

ECOLOGICAL RESEARCH ASSESSMENT FOR THE ROARING FORK WATERSHED, COLORADO

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EXECUTIVE SUMMARY

The purpose of this assessment is to review existing research, identify available spatial data sources, and suggest topics for future study that are particularly relevant to the Roaring Fork Watershed, of west-central Colorado. This assessment is not intended to cover all ecological concepts in great depth or suggest detailed research projects but rather to provide a biological focus for the Board of the Aspen Field Biology Laboratory (AFBL) to use when making decisions about how to allocate existing and future resources. The focus of this assessment does not discount the complex interactions of physical, climatic and biological processes that are operating at regional and global scales beyond the watershed, nor does it question the relevance of scientific research that has or will be conducted outside of the Roaring Fork Watershed. The issues presented in this report and suggestions for future research are intended to highlight topics that are particularly relevant to a region that is subjected to increasing impacts from a variety of sources including housing, recreation and climate change.

A wide variety of ecological issues influencing the Roaring Fork Watershed have been identified through the literature search and dialogue with biological professionals. Key ecological concepts repeatedly mentioned by resource managers and biologists consulted for this project included migration corridors, habitat fragmentations, habitat conditions and associated disturbance processes (e.g., fire regimes, invasive plants, and bark beetle outbreaks), altered hydrologic regimes, and global climate effects. Associations between these concepts were commonly noted, such as fragmentation of a habitat or altered hydrologic regimes leading to lowered habitat conditions. Subsequently, these broad concepts were addressed by describing a few examples of biological systems that are being stressed and accordingly could benefit from research. Issues relating to urbanization and recreation were repeatedly discussed and appear to be a common thread in the disturbance of a number of ecological processes.

A thorough literature search of studies conducted in this region up to the present time by state and federal agencies, environmental organizations, private consultants, and academic outlets identified over 50 documents that were reviewed for this assessment. In addition, a list of GIS database sources is presented for use by future investigators. Different spatial and temporal scales should be considered when designing research projects that will address concepts mentioned in this report. Finally, the ecological concepts identified for the Roaring Fork Watershed by this assessment are evolving systems, and should therefore be reassessed and updated regularly.

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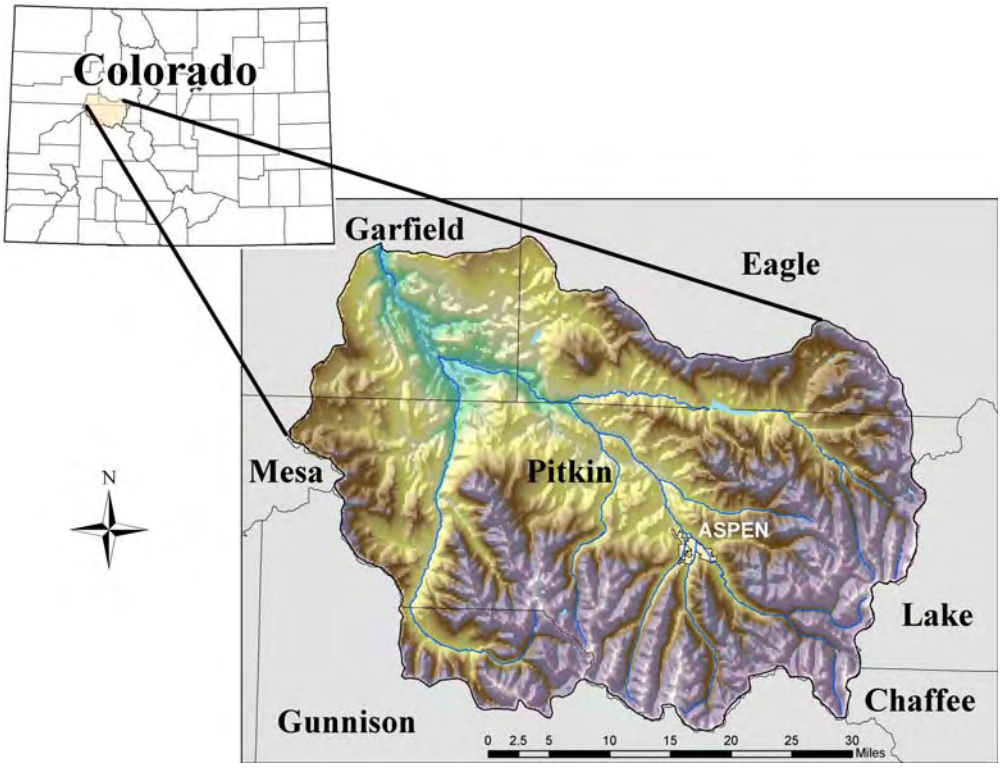
PURPOSE

The purpose of this assessment is to review existing research, identify available spatial data sources, and suggest topics for future study that are particularly relevant to the Roaring Fork Watershed of west-central Colorado. This assessment is not intended to cover all ecological concepts in great depth or suggest detailed research projects but rather to provide a biological focus for the Board of the Aspen Field Biology Laboratory (AFBL) to use when making decisions about how to allocate existing and future resources.

BACKGROUND

Area of Interest. The Roaring Fork Watershed is situated in the central portion of Colorado's Western Slope and is encompassed, to a large extent, by Pitkin County (Figure 1). The Roaring Fork watershed was selected as an appropriate area of interest for this assessment because it represents a hydrologic boundary that is important to federal, state, and public entities; incorporates the urban wildlife interface; and includes the "northern" portion of the Elk Mountains which are the primary focus of AFBL's research program. In this report, the designation of "northern" refers to the portion of the Elk Mountain range that lies to the north of the Pitkin/Gunnison County line and includes the Maroon Bells-Snowmass Wilderness (Figure 2).

Figure 1. The Roaring Fork Watershed lies within or adjacent to seven counties in the central portion of Colorado's Western Slope.



It should be noted that AFBL's founder, Bob Lewis, used the terms "northern" and "southern" Elk Mountains in connection with his proposal to establish an Elk Mountain Bioregion. Lewis believed the Elk Mountain Range had been inappropriately divided by the Pitkin/Gunnison County boundary in the 1880's, and that subsequent divisions of the region by the U.S. Forest Service did not support coordinated management of important natural resources. While the question of creating a larger Bioregion for the Elk Mountains remains, biological research conducted in the Roaring Fork Watershed and "northern" Elk Mountains only stands to compliment the extensive contributions of scientists working in the "southern" Elk Mountains with the Rocky Mountain Biological Laboratory in Gothic, Colorado. Coordination of field experiments and long-term monitoring throughout a broader region should also support adaptive management by Federal, State, and County Agencies.

The Roaring Fork Watershed is highly diverse due to the four life zones and seven ecosystems that exist here, and consequently harbors a variety of endemic or rare and imperiled species. In reference to a portion of the mountains found in the Roaring Fork Watershed Weber (1996) states, "The Elk Mountains, an essentially east-west-trending mountain range, has the richest mountain flora on the Western Slope" due to the region's diversity of life zones. The four life zones found within the Watershed include the foothills, montane, subalpine, and alpine, and are defined by certain plant communities and associated ecosystems (Huggins 2004). The foothills of the Roaring Fork Watershed typically include some mix of dryland grasses, sagebrush, Gambel oak, chokecherry and serviceberry. Montane forests are primarily willow, cottonwood and aspen trees. The subalpine zone is characterized by meadows and aspen trees mixing with the spruce-fir forest. The alpine zone is subject to extreme weather conditions that reduce the size and modify the structure of plants including Englemann spruce, subalpine fir, and Alpine willow.

Elevations within the Roaring Fork Watershed range from approximately 5,724 feet (1744m) to 14,265 feet (4,350 m). Consequently, the climate within the Roaring Fork Watershed consists of short summers that are cool and dry, and long winters that are cold and moist. Average minimum and maximum temperatures over the 15-year period from 1980-2005 at the Aspen weather station were 27.7 and 55.5 degrees Fahrenheit respectively (Western Regional Climate Center 2006). Average total precipitation and snowfall during this same period were 24.2 and 173.0 inches respectively.

Historically, lands within the upper stretches of the Roaring Fork Watershed underwent significant alterations from mining and timbering operations, and were later followed by agricultural activities in the valley bottoms. More recently, developments tied to recreational activities, such as ski areas, golf courses and trails, as well as residential and commercial developments, have become pervasive in the valley. Spackman et al. 1999 state, "These various land uses introduce problems associated with habitat fragmentation, hydrological alterations, non-native species invasions, and restricted fire regimes."

Key Players. Increases in urbanization levels in the Roaring Fork Watershed have made the public entity of great importance with regards to their ecological impacts on the surrounding environment. The political and urban centers likely to have the greatest impact on the Watershed are Pitkin County and the communities of Aspen and Snowmass Village. Public lands encompass approximately 83% of Pitkin County, with the majority managed within the White River National Forest (Figure 2). The Roaring Fork Watershed includes the Maroon Bells-

Snowmass, and portions of the Collegiate Peaks, Hunter-Frying Pan, and Holy Cross Wilderness Areas, and is largely encompassed within the White River National Forest (WRNF) and Aspen Ranger District (Figure 2).

The majority of private land, and consequently most of the current development, is situated in the productive valley bottoms and immediately adjacent slopes. Increased urbanization in these sensitive habitats has had detrimental impacts on their flora and fauna, especially on species that are less tolerant of such disturbances (Odell and Knight 2001; Odell et al. 2003). From 1960 to 1980 Pitkin County had a population growth of 16% and saw its agricultural lands reduced by half, before slowing to a 1% growth rate in the 1990's. While growth rates since 2000 have remained low, the percentage of housing permits has remained high at 8.1%. The city of Aspen enforced a building permit moratorium in 2006 because the pace of construction was too great to be absorbed and serviced by the community. In 2006, the US Census Bureau estimated Pitkin County's population at 14,900 people.

The White River National Forest is responsible for management of the largest proportion of land in the Roaring Fork Watershed with approximately 551,791 acres in Pitkin and Gunnison Counties (Figure 2, Table 1). This Forest is one of the oldest and largest in the National Forest System, with portions in 9 counties (Figure 3A). While the immense size of the White River National Forest provides excellent large tracts of wilderness managed by one agency, the issues facing the Forest are varied and widespread. The White River National Forest is managed by 7 districts with the Aspen Ranger District controlling the majority of management actions performed in the National Forests of the Roaring Fork Watershed (Figure 3B).

The Bureau of Land Management (BLM) manages several biologically important areas, mostly scrub oak habitat in the lower end of the watershed. Management of these fragmented parcels is performed by the Glenwood Springs Office and includes the 4,300-acre Thompson Creek Recreation Management Area near Carbondale. The Middle Thompson Creek area was designated by the Colorado Natural Heritage Program Inventory as an area of very high biodiversity threatened by recreation (Spackman 1999).

The Colorado Division of Wildlife (CDOW) manages all hunting and fishing activities in the Roaring Fork Watershed, which contains trophy elk herds and gold water fishing stretches along several rivers and creeks. Actions for the protection and recovery of a number of endangered or threatened species are being considered for this region (Appendix A). The CDOW also manages the Basalt, Coke Oven, and Watson Divide State Wildlife Areas in the Roaring Fork Watershed. In addition to managing wildlife and associated habitats, the CDOW is responsible for handling the increasing number of wildlife-human interactions and conflicts occurring in the Roaring Fork Watershed.

Figure 2. Federal land delineations in relation to the Roaring Fork Watershed.

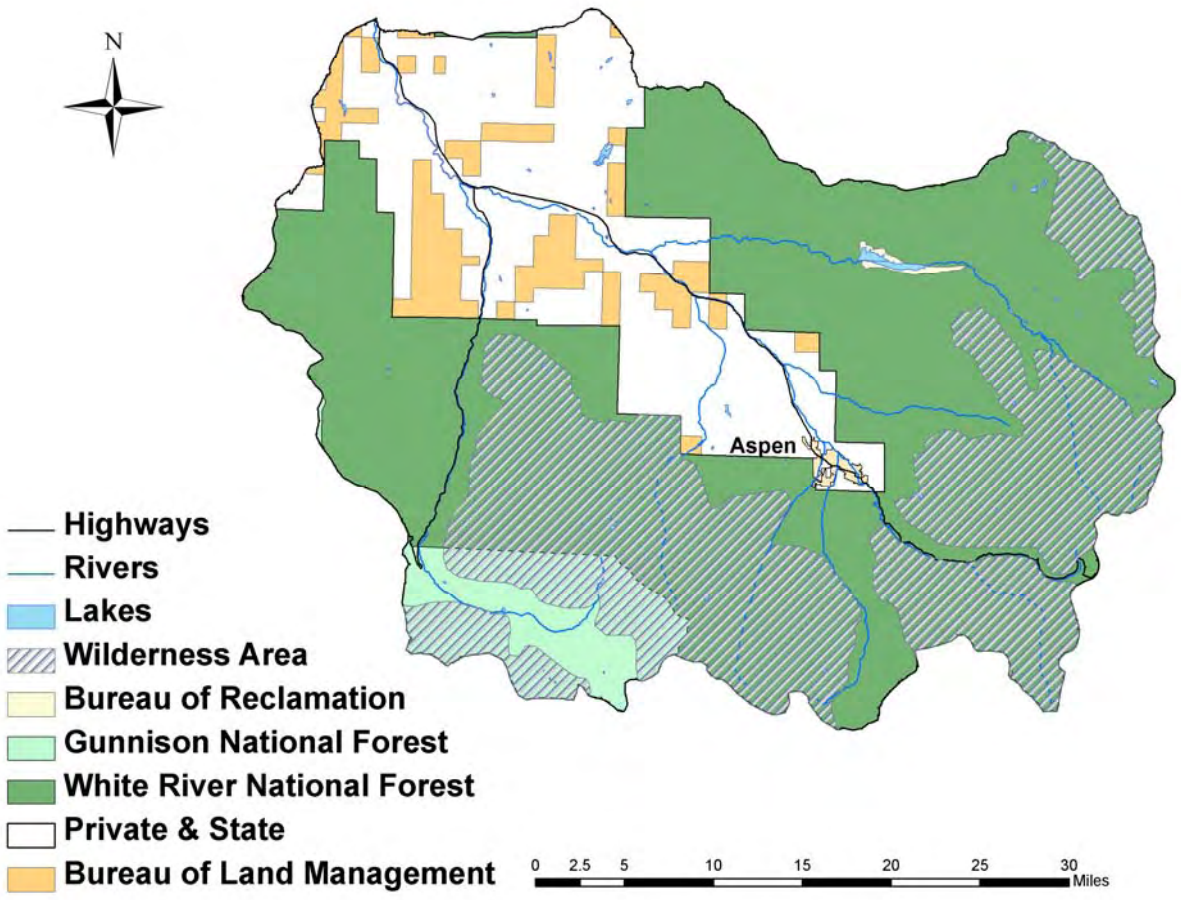


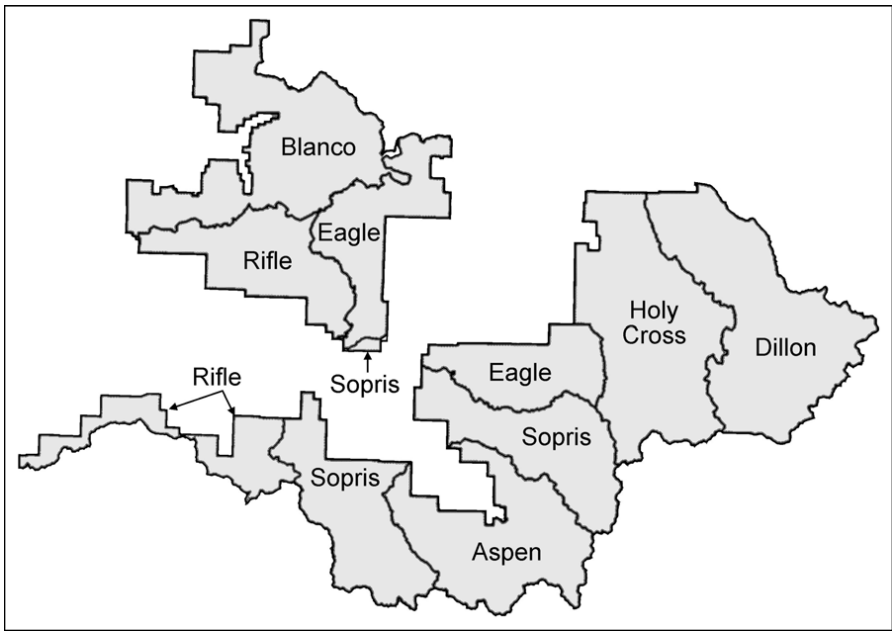
Table 1. Acres of National Forest System lands, by county, within the White River National Forest as of September 1997 (taken from the summary of the final environmental impact statement to accompany the White River National Forest Land and Resource Management Plan – 2002 Revision).

	County								
	Eagle	Garfield	Gunnison	Mesa	Moffat	Pitkin	Rio Blanco	Routt	Summit
Acres	595,542	478,628	60,880	83,069	3,679	490,911	247,318	6,128	309,671

Figure 3. Layout of the White River National Forest in Colorado with county boundaries (A) and ranger district delineations used for management of the Forest (B). Maps taken from USDA FS (2002).

A.

B.



Research in the Roaring Fork Valley. The majority of the research conducted in the Roaring Fork Watershed has been performed by federal and state agencies managing land in this region. Very little research has been conducted by outside organizations such as universities, with only one thesis identified as having its study area within the area of interest (see Odell 2000). Projects currently being conducted or recently completed in the area include a stream health assessment for the Roaring Fork Watershed (pers. comm. John Emerick and Dee Malone, Private Consultants), and a black bear (*Ursus americanus*) study investigating urban conflicts associated with these animals (pers. comm. Sharon Baruch-Mordo, Colorado State University). The Colorado Natural Heritage Program (CNHP) conducted a detailed biological inventory for the Roaring Fork Watershed (Spackman et al. 1999), and local environmental organizations such as Wilderness Workshop (WW) and Pitkin County have partnered in such projects. This inventory should be considered a vital conservation reference for future researchers. It can be used to make decisions on the status of species and areas of focus in the Roaring Fork Watershed. See Appendix A for a complete list of fauna and flora of concern, potential conservation areas, and descriptions of designation methods identified and used by the CNHP survey. The City of Aspen, Snowmass Village, and the various ski resorts in the area have contracted a number of additional surveys to private consulting firms (e.g., Heede 2006). Historically, many of the investigations conducted by the federal and state agencies have been in response to recreation issues, such as ski area expansions and trail construction. Finally, sporadic surveys of flora and fauna have been conducted in the Roaring Fork Watershed by a host of biologists during the past century. Most of these projects were focused on documenting ranges for species, with specimens deposited in museums around the country and site location records published mainly in natural history books (e.g., Fitzgerald 1994).

As of 2006 and some 75 years after its founding, the Rocky Mountain Biological Laboratory (RMBL) near Gothic, Colorado has become renowned for its contributions to high altitude research and education in the Elk Mountains with thousands of published works contributed by its visitors (citations listed on CD insert). Unfortunately, RMBL's visitors have not studied northern portions of the Elk Mountains with the same intensity and rigor as the southern parts of this range. This lack of information is particularly important due to recent changes associated with rapid urbanization, transportation, and recreation, all of which impact wildlife habitats and deplete natural resources in the Roaring Fork Watershed. Bob Lewis, a biologist, inventor and educator from Aspen, Colorado noticed this lack of knowledge and subsequently initiated a variety of education, research, and conservation projects throughout the Roaring Fork Watershed over the period of 55 years. In 2003, Lewis continued his efforts by creating a Colorado non-profit Corporation called the Aspen Field Biology Laboratory (AFBL). Today the AFBL is continuing efforts to support applied field research in the northern Elk Mountains and Roaring Fork Watershed by hosting the Roaring Fork Stream Health Initiative and black bear-human interactions studies mentioned above. In the future, AFBL plans to continue its support of important ecological studies in the Roaring Fork Watershed through grants and the Bob Lewis Fellowship awards.

SCIENTIFIC LITERATURE IDENTIFICATION

Efforts to identify scientific literature based on research conducted in the Roaring Fork Watershed were carried out through several channels. Some unpublished, privately contracted, or city-conducted reports are not listed in this report due to difficulty in obtaining them. A list of identified scientific literature, both peer-reviewed and grey literature, is provided in Appendix B. The following search methods were used to identify scientific literature or research conducted in the Roaring Fork Watershed:

Search of online research databases:

1. Wildlife & Ecology Studies Worldwide – 1935 to present; worlds largest index to literature on wild mammals, birds, reptiles, and amphibians; covers all aspects of wildlife and wildlife management; updated quarterly

2. Biological Abstracts – 1969 to present; index of all literature in the biological sciences, updated bi-monthly

Search of library catalogs:

1. Colorado State University, Colorado Division of Wildlife, and U.S. Geological Survey Fort Collins Science Center Library catalogs – includes all books, reports, publications, management plans, etc. pertinent to the Roaring Fork Watershed

2. Rocky Mountain Biological Laboratory Database of journal publications, books, book chapters, and theses conducted at the laboratory in the Southern Elk Mountains of Gunnison County (link: http://www.rmbl.org/). A PDF containing 1,272 citations from this website is provided on the accompanying CD (see file RMBL Lit List).

Communication with local experts:

1. Queried White River National Forest, Bureau of Land Management, Wilderness Workshop, and Colorado Division of Wildlife biologists from the area of interest in regards to what research had been conducted in the Roaring Fork Watershed. See Appendix C for a list of local biological experts that provided input for this assessment.

PROPOSED ECOLOGICAL RESEARCH TOPICS

A wide variety of ecological issues facing the Roaring Fork Watershed have been identified through the literature search and dialogue with biological professionals. These issues are presented in this section along with some suggestions for research topics that may address them or provide future guidance to the land managers working in this area. In order to identify which systems (or conservation targets within these systems) are under the greatest conservation threat, the Nature Conservancy's conservation strategy (referred to as the 5-S Framework) was used. The 5-S Framework first identifies which *Systems* are the conservation targets. The target may range from something as simple as an endangered species to a more complicated system, such as an ecological community (i.e., groupings of co-occurring species that are dependent upon one another). *Stresses*, or the second "S", are the types of actions lowering the viability of the conservation targets (e.g., disturbances leading to lowered elk reproduction). *Sources* of the stress are the action causing the degradation (e.g., recreating on hiking trails through sensitive elk calving grounds during calving periods). In the case of the Roaring Fork Watershed the systems or targets, stresses, and to some degree sources, have in principal been identified by the land managers during dialogues, and by the CNHP's "Roaring Fork Watershed biological inventory 1997-1999" (Spackman 1999). The CNHP inventory alone identified 28 targeted plant species, 19 targeted animal species, and 29 significant plant communities, which led to the designation of 55 potential conservation areas (Appendix A). However, in what manner the identified sources are stressing these systems or targets, and to what degree they are being stressed is largely unknown. Once the manner and degree in which the sources are stressing the systems have been identified through research, the managers of these lands can then consider proper *strategies* and *success measures*.

Migration Corridors & Habitat Fragmentation

Determination of migration corridors and effects of habitat fragmentation involving a variety of species were ecological concepts repeatedly expressed to be of high interest to managers and biologists working in the Roaring Fork Watershed. Migration corridors provide safe connections between core areas of an animal's habitat such as summer and winter ranges. Insight into migration corridors may aid land managers in making decisions on which areas to assign conservation status, and where to reduce recreation (at least seasonally). Species of particular interest include but are not limited to elk (*Cervus elaphus*), mule deer (*Odocoileus hemionus*), lynx (*Lynx canadensis*), and potentially wolverines (*Gulo gulo*) and wolves (*Canis lupus*). In the northern Elk Mountains, elk using the Snowmass Village area are of particular interest due to highly altered migration corridors and significantly fragmented wintering grounds. Baseline work conducted for the Snowmass Ski Area Final Environmental Impact Statement (USDA-FS 1994) stated "The Town of Snowmass Village residential and commercial development, combined with ski area development, has significantly reduced the elk migration corridor to approximately ten percent of its size in 1966". In addition, construction of fences and roads into new developments since 1994 has further exacerbated the problem. Current wildlife management practices suggest avoiding construction of potential barriers such as roads in saddles, meadows, riparian zones, ridges, and other areas used as wildlife travel corridors (Mannan et al. 1996). However, many roads and trails were built before such knowledge was gained, or were developed because economic pressures were given priority. Therefore, research that provides insight into how such obstacles to migration currently affect the wildlife in these areas is greatly needed. Intensive radiotracking studies (likely to use satellite radio collars) will

need to be conducted over all seasons in order to identify where the corridors are located and when they are being used by these species. A study funded by the Town of Snowmass Village on elk movements was initiated but never compiled into a final report or publication. Therefore some baseline data may be available to supplement new research on elk migration.

Fragmentation of healthy habitat, particularly in the lower elevations of the Roaring Fork Valley, should be considered one of the largest threats to wildlife at the present time. As urbanization continues to increase in the Roaring Fork Valley, the likelihood of good wildlife habitat being further fragmented will continue to rise. Urbanization can have serious fragmentation impacts on landscapes through road and utilities development, demands for water consumption, use of space by buildings, etc. Such fragmentation may lead to the loss of migration corridors (see above) or to the abandonment of an area altogether. As a result of private land and ski area development, elk calving habitat has been reduced in availability and quality, particularly in the Snowmass Village area (USDA-FS 1994). Research is needed to determine if elk populations that have been displaced from historic calving grounds have decreased in numbers or are experiencing lowered health. In addition, both historic and replacement habitats should be evaluated for a variety of ecological factors including but not limited to fragmentation, vegetation condition, sustainability, and carrying capacity.

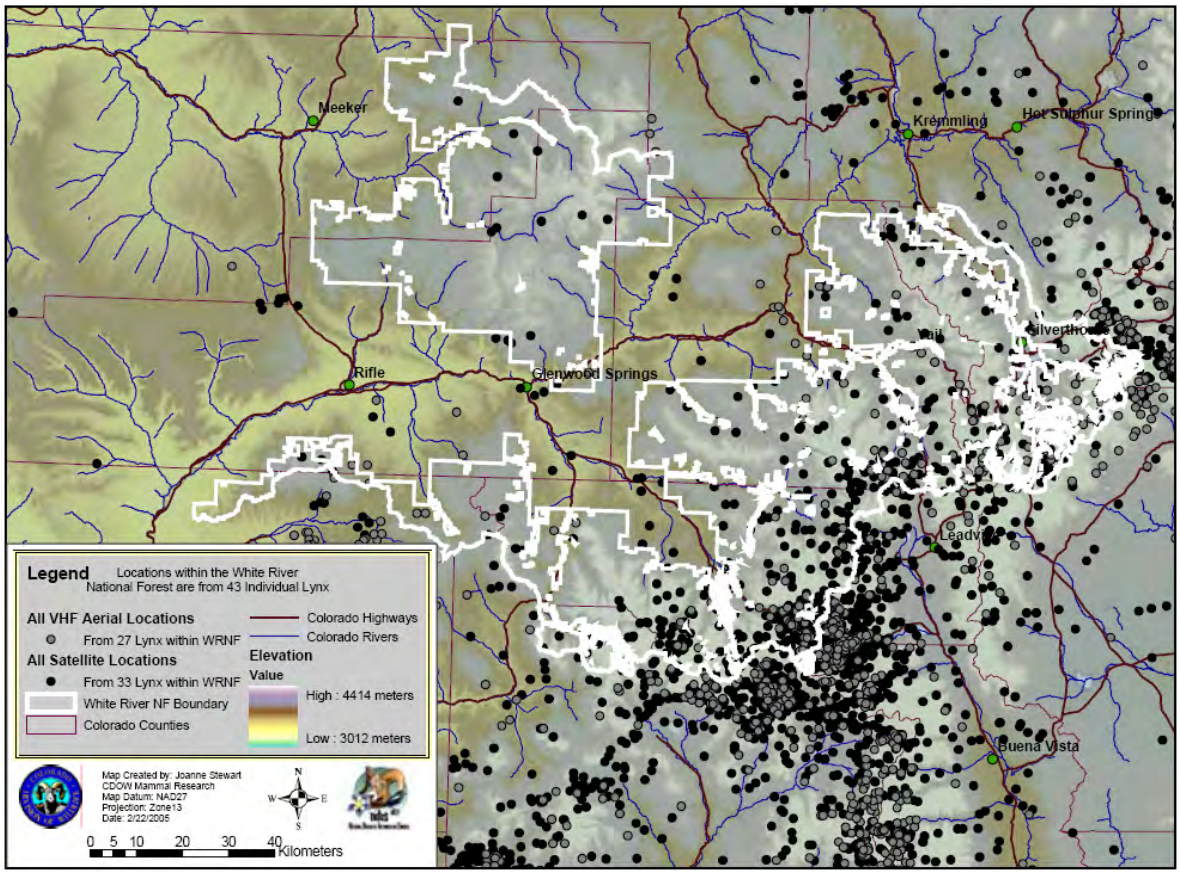
With increased urbanization comes greater recreational demand on the landscape, which may also have serious impacts on wildlife using these areas (Knight and Gutzwiller 1995). Recreational trails fragment sensitive elk calving grounds (e.g., Government Trail), as well as critical riparian systems used by a variety of wildlife, such as black bear, bald eagles (*Haliaeetus leucocephalus*), and great blue herons (*Ardea Herodias*; e.g., Rio Grande Trail and East of Aspen Trail). Although seasonal closures on some recreation trails are established, the degree to which they are enforced may vary. The Hay Park Trail near the base of Mount Sopris currently transects an elk winter range and potentially causes disturbances to elk on warm winter days when recreationists use the area. Research examining the impacts that trails have on wildlife, and the effectiveness of seasonal closures is needed.

Bighorn sheep (*Ovis canadensis*) are a model species for examining the negative impacts of recreation pressures that potentially lead to fragmentation of critical habitat. Bighorn sheep are highly susceptible to human-induced stress, which may cause the abandonment of habitat (MacArthur et al. 1982). Bighorns are known to use habitat in both summer and winter along the ridgelines between Hunter, Highland, and Loge Peaks. Stress induced by winter recreational users at the Aspen Highlands Ski Area may be significant because bighorn sheep are most susceptible to physiological stress during this time of year (USDA-FS 1997). In addition, summer hikers to the area may be influencing the continued use of these areas by bighorn sheep. Recreation impacts during both summer and winter, including the degree to which sheep are stressed and the extent to which the Aspen Highlands and adjacent ridges are used, should be investigated. The declining sheep population in the Crystal Valley should also be studied for recreationally induced stresses. Classification of different age cohorts may provide insight into how individuals manage such stresses differently. Similar work could also be carried out for the white-tailed ptarmigan (*Lagopus leucurus*) that use this habitat.

When considering movements of species with large home ranges, such as carnivores like lynx or ungulates like moose (*Alces alces*) immigrating into the area, larger spatial scales should be considered beyond the more local migrations mentioned above. Landscape linkages should

provide safe movement corridors across large blocks of forested landscapes and generally have low levels of disturbance. Lynx have recently been well documented in the northern Elk Mountains and Roaring Fork Watershed through radiotelemetry work conducted by the CDOW (Shenk 2005, see Figure 4), a remote camera set up at a scent station (pers. comm. Phil Nyland, U.S. Forest Service), and via an individual that was naturally injured and found in the Aspen area. If populations of this species continue to increase as suggested by recent recruitment statistics from CDOW (Shenk 2006) lynx will continue to expand into suitable habitat of the Elk Mountains and will require adequate landscape linkages to do so. Lynx are currently using the Collegiate Peaks/Taylor Park area southeast of Aspen, and could easily expand further into the Roaring Fork Watershed. Identifying if these corridors currently exist, and if so, which ones are more likely to be used would be highly beneficial to land managers. Research should also investigate the potential for cascading effects from altered hydrologic regimes. Such alterations could reduce willow growth, lead to lower snowshoe hare (*Lepus americanus*) populations, and ultimately create unsuitable prey bases for lynx.

Figure 4. All Lynx locations within the White River National Forest: February 4, 1999 – February 1, 2005 (Shenk 2005).



Habitat Condition & Disturbance Processes

Fire Suppression–. In many areas of the Roaring Fork Watershed managers of public lands have become hesitant to use fire as a habitat improvement tool. This reluctance is due to the liability associated with burning down privately owned structures on adjacent lands. As the degree of urbanization on private lands continues to increase the situation will be compounded and naturally occurring fires suppressed to even greater levels. The alteration of historic fire regimes may be a direct cause of poor habitat condition, which was mentioned as a high concern by a number of land management experts. Shrub and tree communities that need shorter fire return intervals, such as Gambels Oak (*Quercus gambelii*) and pinyon-juniper (*Pinus edulis, Juniperus sp.*), should be studied to determine how current conditions vary in areas where fire has been suppressed. Many of the shrubs have taken on a clubbed appearance, which has potentially lowered productivity of the plants and reduced their accessibility to wildlife. Browse may also become clubbed and stunted when ungulates such as elk over-utilize an area. Elk may be restricted to smaller winter ranges in response to urbanization and fragmented habitats or populations may be higher than the habitat can support due to the absence of large predators. Thus, a number of studies could be initiated to address these questions.

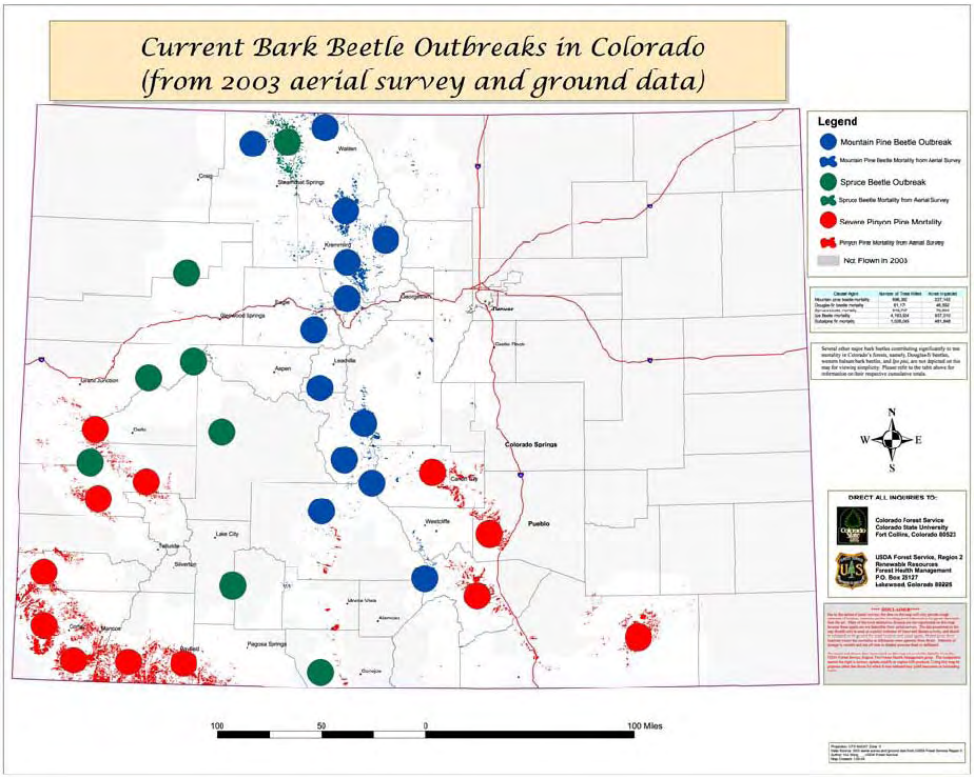
Invasive Plants–. In addition to low regeneration issues, the high amount of ground surface that has been disturbed recently for construction projects has opened up areas for invasive plant species. These invasive species subsequently spread to adjacent natural areas and slowly decrease the native species volume and diversity. Research is needed to understand to what degree these invasions are occurring and to identify the major sources of their introduction (i.e., recreation trails, cattle grazing, development). For example, portions of the old ski area near Marble have become inundated with toad flax (*Linaria vulgaris*). In addition, the top two potential conservation areas listed by the Roaring Fork Watershed Inventory (Spackman 1999) include riparian areas along the Castle and Maroon Creek confluences with the Roaring Fork River as well as in the Northstar Preserve east of Aspen. Management of invasive plant species was suggested to be a critical action for the preservation of these sensitive areas. Efforts to remove invasive species in these areas not only need to be undertaken, but research should determine mechanisms that foster their introduction. Results could provide managers with evidence they can use to decide if activities such as recreation in these areas would lead to alien plant invasions. Currently, the WRNF and BLM inventory, manage, and monitor invasive plant species on public lands in the Roaring Fork valley. Invasive species of concern are listed at http://www.co.blm.gov/botany/weedhome.htm. However, the degree to which these plants are introduced via development on private lands often goes undocumented. Therefore, research also needs to focus on private lands where these species are likely to be introduced but perhaps less likely to be managed.

Bark Beetle Outbreaks–. One of the biggest disturbance processes likely to affect the Roaring Fork Watershed in the coming decade is the combination of drought and bark beetle outbreaks (Figure 5). Potential outbreaks of the spruce bark beetle alone could dramatically alter portions of the White River National Forest and Roaring Fork Watershed in the coming years, with predictions for loss of mature spruce forests as high as 80% or more. Forests in counties surrounding the Watershed have seen dramatic die-offs due to a combination of drought and bark beetle stresses (Figure 6). Research suggests that this process is a naturally occurring one

working in combination with fire regimes (Bebi et al. 2003). Most areas within the Roaring Fork Watershed have yet to be affected by this phenomenon but almost assuredly will be in the coming years. This presents the opportunity for pre and post exposure inventory surveys. How these forest communities, including understory vegetation and wildlife occurrences, change from pre to post exposure could provide valuable information affecting future management responses (e.g., logging, snag regeneration, controlled burns, biological controls, or combinations of actions).

Figure 5. Forest infected with mountain pine beetle (Leatherman 2005).

Figure 6. Map depicting potential sources of bark beetle invasion in the Roaring Fork Watershed as identified by aerial survey and ground data (Leatherman 2003).



Hydrologic Regimes

Much of the Roaring Fork Watershed is typified by riparian habitat that is vital to a wide variety of wildlife. Flow regimes have been highly altered by diversions within the Upper Roaring Fork River and Hunter-Frying Pan Watersheds, which send water through a series of ditches and tunnels to reservoirs east of the continental divide. How these altered flow regimes affect the vegetation growth, aquatic insect growth, and survival of native fish and amphibians in these systems is largely unknown. Although a limited number of studies were conducted on survival and reproductive success of several fish species within the first decade after these alterations took place, no follow up research on long-term impacts caused by these changes have been studied.

As the Roaring Fork Watershed continues to develop the degree of water consumption will also continue to rise, placing a greater strain on an already limited resource. Research on the effects of water used on fish and wildlife (with particular concern towards endangered species such as the Colorado River cutthroat trout (*Oncorhynchus clarki*) and boreal toad (*Bufo boreas*)) are of high importance to the future sustainability of these species. Pre and post data collected to evaluate the response of these systems to the use of mimicked flood regimes could be informative. Areas of particular concern for the Colorado River cutthroat trout as identified by the CNHP inventory (Spackman 1999) include but are not limited to the upper Roaring Fork River, Avalanche Creek and Lake, Middle Thompson Creek, Lost Man Creek, and Frying Pan River. Areas of interest for the boreal toad include Conundrum, Snowmass, and possibly Hunter Creeks (Spackman 1999). Although observations of boreal toads have been made at a number of locations within the watershed (Table 2), which areas of the watershed are being used consistently and are needed for breeding and hatching remains unclear. These regions should be surveyed more thoroughly to better determine their importance for this species.

Table 2. Observations of adult boreal toads (*Bufo boreas*) in the Roaring Fork Watershed (Spackman 1999).

date of observation	number of boreal toads	location
September 5, 1998	1 adult	Pitkin Co. Roaring Fork River, North Star Nature Preserve. 8,035 feet.
August 3, 1998	2	Pitkin Co. Snowmass Creek, approximately 1 – 2 miles below Snowmass Lake. 10,100 feet.
July 25, 1998	1	Pitkin Co. Snowmass Lake. 10,980 feet.
August 25, 1997	1 adult	Pitkin Co. Fryingpan River, Twin Meadows above Chapman. 9400 feet.
July 13, 1997	1	Pitkin Co. Approximately 5.5 miles up trail from Snowmass Falls Ranch trailhead. 10,000 feet.
June 16, 1997	1	Pitkin Co. Approximately 4 miles from East Maroon trailhead, 1 mile past wilderness boundary. 9,200 feet.
August 1995	2 adults	Pitkin Co. Lincoln Creek and Galena Creek. 11,000 feet
July 30, 1995	1 adult	Pitkin Co. Buckskin Pass. Forest Service trail 1975 on Snowmass Creek. 10,800 feet.

Additional effects on water quality may result from a variety of sources including treatment of larger amounts of water for urban use; the introduction of toxins such as magnesium chloride, oil, and gas collected from runoff of streets and highways; erosion and sedimentation along roads and highways as well as at construction sites near riparian areas. Finally, historic mining locations such as the Ruby Mine in the upper Lincoln Creek drainage may continue to contribute to water contamination and have detrimental effects on these riparian areas, at least in the upper stretches of the systems. Research is needed on the potential for such effects. For example, willows growing in areas where mine tailings exist can absorb heavy metals such as cadmium. Subsequently, ptarmigan that feed on these shrubs can develop kidney and bone problems (Kershaw et al. 1998). Similar investigations should determine if these heavy metals are being transported by rivers and streams in the Roaring Fork Watershed and taken up by downstream plants in significant amounts away from the mine sites.

Global Climate Change & Air Quality

A relatively high percentage of the Roaring Fork Watershed consists of alpine communities. Therefore, serious consideration should be given to determining the effects of global climate changes on these fragile high-elevation systems. Effects of global warming on snowpack and sensitive alpine plant species could drastically alter this ecosystem by lowering its species diversity and jeopardizing the continued existence of endangered species such as the alpine poppy (*Papaver kluanense*). Portions of the northern Elk Mountains and Collegiate Peaks currently provide some of the most intact and least disturbed alpine communities in Colorado. Spackman et al (1999), in reference to the potential conservation area on Twining Peak, stated "The high concentration of rare plants on this peak is matched only by a handful of other alpine locations in the state". Recent studies have begun to show that tree lines are encroaching into the higher elevations traditionally occupied by alpine flora, leading to lower ecosystem diversity and loss of natural heritage as a result of higher temperatures and increased CO_2 input (Grace et al. 2002, Handa et al. 2006). How climate change in the Roaring Fork Watershed will affect snowpack, run off, and tree line limitations is largely unknown, but may have widespread impacts on alpine communities and riparian areas downstream.

One of the processes mentioned by several biologists that lead to global warming, and subsequently impacts on sensitive alpine communities is degradation of air quality. With increased oil and gas development on many of the private and public lands of the Piceance Basin and Roan Plateau, one of the first downwind ecosystems to catch air pollution fallout from these projects is likely to be the Roaring Fork Watershed. In addition, increased transportation levels going into and out of Aspen have consistently had negative affects on air quality (Aspen Environmental Health Department 2006). A recent report by Heede (2006) suggests that air traffic from Pitkin County Airport (both private and commercial), commuter vehicle traffic from highway 82, and electricity production are major contributors to Aspen's greenhouse gas emissions (Figure 7, Table 3). In the past, results from such air quality assessments have generally been related to human health. However, quantifying how these pollutants are accumulating and affecting natural systems (e.g., alpine) should be investigated particularly at nearby or downwind locations of major pollutant sources.

Figure 7. Major sources of emissions in Aspen, Colorado during 2004. General aviation consists of privately owned jets, Com'l represents commercial activities, and vehicle traffic is represented by that contributed on Highway 82 both in town and by tourists. Graph taken from Heede 2006.

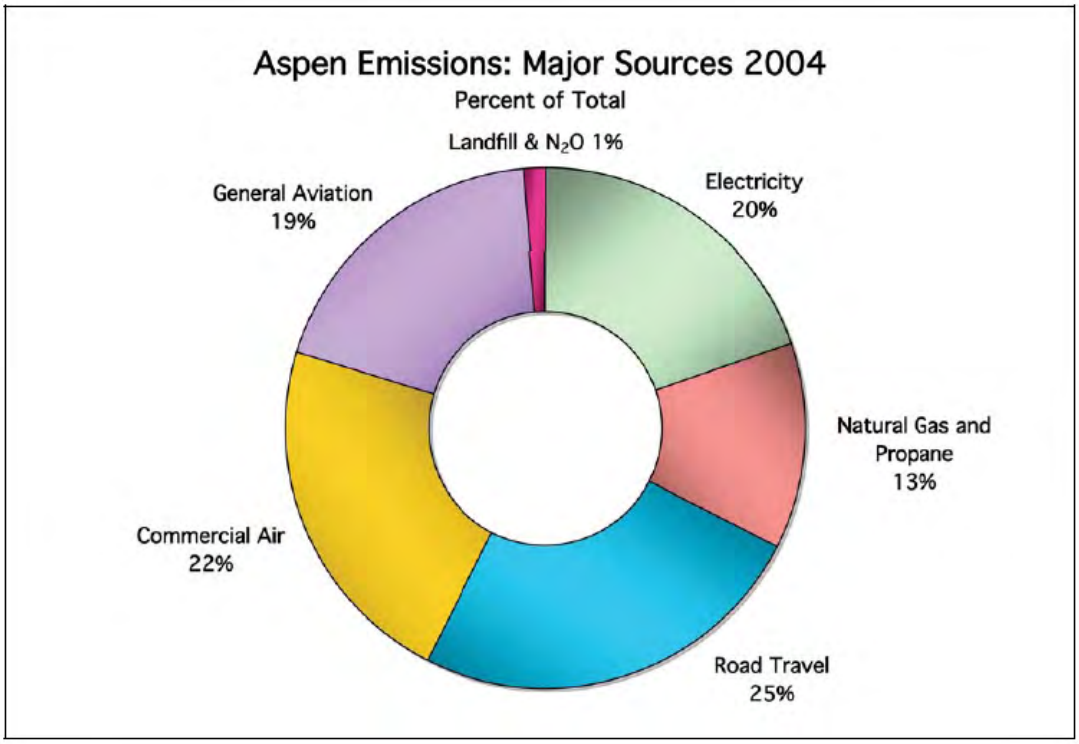


Table 3. Summary of greenhouse gas emission sources in Aspen, Colorado (Heede 2006).

SOURCE	TONS $CO_{2\text{-}e}$	PERCENT
Electricity (buildings)	166,557	19.8
Natural Gas & Propane (buildings)	106,754	12.7
Ground Transportation	211,175	25.1
Air Travel: Commercial	186,631	22.2
Air Travel: Private	157,856	18.8
Landfill	11,577	1.4
Nitrous oxide:	325	0.04
Total	840,875	100.0

The ecological concepts mentioned in this report are, in many cases, closely associated to each other because they share similar stresses or sources of stress (e.g., impacts of urbanization on migration corridors, disturbance processes such as introduction of invasive plants, and air quality). In addition, the ecological concepts considered in this assessment should be examined at a variety of spatial and temporal scales to insure that impacts from areas adjacent to the Roaring Fork Watershed are taken into account. Finally, ecological concepts impacting the Roaring Fork Watershed are part of a continuously evolving system. Therefore, the identification and assessment of these concepts should be reassessed and updated regularly.

Summary of Proposed Ecological Research Topics

Migration Corridors and Habitat Fragmentation

- Determination of elk and lynx migration corridors
- Fragmentation of migration corridors via urbanization and recreation disturbances
- Impacts of seasonal recreation on, reproductive success, stress levels, and abandonment of habitat for elk, black bears, bald eagles, great blue herons, and bighorn sheep
- Suitability of habitat for lynx due to altered hydrologic regimes, lowered willow growth, and reduced snowshoe hare populations

Habitat Condition and Disturbance

- Impacts of restricted fire regimes and over browsing by ungulates to woody plants
- Determination of mechanisms that foster invasive plant species introduction and persistence, particularly on private lands
- Inventories of floral and faunal forest community dynamics at pre and post exposure stages to bark beetle outbreaks.

Hydrologic Regimes

- Effects on riparian and stream health due to altered hydrologic regimes
- Responses of riparian and stream communities to mimicked floods
- Documentation of breeding and hatching use by endangered cutthroat trout and boreal toads at sites where only an observation of the species is known
- Impacts of contaminated water sources on riparian flora and fauna such as willow and ptarmigan

Global Change and Air Quality

- Effects on snowpack, run off, and species diversity
- Impacts on the alpine community from lowered air quality

GIS DATABASE LAYERS

Geographic information system (GIS) databases that contain layers for the Roaring Fork Watershed are available, both free and for charge, through a number of outlets depending on the type of layers desired. This section lists the agencies that provide GIS layers to the public along with their website address where most files available are listed. A list of layers likely to be used as a foundation for most projects in this area can be purchased by the City of Aspen and Pitkin County, and is found in Appendix D.

Bureau of Land Management: contact GIS Specialist Denise Gergen (Glenwood Springs Office), Denise_Gergen@blm.gov

City of Aspen & Pitkin County: http://www.aspenpitkin.com/depts/46/

Colorado Department of Transportation (CDOT): http://www.dot.state.co.us/app_DTD_DataAccess/GeoData/index.cfm?fuseaction=GeoDataMain&MenuType=GeoData

Colorado Division of Wildlife's Natural Diversity Information Source (NDIS): http://ndis.nrel.colostate.edu/ftp/index.html

Colorado Vegetation Classification Project (CVCP), a joint project by the CDOW, BLM, and USFS in Colorado: http://ndis.nrel.colostate.edu/coveg/

Roaring Fork Stream Health Initiative: contact Private Consultants John Emerick Ph.D and Delia Malone (Aspen), jemerick@sopris.net , deliamalone@earthlink.net

U.S. Forest Service, White River National Forest: contact Forest GIS Coordinator Jim Evans (Glenwood Springs Office), jevans@fs.fed.us

U.S. Geological Survey (USGS) Seamless Data Distribution (e.g., DEM's, DRG's): http://seamless.usgs.gov/website/seamless/viewer.php

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APPENDICES

Appendix A. List of flora and fauna of special concern (Table 1), imperilment rank (Table 2), and potential conservation areas (Table 3) identified for the Roaring Fork Watershed by the Colorado Natural Heritage Program Biological Inventory conducted in 1997-1999.

Table 1. List of targeted elements, organized by taxonomic group, identified.

Element Name	Element Common Name	Global Rank	State Rank	Fed Status	State Status	Fed Sens
AMPHIBIANS						
Bufo boreas	boreal toad	G5T2Q	S1	C	E	FS
Rana pipiens	northern leopard frog	G5	S3		SC	FS
BIRDS						
Falco peregrinus anatum	american peregrine falcon	G5T4	S2B, SZN	LE	T	
Haliaeetus leucocephalus	bald eagle	G4	S1B, SZN	LT	T	
Cypseloides niger	black swift	G4	S3B			FS
Aegolius funereus	boreal owl	G5	S2			FS
Leucostica australis	brown-capped rosy finch	G4	S3S4B, S4N			
Accipiter cooperii	Cooper's hawk	G5	S3S4B, S4N			
Podiceps nigricollis	eared grebe	G5	S3B, SZN			
Sayornis phoebe	eastern phoebe	G5	S3B, SZN			
Vireo vicinior	gray vireo	G4	S2B, SZN			
Ardea herodias	great blue heron	G5	S3B, SZN			
Accipiter gentilis	northern goshawk	G5	S3B, SZN			FS
Circus cyaneus	northern harrier	G5	S3B, SZN			
Contopus borealis	olive-sided flycatcher	G5	S3S4B			FS
Pandion haliaetus	osprey	G5	S3B, SZN			FS
Progne subis	purple martin	G5	S3B, SZN			FS
Amphispiza belli	sage sparrow	G5	S3B, SZN			
Accipiter striatus	sharp-shinned hawk	G5	S3S4B, S4N			
Porzana carolina	sora	G5	S3S4B, SZN			
MAMMALS						
Felis lynx canadensis	lynx	G5	S1	C	E	FS
Gulo gulo	wolverine	G4	S1		E	FS
Myotis californicus	California myotis	G5	S3S4			
Myotis yumanensis	yuma myotis	G5	S3			
Notiosorex crawfordi	desert shrew	G5	S3			

Table 1. *continued*

Plecotus townsendii pallescens	pale lump-nosed bat	G4	S2		
Sorex hoyi montanus	pygmy shrew subsp.	G5T2T3	S2		FS
Sorex merriami	Merriam's shrew	G5	S2		
Sorex nanus	dwarf shrew	G4	S2S3		FS
Sorex preblei	Preble's shrew	G5	S1?		
FISH					
Catostomus latipinnis	flannelmouth sucker	G3G4	S3S4	SC	
Gila robusta	roundtail chub	G2G3	S2		
Oncorhynchus clarki pleuriticus	Colorado River cutthroat	G4T3T4	S3	SC	FS
Prosopium williamsoni	mountain whitefish	G5	S3		
REPTILES					
Coluber constrictor mormon	western yellowbelly racer	G5T5	S3		
Elaphe guttata	corn snake	G5	S3S4		
PLANTS					
Arnica angustifolia ssp. *tomentosa*	alpine arnica	G5T5	S1		
Asplenium trichomanes-ramosum	green spleenwort	G4	S1S2		
Astragalus molybdenus	Leadville milkvetch	G3	S2		
Braya glabella	arctic braya	G5	S1		
Crepis nana	dwarf hawksbeard	G5	S2		
Cryptantha cana	mountain cat's-eye	G5	S2		
Cryptogramma stelleri	slender rock-brake	G5	S2		
Cypripedium fasciculatum	purple lady's-slipper	G4	S3		FS
Cypripedium pubescens	yellow lady's slipper	G5	S2		
Cystopteris montauna	mountain bladder fern	G5	S1		
Draba crassa	thick-leaf whitlow-grass	G3	S3		
Draba globosa	rockcress draba	G3	S1		
Draba grayana	Gray's Peak whitlow-grass	G2	S2		
Draba lonchocarpa var. *lonchocarpa*	draba	G4T4	S3		
Draba oligosperma	woods draba	G5	S2		
Draba porsildii	Porsild draba	G3G4	S1		
Draba spectabilis var. *oxyloba*	draba	G3?T3Q	S3		
Draba streptobrachia	Colorado Divide whitlow-grass	G3	S3		
Draba ventosa	tundra draba	G3	S1		
Erigeron humilis	low fleabane	G4	S1		
Erigeron lanatus	woolly fleabane	G3G4	S1		
Eriogonum coloradense	Colorado wild buckwheat	G2	S2		
Eriophorum altaicum var. *neogaeum*	altai cottongrass				

Table 1. *continued*

Iliamna grandiflora	large-flower globe-mallow	G3?Q	S1	
Machaeranthera coloradoensis	Colorado tansy-aster	G2	S2	
Papaver lapponicum ssp. *occidentale*	alpine poppy	G4T4	S2	
Penstemon harringtonii	Harrington beardtongue	G3	S3	FS
Penstemon mensarum	Grand Mesa penstemon	G3	S3	
Platanthera sparsiflora var. *ensifolia*	canyon bog-orchid	G4G5T3	S2	
Ranunculus karelinii	tundra buttercup	G4G5	S2	
Saxifraga cespitosa ssp *monticola*	tundra saxifrage	G5T5	S1	
Sullivantia hapemanii var. *purpusii*	hanging garden sullivantia	G3T3	S3	
INVERTEBRATES				
Adelpha bredowii	sister	G4G5	S3	
Aeshna californica	California darner	G5	SU	
Callophrys affinis affinis	green-winged hairstreak	G4T?	S3S4	
Erebia theano demmia	demmia alpine	G4T2	S2	
Euphilotes rita emmeli	desert buckwheat blue	G4T2	S1	
Hesperopsis libya	mohave sooty-wing	G5	S2	
Lycaena editha		G5	S2S3	
Lymnaea stagnalis	swampy lymnaea	G5	S2	
Nymphalis californica	California tortoise shell	G5	S3S4	
Oarisma edwardsii	Edward's skipperling	G4	S3	
Ochlodes yuma	yuma skipper	G5	S2S3	
Oeneis alberta	Alberta arctic	G5	S3	
Oeneis jutta reducta	Rocky Mountain arctic jutta	G5TU	S1	
Oeneis polixenes	polixenes arctic	G5	S3	
Oenieis taygete	white-veined arctic	G5?	S3	
Papilio bairdii	Baird's swallowtail	G4	S3S4	
Papilio indra minori	short-tailed black swallowtail	G5TU	S1S2	
Pyrgus ruralis	two-banded skipper	G4	S3	
Satyrium fuliginosum	sooty gossamer wing	G4	S3	
Speyeria egleis	egleis fritillary	G5	S2	
PLANT COMMUNITIES				
Abies lasiocarpa -Picea engelmannii -Populus angustifolia/ Lonicera involucrata	montane riparian forest	G4	S3	
Abies lasiocarpa/ Rubus parviflorus	subalpine forest	G5	S2	
Abies lasiocarpa-Picea engelmanii/ Mertensia ciliata	montane riparian forest	G5	S5	

Table 1. *continued*

Abies lasiocarpa-Picea engelmannii/ Alnus incana	montane riparian forest	G5	S4S5
Artemisia tridentata vaseyana/ Carex geyeri	west slope sagebrush shrubland	G3	SU
Artemisia tridentata vaseyana/ Symphoricarpos oreophilus	west slope sagebrush shrubland	G3G4	S3S4
Carex aquatilis-Carex utriculata wetland	montane wet meadow	G4	S4
Carex rupestris-Trifolium dasyphyllum	alpine meadows	G3G$	S3S4
Festuca idahoensis-Festuca thurberi	montane grassland	G3G4	S3S4
Geum rossii/ Trifolium spp.	alpine meadow	G3G4	S3S4
Picea pungens/ Alnus incana	montane riparian forest	G3	S3
Picea pungens/ Cornus sericea	montane riparian forest	G1	S2
Pinus edulis- Juniperus osteosperma/ Stipa comata	xeric western slope pinyon-juniper woodlands	GU	SU
Populus angustifolia - Picea pungens/ Alnus incana	montane riparian forest	G3	S3
Populus angustifolia/ Alnus incana	montane riparian forest	G3?	S3
Populus angustifolia/ Betula occidentalis	montane riparian forest	G3?	S2
Populus angustifolia/ Cornus sericea	cottonwood riparian forest	G4	S3
Populus angustifolia/ Prunus virginiana	narrowleaf cottonwood/ common chokecherry	G2G3	S1
Populus angustifolia-Pseudotsuga menziesii	montane riparian forest	GU	S2
Pseudotsuga menziesii/ Carex geyeri	lower montane forest	G5Q	S3
Pseudotsuga menziesii/ Cornus sericea	lower montane riparian forest	G4	S2
Pseudotsuga menziesii/ Pachistima myrsinites	lower montane forest	G2G3	S2S3
Psuedotsuga menziesii/ Quercus gambelii	western slope douglas fir forests	G5	S4
Psuedotsuga menziesii/ Symphoricarpos oreophilus	western slope douglas fir forests	G5	S4
Quercus gambelii-Amelanchier utahensis	mixed mountain shrubland	G3G5	SU
Quercus gambelii/ symphoricarpos	mixed mountain shrubland	G5	S3S4

Table 1. *continued*

oreophilus			
Quercus gambelii-Cercocarpus montanus/ Carex geyeri	mixed mountain shrubland	G3	S3
Salix drummondiana/ Calamagrostis canadensis	lower montane willow carr	G3	S3
Salix drummondiana/ Carex utriculata	montane willow carr	GU	S3
Salix exigua/mesic graminoid	coyote willow/mesic graminoid	G5	S5
Salix geyeriana-Salix monticola/ Calamagrostis canadensis	montane willow carr	G3	S3
Salix monticola/ Calamagrostis canadensis	montane willow carr	G3	S3
Salix planifolia/ calamagrostis canadensis	subalpine riparian willow carr	G3	S3
Salix planifolia/ Caltha leptosepala	subalpine riparian willow carr	G4	S4
Salix planifolia/ Carex aquatilis	subalpine riparian willow carr	G5	S4
Salix planifolia/ Deschampsia cespitosa	subalpine riparian willow carr	G2G3	S3

Table 2. Definitions for Colorado Natural Heritage Imperilment Ranks.

Global imperilment ranks are based on the range-wide status of a species. State imperilment ranks are based on the status of a species in an individual state. State and Global ranks are denoted, respectively, with an "S" or a "G" followed by a character. **These ranks should not be interpreted as legal**

G/S1 Critically imperiled globally/state because of rarity (5 or fewer occurrences in the world/state; or very few remaining individuals), or because of some factor of its biology making it especially vulnerable to extinction.

G/S2 Imperiled globally/state because of rarity (6 to 20 occurrences), or because of other factors demonstrably making it very vulnerable to extinction throughout its range.

G/S3 Vulnerable through its range or found locally in a restricted range (21 to 100 occurrences).

G/S4 Apparently secure globally/state, though it might be quite rare in parts of its range, especially at the periphery.

G/S5 Demonstrably secure globally, though it may be quite rare in parts of its range, especially at the periphery.

GX Presumed extinct.

G#? Indicates uncertainty about an assigned global rank.

G/SU Unable to assign rank due to lack of available information.

GQ Indicates uncertainty about taxonomic status.

G/SH Historically known, but not verified for an extended period, usually.

G#T# Trinomial rank (T) is used for subspecies or varieties. These taxa are ranked on the same criteria as G1-G5.

S#B Refers to the breeding season imperilment of elements that are not permanent residents.

S#N Refers to the non-breeding season imperilment of elements that are not permanent residents. Where no consistent location can be discerned for migrants or non-breeding populations, a rank of SZN is used.

SZ Migrant whose occurrences are too irregular, transitory, and/or dispersed to be reliable identified, mapped, and protected.

SA Accidental in the state.

SR Reported to occur in the state, but unverified.

S? Unranked. Some evidence that species may be imperiled, but awaiting formal rarity ranking.

Notes: Where two numbers appear in a state or global rank (e.g., S2S3), the actual rank of the element falls between the two numbers.

Table 3. Roaring Fork Watershed Potential Conservation Areas were identified during the 1997-1999 Roaring Fork Watershed Biological Inventory. The Biodiversity Significance, Protection Urgency, and Management Urgency Ranks are included (see pages 27-28 for rank definitions). PCAs are listed in approximate order for conservation attention.

PCA Name	Biodiversity Rank	Protection Urgency Rank	Management Urgency Rank
Maroon-Castle Creek	B2	P2	M1
Upper Roaring Fork River	B2	P3	M2
Avalanche Creek	B2	P3	M3
Middle Thompson Creek	B2	P3	M3
Taylor Pass	B2	P3	M3
Twining Peak	B2	P4	M2
The Crown	B2	P4	M3
Warren Peak	B2	P4	M3
New York Creek	B2	P4	M4
Woody Creek Headwaters	B2	P4	M4
Roaring Fork River at Brush Creek	B3	P2	M1
Lost Trail Creek	B3	P2	M2
Roaring Fork at Old Snowmass	B3	P2	M3
Williams Hill	B3	P2	M3
North Fork Fryingpan	B3	P3	M2
Smith Gulch	B3	P3	M3
West Maroon Creek	B3	P3	M3
Cerise Gulch	B3	P3	M3
The Grottos	B3	P4	M1
Mountain Boy Park	B3	P4	M2
Conundrum Creek	B3	P4	M3
East Maroon Creek	B3	P4	M3
East Snowmass Creek	B3	P4	M3
Lost Man Creek	B3	P4	M3
McClure Pass	B3	P4	M3
Grizzly Creek	B3	P4	M3
Snowmass Creek at Snowmass Peak	B3	P4	M3
Light Hill	B3	P4	M3
Fryingpan River	B3	P4	M4
Rocky Fork Creek	B3	P4	M4
Whitehouse Mountain	B3	P4	M4
Capitol Peak	B3	P4	M4
Big Kline Creek	B3	P4	M4
Missouri Heights	B4	P1	M1
Crystal Springs Road	B4	P1	M2
Crystal River at Potato Bill Creek	B4	P1	M2
Cattle Creek at Coulter Creek	B4	P2	M1
Fourmile Creek at Sunlight	B4	P2	M2
Toner Creek	B4	P2	M2
Woody Creek at Horseshoe Draw	B4	P2	M2

Table 3. *continued*

Hunter Creek	B4	P2	M3
Ranch at the Roaring Fork	B4	P3	M2
El Jebel	B4	P3	M3
Basalt Mountain	B4	P3	M3
Christine State Wildlife Area	B4	P4	M3
East Creek	B4	P4	M3
Taylor Creek	B4	P4	M3
Roaring Fork River at Cattle Creek	B5	P1	M1
Kaiser Stevens Ditch	B5	P3	M3
Seven Castles	B5	P3	M4
Richmond Hill	B5	P4	M2
Sutank	B5	P4	M2
Avalanche Lake	B5	P4	M3
Cattle Creek	B5	P4	M4
Eagle Mountain	B5	P4	M4

Definitions of the Biodiversity Significance, Protection Urgency, and Management Urgency Ranks used in Table 3 above. These rankings were assigned to all Potential Conservation Areas found in Table 3 as delineated by the Colorado Natural Heritage Program and the Roaring Fork Watershed Inventory (Spackman 1999).

Ranking of Potential Conservation Areas

One of the strongest ways that CNHP uses element and element occurrence ranks is to assess the overall biodiversity significance of a PCA, which may include one or many element occurrences. Based on these ranks, each PCA is assigned a **biodiversity** (or B-) **rank**:

B1 Outstanding Significance: only location known for an element or an excellent occurrence of a G1 species.
B2 Very High Significance: one of the best examples of a community type, good occurrence of a G1 species, or excellent occurrence of a G2 or G3 species.
B3 High Significance: excellent example of any community type, good occurrence of a G3 species, or a large concentration of good occurrences of state-rare species.
B4 Moderate or Regional Significance: good example of a community type, excellent or good occurrence of state-rare species.
B5 General or State-wide Biodiversity Significance: good or marginal occurrence of a community type, S1, or S2 species.

If an element occurrence is unranked due to a lack of information the element occurrence rank is considered a C rank. Similarly, if an element is a GU or G? it is treated as a G4.

Protection Urgency Ranks

Protection urgency ranks (P-ranks) refer to the time frame in which conservation protection should occur. In most cases, this rank refers to the need for a major change of protective status (e.g., agency special area designations or ownership). The urgency for protection rating reflects the need to take legal, political, or other administrative measures to alleviate threats that are related to land ownership or designation. The following codes are used to indicate the rating which best describes the urgency to **protect** the area:

P1 Immediately threatened by severely destructive forces, within 1 year of rank date; protect now or never!
P2 Threat expected within 5 years.
P3 Definable threat but not in the next 5 years.
P4 No threat known for foreseeable future.
P5 Land protection complete or adequate reasons exists not to protect the PCA; do not act on this PCA.

A protection action involves increasing the current level of legal protection accorded one or more tracts within a potential conservation area. It may also include activities such as educational or public relations campaigns or collaborative planning efforts with public or private entities to minimize adverse impacts to element occurrences at a site. It does not include management actions. Threats that may require a protection action are as follows:
1) Anthropogenic forces that threaten the existence of one or more element occurrences at a PCA; e.g., development that would destroy, degrade or seriously compromise the long-term viability of an element occurrence and timber, range, recreational, or hydrologic management that is incompatible with an element occurrence's existence; 2) The inability to undertake a management action in the absence of a protection action; e.g., obtaining a management agreement; 3) In extraordinary circumstances, a prospective change in ownership or management that will make future protection actions more difficult.

Management Urgency Ranks

Management urgency ranks (M-ranks) indicate the time frame in which a change in management of the element or PCA should occur. This rank refers to the need for management in contrast to protection (e.g., increased fire frequency, decreased herbivory, weed control, etc.). The urgency for management rating focuses on land use management or land stewardship action required to maintain element occurrences at the potential conservation area.

A management action may include biological management (prescribed burning, removal of exotics, mowing, etc.) or people and site management (building barriers, rerouting trails, patrolling for collectors, hunters, or trespassers, etc.). Management action does not include legal, political, or administrative measures taken to protect a potential conservation area. The following codes are used to indicate the action needed to be taken at the area:

M1 Management action required immediately or element occurrences could be lost or irretrievably degraded within one year.
M2 New management action will be needed within 5 years to prevent the loss of element occurrences.
M3 New management action will be needed within 5 years to maintain current quality of element occurrences.
M4 Although not currently threatened, management may be needed in the future to maintain the current quality of element occurrences.
M5 No serious management needs known or anticipated at the PCA.

Appendix B. Literature identified for the Roaring Fork Watershed or closely associated areas.

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Appendix C. List of state, federal, environmental, and educational biological experts that provided input for the assessment.

State & Federal:

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Colorado Division of Wildlife, Kevin Wright, District Wildlife Manager, Aspen-Snowmass Villiage, (970) 947-, Kevin.Wright@state.co.us .

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Wilderness Workshop, Sloan Shoemaker, Executive Director, Carbondale, (970) 963-3977, sloan@wildernessworkshop.org .

Appendix D. List of GIS layers available for acquisition by the City of Aspen & Pitkin County GIS Department and the BLM.

City of Aspen and Pitkin County GIS Department

Boundaries	**Ala Carte Price**
Aspen	$25
Basalt	$25
Carbondale	$25
Snowmass	$25
Towns	$25
Caucus	$25
Growth Management Area	$25
Pitkin County Boundary	$25
USGS Quadrangle Boundaries	$25
Statewide County Boundaries	$25
Urban Growth Boundary	$25
Wilderness Boundaries	$25
Zipcodes	$25

Districts	**Ala Carte Price**
BOCC Districts	$25
Fire Districts	$25
Historic Districts	$25
Voting Districts	$25
School Districts	$25
Tax Districts	$25
City of Aspen Zoning	$100
Pitkin County Zoning	$100

Environmental	**Ala Carte Price**
Vegetation	$100
Wildfire	$100

Hydrography	Ala Carte Price
Ditches	$50
Waters-Lakes & Ponds	$75
Waters-Rivers & Streams	$75

Parcel	Ala Carte Price
Lots & Blocks- Original Aspen Townsite	$25
Condominiums	$50
Subdivisions	$50
Federal Lands	$75
Public Land Survey	$75
Mines	$100
Countywide Parcels	$500

Places	Ala Carte Price
Backcountry Huts	$25
Campgrounds	$25
Cemeteries	$25
Community Facilities	$25
Employee Housing	$25
Fire Stations	$25
Lodges	$25
Peaks & Passes	$25
Ski Areas	$25
Plan Areas	$50
Scenic Areas & Ridgelines	$50
Historic Places	$75
Openspace Easements	$75
Parks & Openspace	$75
Structures	$100
Addresses	$600

Transportation	Ala Carte Price
Airport Runway	$25
Busstops	$25
Mile Markers	$25
Railroad	$25
Railroad ROW	$25
Ski Lifts	$25
X-Country Trails	$25
Drives	$75
Trails	$75
Roads-Major	$25
Roads-Edge of Pavement	$100
Roads-Centerline without Address Ranges	$500
Roads-Centerline with Address Ranges	$2000 (see license agreement)

Topography	Ala Carte Price
100 ft Contours-Countywide	$75
2003 10 ft Contours-Countywide PLS Sections	$30/ea
2004 2 ft Contours-Aspen & Redstone PLS 1/4 Sections	$30/ea

Imagery

Digital Aerial Photographs – .TIF available (not orthorectified)	Ala Carte Price
1991 Countywide Sections	$25/ea
1997 State HWY 82-Glenwood to Aspen Sections	$25/ea

Digital Oblique Photographs – .TIF available (not orthorectified)	Ala Carte Price
1991 Aspen Area	$25/ea
2000 Ruedi Reservoir	$25/ea
2000 Carbondale	$25/ea
2004 Aspen Area-5 Images	$25/ea

Digital Aerial Orthophotographs – .TIF & .SID available	Ala Carte Price
1993-1999 Countywide USGS Quarter Quads	$25/ea
1997 State HWY 82-Glenwood to Woody Creek Sections	$25/ea
1997 Aspen Metro Area Sections	$25/ea
2004 Aspen Metro Area PLS 1/4 Sections	$30/ea
2005 Pitkin County PLS Sections	$30/ea

Digital Raster Graphics-.TIF available	Ala Carte Price
Countywide USGS 7.5 Minute Topo Quads	$25/ea

Digital Elevation Models – .TIF, TIN & GRID available	Ala Carte Price
Pitkin County Region 30m Grid	$125
Pitkin County Region Shade 30m Grid	$125
Pitkin County Region Shade 30m .TIF	$75
Roaring Fork River Valley 30m Grid	$125
Roaring Fork River Valley Shade 30m Grid	$125
Roaring Fork River Valley Shade 30m .TIF	$75
Crystal River Valley 10m Grid	$125
Crystal River Valley Shade 10m Grid	$125
Crystal River Valley Shade 10m .TIF	$75
Aspen Metro Area 10m Grid	$125
Aspen Metro Area Shade 10m Grid	$125
Aspen Metro Area Shade 10m .TIF	$75
2004 Aspen Area TIN	$150
2003 Redstone Area TIN	$75
2003 partial County TIN	$150

Satellite Imagery	Ala Carte Price
2000 Pitkin County 15m Landsat Image	$50
2005 Pitkin County Satellite Image	$50

BLM Layers (Glenwood Springs Office)

- Roads
- Streams
- Springs
- Lakes
- Township and range/sections
- Admin boundaries
- Land ownership
- Slope data
- Contours
- Range allotments
- Gas leases/wells
- Visual Resource Management Spec.
- Recreation Opportunity Spec.
- Areas of Critical Environmental Concern
- Special Recreation Management Areas
- Wilderness Study Areas
- Soils
- Watersheds (5th & 6th)