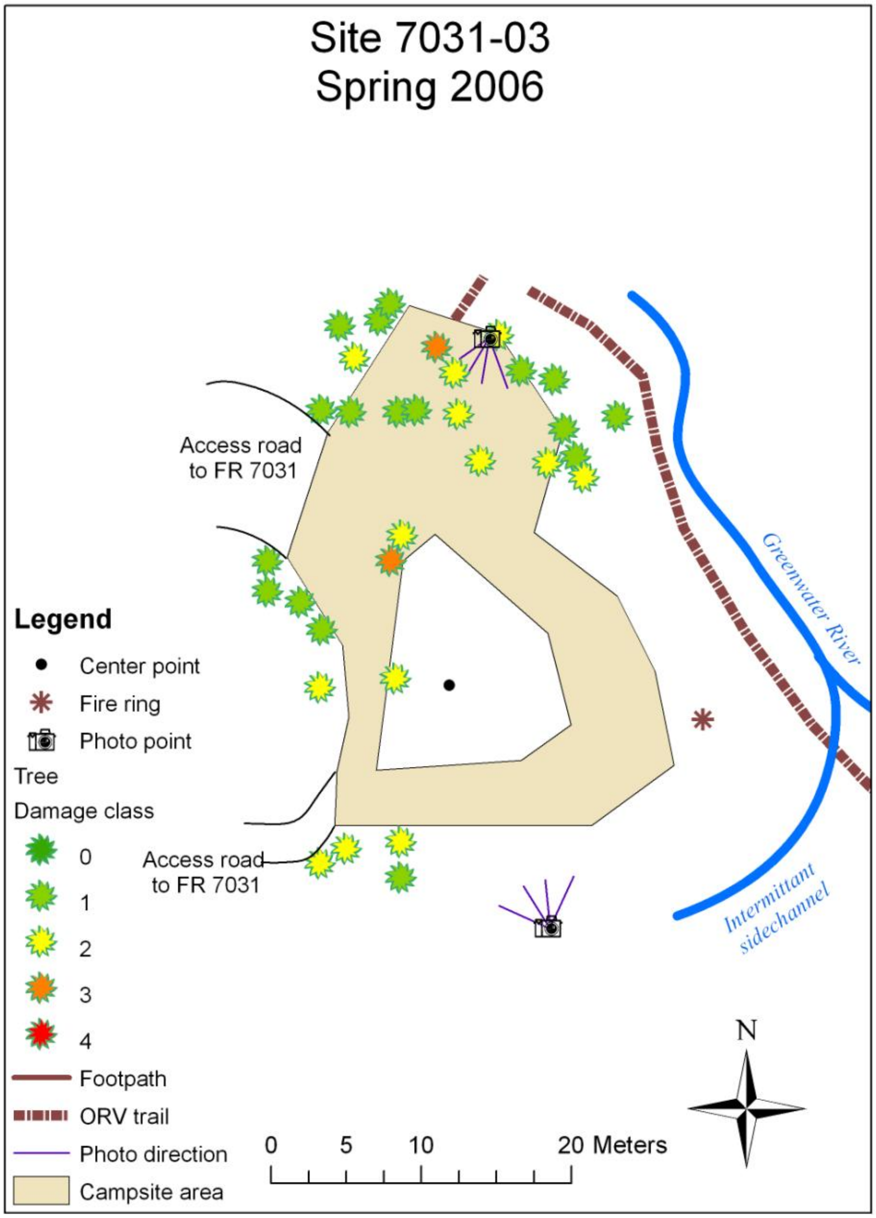

Figure 38. Map of campsite #7031-03, spring 2006.

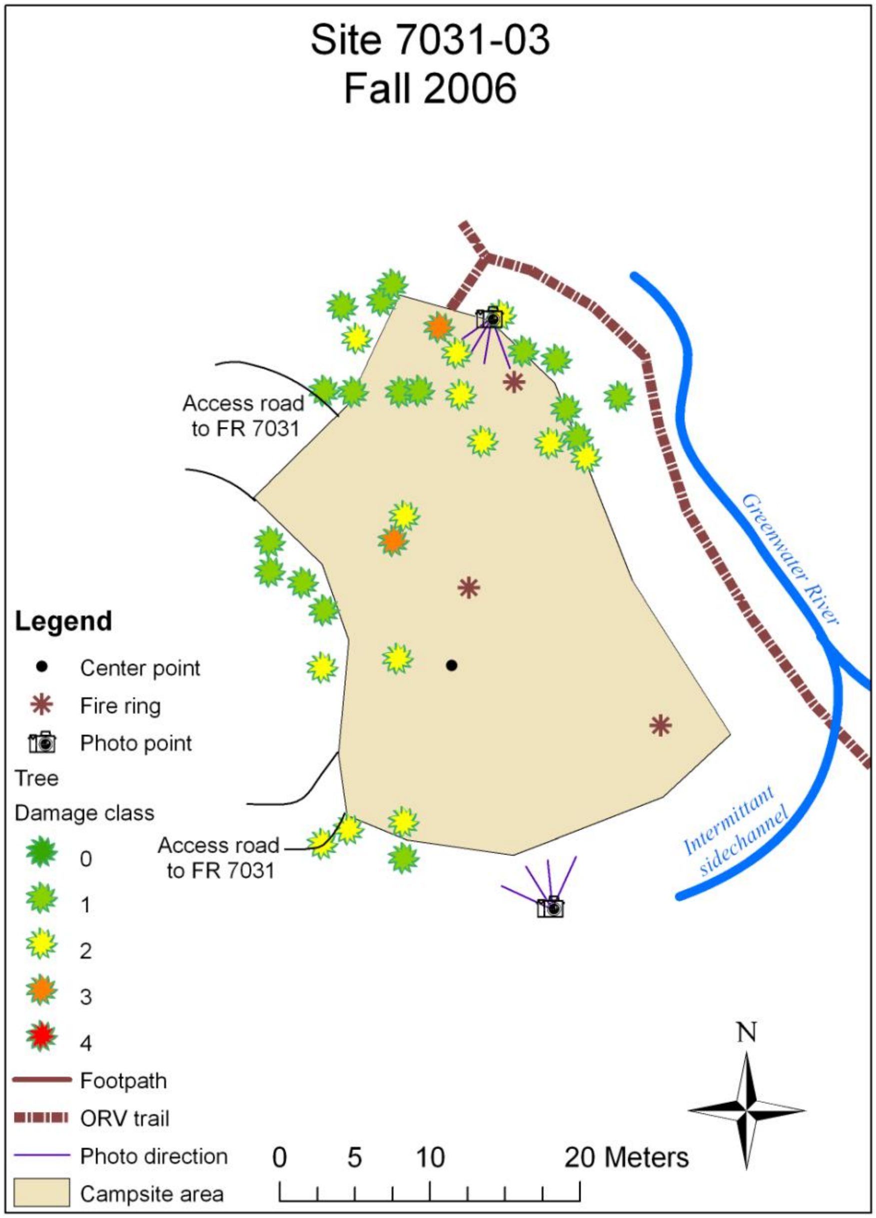

Figure 39. Map of campsite #7031-03, fall 2006.

The site is popular with RV and tent campers, and has two full pull-through parking routes (one of which was blocked by fences and signs in 2006). The campsite is heavily used, sunny, and muddy in the spring or after summer rains.

Campsite 7031-04 (Figures 40 and 41) is an enormous site near the end of FR 7031. The site was occupied, sometimes by more than one group, nearly every weekend during summer 2006. The site has several associated satellite tent areas in adjacent wooded areas. Much of the site is on heavily compacted, gravelly soils.

Campsite 7031-05 (Figure 42) is a small campsite accessed from FR 7031 just upstream of campsite 7031-04. A side channel of the Greenwater River flowed through the site for the first portion of summer 2006 (Figure 7), precluding biophysical baseline data collection and camping. After the water retreated in mid-summer, the site was lightly used by tent campers and one RV group.

Campsite 7000-01 (Figures 43 and 44) is a medium sized, shady campsite adjacent to Pyramid Creek near the Greenwater Lakes trailhead. The campsite received medium use throughout the season, but I suspect that several of the groups used it as a free alternative to parking at the trailhead, which required a Northwest Forest Pass. Delineating campsite boundaries in the duff was a challenge.

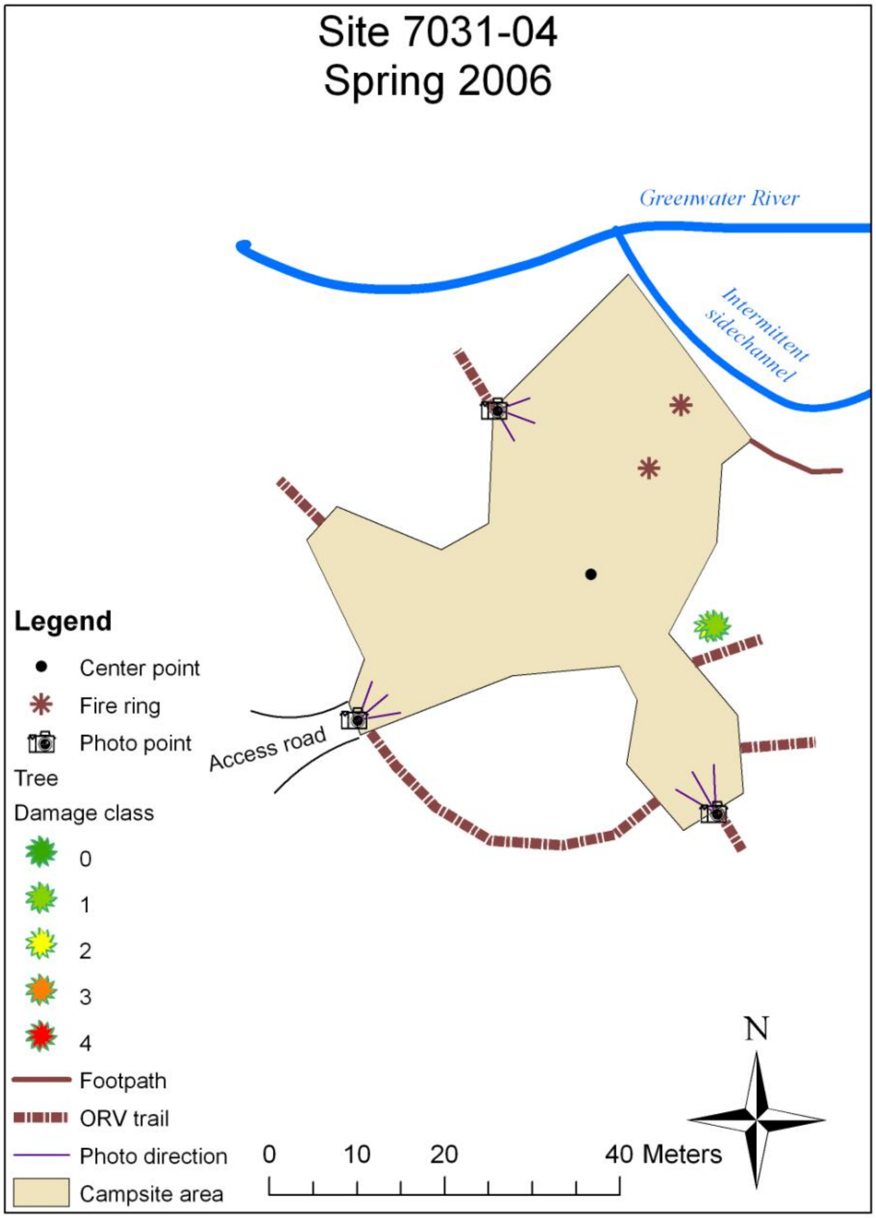

Figure 40. Map of campsite #7031-04, spring 2006.

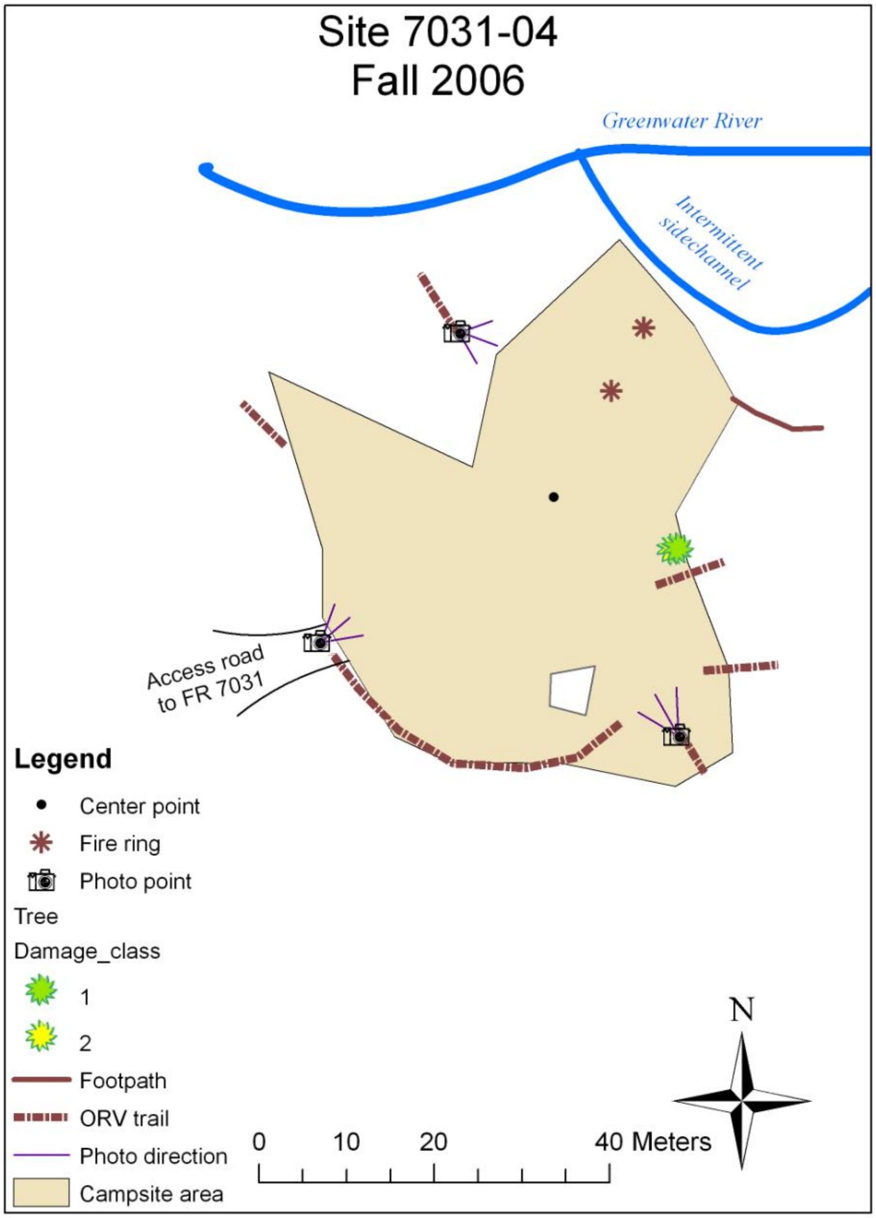

Figure 41. Map of campsite #7031-04, fall 2006.

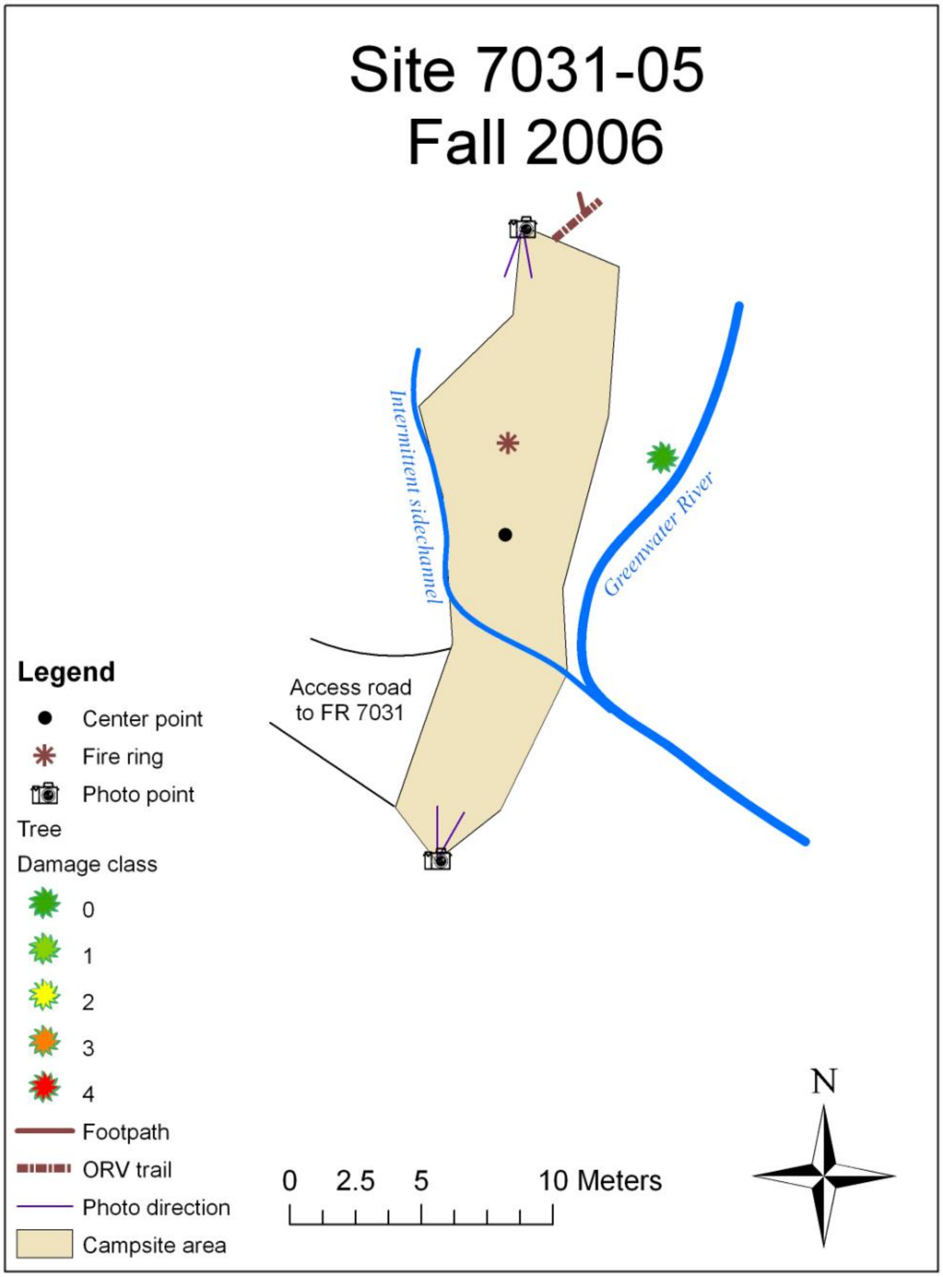

Figure 42. Map of campsite #7031-05, fall 2006 (no spring map because of high water).

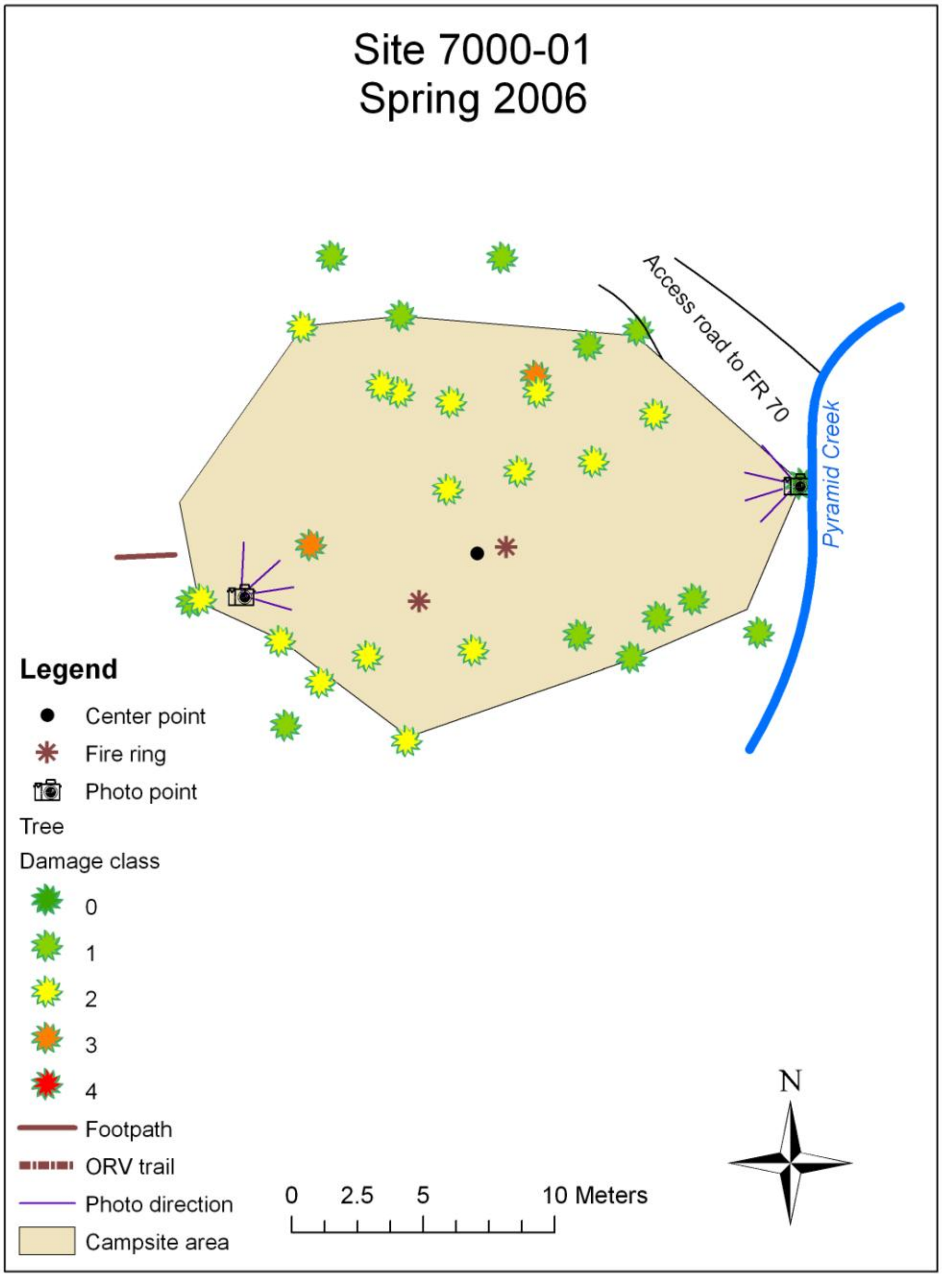

Figure 43. Map of campsite #7000-01, spring 2006.

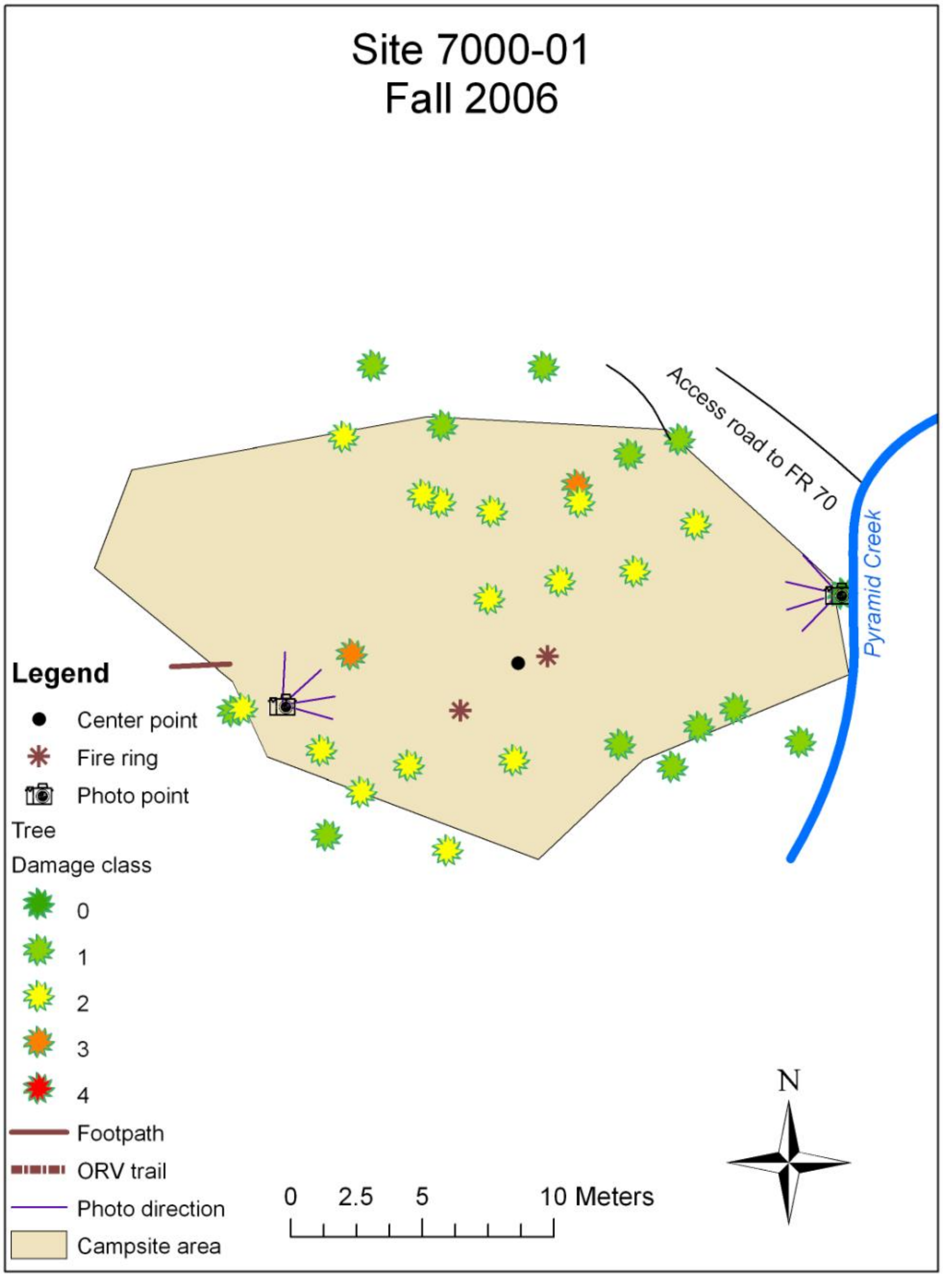

Figure 44. Map of campsite #7000-01, fall 2006.

Campsite 7000-02 (Figures 45 and 46) consists of a large parking area on the FR 70 shoulder and a separate, large, sunny campsite immediately adjacent to Pyramid Creek. The entire southern boundary of the campsite is defined by the Pyramid Creek shoreline. Satellite sites are located on a higher terrace to the north. The site receives heavy use by RV and tent campers.

Campsite 7000-03 (Figures 47 and 48) is a lightly used former road bed and adjacent forest tent area accessed off FR 70. It is a shady site immediately adjacent to Pyramid Creek. Delineating campsite boundaries was a challenge in the duff. The site was a marginal option for small RVs because of a steep drop off from FR 70.

Photo monitoring

Monitoring photographs were taken during spring and fall at all campsites except 7031-05, which was only surveyed during fall, 2006. All photographs are included in Appendix C, and one pair of photographs from each campsite cluster is shown in Figures 49-52 as examples.

Seasonal Variation

The monitoring protocol was developed with long-term monitoring in mind, not single-season change; vegetation will likely take several years to establish in the compacted fringes of campsites. In cases where campsite canopy cover was not extensive, grasses and forbs seemed well established around the edges of campsites during the spring data collection period. Upon

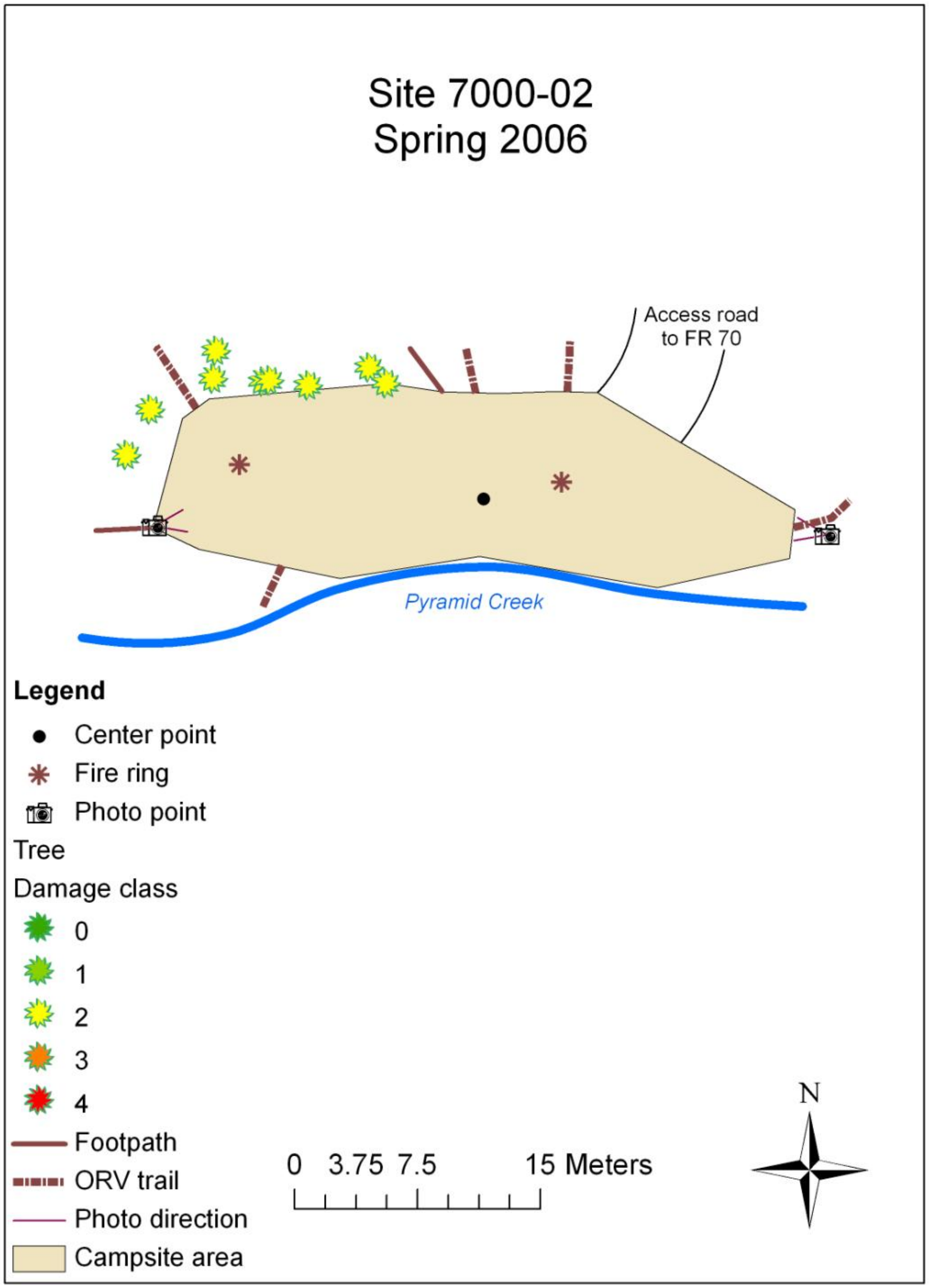

Figure 45. Map of campsite #7000-02, spring 2006.

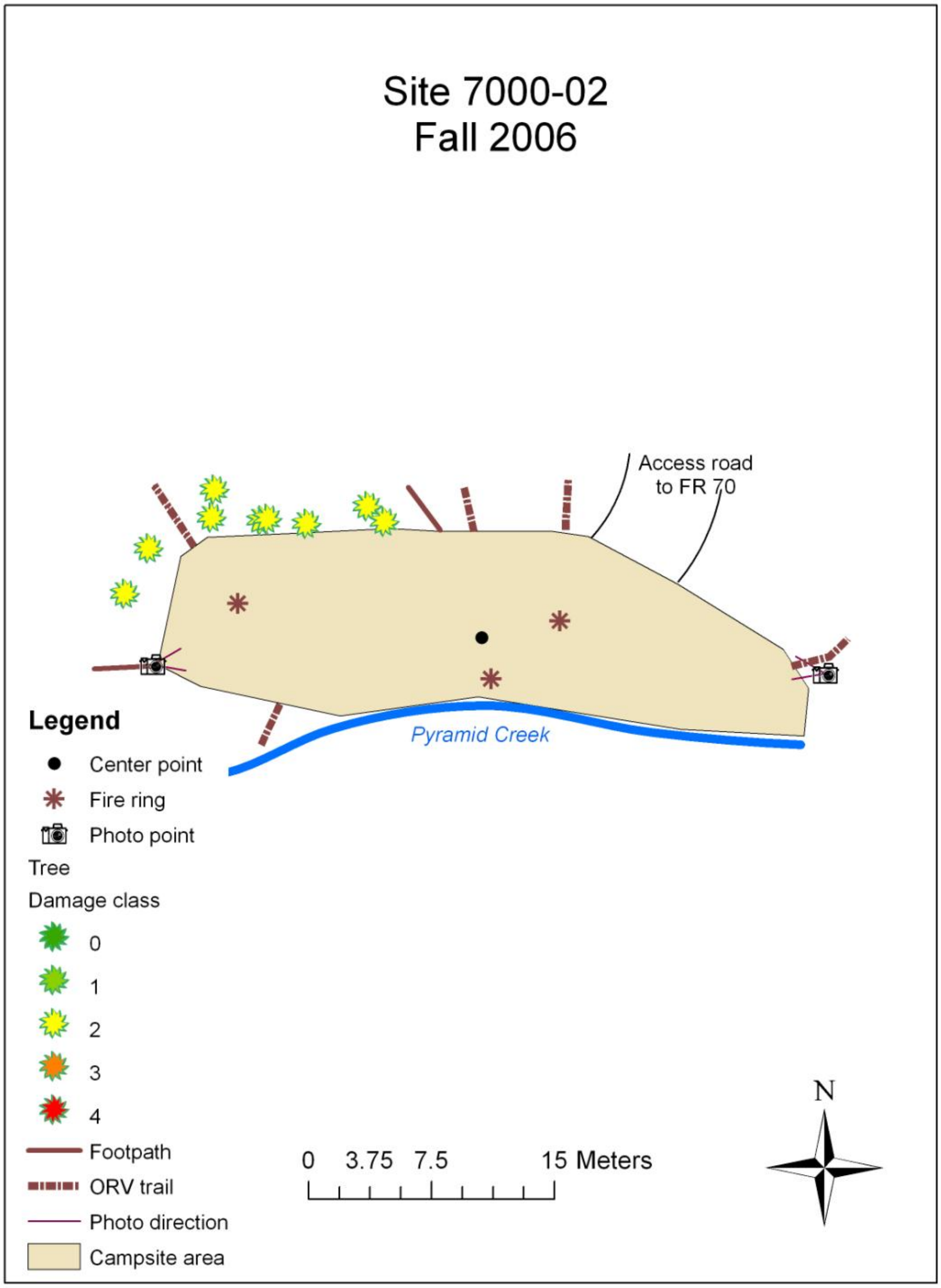

Figure 46. Map of campsite #7000-02, fall 2006.

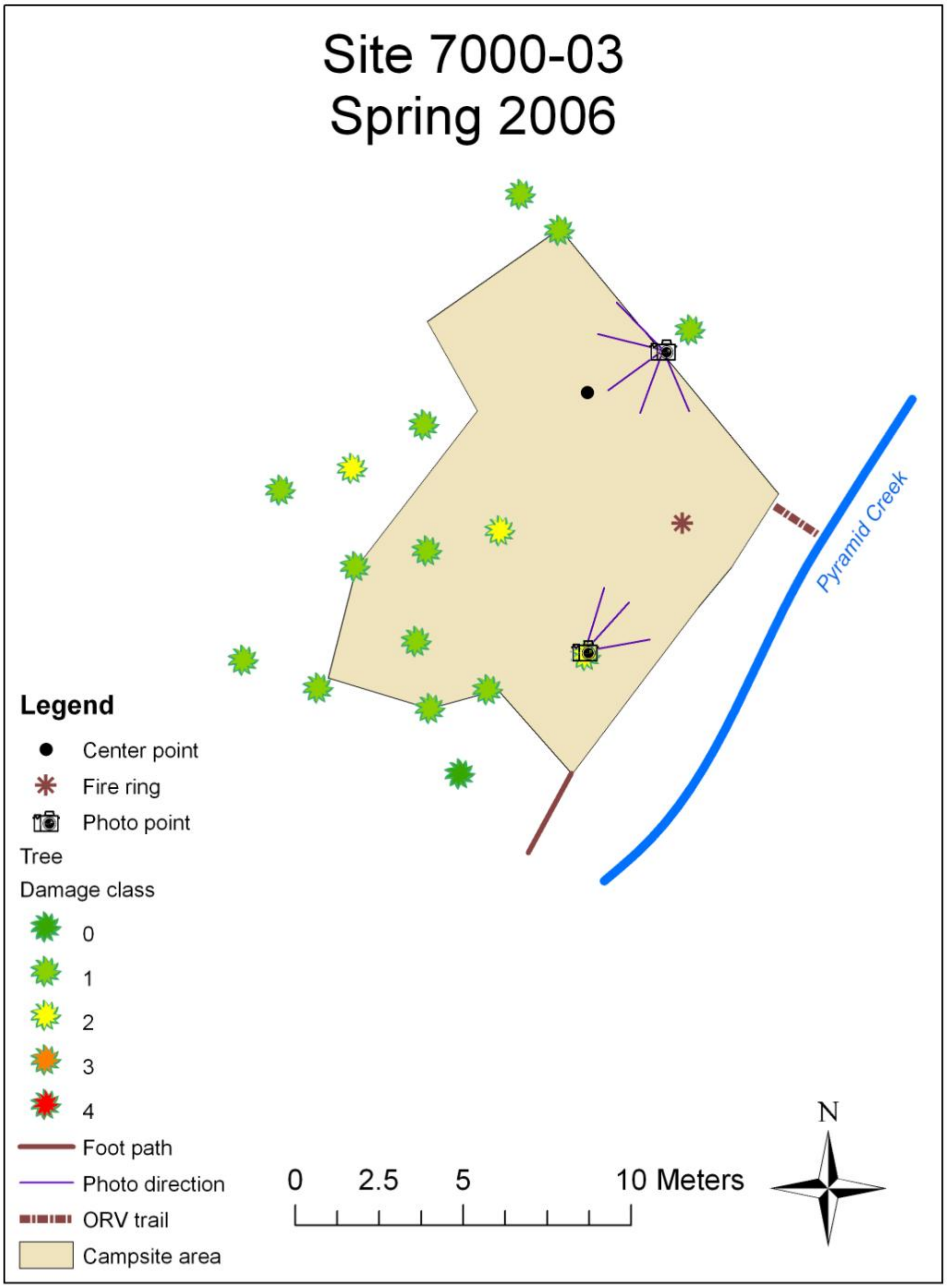

Figure 47. Map of campsite #7000-03, spring 2006.

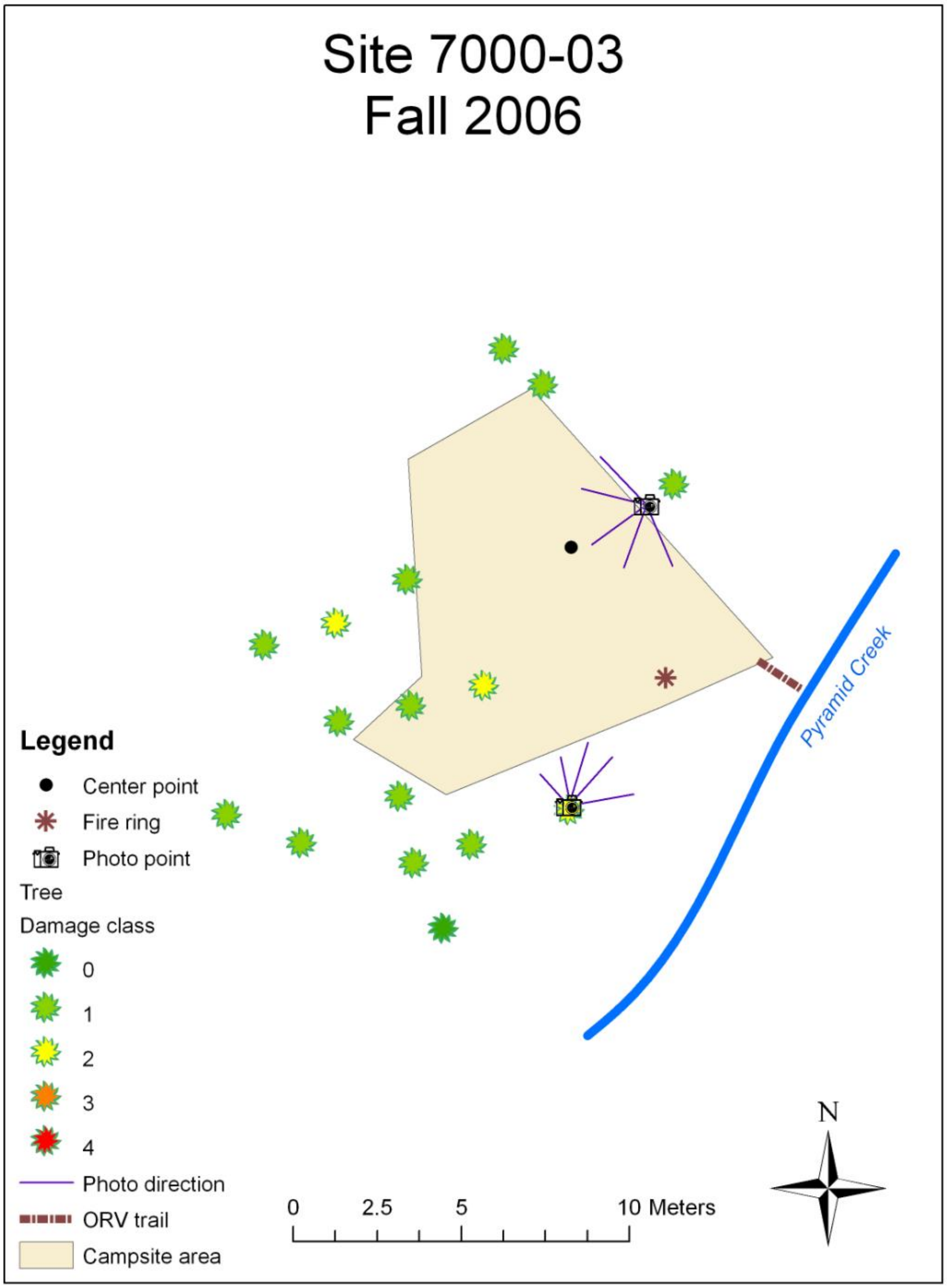

Figure 48. Map of campsite #7000-03, fall 2006.

Figure 49. Spring (top) and fall 2006 photos of site 7010-02. Note seasonal vegetation changes.

Figure 50. Spring (top) and fall 2006 photos of site 7030-04.

Figure 51. Spring (top) and fall 2006 photos of site 7031-04. Note installed fence and sign.

Figure 52. Spring (top) and fall 2006 photos of site 7000-01.

returning in the fall, however, grasses and forbs had been trampled or had entered dormancy for the dry late summer/early fall season. Regardless of the season in which monitoring data collection occurs in the future, managers should assure that the sites are measured at a consistent time of year to avoid errors stemming from seasonal vegetation fluctuations (Hall, 2001).

Many of the campsites in the Greenwater study area were quite large. While long term size data is not available, my informal observations over the course of the summers of 2005 and 2006 indicated that several of the sites were in the process of being enlarged by users. Campsite users cut, dug, or ran over established alder and willow thickets, and often parked vehicles on grasses and forbs around the periphery of the sites. Over the course of several years of monitoring, these modifications could result in measurable changes in average campsite size, or they could be offset by little-used areas of campsites that recover naturally.

Challenges

Three notable challenges presented themselves over the course of the spring and fall monitoring sessions. The first challenge was establishing secure monuments from which to take radial measurements proved difficult in heavily used campsites. While taking reverse bearings from notable trees or other landmarks proved a fair method, semi-permanent sub-surface monuments would likely be more reliable over the long term. A piece of rebar countersunk below grade would have worked in most sites, assuming the surveyor used a metal detector upon revisiting the site. For this study, recreation managers requested that I not install rebar, since it could eventually pose a safety hazard if left in place.

The second challenge involved leaf-out and new growth of trees surrounding the campsites. Over the long term, photo monitoring of sites treated with vehicle barriers may become increasingly difficult because of encroaching vegetation. Fast-growing trees such as alder, willow, and cottonwood are common along the Greenwater River, and once they are no longer cleared to make room for vehicles, they will likely make consistent photo monitoring difficult. While leaf-out did not pose a threat to quality of the baseline data, repeated photo monitoring may be difficult.

The third challenge is in delineating the campsite from the surrounding area, or one campsite from a nearby but independent campsite. Measured campsite areas varied from spring to fall measurements (Table 8). All campsite boundary measurements are prone to surveyor error, but additional factors added to variable measurements over the season. Some campsites in the study area have multiple fire rings, several suitable tent sites, and several general areas that have been used as the central camp. For example, one large campsite (7031-04) was in use every weekend during the summer, but seldom followed the same pattern of use. On busy weekends, up to three separate parties occupied the campsite, and remained independent of each other, with separate campfires and gathering areas. On other weekends, the same site was occupied by groups ranging from a few people to forty, all using the same campfire area. Satellite areas were obviously associated with the main camp, but seemed to serve only as occasional tent sites based on informal observations over the summer. The surveyor must decide for each site what constitutes the primary campsite area and what constitute peripheral impacts. Some researchers (e.g., Kangas et al., 2007), have simply omitted satellite areas, but have not provided criteria with which to distinguish satellite areas from the primary camping area. Consistency was a challenge for me with just four months between visits; with multiple surveyors over several years, consistency will be a serious problem. Even with the challenges presented by monitoring campsites, it will be an important campsite management tool in the future.

Table 8.
Campsite Area Measurements, Spring and Fall 2006, and Potential Explanations of Differences

	Campsite area (m^2)		
Campsite	Spring	Fall	Potential explanation (in addition to measurement error)
7010-01	192.7	192.6	Boundary poorly defined in duff.
7010-02	396.0	527.8	Seasonal variation in grasses and forbs.
7010-03	98.5	149.4	Seasonal variation in grasses and forbs.
7030-01	150.9	111.7	Delineation between campsite and access road.
7030-02	588.0	547.3	Boundary poorly defined in duff, delineation between campsite and access road.

Table 8 (continued)

Campsite	Campsite area (m^2) Spring	Fall	Potential explanation (in addition to measurement error)
7030-03	107.8	230.4	Seasonal variation in grasses and forbs, delineation between campsite and access road.
7030-04	265.2	317.9	Seasonal variation in grasses and forbs.
7031-01	195.5	130.3	Seasonal variation in grasses and forbs.
7031-02	349.6	328.0	Seasonal variation in grasses and forbs.
7031-03	444.3	685.7	Seasonal variation in grasses and forbs.
7031-04	1,498.6	2,061.5	Seasonal variation in grasses and forbs, delineation between campsite and satellite areas.
7031-05	--	110.0	No spring data collected.
7000-01	263.3	315.1	Boundary poorly defined in duff, delineation between campsite and access road.
7000-02	363.5	367.2	Seasonal variation in grasses and forbs.
7000-03	114.9	79.1	Boundary poorly defined in duff, delineation between campsite and access road.

CHAPTER VI

CONCLUSIONS, MANAGEMENT RECOMMENDATIONS, AND FURTHER RESEARCH

Conclusions

Based on my observations and analysis, the low-cost, low-impact barriers and signs installed as part of this research were effective in preventing vehicle access to riparian campsites in the Greenwater River Watershed. With one exception, I found the fences in place and functional before, during, and after busy weekends during the summer of 2006. While vehicle access could still be gained by dedicated, intentional disregard for the posted appeals and regulations, this did not seem to be the norm. Campers that insist upon driving on streambanks and/or into streams will likely only be stopped by impassable, immovable barriers.

Anecdotal evidence in the Cle Elum Ranger District of the Wenatchee National Forest, showed that intermediate measures such as arranged logs and smaller boulders were completely ineffective at reducing vehicle traffic to riparian areas. Determined campers would simply drag the obstruction out of their way with vehicles and set up camp. In contrast, the lightweight fences employed in this project were found intact at every weekend visit during the summer. This could have been the result of any number of variables involved, but does indicate that fences may be a better intermediate step toward a permanent vehicle barrier than small boulders and logs.

Campers' opinions and preferences gathered with the in-person survey tended to support active management of dispersed campsites, but not at the expense of a semi-natural setting. Many campers exhibited a strong sense of place for their particular campsite, having visited the area, and sometimes the individual campsite, for decades. This sense of ownership, however, often failed to translate to truly responsible behavior (e.g., parking and camping away from the stream bank). In most cases, campers seemed willing, and even enthusiastic, about changing behaviors that they learned were degrading the function of the ecosystem.

Long term biophysical monitoring would be necessary to gauge the effectiveness of fences in passively reestablishing a native riparian vegetation community. Given campers' stated preferences, however, a more permanent solution to vehicle traffic, such as large, countersunk boulders, would likely be more effective and better received by campers. Anecdotal evidence from other watersheds indicates that boulders, if large enough and properly installed, effectively prevent vehicle access to dispersed riparian campsites, but I could not find any systematic evaluation of barriers during the literature review.

Management Recommendations

Campsite Access Management

I recommend using lightweight fences and temporary signs only as intermediate measures while funding is secured and permitting is completed for longer lasting measures such as countersunk boulder barriers and permanent signs.

Resource managers with the Forest Service and campers expressed surprise throughout the season at the apparent success of the wood fences. Most fences remained unmolested for the duration, with little evidence of vandalism or modification by user groups. Interviewed campers had generally favorable opinions on the fences. The fences should, however, be considered a temporary measure at most. Long term durability of the fences is questionable, even without vandalism; snow, wind, high humidity, wildlife, and sun will eventually destroy them. Vandalism may also increase with decreased enforcement presence in late fall, winter, and early spring months. As individual fences begin to deteriorate without maintenance, campers' temptation to remove or vandalize them may increase. While the fences are inexpensive, easy to install, and accepted by campers, they are not a long term solution to vehicular damage to riparian areas.

Ultimately, the most beneficial use of low-impact, low-cost wood fences may be as temporary stop-gap measures to reduce vehicle impacts and increase user awareness until more permanent solutions can be implemented. They can be installed throughout a small watershed in just a day or two of work, without heavy equipment, and with little material cost. Once funding is secured for boulder installation, they are easily removed to make way for the boulders. In the Greenwater, visitors would likely view the boulders as a direct result of their input, providing increased feelings of ownership for their sites.

Large boulders have been used extensively by the Forest Service and other land management agencies to control vehicle access in recreation areas. Unlike fences, adequately sized and seated boulders should require little or no maintenance to remain effective. Users interviewed in this study also preferred boulders over all other management actions, suggesting that boulders present an opportunity to improve the camping experience of visitors while protecting sensitive streambanks from vehicle damage. Boulders present logistical and economic obstacles, though, and might only be possible for cash-strapped public agencies through partnerships with local businesses, environmental and recreational non-profits, and grant-funding programs. Boulder placement also requires greater permitting and regulatory compliance, depending on the implementation location. As a federal agency, the Forest Service is required to comply with the National Environmental Policy Act (among other regulations) for any major action that significantly affects the quality of the human environment. While some locations may be categorically exempt (e.g., for road maintenance), others may require an environmental assessment costing tens of thousands of dollars and consuming months of staff time to complete.

Boulders must be large enough and anchored deeply enough to prevent movement with light trucks with winches and chains, but no standard specifications have been developed for this purpose. Concerted efforts by bored and/or intoxicated campsite occupants have moved large rocks from former vehicle trails in nearby watersheds, and the Greenwater Watershed would likely be no different. A combination of inexpensive educational plaques and in-person visits by Forest Service or other educational staff would also reduce the probability of vandalism to the boulders (Christensen & Davis, 1984; Johnson & Swearingen, 1988; Martin, 1992; Oliver et al., 1985; Swearingen & Johnson, 1995).

Other campsite access management measures such as guardrails and cement eco-blocks are not recommended if camping is to be allowed. Campers reacted very negatively to both of these options. Most found them ugly, or incongruent with the natural landscape. Guardrails are not as cost-effective as native boulders or wood fences, and many respondents commented that guardrails did not seem to welcome campers. Eco-blocks met with similar comments, and have the additional shortcoming of being relatively easy to move. One respondent commented that he could roll them over by hand by using a two-by-four as a lever; another commented that he had dragged them with his pickup. Guardrails and eco-blocks, therefore, do not seem to be promising options.

As an alternative strategy, fences and signs installed and removed annually, and then monitored weekly, would provide an easy avenue for Forest Service employees to visit each site and talk with campers in the area without regulatory overtones. Simple campsite monitoring methodologies such as Frissell's (1978) can be implemented by seasonal staff when installing or removing the barriers, forming a comprehensive database with little effort.

Education and Outreach

I recommend employing in-person education and outreach in combination with small, unobtrusive signs at individual campsites to take advantage of the benefits of both (Christensen & Davis, 1984; Johnson & Swearingen, 1988; Martin, 1992; Oliver et al., 1985; Swearingen & Johnson, 1995). Most respondents were repeat visitors to the watershed, and many had been visiting the watershed for generations, so educating the general public is unlikely to be efficient, given the dispersed zip code origins of campers. Campers also reported learning about rules and regulations from friends, relatives, and other campers, so an effectively delivered message would likely have a snowball effect within the groups that often camp together.

Firewood

For camping to remain compatible with sustainable land management goals, campfires will likely need to be more restricted. I recommend limiting or eliminating wood gathering for campfires in the Greenwater Watershed, as is common practice at developed campgrounds. Most heavily used campsites have very little suitable firewood nearby. Decades of use have left the ground bare of dead wood, forcing would-be firewood gatherers to travel farther from their campsites to gather wood and to gather wood from inappropriate sources. Green trees are often felled, even though they burn poorly. Campers also gather wood from engineered log jams or human-placed in-stream wood designed for fish habitat enhancement. The bulk of campers reported that they would still camp in the Greenwater watershed if they were required to bring their own wood, so restrictions are unlikely to be controversial. Finally, requiring campers to import wood would support a local market while reducing camping-related ecosystem impacts.

Alternatively, an upland area could be identified for wood gathering for campers. This would provide campers with a resource-gathering experience, and provide greater flexibility than requiring wood importation. Unfortunately, with either measure, a certain level of illegal or irresponsible wood gathering is likely as long as campfires are permitted. Fires are an integral part of the dispersed camping experience, and as such, banning them would be highly unpopular with campers. At a minimum, Forest Service employees should educate campers in-person or through flyers or signs regarding responsible firewood gathering.

Biophysical Campsite Monitoring

I recommend periodic monitoring of campsites to identify areas that should be restored, treated with vehicle barriers, or closed outright. Biophysical site monitoring is time- and resource-intensive, requiring many hours of staff time that is currently in short supply in the Forest Service. Monitoring, however, will support arguments for effective campsite management. With compelling results, grant funding and region-level support will be easier to leverage for ranger district-level resource managers. Significant results will likely take several years (Cole & Spildie, 1999). Monitoring every 3 or 4 years, instead of annually, will return results while minimizing the staff time required (Cole, 1989c). Non-profit partnerships and volunteer involvement may also be beneficial in achieving monitoring goals without expending large amounts of staff time.

Besides monitoring change, an inventory and digital map of heavily used sites would be beneficial for bringing new employees up to speed and for coordinating between the various disciplines (natural resource management, recreation management, fire prevention, and law enforcement) within the Forest Service. Many of the front-line public contact rangers are seasonal employees, and positions tend to experience high turnover. Maps and inventories would reduce the learning curve associated with new employees early in the summer.

Further Research

Barriers and Signs

As an outcome of the preliminary results of this research, and funding from Pierce County Surface Water Management, several sites in the Greenwater Watershed were treated by the Forest Service and South Puget Sound Salmon Enhancement Group with large, countersunk boulders. Using the same in-person survey materials, another researcher could perform follow-up surveys throughout the watershed to determine users' satisfaction with these more permanent solutions. While preliminary results indicated that campers favored the boulder treatment, actual opinions of the campsites after treatment may have substantially changed.

The signs used for this research were developed with input from Forest Service staff from two National Forests, and were based on anecdotal evidence that suggested that a regulatory message paired with an explanation of the management action, provided good results in camper compliance. An image of an American flag was suggested by another Forest Service employee to reduce vandalism. Recreation management literature has established a body of knowledge in sign message effectiveness, but results are inconsistent, at best.

Future research to determine the best sign designs and messages for front-country dispersed camping use would be helpful in guiding decisions by recreation managers.

Finally, since the barriers used in this study were so easily removable, a study to determine whether the signs alone would have caused the same effect would be helpful. If the signs provide the same benefits, the fences could be left out of the campsites, saving time and money.

Camper Surveys

Campers were generally enthusiastic about participating in the survey, expressing interest in most of the topics covered. Future research examining demographics and interests of the dispersed camping community in other watersheds would be helpful in forming watershed-specific resource management policies that protect sensitive areas while improving the recreational experience of campers. In some cases, surveys may also front-load restoration actions in a watershed like the Greenwater where many of the campers return year after year to the same area or campsite.

Campsite Monitoring

As geographic information systems (GIS) become more sophisticated and accessible, researchers will be able to easily monitor impacts over larger spatial scales. Watershed-wide campsite monitoring with interval-level data would be a realistic goal for one or two seasonal employees. Hand-held global positioning system (GPS) units are increasingly accurate, and will soon provide affordable, engineering-grade surveys for large areas. Research in longitudinal, watershed-wide impacts from dispersed camping is ripe for exploration.

While sophisticated GPS equipment will soon likely replace methods relying on compass and measuring tape, the issue of surveyor bias and campsite boundary delineation remains problematic. A larger scale power analysis than attempted by Cole (1989c) applied to front country campsites would allow recreation managers to make informed decisions on the value of interval-level data collection and analysis versus a faster, cheaper condition-class assessment of campsites by developing guidelines for how much change is necessary before it will be reliably detected.

Existing monitoring protocols that include mapping could be improved with the addition of a third dimension to predict runoff patterns, bank failures, and the likelihood of flooding. Simple, two-dimensional maps fail to capture the complex nature of many riparian campsites, which are located in dynamic fluvial environments. Soil analysis would be helpful, especially those for which vegetation is heavily seasonally influenced. Some monitoring protocols suggested by Cole (1989c) utilize soil penetrometer to judge compaction along transects. Soil water infiltration rates could also be measured using infiltration rings to inform runoff estimates and judge soil suitability for vegetation recovery.

As an alternative to time-intensive interval-level data, resource managers should consider a simple, condition-class method such as Frissell's (1978) to develop a qualitative data set at broader geographic scales. While condition-class methods lack the detail necessary for statistical analysis, the level of information gained may be adequate for decision support.

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APPENDIXES

Appendix A

Survey Instrument, Introductory Statement, and Take-Home Flyer

Survey #____________ Date_____________ Site________________ Weather________________

Greenwater River Survey Instrument
Central Washington University and Mt. Baker-Snoqualmie National Forest

1. What is your home zip code?

2. How many people in your group fall into each of the following age categories?

Male	0-5 yrs:	6-17:	18-29:	30-54:	55 and over:

Female	0-5 yrs:	6-17:	18-29:	30-54:	55 and over:

3. I am going to read you a list of types of vehicles. As I read each one, please tell me how many of that type of vehicle your group brought on this trip.

Passenger car:	Pickup truck:	SUV:	Van:
Pickup camper:	Tent trailer:	Camper trailer:	Motor home:
Other trailer:	Trail motorcycle:	4-wheeler/quad:	Other:

4. How many nights (if any) will your group occupy this site on this trip?

Day use	1 night	2 nights	3 nights	4 nights	5 nights	6 nights	7+ nights

5. Have you personally visited this watershed before? The watershed includes lands accessed by Forest Road 70 and spurs, such as Forest Road 7010.
If No, skip to question 6.

Yes	No

5a. During what year was your first recreation visit to the Greenwater watershed?

5b. How many times, total, have you visited this watershed?

6. On the following scale, how do you rate this campsite?

Very good	Good	Fair	Poor	Very poor

7. I am going to read you a list of reasons that might have played a role in your choice of this campsite. After each item, please say "yes" if it was a reason you chose the site, or "no" if it was not a reason you chose the site.

Near water	Shade	Sun	Near fishing
Near swimming	Near paved roadway	Privacy	Natural setting
Availability of Firewood	Other sites were full	Tradition	Other:

8. I am going to read you a list of activities that may or may not have been reasons for your decision to camp in the Greenwater watershed. After each item, please say "yes" if it was a reason for camping here, or "no" if it was not.

Camping	Picnicking	Swimming	Wading
Sunbathing	Fishing	Hunting	Orienteering
Gathering berries, mushrooms, or other forest products.	Sitting around a fire	Relaxing	Other:

9. Would you still camp here if you were required to bring your own firewood?

Yes	No

10. On the following scale, how concerned are you about the condition of areas used for recreation in the Greenwater watershed?

Very concerned	Slightly concerned	Not concerned

If not concerned, skip to question 11.

10a. What concerns you about the recreation areas in the Greenwater watershed?

11. In which of the following ways would you like to see this area changed?

More informational signs	Informational flyers at base of Forest Road	Garbage cans/ dumpsters	Toilets/outhouses
Picnic tables	Permanent fire rings	Increased fishing opportunities	
Designated parking	Cleaner campsites	Grassier campsites	Other:

12. In an effort to improve water quality in this watershed, the Forest Service is considering a variety of options to protect sensitive shorelines from vehicle damage. Looking at the sheet of photographs I have given you, what are your two favorite options? What two options are your least favorites?

Top two:

Bottom two:

13. I am going to read you a list of forest-related topics about which forest rangers could inform you during a campsite visit. After each topic, please say "yes" if you would like to learn about the topic from forest rangers, or "no" if you are not interested in learning about the topic from forest rangers.

Rules/regulations	Fire levels/burn bans	Water quality	Potential threats
Area hiking trails	ORV recreation areas	Local fishing	Local hunting
Natural history	Plants	Animals	Ecosystems
Low-impact camping practices	Catch-and-release fishing practices	Job opportunities	Other:

14. Which of the following do you use to learn about forest rules and regulations?

Signs	Rangers	Ranger Stations	Radio
Television	Newspaper	Internet	Other:

Greenwater River Survey Instrument
Introduction

Hi, my name is Eli Asher; I'm a graduate student in the Resource Management Program at Central Washington University. I am interviewing campers in this area as part of my master's thesis research. I would greatly appreciate ten minutes of your time to tell me about your camping experience here by answering a handful of questions. Participation is completely voluntary, and you can stop the interview at any time for any reason. You will not be identifiable or linked to your answers.

If campers agree to participate:

I will be asking you a variety of questions about your camping experience in this area. When I refer to this "watershed," I am talking about the areas accessed by Forest Road 70 (the main road along the Greenwater River) and all spurs that branch off of Forest Road 70. For example, spur road 7010, which leaves Forest Road 70 and follows Midnight Creek for about a mile upstream.

CENTRAL WASHINGTON UNIVERSITY

Greenwater River Restoration Demo Project

Thank you for agreeing to participate in my Greenwater River master's thesis project. I sincerely appreciate your time and consideration. This project is a small part of an ongoing effort to improve water quality and fish habitat in the Upper White River Watershed. The Greenwater River and tributaries have been selected for this project because of their popularity with campers, the severity of damage inflicted by a few recreation users, and its habitat potential for salmon spawning and rearing. The Greenwater River currently sustains a naturally spawning population of coho salmon that rely on Forest Service-installed habitat improvements. Campers and other area users have damaged these structures and sensitive streamside vegetation (many unknowingly). Activities such as hacking, chopping, and shooting trees, driving vehicles on stream banks, and gathering large pieces of wood from the stream channel area all negatively affect water quality and salmon habitat. One of the Forest Service's purposes is to provide diverse recreational opportunities for the public; this project's goal is to determine the effectiveness and acceptability of low-impact fences to block vehicle access to stream banks in some of the most heavily impacted sites in the watershed.

Throughout this summer and following years, several environmental parameters are being measured in campsites in this area in an effort to find solutions to environmental problems that are acceptable to campers while still proving effective in protected threatened and endangered species in the area. If you have questions about this or other fisheries research projects, or would like to see the results of the project upon its completion, please feel free to contact either Eli Asher or Tyler Patterson at the North Bend Ranger Station (contact information below). Once again, please accept my sincere thanks for your participation in this project.

Eli Asher, Graduate Student, Central Washington University (ashere@cwu.edu)

Tyler Patterson, South Zone Fisheries Biologist (tpatterson@fs.fed.us)
Mt. Baker-Snoqualmie National Forest
42404 SE North Bend Way
North Bend, WA 98045
(425) 888-1421

Appendix B
Biophysical Monitoring Site Form

Site Number ___________________ Date __________________ Surveyor _____________________

Site Form

Area measurements

Flag number	Bearing (degrees)	Distance (m)
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		

Damaged trees

Tree #	Damage class	Relative location

Fire rings

Diameter	Bearing	Distance

Photos

Photo point	Number	Bearing

Linear meters of non-vegetated streambank ______________

Human waste present _____yes_____no____

Garbage/trash description

____

Canopy description

____

Groundcover description

____

Social trail/road description

____

____

____

____

Notes

____

____

____

____

____

____

____

____

Site Form Instructions

Flags: Insert flags in numerical order (starting with #1) (at least 10, no more than 20) into soil where primary site boundary changes direction. Find site boundary by examining vegetation breaks (e.g., grass or moss gives way to trampled soil, or changes in duff layer (e.g., mostly whole leaves and twigs change to crushed leaves and twigs).

Center point: Locate center point at a stationary point, such as a prominent stump, or drive rebar below surface of soil. Mark center point on site form and photos.

Area measurement: Record compass bearings from center point to each flag. Measure and record distance in meters to each flag from center point.

Damaged trees: Record location (relative to flags) and class of all trees larger than eight inches diameter at breast height within three meters of the primary site boundary into the following four classes:

- Class 0: little or no human-caused damage
- Class 1: light damage, including nails, chop marks, superficial saw marks, knife holes, etc., that does not extend significantly beyond the bark layer into hard wood.
- Class 2: moderate damage that extends into hard wood, but does not exceed 25% of the circumference of the tree trunk.
- Class 3: serious damage that extends into hard wood, and exceeds 25% of the circumference of the tree trunk

Fire rings: Record location (relative to center or flags) and diameter at widest point of all fire rings.

Photos: Find two photo points (permanent features), visible to each other, from which to photograph site. Record photo point, compass bearing, and file/frame number of each photograph.

Canopy description: approximate canopy closure (0-25%; 26-50%; 51-75%; 76-100%), predominate tree types.

Groundcover description: approximate cover (0-25%; 26-50%; 51-75%; 76-100%) and type of grass, moss, forbs, etc.

Roads/trails: Record location (relative to flags) of access roads and social roads/trails into and out of campsite, and classify them as follows:

- Class 1: social foot trail; duff, grass, or moss intact
- Class 2: social foot trail; mineral soil exposed
- Class 3: former vehicle access/social trail, duff, grass, or moss regenerated
- Class 4: current vehicle access/social trail, some duff or groundcover (>50%)
- Class 5: current vehicle access, mineral soil or cobble exposed, little (<50%) duff or groundcover present

Linear meters of non-vegetated stream bank: Measure non-vegetated stream bank associated with campsite with meter tape and record.