Appendix A.

Biological Report

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I-70 Mountain Corridor PEIS

Biological Report

Arapaho and Roosevelt and White River National Forests

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BR.1. Introduction

This Biological Report (BR) is in response to a Programmatic Environmental Impact Statement (PEIS) being conducted for I-70 from Glenwood Springs to C-470 (Corridor). The purpose of this BR is to determine the likely effects of the alternatives on federally listed species (endangered, threatened, and proposed), U.S. Forest Service (USFS)-sensitive species, management indicator species (MIS), and other species or habitats potentially affected by the project alternatives at a Tier 1 level of detail. This is in accordance with direction in the 1997 revision of the *Land and Resource Management Plan for Arapaho and Roosevelt National Forests and Pawnee National Grassland* and the 2002 revision of the *White River National Forest Land and Resource Management Plan* (Forest Plans).

The BR begins with a description of the project background, including the project area, consultation history, and details of each project alternative, as well as a description of Corridor context, detailing the species considered and evaluated in this BR. Following this background material, the BR includes the following principal sections. The BR addresses all alternatives for species according to their known distribution within the White River National Forest (WRNF) or Arapaho and Roosevelt National Forests (ARNF), or by their designation as management indicators by either forest.

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Twenty-one alternatives were fully evaluated in the Draft PEIS to increase capacity, improve accessibility and mobility, and decrease congestion along the Corridor. This BR addresses the following issues related to biological resources in the Corridor:

- Wildlife and plant habitat loss

- Road effects on adjacent habitats
- Increased barrier effect of I-70 on wildlife
- Increased noise
- Potential for induced growth

More in-depth analyses will be conducted at the Tier 2 level of study, when specific projects are proposed in phases along the Corridor.

BR.2. Project Background and Corridor Impact Context

BR.2.1 Description of the Project Area

The study corridor extends from Glenwood Springs (milepost 116) east to the connection with C-470 (milepost 260). This 144-mile stretch of I-70 traverses five counties—Garfield, Eagle, Summit, Clear Creek, and Jefferson—and more than 20 communities. The Corridor is located, in part, within both the WRNF and the ARNF. While National Forest System Lands exist throughout the Corridor, jurisdiction of adjacent lands alternates along the Corridor between private and public ownership. I-70 directly abuts National Forest System Lands for approximately 50 miles throughout the Corridor. The majority of National Forest System Lands directly adjacent to I-70 are within the WRNF, with a total of 41 miles along I-70 directly adjacent to WRNF lands and 9 miles of I-70 directly adjacent to ARNF lands. Throughout the remaining portions of the Corridor, I-70 is directly abutted by U.S. Bureau of Land Management (BLM) and privately owned lands.

These National Forest System Lands contain various life zones and habitats. Elevations within the Corridor range from a low of approximately 6,000 feet at the eastern end of the Corridor to approximately 11,200 feet at the Eisenhower-Johnson Memorial Tunnels, located at the Continental Divide. The Corridor crosses four major life zones that are defined by changes in climate with elevation increases, which, in turn, are reflected by the broad changes in vegetation communities (Marr 1961; Nelson 1977). These life zones from lower to higher elevations are as follows: Foothills, Montane, Subalpine, and Alpine.

The Foothills Zone occurs at lower elevations from less than 6,000 feet to approximately 8,000 feet but may extend to above 9,000 feet on south exposures. It is relatively complex and may contain ponderosa pine (*Pinus ponderosa*) woodlands, piñon-juniper woodlands, deciduous scrublands such as scrub oak (*Quercus berberidifolia*) and sagebrush, grassland habitats, or some combination thereof, depending on slope exposure and soils. This zone covers a vast area of the Western Slope, where it is characterized by piñon-juniper woodland and sagebrush scrubland.

The Montane Zone extends from approximately 8,000 to 9,000 feet and is characterized by open stands of ponderosa pine, at lower elevations, and more xeric sites on the Eastern Slope, but ponderosa pine is nearly absent in this portion of the Western Slope. Douglas-fir (*pseudootsuga menziesii*) forests predominate at the upper elevations and more mesic sites of this zone.

The Subalpine Zone occurs above 9,000 feet, extends to treeline, and is typified by a co-dominance of Engelmann spruce (*Picea engelmannii*) and subalpine fir (*Abies lasiocarpa*). Lodgepole pine (*pinus contorta* var. *latifolia*) and aspen (*Populus* spp.) occur in both the Montane and Subalpine zones primarily from past disturbances such as fire. Bristlecone pine (*Pinus aristata*) and limber pine (*Pinus flexilis*) characterize rocky wind-swept ridges but are not prominent along the Corridor.

The Alpine Zone consists of a mixture of meadows, tundra, and rock-field communities above approximately 11,200 feet. The transition zone between the Subalpine and the Alpine is characterized by krummholz of Engelmann spruce and subalpine fir, thickets of willows (*Salix* spp.), and grass-sedge dominated meadows. The Alpine Zone occurs only in areas above the EJMT portals in the Corridor.

Other prominent natural features of the Corridor include extensive rocky cliff areas, especially around Georgetown and Idaho Springs. I-70 also follows valley bottoms throughout the Corridor and is, therefore, located in close proximity to portions of major creeks and rivers, as well as their riparian zones. Examples include Clear Creek, Gore Creek, and Eagle River.

In addition to the natural features described above, the Corridor and surrounding area contain various human-created features that influence the structure and function of the natural environment. The I-70 Draft PEIS identified interference with wildlife movement due to the barrier effects created by I-70 as one of the most serious issues affecting wildlife in the Corridor (Chapter 3, Section 3.2.1). Highways, roads, towns, single home sites, and recreational developments along the Corridor influence which areas are available for wildlife. Current and historic human activities within the Corridor have been instrumental in creating the current distribution of habitats and wildlife species in the Corridor. Important anthropogenic factors include fire regime, mining, agricultural development, livestock grazing, land development, road construction, and recreation development. Secondary or indirect impacts from these activities include non-native plant invasions, degraded water quality, and human intrusion into wildlife habitats. Although mining, logging, and grazing historically had the greatest influence, human settlements currently have the greatest indirect effect on the natural systems in the Corridor. Because development tends to be concentrated in the valley bottoms, some of the most notable effects are loss of high-quality riparian, wetland, and floodplain habitats and habitat fragmentation that includes reduced access to these habitats.

BR.2.2 Consultation History

White River National Forest consulted with U.S. Fish and Wildlife Service (USFWS) for their 2002 Forest Plan, which included a Biological Evaluation and a list of appropriate species received from USFWS in August 2008, pursuant to 50 CFR 402.12(c) and the Endangered Species Act (ESA). Ongoing consultation with USFWS has included the preparation of a "forest-specific" list of species to be addressed by projects on the WRNF.

Arapaho and Roosevelt National Forests personnel also consulted with USFWS and received concurrence for the revised Forest Plan in 1997.

The species list presented in **Section BR.2.6** of this BR reflects the WRNF and ARNF Forest Sensitive and MIS species lists dated May 14, 2009, and incorporates USFWS threatened, endangered, and candidate species list dated August 28, 2008.

Informal consultation with USFWS has occurred throughout the PEIS process, including preparation of a draft Biological Assessment (once a Preferred Alternative was identified) and participation in a program that addressed habitat fragmentation and the barrier effect on wildlife of the Corridor. This program called A Landscape Level Inventory of Valued Ecosystem Components (ALIVE) was formed in 2002 with personnel from USFS, USFWS, BLM, Federal Highway Administration (FHWA), Colorado Division of Wildlife, and Colorado Department of Transportation (CDOT). The group developed a long-term strategy for identifying effects of project alternatives and identified areas where crossing difficulties may affect threatened, endangered, or sensitive species, with the lynx (*Lynx canadensis*) as a primary concern. Linkage interference zones were designated along the Corridor as important wildlife crossing areas as part of the ALIVE Committee tasks. The group then developed recommendations to improve porosity of I-70 for wildlife through future construction of new wildlife crossings, improving existing bridges and culverts, and using other techniques including fencing and land conservation strategies. The group reconvened three times in 2008 to initiate the development of a program of cooperation for implementation of the recently signed Memorandum of Understanding. The group updated information on animal-vehicle collisions (AVCs), created an updated inventory of roadway barriers along I-70, and confirmed that there are no new linkage interference zones. See Biological Resources Technical Report for details.

Formal consultation with USFWS was initiated for the PEIS in August 2010 when FHWA submitted the Biological Assessment to USFWS for final approval. Consultation with USFWS has continued, most recently when CDOT received an updated species list on August 28, 2008.

Section 7 of the ESA describes guidelines for interagency cooperation between USFS and USFWS regarding proposed, threatened, or endangered species on this project. Forest Service Manual supplement 2600-90-6 provides definitions relating to “consultation” and “conference.”

Before issuing a Section 404 permit authorizing the placement of dredged or fill material into waters of the U.S., U.S. Army Corps of Engineers (USACE) must evaluate a proposed project to determine its compliance with Section 404(b)(1) Guidelines for Specification of Disposal Sites for Dredged or Fill Material (40 CFR Part 230). For the purposes of this legislation, the alternative chosen must be the least environmentally damaging practicable alternative (LEDPA). The Preferred Alternative Minimum Program of Improvements (Minimum Program) and Preferred Alternative Maximum Program of Improvements (Maximum Program) are practicable (can be done in terms of technology, logistics, and cost) and have the least impacts on aquatic resources. These alternatives are, therefore, the LEDPA.

BR.2.3 Existing Highway-Related Impacts

Specific data about the level of impact created by the existing I-70 highway facility within the Corridor are limited. What is currently known is discussed below. More definitive analyses would be developed for specific Tier 2 projects, including obtaining data from habitat and occurrence surveys for threatened, endangered, USFS-sensitive, and MIS.

The footprint of the existing highway occupies relatively little habitat, compared to the amount available in the surrounding area. However, because I-70 is often located along valley bottoms throughout the Corridor, it impinges upon some of the less common and more valuable habitats in the area of potential effect (APE). In general, valley bottoms contain watercourses that support riparian vegetation and wetlands. These habitat types are important to a wide variety of wildlife in Colorado and are easily compromised by disturbance.

Fragmentation of large animal ranges/habitats and movement corridors caused by I-70 is an even more important issue than habitat loss. Identification of linkage interference zones was used to estimate the amount of movement corridor interference caused by the existing highway in the Corridor. Linkage interference zones are locations along the Corridor where evidence suggests that the existing highway’s barrier effect impedes traditional wildlife movement corridors. Linkage interference zones were identified based largely on expert opinion and the location of existing barriers to at-grade crossings, including guardrails and fencing. AVC data were also considered. A high rate of AVCs in an area was assumed to indicate that that portion of the highway intersected an important animal movement corridor. Additional information about historic movement patterns of mule deer (*Odocoileus hemionus)*, elk (*Cervus elaphus)*, bighorn sheep (*Ovis canadensis)*, and, when data were available, carnivores, was also considered.

The Colorado State Patrol reported a total of 923 AVCs in the Corridor for the 1990 to 1999 period. These data are considered an incomplete picture of AVCs along the Corridor because only animals large enough to damage a vehicle when struck were included, and only a small number of those AVCs are reported. Based on interviews with Department of Transportation and wildlife agency personnel nationwide, Romin and Bissonette (1996) estimated 16 to 50 percent of all AVCs are reported. A study conducted in Nevada compared observed roadkilled deer to reported AVCs along a stretch of highway and estimated only 20 percent of AVCs were reported (Messmer et al. 2000).

Forman and Alexander (1998) coined the term "road effect zone" to encompass a wide range of impacts on wildlife, including noise, traffic disturbances, and input of contaminants into habitats from road maintenance and operations. The width of the road effect zone varies with species and terrain (Singleton et al. 2002). Rost and Bailey (1979) indicated effects occurred approximately 600 feet for mule deer and elk in forest habitats but could extend up to 1,200 feet in shrub habitats. Forman and Deblinger (2000) addressed moose (*Alces alces*), deer, amphibians, forest birds, and grassland birds and calculated an average road effect zone of almost 2,000 feet for their Massachusetts study. Influences of highway activity and noise may be greater for the more sensitive species such as lynx or wolverine (*Gulo gulo)* and may limit their movements through areas adjacent to the road (WRNF, 2002a, b). Winter maintenance material used to improve traction and/or melt ice from roadways is known to affect downstream (downgradient) habitats. Sand is especially evident at the higher elevations of the Corridor, such as on Vail Pass and approaches to EJMT where application is more frequent than at lower elevations. CDOT is currently studying the means to control winter maintenance material and reduce the amount that escapes the roadway, with some in place (for example, Berthoud Pass).

BR.2.4 Development Influence

In addition to I-70, human population centers, increasing development, and human intrusion act as barriers to wildlife that historically crossed the Corridor in their migration or daily movements to access key habitats that supply forage or prey, cover, and water; to repopulate additional areas; and to fulfill breeding and young-rearing requirements. Transportation corridors and the communities that have developed have been a prominent cause of habitat fragmentation in the Colorado mountains in general (USDA, 2002b). Mountain valleys that contain important habitats and serve as wildlife migration and movement pathways are often subject to development.

BR.2.5 Project Alternatives

In addition to the No Action Alternative, 20 action alternatives were considered in the Draft PEIS. These alternatives included a Minimal Action Alternative, 4 Transit alternatives, 3 Highway alternatives, and 12 Combination alternatives. All alternatives include select Minimal Action components such as interchange modifications, auxiliary lanes, and curve safety modification (seeSection BR.1).

It is important to note that while the study corridor extends from Glenwood Springs (milepost 116) east to the connection with C-470 (milepost 260), each alternative occurs in different areas of the Corridor, and no project alternative includes improvements along the entire 144 miles. It should be noted that no alternative analyzed in this PEIS includes improvements through Glenwood Canyon between milepost 117 and milepost 129.

Section BR.2.5.1 provides a description of the Preferred Alternative. See the *I-70 Mountain Corrridor PEIS Description of Alternatives Technical Report* (CDOT, August 2010) for additional information about the identification of the Preferred Alternative and the Collaborative Effort process.

BR.2.5.1 Preferred Alternative

The Preferred Alternative consists of near-term and general long-term improvements for the I-70 Mountain Corridor. These improvements are designed to meet the travel demand for 2050, while addressing the immediate needs in the Corridor. To achieve the long-term vision and address the future uncertainties, trigger points and stakeholder involvement will be used to reassess the Corridor needs to determine the most appropriate transportation improvements to meet the future demands within the Corridor.

The Preferred Alternative is a multimodal solution and includes non-infrastructure related components, Advanced Guideway System, and highway improvements.

- **Non-infrastructure Related Components** – These are strategies that can begin in advance of major infrastructure improvements to address some of the immediate issues in the Corridor. These strategies and the potential tactics for implementation require actions and leadership by agencies, municipalities and other stakeholders beyond CDOT and FHWA. The strategies include, but are not limited to the following:
  - Increased enforcement
  - Bus, van or shuttle service in mixed traffic
  - Programs for improving truck movements
  - Driver education
  - Expanded use of existing transportation infrastructure in and adjacent to the Corridor
  - Use of technology advancements and improvements which may increase mobility without additional infrastructure
  - Traveler information and other intelligent transportation systems (ITS)
  - Shift passenger and freight travel demand by time of day and day of week
  - Convert day trips to overnight stays
  - Promote high occupancy travel and public transportation
  - Convert single occupancy vehicle commuters to high occupancy travel and/or public transportation
  - Implement transit promotion and incentives
  - Other transportation demand management (TDM) measures yet to be determined

- **Advanced Guideway System** – The Advanced Guideway System is a central part of the Preferred Alternative and includes the commitment by the lead agencies to the evaluation and implementation of Advanced Guideway System within the Corridor. The evaluation would include a vision of transit connectivity beyond the study area and local accessibility to such a system. At this Tier 1 level, Advanced Guideway System represents a mode encompassing a range of technologies, not a specific technology. A specific Advanced Guideway System technology will be determined in subsequent study or a Tier 2 document. CDOT is committed to provide funding for studies to determine the viability, including cost vs. benefits, safety, reliability, environmental impacts, technology, and other considerations of Advanced Guideway System. These studies will involve the CE stakeholder committee and follow the I-70 Mountain Corridor Context Sensitive Solutions (CSS) process.

  Advanced Guideway System provides transit service from C-470 to the Eagle County Regional Airport, a distance of approximately 118 miles. It is a fully elevated system on two tracks and aligns to the north, south or in the median of the I-70 Mountain Corridor. Advanced Guideway System connects with the RTD network in Jefferson County and with local and regional transit services at most of the 15 proposed stations along the route.

  New tunnel bores at both the EJMT and the Twin Tunnels are required with Advanced Guideway System. At the EJMT the proposed third tunnel bore will be located to the north of the existing tunnel bores and will accommodate bidirectional Advanced Guideway System. At the Twin Tunnels, the proposed third tunnel bore will be located to the south of the existing tunnel bores and will accommodate bidirectional Advanced Guideway System.

- **Highway Improvements** – Additional highway improvements are needed to address current Corridor conditions and future demands. No priority has been established for improvements and they must be planned considering all elements of the Preferred Alternative and be consistent with local land use planning. The “specific” highway improvements are called out specifically as the triggers for consideration of the future highway and non-Advanced Guideway System transit capacity improvements and will need to be completed prior to implementation of any future highway and non-Advanced Guideway System transit capacity improvements The “other” highway improvements are not subject to the parameters discussed under the triggers.

- Specific highway improvements:
  - Six–lane component from Floyd Hill through the Twin Tunnels - Includes a bike trail and frontage roads from Idaho Springs to Hidden Valley and Hidden Valley to US 6
  - Empire Junction (U.S. 40/I-70) interchange improvements
  - Eastbound auxiliary lane from EJMT to Herman Gulch
  - Westbound auxiliary lane from Bakerville to EJMT
- Other highway improvements:
  - Truck operation improvements (pullouts, parking and chain stations)
  - Curve safety improvements west of Wolcott
  - Safety and capacity improvements in Dowd Canyon
  - Interchange improvements
  - Additional auxiliary lanes:
  - Avon to Post Boulevard (exit 168) (eastbound)
  - West of Vail Pass (eastbound and westbound)
  - Eastbound auxiliary lane from Frisco to Silverthorne
  - Morrison to Chief Hosa (westbound)

These improvements representing the initial set of improvements are the minimum program of improvements and are expected to be implemented in the near-term. Agencies and stakeholders will review progress and effects of these improvements at least every two years to determine if there is a need for additional highway and non-Advanced Guideway System transit capacity improvements. For the long-term improvements, to meet the 2050 travel demand, the Preferred Alternative is equivalent to the Combination Six-Lane Highway with Advanced Guideway System Alternative, if deemed necessary. For NEPA analysis, this represents the maximum program of improvements and impacts and is analyzed in Chapter 3 of this document. The Preferred Alternative Maximum Program, for analysis purposes, consists all of these improvements: those listed above and those included with the Six-Lane Highway and Combination Six-Lane Highway with Advanced Guideway System Alternative.

The Six-Lane Highway widening improvements included with the Preferred Alternative Maximum Program include both 55 mph and 65 mph design options, which will be determined in Tier 2. The 55 mph option uses the existing I-70 alignment. The 65 mph design requires additional tunnels at Dowd Canyon, Hidden Valley and Floyd Hill. At Dowd Canyon two tunnels are required for eastbound and westbound traffic. These tunnels accommodate three lanes in each direction. At Hidden Valley and Floyd Hill, two new tunnels are required – one for westbound traffic just east of the Twin Tunnels near Hidden Valley and one for eastbound traffic at Floyd Hill. Each of these tunnels accommodats three lanes in one direction. Traffic in the other direction will use the existing I-70 configuration.

Table BR - 1 lists the improvements associated with the Preferred Alternativ,.

Table BR - 1. Elements of Preferred Alternative

Transportation Elements Preferred Alternative	Preferred Alternative			
	Minimum Program 55 mph	Minimum Program 65 mph	Maximum Program 55 mph	Maximum Program 65 mph
Transportation Management				
Transportation Management				
Advanced Guideway System				

Transportation Elements Preferred Alternative	Preferred Alternative			
	Minimum Program 55 mph	Minimum Program 65 mph	Maximum Program 55 mph	Maximum Program 65 mph
AGS (MP 142-260)				
Highway Improvements				
Specific Highway Improvements				
Six-lane highway Floyd Hill through Twin Tunnels with bike trail and frontage roads from Idaho Springs to Hidden Valley to U.S. 6				
Empire (MP 232)				
EB auxiliary lane – EJMT to Herman Gulch				
WB auxiliary lane – Bakerville to EJMT				
Other Highway Improvements - Interchanges				
Glenwood Springs (MP 116)				
Gypsum (MP 140)				
Eagle & Spur Road (MP 147)				
Edwards & Spur Road (MP 163)				
Avon (MP 167)				
Minturn (MP 171)				
Vail West (MP 173) / Simba Run				
Copper Mountain (MP 195)				
Frisco / Main St. (MP 201)				
Frisco / SH 9 (MP 203)				
Silverthorne (MP 205)				
Loveland Pass (MP 216)				
Silver Plume (MP 226)				
Georgetown (MP 228)				
Downieville (MP 234)				
Fall River Road (MP 238)				
Idaho Springs West (MP 239)				
Idaho Springs / SH 103 (MP 240)				
Idaho Springs East (MP 241)				
Base of Floyd Hill / US 6 (MP 244)				
Hyland Hills/Beaver Brook (MP 247 – MP 248)				
Lookout Mountain (MP 256)				
Morrison (MP 259)				
Other Highway Improvements – Curve Safety Modifications				

Transportation Elements Preferred Alternative	Preferred Alternative			
	Minimum Program 55 mph	Minimum Program 65 mph	Maximum Program 55 mph	Maximum Program 65 mph
West of Wolcott (MP 155–156)				
Dowd Canyon (MP 170–173)				
Fall River Road (MP 237–238)				
East of Twin Tunnels (MP 242–245)	Included in Six-Lane Highway Widening			
Other Highway Improvements – Auxilary Lanes				
Avon to Post, Uphill (EB) (MP 167–168)				
West side of Vail Pass, Downhill (WB) (MP 180–190)				
West side of Vail Pass, Uphill (EB) (MP 180–190)				
Frisco to Silverthorne (EB) (MP 202.7–205.1)				
Morrison to Chief Hosa, Uphill (WB) (MP 253–259)				
Tunnels				
Dowd Canyon				
EJMT – third bore				
Twin Tunnels – third bore				
Hidden Valley Tunnel WB				
Floyd Hill Tunnel EB – w/65				
Other Improvements				
Truck operation improvements (pullouts, parking and chain stations)				
Black Gore Creek and Clear Creek Sediment Control				

Key to Abbreviations

MP = milepost EJMT = Eisenhower-Johnson Memorial Tunnels EB = Eastbound WB = Westbound

BR.2.5.2 Alternatives Evaluated in the Draft PEIS

No Action

The No Action Alternative consists of projects on the existing network and represents a suppression of travel demand. This includes ongoing highway maintenance and any other projects that have a committed source of funding within the 20-year plan, including the Gaming area access, Hogback parking facility, Eagle County Airport interchange, and SH 9. Corridor-wide maintenance includes safety and signage improvements, bridge reconstruction and replacement, road resurfacing, rockfall mitigation, tunnel enhancement projects, sediment control, and routine maintenance.

Minimal Action

The Minimal Action Alternative isdesigned to more fully maximize the capacity of existing I-70 without major capacity improvements, yet it still represents a suppression of travel demand.

Several components of the Minimal Action Alternative are combined with the other Action Alternatives. These improvements, referred to throughout the PEIS as "Minimal Action components," include interchange modifications, curve safety modifications, and auxiliary lanes and are shown on **Figure BR - 1**. Minimal Action components include the same interchange modifications for all alternatives but may or may not include auxiliary lanes and curve safety modifications depending on whether the alternative is a Transit, Highway, or Combination Alternative.

Rail with Intermountain Connection

The Rail with Intermountain Connection Alternative consists of (1) an on-grade electrified facility with elevated sections, where needed, for wildlife crossings and geologic hazards between Vail and C-470, combined with (2) a mode shift to the diesel-powered Intermountain Connection, which involves the use of the Union Pacific Railroad track from the Minturn interchange to Eagle County Airport and require new track from Vail to Minturn and from west of Eagle to Eagle County Airport. The Rail with Intermountain Connection alignment is adjacent to I-70, with portions in the median.

Photo simulation of the Rail with Intermountain Connection alternative in the vicinitv of Silver Plume.

Advanced Guideway System

The Advanced Guideway System Alternative is a fully elevated system that uses new or emerging technologies providing higher speeds than the other transit technologies under study. The Advanced Guideway System is based on an urban magnetic levitation (maglev) system researched by the Federal Transit Administration. The system uses High-Speed Surface Transportation vehicles developed in Japan over the past 25 years, with a history of proven performance and certification by the Japanese government but need to be heavily modified to meet the constraints of the Corridor. The former Colorado Intermountain Fixed Guideway Authority proposed another system

Photo simulation of the AGS alternative in the vicinity of Silver Plume.

considered under the Advanced Guideway System, a monorail system, but it has not been tested to verify its performance. Nevertheless, either system serves as an example of the types of systems to be evaluated.

Bus in Guideway

The Bus in Guideway system consists of a bi-directional 24-foot-wide guideway (including guiding rails) from the Eagle Airport to C-470. This system uses guidewheels to provide steering control, thus permitting a narrow guideway and improving operations. The dual-mode buses use electric power in the guideway and diesel power outside the guideway. The diesel buses use diesel power at all times. The use of electric power enables the dual-mode bus to reach Corridor speeds of up to 70 mph. For a vehicle to be authorized to use the guideway, the vehicle operator must have a Commercial Driver's License with Passenger Endorsements, and the vehicle must be equipped with compatible guidance mechanisms, as the lack of shoulders and the presence of barriers prevent other vehicles from using the guideway.

Photo simulation of the Bus in Guideway alternative in the median in Lawson.

The guideway is aligned within the median, except for Tenmile Creek (milepost 190 to milepost 194), where it is to be placed on the north side of I-70 similar to the Advanced Guideway System and Rail with Intermountain Connection alternatives. For this portion, the footprint abuts the I-70 edge of pavement. The guideway is elevated on Vail Pass and Tenmile Creek (milepost 180 to milepost 194), similar to the Rail with Intermountain Connection and Advanced Guideway System Alternatives to minimize impacts on wildlife and wetlands.

Six-Lane Highway 55 mph

The Six-Lane Highway 55 mph Alternative includes additional traffic lanes in select locations within the Corridor. In the Dowd Canyon area (Eagle-Vail to Vail West), there are two additional lanes between milepost 170 and milepost 173, one eastbound and one westbound. In the Continental Divide to Floyd Hill area, there are two additional lanes between milepost 213.5 (Eisenhower-Johnson Memorial Tunnels) and milepost 247 (Floyd Hill), one eastbound and one westbound. Elevated eastbound lanes may be used in the Idaho Springs area (milepost 238.9 to milepost 241.4). A paved ditch for snow storage is provided on one side of the highway.

Photo simulation of the Six-Lane Highway (55 and 65 mph) alternatives in Idaho Springs.

Six-Lane Highway 65 mph

The Six-Lane Highway 65 mph Alternative more directly addresses Corridor safety issues with the utilization of new tunnels in addition to widening the existing template as proposed under the Six-Lane Highway (55 mph) alternative. Features of this alternative include the following:

- In Eagle County, two new tunnel bores are constructed through Dowd Canyon to accommodate six lanes of I-70 in lieu of widening the existing roadway.

- In Clear Creek County, one new tunnel bore to accommodate westbound traffic is constructed from the Twin Tunnels to Hidden Valley, with the addition of one new tunnel bore for eastbound I-70 between Hidden Valley and Floyd Hill.
- In addition, highway curve safety modifications occur near the new tunnels and at Fall River Road in Clear Creek County.
- Interstate 70 is widened to six lanes throughout the remainder of Clear Creek County as described in the Executive Summary of the 2004 Draft PEIS.

Reversible/HOV/HOT Highway Lanes

A reversible lane facility has the capability to change traffic flow directions as needed to accommodate peak direction demand. Reversible lanes are built from the west side of the Eisenhower-Johnson Memorial Tunnels to just east of Hyland Hills. From the Eisenhower-Johnson Memorial Tunnels to just east of the U.S. 6/base of Floyd Hill interchange, two additional lanes are provided in the center between the two eastbound and two westbound general purpose lanes, separated by a barrier. One of the lanes provides access to/from U.S. 6/Clear Creek Canyon and the other continues east along I-70, ending between Hyland Hills and Beaver Brook. The only entrance and exit from the reversible lanes evaluated for Tier 1 studies is at the termini at U.S. 6 and at the Empire Junction interchange. Tunnel requirements are the same as those for the Six-Lane Highway 55 mph alternative. Two additional general-purpose lanes in Dowd Canyon (milepost 170 to milepost 173), but not barrier separated or reversible, are also part of this alternative.

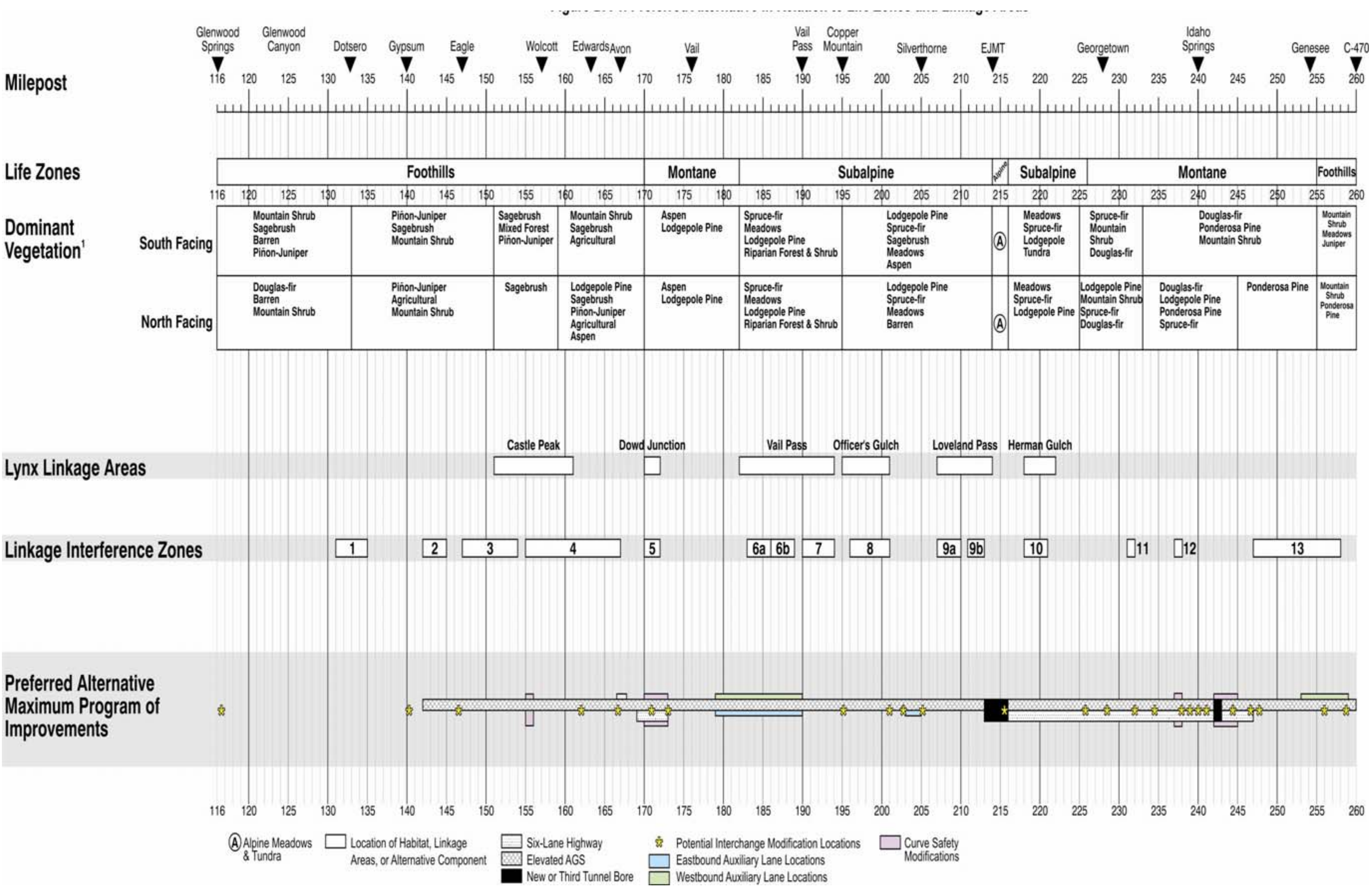
Combination Alternatives

All Combination Alternatives combine a single-mode Transit Alternative with the Six-Lane Highway 55 mph Alternative. For example, the single-mode Rail with Intermountain Connection Alternative, as described previously, from Eagle County Airport to C-470 is combined with the Six-Lane Highway 55 mph alternative, as described previously, in Dowd Canyon and in Clear Creek County between Eisenhower-Johnson Memorial Tunnels and Floyd Hill.

The following Combination alternatives have been considered:

- Combination Six-Lane Highway with Rail and Intermountain Connection
- Combination Six-Lane Highway with Advanced Guideway System
- Combination Six-Lane Highway with Dual-Mode Bus in Guideway
- Combination Six-Lane Highway with Diesel Bus in Guideway

Figure BR - 1. Project Alternatives In Relation to Life Zones, Dominant Vegetation, and Key Wildlife Areas



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BR.2.6 Species Considered and Evaluated

This section provides the review of the species considered for evaluation in the BR. A list of species with status under the federal ESA for the affected counties in the Corridor was initially developed based on programmatic consultation with USFWS and USFS, ALIVE Committee involvement in the PEIS, and knowledge of the area. National Forest Region 2 sensitive species and MIS that may occur or be influenced by the project activities on the WRNF or the ARNF were also evaluated for potential impacts. The Regional Forester provided the Region 2 Endangered, Threatened, Proposed and Sensitive Species matrix (May 2009), which includes the threatened and endangered species listed in **Table BR - 2**. The consideration of the species identified through the sources described above resulted in the following series of tables that are presented in this section, including:

- **Table BR - 2**. Federally Listed Species That May Occur on the WRNF (WR) and the ARNF (AR) or That May Be Influenced by Project Activities (Rocky Mountain Region – TEPS Species, May 2009)
- **Table BR – 3**. Region 2 Forest Service Sensitive Species Known or Suspected to Occur on WRNF (WR) and ARNF (AR), or That May Be Influenced by Project Activities (Rocky Mountain Region – TEPS Species, May 2009)
- **Table BR - 4**. MIS (Not Previously Covered in **Table BR - 2** or **Table BR – 3**) That May Occur or Be Influenced by Project Activities
- **Table BR – 5**. Summary of Species Included in Project Analysis

The APE was evaluated for each species to include habitat that could be directly or indirectly affected by project alternatives. This BR does not discuss further those species noted as not being included on **Table BR - 2** and **Table BR – 3**. **Table BR – 5** provides the list of federally listed threatened or endangered species, USFS sensitive species, and USFS MIS that are evaluated in **Sections BR.3** and **BR.4.2**. Species were not included if they or their habitat was not found, were unlikely to be present within the Corridor, or were unlikely to be influenced by the project, based on best available scientific information. The reasons for excluding species from further consideration are provided in **Table BR - 2** and **Table BR – 3**. Additional rationale for exclusion of sensitive species is provided as necessary directly following **Table BR – 3**. If suitable habitat is present along the Corridor, species were retained for further evaluation.

Table BR - 2. Federally Listed Species That May Occur on the WRNF (WR) and the ARNF (AR) or That May Be Influenced by Project Activities (Rocky Mountain Region - TEPS Species, May 2009)

Common Name	Species	Status	National Forest	MIS / Indicator Community	Species Included	Reason for Exclusion (or inclusion with plant species)
Mammals						
Canada lynx	*Lynx canadensis*	Threatened	AR[K]/WR[K]	No	Yes	
Preble's meadow jumping mouse	*Zapus hudsonius preblei*	Threatened	AR[K]	No	No	Suitable habitat only along Corridor outside National Forest System Lands. Suitable habitat and individuals are known to occur near I-70, between mp 247 and mp 248 (J. Peterson pers. comm. with L. Hettinger, 2004). This area is approximately 22 miles east of National Forest System Lands. Project is not expected to have indirect effects on this habitat or individuals on National Forest System Lands.

Common Name	Species	Status	National Forest	MIS / Indicator Community	Species Included	Reason for Exclusion (or inclusion with plant species)
Gunnison's prairie dog	*Cynomys gunnisoni*	Candidate		No	No	No habitat or species in the area of potential effect (APE).
Birds						
Least tern▲	*Sterna antillarum*	Endangered	AR[N]	No	Yes	
Piping plover▲	*Charadrius melodus*	Threatened	AR[N]	No	Yes	
Whooping crane▲	*Grus americana*	Endangered	AR[N]	No	Yes	
Mexican spotted owl	*Strix occidentalis lucida*	Threatened	AR[L]/WR[L]	No	No	No habitat or species in the APE. In Colorado, owls are known to inhabit Mesa Verde National Park (www.rmbo.org) and other areas in the state, such as the Wet Mountains and Dinosaur National Park. Suitable habitat may occur in Glenwood Canyon, but no activities associated with any alternatives are proposed in the canyon (mp 117 to mp 129). The APE does not extend into any critical habitat (www.fws.gov/ifw2es/mso).
Greater (northern) sage grouse	*Centrocercus urophasianus*	Candidate	AR[N]/WR[K]	No	No	As its name suggests, sage grouse depend on healthy sage grasslands habitat (www.nwf.org). While sagebrush occurs intermittently throughout the Corridor, but primarily in Eagle County, no impacts on sagebrush occur on National Forest System Lands. Populations have not been documented in the APE (D. Lowry and K. Giezentanner pers. comm. with D. Solomon, 2006a).
Fish						
Bonytail chub*	*Gila elegans (presumed-historical)*	Endangered	AR[N]/WR[N]	No	Yes	
Colorado pikeminnow*	*Ptychocheilus lucius*	Endangered	AR[N]/WR[N]	No	Yes	
Humpback chub*	*Gila cypha*	Endangered	AR[N]/WR [N]	No	Yes	
Razorback sucker*	*Xyrauchen texanus*	Endangered	AR[N]/WR[N]	No	Yes	
Pallid sturgeon▲	*Scaphirhynchus albus*	Endangered	AR[N]	No	Yes	
Greenback cutthroat trout▲	*Oncorhynchus clarki stomias*	Threatened	AR[K]/WR[K]	Yes/montane aquatic	Yes	
Invertebrates						
Uncompahgre fritillary butterfly	*Boloria acrocnema*	Endangered	WR[L]	No	No	No habitat or occurrence in vicinity of the Corridor. Preferred habitat is stands of snow willow at elevations greater than 13,200 feet in the San Juan Mountains of southwest Colorado (ecos.fws.gov/docs/frdocs/1991/91-14970.html and www.butterflyrecovery.org). Surveys conducted in areas surrounding Loveland Pass have excluded this area

Common Name	Species	Status	National Forest	MIS / Indicator Community	Species Included	Reason for Exclusion (or inclusion with plant species)
						as occupied habitat (K. Giezentanner pers. comm., 2006). The maximum elevation of project alternatives occurs at 11,200 feet and does not enter suitable habitat for this species.
Plants						
Colorado butterfly plant	*Gaura neomexicana* ssp. *coloradensis*	Threatened	ARΨ	No	No	Does not occur in the APE; all locations downstream from the Corridor are on side tributaries outside the areas that could be affected by water depletions in the Platte River drainage (Mayo, 2004).
Western prairie fringed orchid▲	*Platanthera praeclara*	Threatened	AR	No	Yes	No plants or habitat along Corridor; nearest locations in Nebraska; downstream effects possible (mainstem Platte River).
Ute ladies'-tresses orchid▲	*Spiranthes diluvialis*	Threatened	AR	No	Yes	Plants and potential habitat present outside National Forest System Lands, but in APE; downstream effects possible (Clear Creek and Platte River drainages).
Colorado hookless cactus	*Sclerocactus glaucus*	Threatened		No	No	No plants or habitat recorded in the APE. Plant is endemic to desert shrub communities west of Glenwood Springs (S. Popovich pers. comm., 2007). Is found west of the WRNF but not on Forest lands (K. Giezentanner pers. comm., 2007). Populations occur on benches along the Green, Colorado, and Gunnison rivers. No construction activities are proposed along the Colorado River in Garfield County.
DeBeque phacelia	*Phacelia submutica*	Candidate		No	No	No plants or habitat in APE; occurs west of Glenwood.
Parachute beardtongue	*Penstemon debilis*	Candidate		No	No	No plants or habitat in APE; occurs west of Glenwood.

Notes:
▲ Water depletions are not known at this point in the evaluation, but if they occur, these Platte River Basin species may be affected.
**Water depletions are not known at this point in the evaluation, but if they occur, these Colorado River Basin species may be affected.*
K – Species currently documented to occur on National Forest System Lands.
L – Species or habitat is suspected to occur on National Forest System Lands but unconfirmed.
N – Species not known or suspected to occur on National Forest System Lands; however, it may occur in planning area vicinity. Requires evaluation whether indirect effects from project alternatives may occur.
Ψ This species is suspected to occur downstream but is unconfirmed on the Arapaho and Roosevelt National Forests.
† These species are suspected to occur but are unconfirmed on this National Forest.

The Regional Forester provided the Region 2 TEPS Species matrix (2009), which includes the sensitive species listed in **Table BR – 3**. These species were evaluated to determine those that occur in the national forest or that may be affected by the project, which should be analyzed further. Similarly, this BR does not discuss further those excluded through this screening process.

Table BR – 3. Region 2 Forest Service Sensitive Species Known or Suspected to Occur on WRNF (WR) and ARNF (AR), or That May Be Influenced by Project Activities (Rocky Mountain Region – TEPS Species, May 2009)

Common Name	Species	National Forest	MIS / Indicator Community	Species Included	Reason for Exclusion
Mammals					
Pygmy shrew	*Sorex hoyi montanus*	AR[K]/WR[L]	No	Yes	
Fringed myotis	*Myotis thysanodes*	AR[N]/WR[L]	No	No	There have been six observations in Colorado since 1990. None were in the Corridor, but the nearest ones were in eastern Garfield and northern Teller counties (Kienath, 2004). Species and habitat have not been documented in the vicinity of the Corridor near the ARNF (D. Lowry pers. comm. with D. Solomon, 2006a). The bat is suspected to occur on the WRNF but is expected to be at elevations below much of the Corridor activities (K. Giezentanner pers. comm. with D. Solomon, 2006a).
Spotted bat	*Euderma maculatum*	WR[K]	No	No	No habitat or species in the APE. Suitable habitat and individuals are known to occur at lower elevations than that of National Forest System Lands within the APE (Fitzgerald et al., 1994). Known from seven Western Slope counties, but only Garfield County would have project alternatives (interchange at mp 116). No downstream effects on habitat or individuals from the project on National Forest System Lands are expected.
Townsend's big-eared bat	*Corynorhinus townsendii*	AR[K]/WR[K]	No	No	Suitable habitat only along Corridor is outside National Forest System Lands. This bat is known from the western two-thirds of the state at lower elevations (7,500 feet and below) than that of National Forest System Lands within the Corridor (Fitzgerald et al., 1994), and from caves in area. No downstream effects on habitat or individuals from the project on National Forest System Lands are expected.
White-tailed prairie dog	*Cynomys leucurus*	AR[L]	No	No	No habitat or species in the APE. Prairie dog colonies exist in the eastern foothills and prairies, and potential habitat exists in Garfield and Eagle counties. Prairie dogs are not present on the WRNF (K. Giezentanner pers. comm. with L. Hettinger, 2006b). There is potential habitat on the ARNF, but the presence of prairie dogs has not been documented. The Corridor would not intrude on these habitats.
River otter	*Lontra canadensis*	AR[K]/WR[L]	No	Yes	
American marten	*Martes americana*	AR[K]/WR[K]	No	Yes	
North American wolverine	*Gulo gulo*	AR[L]/WR[K]	No	Yes	
Bighorn sheep	*Ovis canadensis*	AR[K]/WR[K]	Yes	Yes	

Common Name	Species	National Forest	MIS / Indicator Community	Species Included	Reason for Exclusion
Birds					
American bittern	*Botaurus lentiginosus*	AR[K]	No	No	It is unlikely that habitat or individuals are found in the APE. This bird is a wetland-riparian obligate requiring large wetlands with dense herbaceous cover, as well as open water. Habitat in the APE is not suited to this shy and reclusive species (USFS, 1997). Both the Colorado Breeding Bird Atlas and Andrews and Righter (1992) discount the presence of this species on the WRNF.
Bald eagle	*Haliaeetus leucocephalus*	AR/WR	No	Yes	
Northern goshawk	*Accipiter gentilis*	AR[K]/WR[K]	No	Yes	
Ferruginous hawk	*Buteo regalis*	AR[K]/WR[K]	Yes on Pawnee NG/ short-grass & mid-grass prairie	No	The species conservation assessment indicates there are an estimated 300 nests in Colorado (Collins and Reynolds, 2005). No species or habitat in the APE (D. Lowry pers. comm. with D. Solomon, 2006b). Colorado Breeding Bird Atlas indicates the majority of sightings were on the Eastern Plains with rare to uncommon sightings in the Colorado Plateau (CDOW, 2003). The hawk has been sighted in Garfield County but is generally considered a transient in the area. The hawk is considered a transient species for the WRNF.
American peregrine falcon	*Falco peregrinus anatum*	AR[K]/WR[K]	No	Yes	
Northern harrier	*Circus cyaneus*	AR[K]/WR[K]	No	No	No habitat or species in the APE, as the northern harrier requires open habitats such as fields, prairies, and marshes where it can hunt for small mammals, birds, reptiles, and amphibians. It also nests in open areas on the ground (NatureServe, 2006). NatureServe classifies the harrier as vulnerable in Colorado. The species conservation assessment states they use an array of habitats but generally avoid high elevations in the Rocky Mountains (Slater and Rock, 2005). Also, the APE is not considered potential habitat for the harrier as the species is not a montane breeder. The Corridor is certainly not important to the species (Leukering, 2006).
Columbian sharp-tailed grouse	*Tympanachus phasianellus columbianus*	WR[L]	No	No	No habitat or species in the APE. The range for this grouse has contracted in northwest Colorado, but the population is stable (http://ndisweb.nrel.colostate.edu). Colorado Division of Wildlife mapping shows no potential habitat in Corridor counties.
White-tailed ptarmigan	*Lagopus leucurus*	AR[K]/WR[K]	No	Yes	
Long-billed curlew	*Numenius americanus*	AR[K]	No	No	No habitat or species in the APE. Curlew have been observed in Jefferson County (NatureServe 2006); however, the APE does not extend out of the foothills and does not affect any open grasslands or prairies at low elevations where long-billed curlew populations may be present.

Common Name	Species	National Forest	MIS / Indicator Community	Species Included	Reason for Exclusion
Black tern	*Chlidonias niger*	AR[K]	No	No	In Region 2, these birds are most abundant in prairie pothole areas. The species conservation assessment (Naugle, 2004) notes they may occur in isolated pockets in Colorado and Wyoming. No habitat or individuals in the APE. Kingery (1998) observed black tern on the west slope of the Rockies. The only confirmed breeding populations are in the San Luis Valley and the Arapaho National Wildlife Refuge in northern Colorado (USFWS, 2006a). The APE does not extend into any of these areas.
Yellow-billed cuckoo	*Coccyzus americanus occidentalis*	AR[N]	No	No	
Burrowing owl	*Athene cunicularia*	AR[K]	Yes on Pawnee NG/ prairie dog towns	No	No habitat or species in the APE. Colorado Division of Wildlife GAP maps indicate that no populations have been recorded for the APE (McDonald et al., 2004). Jefferson County is the only county affected by the Corridor that had sightings of burrowing owls in a 1999 survey of Colorado (VerCauteren et al., 2001). The APE does not extend out of the foothills to areas where prairie dog colonies may exist. No populations have been observed in the APE (USFS, 2005).
Boreal owl	*Aegolius funereus*	AR[K]/WR[K]	No	Yes	
Flammulated owl	*Otus flammeolus*	AR[K]/WR[K]	No	Yes	
Black swift	*Cypseloides niger*	AR[K]/WR[K]	No	Yes	
Lewis's woodpecker	*Melanerpes lewis*	AR[K]/WR[L]	No	No	The species conservation assessment notes that the distribution of this woodpecker closely matches that of ponderosa pine in the western U.S. (Abele et al., 2004). Suitable habitat exists along the Corridor outside National Forest System Lands. In western Colorado, Lewis's woodpecker are fairly common summer residents in central and southwestern valleys, but rarely north of the Colorado River (NDIS website). The woodpecker is known from ARNF lands in Jefferson County, approximately 2 miles north of the Corridor between mp 251 and mp 258. Project alternatives are not expected to affect those woodpeckers. The woodpecker is suspected to occur on the WRNF but has not been confirmed.
American three-toed woodpecker	*Picoides dorsalis*	AR[K]/WR[K]	No	Yes	
Olive-sided flycatcher	*Contopus cooperi*	AR[K]/WR[K]	No	Yes	
Purple martin arboricola	*Progne subis*	AR[K]/WR[K]	No	No	Rare passover migrant in the APE. Purple martins are uncommon breeders in the western mountains of Colorado and are accidental inhabitants of the Eastern Plains. They occur only as rare spring and fall migrants in these areas (www.rmbo.org). The species conservation assessment (Wiggins, 2005a) states this western subspecies is restricted to Western Slope aspen

Common Name	Species	National Forest	MIS / Indicator Community	Species Included	Reason for Exclusion
					forests and appears patchily distributed. The western third of Colorado has a positive population trend (Wiggins, 2005a).
Loggerhead shrike	*Lanius ludovicianus*	AR^K/WR^K	No	No	Passover migrant only. Shrikes occupy the Eastern Plains of Colorado and desert shrub areas of the San Luis Valley and the desert lowlands of the Western Slope. NDIS information indicates there are no confirmed breeding records in mountain parks or the mountains. The NDIS web page (http://ndisweb.nrel.colostate.edu) indicates the species has apparently been extirpated from some areas of eastern Colorado as a breeding species but has not appeared to have declined in western Colorado. The APE does not extend into either the Eastern Plains or the desert shrublands of the Western Slope. The species conservation assessment states that shrikes currently breed throughout lower elevation areas of Region 2 and are absent only in the higher elevation areas of Colorado and Wyoming (Wiggins, 2005b).
Sage sparrow	*Amphispiza belli*	WR^L	No	No	Sage sparrows are obligate species in large (>300 acres) stands of sagebrush at the lower elevational range for sagebrush (Holmes and Johnson, 2005b). Their population is densest in Moffat County followed by Mesa, Montrose, and Montezuma counties (www.rmbo.org). Sagebrush is the second largest category of shrubland on the WRNF (42,473 acres), and alternatives disturb less than 38 acres, none of which occurs on National Forest System Lands.
Brewer's sparrow	*Spizella breweri*	AR^K /WR^K	Yes on WR – sagebrush shrub communities	Yes	
Amphibians					
Boreal toad	*Bufo boreas boreas*	AR^K/WR^K	Yes on AR – montane riparian & wetlands	Yes	
Northern leopard frog	*Rana pipiens*	AR^K/WR^K	No	Yes	
Wood frog	*Rana sylvatica*	AR^K	No	No	Colorado Natural Heritage Program and ARNF report that the wood frog occurs in Grand, Jackson, and Larimer counties in ponds of the North Platte headwaters. The only other potential water bodies at high elevation in the Corridor are Dillon Reservoir and a small, unnamed pond between Dillon Reservoir and I-70 at mp 204. This species has not been found along the APE, as the Corridor is approximately 50 miles from known locations.
Fish					
Colorado River cutthroat trout	*Oncorhynchus clarki pleuriticus*	AR^K/WR^K	Yes WR & AR –	Yes	

Common Name	Species	National Forest	MIS / Indicator Community	Species Included	Reason for Exclusion
			montane aquatic		
Lake chub	*Couesius plumbeus*	AR[L]	No	No	The lake chub is critically imperiled in Colorado, and the only observed populations exist in two Clear Creek County reservoirs in the St. Vrain drainage and two reservoirs in the upper Cache La Poudre drainage in Larimer County on the ARNF (CDOW, 2006b). There are no records of the lake chub west of the Continental Divide in Colorado. The Corridor does not extend into the St. Vrain drainage or into Larimer County.
Roundtail chub	*Gila robusta*	WR[K]	No	No	The species conservation assessment states the roundtail chub is endemic to the Colorado River in Colorado and Wyoming. Historic distribution included much of Region 2, but little is actually on National Forest System Lands (Rees et al. 2005a). No populations have been documented in the Eagle River or the upper Colorado River (Rees et al., 2005a).
Bluehead sucker	*Catostomus discobolus*	WR[K]	No	Yes	
Flannelmouth sucker	*Catostomus latipinnis*	AR[L]/WR[K]	No	Yes	
Mountain sucker	*Catostomus platyrhynchus*	AR[K]/WR[K]	No	No	The distribution of mountain sucker extends into Utah from southwest Wyoming. No populations have been documented in the Eagle River or the upper Colorado River (Isaak et al., 2003). Mountain suckers have been collected in the Green River, White River basin (Piceance Creek), and Yampa River basin (Steamboat Lake) (Smith and Koehn 1971 in http://ndisweb.nrel.colostate.edu). Only one record of mountain sucker (Snyder 1981 in NDIS website above) exists from the upper reaches of the Colorado River above Grand Junction.
Mollusks					
Rocky Mountain capshell snail	*Acroloxus coloradensis*	AR[K]	No	No	The Rocky Mountain capshell snail is critically imperiled in Colorado and populations have been observed in Lost Lake and Peterson Lake on the ARNF. The species conservation assessment states habitat is clean lakes with rocky substrates (Anderson, 2005). Lakes in the Corridor typically have sediment substrates. The Corridor is considerably south of the two lakes with known populations. The snail is not known on the WRNF. The only high-elevation potential habitat in the Corridor west of the Continental Divide at Dillon Reservoir and a small pond between Dillon Reservoir and I-70 at mp 203.
Pygmy mountainsnail	*Oreohelix pygmaea*	WR	No	No	This species is being dismissed from full analysis of effects and impacts because there are no known occurrences of this species or of its potential habitat in the I-70 Corridor; therefore, no effects or impacts are expected.
Insects					
Caddisfly	*Ochrotrichia susanae*	WR	No	No	This species is being dismissed from full

Common Name	Species	National Forest	MIS / Indicator Community	Species Included	Reason for Exclusion
					analysis of effects and impacts because there are no known occurrences of this species or of its potential habitat in the I-70 Corridor; therefore, no effects or impacts are expected. Susan's purse-making caddisfly is known only from two sites in central Colorado: the type locality at Trout Creek Spring in Chaffee County, and High Creek Fen in Park County. A statewide survey undertaken to provide distributional data for all Trichoptera in Colorado indicated that Susan's purse-making caddisfly was present only at the type locality, Trout Creek Spring (Herrmann et al., 1986). The only other reported collection site for this species is the High Creek Fen area, about 20 miles north of the type locality (Durfee & Polonsky, 1995) http://www.xerces.org/ochrotrichia-susanae/.
Hudsonian emerald	*Somatochlora hudsonica*	AR[K]	No	No	The only observed populations are in aquatic habitats of Boulder and Gilpin counties including Eldora and Teller Lakes (Packauskas 2005). The APE does not extend into either county. All records for the dragonfly are within 40 miles of Boulder, Colorado, and the records are approximately 30 years old. The dragonfly has been removed from the TEPS list for the WRNF (K. Giezentanner pers. comm. with L. Hettinger, 2006b), due to distributional records and lack of suitable habitat.
Great Basin silverspot	*Speyeria nokomis nokomis*	WR[K]	No	No	This butterfly requires moist meadows or wetlands and has been documented in 11 counties along the western and southwestern borders of Colorado but not in any counties where the Corridor is located (Great Plains Wildlife Research web page). There may be potential habitat on the WRNF.
Plants					
Sea pink	*Armeria maritima* ssp. *sibirica*	AR/WR	No	No	No plants or suitable habitat; prefers alpine at greater elevations than in APE.
Dwarf milkweed	*Asclepias uncialis*	AR	No	No	No plants or suitable habitat in APE; prefers lower elevation grasslands.
Park milkvetch	*Astragalus leptaleus*	AR/WR	No	Yes	
Wetherill's milkvetch	*Astragalus wetherilli*	WR	No	No	Not in APE; occurs west and north of Rifle.
Upswept moonwort	*Botrychium ascendens*	AR/WR	No	Yes	
Prairie moonwort	*Botrychium campestre*	AR	No	No	No plants or suitable habitat present in APE; prefers lower elevation grasslands.
Narrow-leaved moonwort	*Botrychium lineare*†	AR	No	Yes	
Paradox moonwort	*Botrychium paradoxum*	AR/WR	No	Yes	
Smooth rockcress	*Braya glabella*	WR	No	No	Not suspected to occur in APE; prefers alpine at greater elevations (12,000 to 13,000 feet); documented in Pitkin County on WRNF.
Lesser panicled sedge	*Carex diandra*	AR/WR	No	Yes	

Common Name	Species	National Forest	MIS / Indicator Community	Species Included	Reason for Exclusion
Livid sedge	*Carex livida*	AR/WR	No	Yes	
Sandhill goosefoot	*Chenopodium cycloides*	AR	No	No	Not in APE; prefers lower elevation grasslands.
Rocky Mountain thistle	*Cirsium perplexans*	WR	No	No	Not present in APE; occurs in Garfield County west and south of Rifle.
Yellow lady's-slipper	*Cypripedium parviflorum* (=*C. Calceolus* ssp. *Parviflorum*)	AR/WR	No	Yes	
Clawless draba	*Draba exunguiculata*	AR/WR	No	No	No plants or suitable habitat in APE; prefers alpine higher than present at EJMT.
Gray's Peak whitlowgrass	*Draba grayana*	AR/WR	No	No	No plants or suitable habitat present in APE; prefers alpine higher than present at EJMT.
Roundleaf sundew	*Drosera rotundifolia*	AR/WR	No	Yes	
Dropleaf buckwheat	*Eriogonum exilifolium*	AR/WR	No	No	No plants or suitable habitat in APE; endemic to North and Middle Park areas.
Altai cotton-grass	*Eriophorum altaicum* var. *neogaeum*	AR/WR	No	Yes	
Russet cotton-grass	*Eriophorum chamissonis*	WR	No	No	APE is outside suspected range, which is south and west of the APE.
Slender cotton-grass	*Eriophorum gracile*	AR/WR	No	Yes	
Hall's fescue	*Festuca hallii*	AR/WR	No	Yes	
Lone Mesa snakeweed	*Gutierrezia elegans*	WR	No	No	APE is outside known range, which is west of APE on Rifle Ranger District.
Weber's scarlet-gilia	*Ipomopsis aggregate* ssp. *Weberi*	AR	No	No	No plants suspected in APE; endemic to Rabbit Ears Pass area.
Simple kobresia	*Kobresia simpliciuscula*	AR/WR	No	Yes	
Colorado tansy-aster	*Machaeranthera coloradoensis*	AR/WR	No	Yes	
Adder's-mouth	*Malaxis brachypoda*	AR	No	No	No plants or habitat in APE; prefers lower elevations.
Budding monkeyflower	*Mimulus gemmiparus*	AR	No	Yes	
Kotzebue's grass-of-Parnassus	*Parnassia kotzebuei*	AR/WR	No	Yes	
Harrington's beardtongue	*Penstemon harringtonii*	AR/WR	No	Yes	
DeBeque phacelia	*Phacelia scopulina* var. *submutica*	WR	No	No	Not in APE; occurs west and south of Rifle.
Front Range or Rocky Mountain cinquefoil	*Potentilla rupincola*	AR	No	Yes	
Porter's feathergrass	*Ptilagrostis porteri*	AR/WR	No	Yes	
Ice cold buttercup	*Ranunculus karelinii* (= *R. gelidus* ssp. *Grayi*)	AR/WR	No	No	No plants or suitable habitat in APE; prefers alpine higher than present at EJMT.
Dwarf raspberry	*Rubus arcticus* var. *acaulis* (=*Cylactis acaulis*)	AR/WR	No	Yes	

Common Name	Species	National Forest	MIS / Indicator Community	Species Included	Reason for Exclusion
Hoary willow	*Salix candida*	AR/WR	No	Yes	
Autumn willow	*Salix serissima*	AR/WR	No	Yes	
Sphagnum	*Sphagnum angustifolium*	AR/WR	No	Yes	
Baltic sphagnum	*Sphagnum balticum*	AR/WR	No	Yes	
Sun-loving meadowrue	*Thalictrum heliophilum*	WR	No	No	Recorded outside APE on the WRNF west and south of Rifle.
Lesser bladderpod	*Utricularia minor*	AR/WR	No	Yes	
Selkirk's violet	*Viola selkirkii*	AR/WR	No	Yes	

Notes:
K – Species currently documented to occur on National Forest System Lands.
L – Species or habitat is suspected to occur on National Forest System Lands but unconfirmed.
N – Species not known or suspected to occur on National Forest System Lands; however, it may occur in planning area vicinity. Requires evaluation whether indirect effects from project alternatives may occur.
†Includes plants corresponding to morphology of B. "furcatum."

The *Environmental Assessment: Forest Plan Amendment for Management Indicator Species* (USDA, 2005a) provides the complete list of MIS of the ARNF, and the *Final Environmental Assessment: Management Indication Species Forest Plan Amendment* (USDA, 2006) provides the list of those of the WRNF. **Table BR - 4** presents the list of MIS. Their represented communities include species found within or adjacent to the project area or potentially affected by the project alternatives. The species noted as included were chosen as representative of the specific management indicator communities within the APE.

Table BR - 4. MIS (Not Previously Covered in Table BR - 1 or Table BR - 2[a]) That May Occur or Be Influenced by Project Activities

Common Name	Species	National Forest	Management Indicator Community (MIC)	Species Included	Reason for Exclusion
Mammals					
Elk	*Cervus elaphus*	AR/WR	Young to mature forest & openings	Yes	
Mule deer	*Odocoileus hemionus*	AR	Young to mature forest & openings	Yes	
Cave bats	All species	WR	Caves and mines	No	Nine caves were surveyed for bats in Garfield and Eagle counties, most of which were on non-Forest Lands (Siemers, 2002). Six species and 163 individuals were observed. The majority of caves were south and east of Glenwood Springs and not in the Corridor. No Corridor alternatives extend into Glenwood Canyon. Given that most caves are located outside the Corridor, no effects are expected on cave bats.
Birds					
American pipit	*Anthus rubescens*	WR	Alpine grasslands	No	This species is strongly associated with alpine grasslands for breeding and rearing of young (USDA, 2006). The pipit is common in all mountain ranges in

Common Name	Species	National Forest	Management Indicator Community (MIC)	Species Included	Reason for Exclusion
					Colorado (www.rmbo.org). Project alternatives affect no alpine habitat .
Virginia's warbler	*Vermivora virginiae*	WR	Dense shrub habitat	Yes	
Hairy woodpecker	*Picoides villosus*	AR	Young to mature forest structural stages	Yes	
Pygmy nuthatch	*Sitta pygmaea*	AR	Existing and potential old-growth forest	Yes	
Golden-crowned kinglet	*Regulus satrapa*	AR	Interior forests	No	This bird prefers dense spruce-fir forests. They are common in Colorado in the summer between 6,000 and 10,000 feet, much more so west of the Continental Divide than in the east. This species requires interior forest habitat with old-growth characteristics, especially the interiors of spruce-fir forests (Kingery, 1998). Because project alternatives closely follow the existing alignment, often within the area of existing disturbance, they are not anticipated to affect this habitat type.
Mountain bluebird	*Sialia currucoides*	AR	Forest openings	Yes	
Warbling vireo	*Vireo gilvus*	AR	Aspen forest	Yes	
Wilson's warbler	*Wilsonia pusilla*	AR	Montane riparian areas and wetlands	Yes	
Fish					
All Trout	All species	WR	Montane aquatic	Yes	
Brook trout	*Salvelinus fontinalis*	AR	Montane aquatic	Yes	
Brown trout	*Salmo trutta*	AR	Montane aquatic	Yes	
Insects					
Aquatic Macroinvertebrates	All species	WR	Montane aquatic	Yes	

[a] *Several species are addressed under multiple categories; MIS, FS sensitive, and/or federally listed.*

Corridor **Project MIS** compiled from the two separate **Forest Plan MIS** lists are as follows:

- For ARNF, mule deer, bighorn sheep, hairy woodpecker, pygmy nuthatch, mountain bluebird, warbling vireo, Wilson's warbler, boreal toad, brook trout, brown trout, and greenback cutthroat trout
- For WRNF, Virginia's warbler, all trout, and aquatic macroinvertebrates
- For ARNF and WRNF, elk and Colorado River cutthroat trout.

These species are selected because their management indicator communities (MICs) or habitat may be influenced by the project and/or because the movement of individuals across I-70 is of concern.

The evaluation considered all threatened, endangered, proposed, sensitive, and MIS for the WRNF and the ARNF and for Garfield, Eagle, Summit, and Clear Creek counties.

Table BR – 5 lists species (TEPS and MIS) that were identified as occurring or having habitat within the project area or potentially affected by the project. Any species, ecosystem, or MIC not listed or discussed below was determined not to occur within the project area and would not be influenced by project activities and, therefore, will not be discussed further for National Forest System Lands.

Table BR – 5. Summary of Species Included in Project Analysis

Federally Listed Threatened or Endangered Species	USFS Sensitive Species	USFS MIS
	Mammals	
• Canada lynx	• Pygmy shrew • River otter • American marten • North American wolverine • Bighorn sheep (Also MIS)	• Elk • Mule deer
	Birds	
• Least tern • Piping plover • Whooping crane	• Bald eagle • Northern goshawk • American peregrine falcon • White-tailed ptarmigan • Boreal owl • Flammulated owl • Black swift • American three-toed woodpecker • Olive-sided flycatcher • Brewer's sparrow	• Virginia's warbler • Hairy woodpecker • Pygmy nuthatch • Mountain bluebird • Warbling vireo • Wilson's warbler
	Amphibians	
	• Boreal toad (Also MIS) • Northern leopard frog	
	Fish	
• Bonytail chub • Colorado pikeminnow • Humpback chub • Razorback sucker • Pallid sturgeon • Greenback cutthroat trout (Also MIS)	• Colorado River cutthroat trout (Also MIS) • Bluehead sucker • Flannelmouth sucker	• All trout • Brook trout • Brown trout
	Plants	
• Western prairie fringed orchid • Ute ladies'-tresses orchid	• Park milkvetch • Upswept moonwort • Narrow-leaved moonwort • Paradox moonwort • Lesser panicled sedge • Livid sedge • Yellow lady's-slipper • Roundleaf sundew • Altai cotton-grass • Slender cotton-grass • Hall's fescue • Simple kobresia • Colorado tansy-aster • Budding monkeyflower • Kotzebue's grass-of-Parnassus • Harrington's beardtongue • Front Range or Rocky Mountain cinquefoil • Porter's feathergrass • Dwarf raspberry • Hoary willow • Autumn willow • Sphagnum • Baltic sphagnum • Lesser bladderpod • Selkirk's violet	
	Insects	
		• Aquatic macroinvertebrates

BR.3. USFS Biological Assessment

This section of the BR presents the biological assessment of threatened and endangered species. Included are descriptions of the distribution; natural history; environmental baseline; direct, indirect, and cumulative effects of alternatives; and a determination of effects and rationale for each species of mammals, birds, fish, invertebrates, and plants. These discussions are based on the best available scientific information.

Downstream Water Depletion. Water-dependent species are sensitive to the effects of depletion. The following provides a general agreement that Tier 2 activities will meet requirements of the Programmatic Biological Opinion for the Colorado River and the Biological Opinion for the Platte River Recovery Implementation Program.

Water depletions from the upper Colorado River basin “may affect” four federally listed Colorado River watershed fish species: the Colorado pikeminnow (*Ptychocheilus lucius)*, razorback sucker((*Xyrauchen texanus*), humpback chub *(Gila cypha)*, and bonytail chub *(Gila elegans)*. Therefore, Section 7 consultation is required for all federal actions that cause or authorize a water depletion to the basin. The 1999 Colorado River Programmatic Biological Opinion addresses water depletions in the Colorado River and its tributaries above its confluence with the Gunnison River. Recovery actions outlined in the Programmatic Biological Opinion provide measures to avoid the likelihood of jeopardy and adverse modification of critical habitat. To offset the cost of implementing recovery actions, a one-time fee is required for new depletions greater than 100 acre-feet (AF)/year. Other provisions of the Programmatic Biological Opinion are that nonfederal water users are required to sign a Recovery Agreement and federal agencies are requested to retain discretionary authority in the event that consultation is reinitiated. There is no fee for historic depletions (before 1988) or depletions (less than 100 AF/year. As long as sufficient progress is being made toward achievement of program objectives, no additional mitigation obligations are imposed.

According to USFWS, any depletion to the Platte River basin (roughly defined as the Palmer Divide north and the Continental Divide east in Colorado) constitutes an action that may affect, and is likely to adversely affect, threatened and endangered (T & E) species that depend on the river for their existence.

Threatened and Endangered species downstream along the central and lower Platte River and Missouri River include the whooping crane (*Grus Americana*), interior population of the least tern (*Sterna antillarum)*, piping plover (*Charadrius melodus*), western prairie fringed orchid (*Platanthera praeclara*), and pallid sturgeon (*Scaphirhinchus albus*). In Colorado, other listed species potentially affected by depletions include those that are dependent on riparian systems near the Corridor such as the threatened Ute ladies’-tresses orchid (*Spiranthes diluvialis*) and the western prairie fringed orchid.

Depletions to the Platte River system due to CDOT activities are addressed by the State of Colorado’s participation in the South Platte Water Related Activities Program (SPWRAP) through the Memorandum of Agreement for Implementation and Operation of the Colorado Portion of the Platte River Recovery Implementation Plan as described in paragraph 4.a. of the Memorandum of Agreement. The State has made and continues to make financial and other contributions to the Plate River Recovery Implementation Plan (PRRIP). In addition, SPWRAP has created a Class X-1 membership specifically for and limited to the State of Colorado for diversions and depletions by State agencies that are comparatively small. CDOT falls into this category because their typical depletive activities such as wetland creation and water quality ponds, as well as water used for compaction; concrete, and dust control do not generally require large amounts of water. According to the Memorandum of Agreement, previously made contributions are deemed payment of all SPWRAP assessments for the Class X-1 membership for the duration of the First

Increment of the PRRIP, which expires in 2020. However, because FHWA is funding the project, Section 7 consultation is required to satisfy FHWA's obligation under the ESA.

An analysis of effects on federally listed species downstream in Nebraska resulting from the Project's Preferred Alternative will be completed during Tier 2 analysis as CDOT cannot anticipate depletions at the programmatic level of design. CDOT, as a Colorado State agency and participant in the PRRIP, will also complete a PRRIP template biological assessment during Tier 2 analysis and submit it to USFWS for streamlined Section 7 consultation provided by participation in the PRRIP. Colorado Department of Transportation is coordinating with USFWS on this matter for documentation in the BA; following streamlined consultation and USFWS's issuance of a biological opinion, CDOT will monitor project-level depletions annually and report to USFWS.

Any project-related depletions to the Colorado or Platte River systems that have not been previously consulted on by USFWS will be addressed when individual quantities of water uses for specific projects are known during Tier 2 and analysis required for NEPA documentation.

BR.3.1 Threatened and Endangered Species

BR.3.1.1 Mammals

Canada Lynx (*Lynx canadensis*), T

The Canada lynx is a species that is federally listed as threatened. It is currently documented to occur on National Forest System Lands, including the ARNF and the WRNF. The Canada lynx is a member of the order Carnivora, family Felidae, and is one of the two species in the genus *Lynx* in Colorado (the other species being the bobcat – *Lynx rufus*). The lynx is a medium-sized cat with long legs; large, well-furred paws; long tufts on the ears; and a short, black-tipped tail (McCord and Cardoza, 1982). Adult males average 22 pounds in weight and 33.5 inches in length (head to tail), and females average 19 pounds and 32 inches (Quinn and Parker, 1987). The lynx's long legs and large feet make it highly adapted for hunting in deep snow.

The Lynx Conservation Assessment and Strategy (Ruediger et al., 2000) (produced by an interagency team of biologists to recommend lynx conservation measures and facilitate consultation under Section 7 of the ESA) stipulates that effects on lynx habitat should be considered within designated Lynx Analysis Units (LAUs) that are larger than 25,000 acres in the Southern Rocky Mountain Geographic Area (SRMGA). These LAUs do not represent actual lynx home ranges but are indicative of the size area used by an individual lynx (Ruediger et al., 2000). **Figure BR - 2** shows the lynx LAUs.

Distribution

USFWS determined the contiguous U.S. distinct population segment of Canada lynx to be threatened on March 24, 2000 (Colorado, Idaho, Maine, Michigan, Minnesota, Montana, New Hampshire, New York, Oregon, Utah, Vermont, Washington, Wisconsin, and Wyoming). Within the area covered by this listing, the species is known to occur in Colorado, Idaho, Maine, Minnesota, Montana, Washington, and Wyoming. USFWS Mountain-Prairie Region (Region 6) is the lead region for this listing.

The contiguous U.S. population probably numbers less than 2,000 individuals (NatureServe, 2006). Critical habitat was designated on November 8, 2006, for areas in Minnesota, Montana, and Washington for the threatened population of Canada lynx in the contiguous U.S. No critical habitat is designated in Colorado.

The distribution of lynx in North America is closely associated with the distribution of North American boreal forest (Agee, 2000). The range of lynx extends south from the classic boreal forest zone into the subalpine forest of the western U.S., and the boreal/hardwood forest ecotone in the eastern U.S. (Agee, 2000; and McKelvey et al., 2000b). Forests with boreal features (Agee, 2000) extend south into the contiguous U.S. along the Cascade and Rocky Mountain Ranges in the west, the western Great Lakes Region, and along the Appalachian Mountain Range of the northeastern U.S. Within these general forest types, lynx are most likely to persist in areas that receive deep snow, to which the lynx is highly adapted (Ruggiero et al., 2000). Lynx are rare or absent from the wet coastal forests of Alaska and Canada (Mowat et al., 2000).

The final rule (2000) determining threatened status for the lynx in the contiguous U.S. summarized lynx status and distribution across four regions that are separated from each other by ecological barriers consisting of unsuitable lynx habitat. These distinct regions are the Northeast, the Great Lakes, the Northern Rocky Mountains/Cascades, and the Southern Rocky Mountains. With the exception of the Southern Rocky Mountains region, each area is geographically connected to the much larger population of lynx in Canada.

Southern Rocky Mountains Region (Colorado, Southeast Wyoming)

Colorado represents the extreme southern edge of the range of the lynx. The southern boreal forest of Colorado and southeastern Wyoming is isolated from boreal forest in Utah and northwestern Wyoming by the Green River Valley and the Wyoming basin (Findley and Anderson, 1956 in McKelvey et al., 2000b). These areas likely reduce or preclude opportunities for genetic interchange with the Northern Rocky Mountains/Cascades Region and Canada, effectively isolating lynx in the Southern Rocky Mountains Region (Halfpenny, Bissell, and Nead, 1982; and Koehler and Aubry, 1994).

A majority of the lynx occurrence records in Colorado and southeastern Wyoming are associated with the "Rocky Mountain Conifer Forest" type. Historic occurrences in the Southern Rockies were in contiguous temperate forests at elevations of 7,800 feet or higher (USDA, 2002c).

A reintroduction program for Canada lynx was initiated in Colorado in 1999. Colorado Division of Wildlife manages this program and reports on the progress each year. A total of 218 lynx have been released in the state since the program's inception. Colorado Division of Wildlife currently tracks via radio collars 95 of the 138 lynx still possibly alive. Colorado Division of Wildlife released 14 lynx in 2006 in the Core Release Area of southwestern Colorado but did not release any additional lynx in 2007, 2008, or 2009 and has no plans to release any additional animals in the near future (CDOW, 2009).

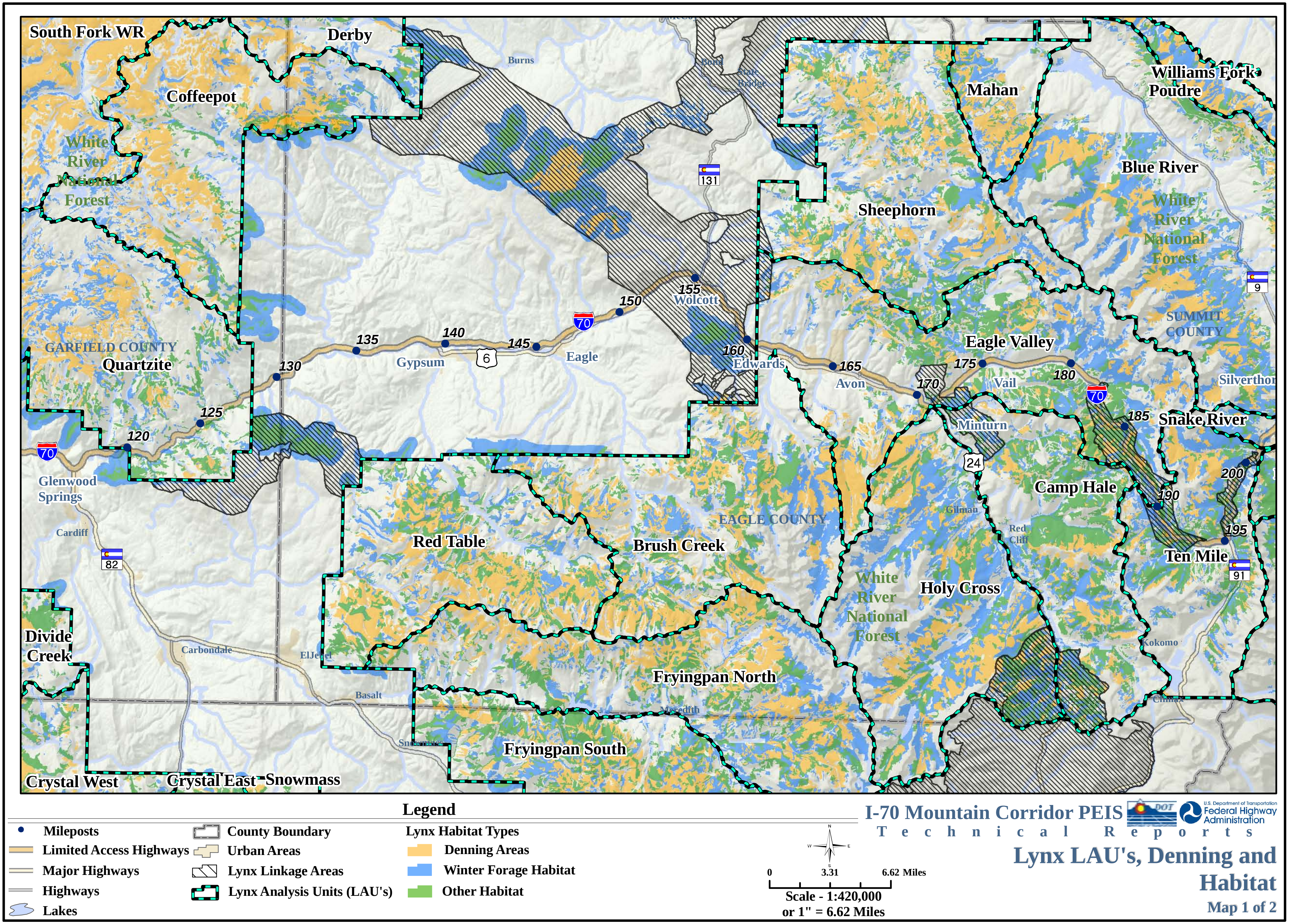
Lynx are located throughout the mountainous areas of Colorado, on all eight national forests in Colorado and southeastern Wyoming. Lynx location maps for 1999 through 2005 clearly show that lynx have been positively located in Garfield, Eagle, Summit, Clear Creek, and Jefferson counties in areas proximate to the Corridor (CDOW, 2005a).

Natural History

The following information was obtained from the *Biological Opinion on the Effects of National Forest Land and Resource Management Plans and Bureau of Land Management Land Use Plans* (USDI, 2000). The complexities of lynx life-history and population dynamics, combined with a general lack of reliable population data for the contiguous U.S., make it difficult to ascertain the past or present population status of lynx in the contiguous U.S.

Home Range and Dispersal

Lynx home range size varies by the animal's gender, abundance of prey, season, and density of lynx populations (Hatler, 1988; Koehler, 1990; Poole, 1994; Slough and Mowat, 1996; Aubry et al., 2000; and Mowat et al., 2000). Documented home ranges vary from 8 to 800 square kilometers (3 to 300 square miles) (Saunders, 1963; Brand et al., 1976; Mech, 1980; Parker et al., 1983; Koehler and Aubry, 1994; Apps, 2000; Mowat et al., 2000; and Squires and Laurion, 2000). Preliminary research supports the hypothesis that lynx home ranges at the southern extent of the species' range are generally large compared to those in the core of the range in Canada (Koehler and Aubry, 1994; Apps, 2000; and Squires and Laurion, 2000).


South Fork WR
Derby
Burns
Bond
State Bridge
Mahan
Williams Fork
Poudre
Coffeepot
White River National Forest
131
Blue River
Sheephorn
White River National Forest
9
155
Wolcott
150
SUMMIT COUNTY
Eagle Valley
GARFIELD COUNTY
135
140
145
70
160
Quartzite
130
Gypsum
6
Eagle
Edwards
165
175
180
Silverthorne
Avon
170
Vail
70
125
185
Snake River
120
Minturn
70
24
Glenwood Springs
200
Camp Hale
190
Gilman
EAGLE COUNTY
Cardiff
Red Table
Brush Creek
Red Cliff
195
82
Ten Mile
91
White River National Forest
Holy Cross
Divide Creek
Kokomo
Carbondale
El Jebel
Fryingpan North
Basalt
Climax
Meredith
Snowmass
Fryingpan South
Crystal West
Crystal East
Snowmass
Legend
Mileposts
Limited Access Highways
Major Highways
Highways
Lakes
County Boundary
Urban Areas
Lynx Linkage Areas
Lynx Analysis Units (LAU's)
Lynx Habitat Types
Denning Areas
Winter Forage Habitat
Other Habitat
0
3.31
6.62 Miles
Scale - 1:420,000
or 1" = 6.62 Miles
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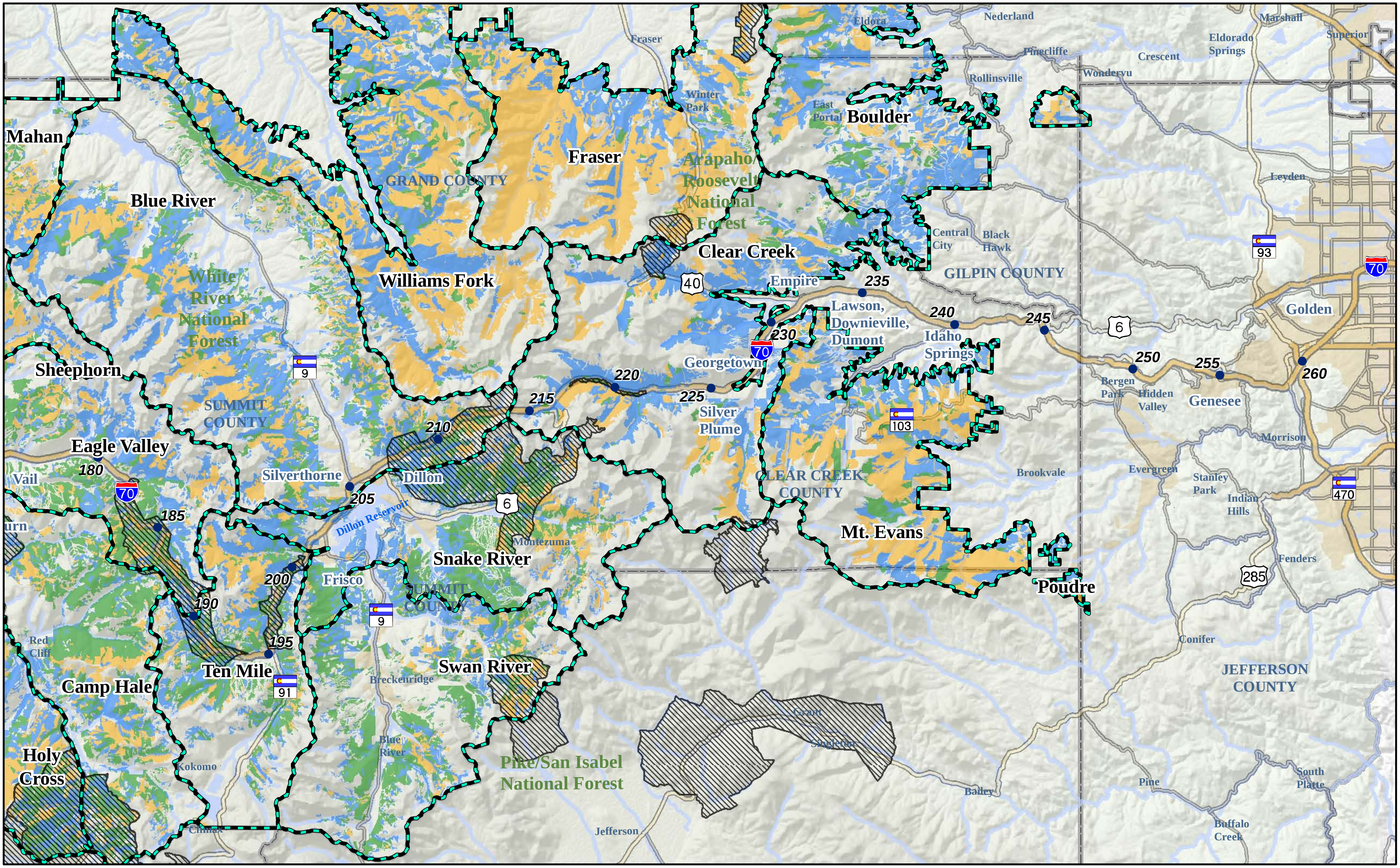
Lynx LAU's, Denning and Habitat
Map 1 of 2



Legend

- Mileposts
- Limited Access Highways
- Major Highways
- Highways
- Lakes
- County Boundary
- Urban Areas
- Lynx Linkage Areas
- Lynx Analysis Units (LAU's)

Lynx Habitat Types
- Denning Areas
- Winter Forage Habitat
- Other Habitat

0 3.31 6.62 Miles

Scale - 1:420,000
or 1" = 6.62 Miles

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Lynx LAU's, Denning and Habitat

Map 2 of 2

Colorado Division of Wildlife (2009) has reported data on lynx locations and movement since reintroduction within the state. The majority of surviving lynx from the entire reintroduction effort continue to use high elevation (greater than 2900 m), forested areas from New Mexico north to Independence Pass, west as far as Taylor Mesa and east to Monarch Pass. Most movements away from the Core Release Area were to the north.

For additional comparative purposes, the minimum number of lynx in the contiguous U.S. is estimated at 2,000 individuals (NatureServe, 2006). The total number of lynx reintroduced to Colorado since 1999 is 218 individuals, or approximately 10 percent of the total contiguous U.S. population. While no exact figures are available for number of reintroduced individuals that have dispersed as far north as I-70, the total number, in comparison to U.S. population size, must be minor (less than 100 animals) (CDOW, 2009). While this does not diminish the importance of establishing lynx habitat connectivity through the I-70 Corridor, it does put into perspective the effect the Corridor Preferred Alternative may have on overall Canada lynx viability.

Diet

Southern populations of lynx may prey on a wider diversity of species than northern populations because of lower average hare densities and differences in small mammal communities. In areas characterized by patchy distribution of lynx habitat, lynx may prey opportunistically on other species that occur in adjacent habitats, potentially including white-tailed jackrabbit (*Lepus townsendii*), black-tailed jackrabbit (*Lepus californicus*), sage grouse (*Centrocercus urophasianus*), and Columbian sharp-tailed grouse (*Tympanichus phasianellus*) (Quinn and Parker, 1987; and Lewis and Wenger, 1998). Relative densities of snowshoe hares (*Lepus americanus*) at southern latitudes are generally lower than those in the north, and differing interpretations of the population dynamics of southern populations of snowshoe hare have been proposed (Hodges, 2000).

Primary forest types that support snowshoe hare are subalpine fir, Engelmann spruce, Douglas-fir, and lodgepole pine in the western U.S. (Hodges, 2000). Lynx seem to prefer to move through continuous forests, using the highest terrain available such as ridges and saddles (Koehler, 1990; and Staples 1995). Cover is important to lynx when searching for food (Brand et al., 1976), but lynx often hunt along edges (Mowat et al., 2000).

Den Site Selection

Lynx use large woody debris, such as downed logs, root wads, and windfalls, to provide denning sites with security and thermal cover for kittens (McCord and Cardoza, 1982; Koehler, 1990; Koehler and Brittell, 1990; Mowat et al., 2000; and Squires and Laurion, 2000). During the first few months of life, kittens are left alone at these sites when the female lynx hunts. Downed logs and overhead cover provide kittens protection from predators, such as owls, hawks, and other carnivores during this period. The age of the forest stand does not seem as important for denning habitat as the amount of downed, woody debris available (Mowat et al., 2000). Den sites may be located within older regenerating stands (more than 20 years since disturbance) or in mature conifer or mixed conifer-deciduous (typically spruce-fir or spruce/birch) forests. Colorado Division of Wildlife reports (2009) that all except one of the 37 lynx den sites found from 2003 to 2006 were scattered throughout the high-elevation areas of Colorado, south of I-70. These den sites were located in Engelmann spruce/subalpine fir forests in areas with significant downfall.

Mortality

Reported causes of lynx mortality vary between studies. The most commonly reported causes include starvation of kittens (Quinn and Parker, 1987; and Koehler, 1990) and human-caused mortality, mostly fur trapping (Ward and Krebs, 1985; and Bailey et al., 1986). Of the total 218 adult lynx released, there have been 115 known mortalities as of May 25, 2009. Starvation was a significant cause of mortality in the first year of releases only. Mortalities occurred throughout the areas through which lynx moved. The primary known causes of death included 30.4 percent human-induced deaths, which were confirmed or probably caused by collisions with vehicles or gunshot. Malnutrition and disease/illness accounted for 18.3 percent of the deaths. Other mortality factors included predation or probable predation by mountain lions (*Puma concolor*), bobcat, and lynx, as well as other trauma-caused deaths. An additional 37.4 percent of known mortalities were from unknown causes (CDOW, 2009h).

Population Dynamics

In the southern portion of the range in the contiguous U.S., lynx populations appear to be naturally limited by the availability of snowshoe hares, as suggested by large home range size, high kitten mortality due to starvation, and greater reliance on alternate prey (Quinn and Parker, 1987; Koehler, 1990; and Aubry et al., 2000).

Environmental Baseline

The Corridor includes lynx winter forage, denning, other habitat, and linkage areas. Eight LAUs intersect the I-70 Corridor, including Quartzite, Eagle Valley, Holy Cross, Camp Hale, Ten Mile, Snake River, Blue River, and Clear Creek. All of the LAUs other than the Clear Creek LAU reside on the WRNF. **Figure BR - 2** provides a map of lynx habitat and linkage areas.

The ALIVE Committee has identified 15 critical lynx-specific linkage interference zones along the Corridor between Glenwood Springs and C-470, where wildlife movements are impeded by the highway (see **Figure BR - 1**). Lynx linkage areas are areas of movement opportunities. They exist on the landscape and can be maintained or lost by management activities or developments. They are not just “corridors” (which implies only travel routes), rather they are broad areas of habitat where animals can travel and find food, shelter, and security.

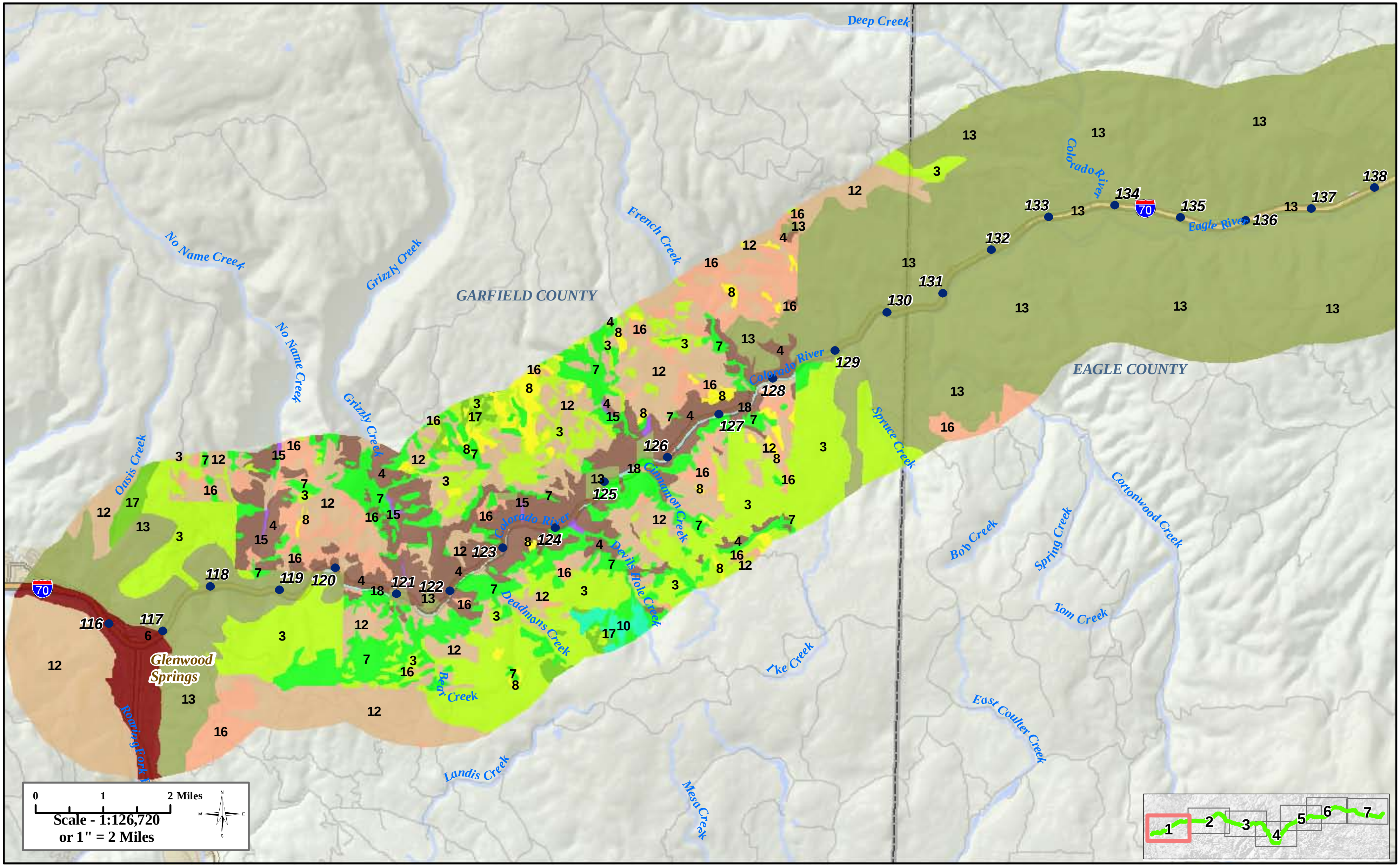
Preferred habitat for the lynx is classic boreal forest and subalpine forest. Of greater importance is the presence of snowshoe hares, their main food source. Lynx can be found in spruce-fir, lodgepole, Douglas-fir, and aspen forests especially when snowshoe hares are present. **Figure BR - 3** (Maps 1-7) illustrate vegetation types that occur throughout the Corridor.

Direct, Indirect, and Cumulative Effects of Alternatives

Action Alternatives

While eight LAUs intersect the Corridor, impacts on lynx winter forage, denning, and other habitat are anticipated to occur within only the following four of these LAUs under any of the project alternatives: Eagle Valley, Ten Mile, Blue River, and Clear Creek. No project alternatives are proposed within portions of the Corridor (Glenwood Canyon) that intersect the Quartzite LAU. While project alternatives are proposed within the portion of the Corridor that intersects the Holy Cross, Camp Hale, and Snake River LAUs, no impacts on habitat are anticipated under any of the project alternatives. The reason why impacts are not expected in these LAUs is that the project alternatives are in very close proximity to the existing highway such that new impacts on forested habitat would be avoided.

Table BR - 6 and **Table BR - 7** provide the estimated direct impacts on lynx winter forage, denning, other habitat, and linkage areas with the Eagle Valley, Ten Mile, and Blue River LAUs in the WRNF. They also provide the percentage of this resource affected within its respective LAU. Note that while the existing I-70 Corridor and the project alternatives cross the Holy Cross, Camp Hale, and Snake River LAUs, no impacts on lynx winter forage, denning, other habitat, or lynx linkage areas are anticipated under any of the action alternatives.



Legend

- Mileposts
- Limited Access Highways
- Major Highways
- Highways
- Lakes
- County Boundary
- Urban Areas
- USFS Land
- BLM Land

Vegetation Types

1	Agricultural
2	Alpine Meadows-Tundra
3	Aspen Forest
4	Barren Land
5	Bristlecone - Limber Pine Forest
6	Developed
7	Douglas-Fir Forest
8	Grass / Forb Meadows
9	Lakes & Ponds
10	Lodgepole Pine Forest
11	Mixed Forest
12	Mountain Shrubland
13	Pinyon-Juniper Woodland
14	Ponderosa Pine Forest
15	Riparian Forest and Shrub
16	Sagebrush Shrubland
17	Spruce - Fir Forest
18	Wetland (general) / Water

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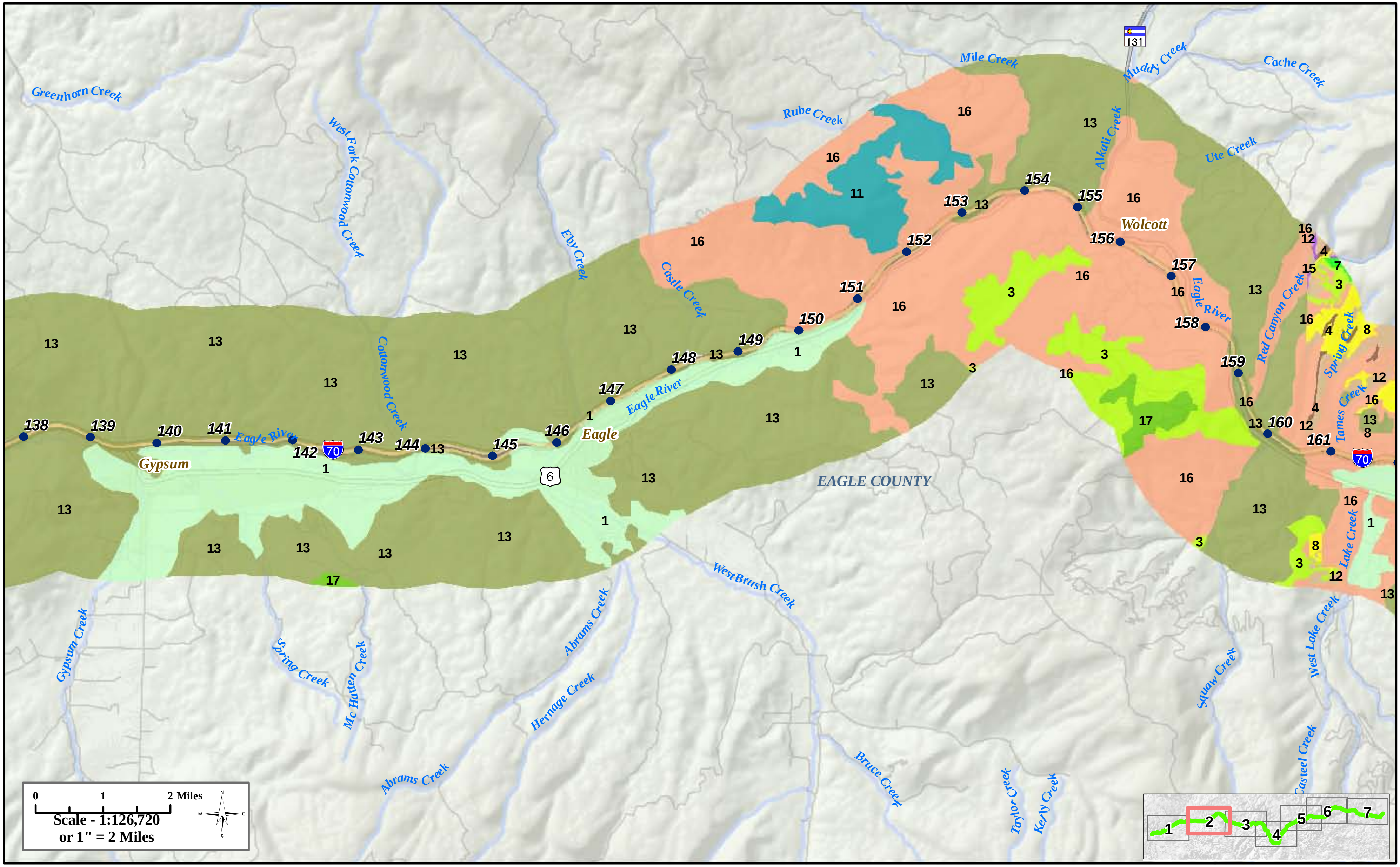
Vegetation

Map 1 of 7



Legend

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- Major Highways
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- USFS Land
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17	Spruce - Fir Forest
18	Wetland (general) / Water

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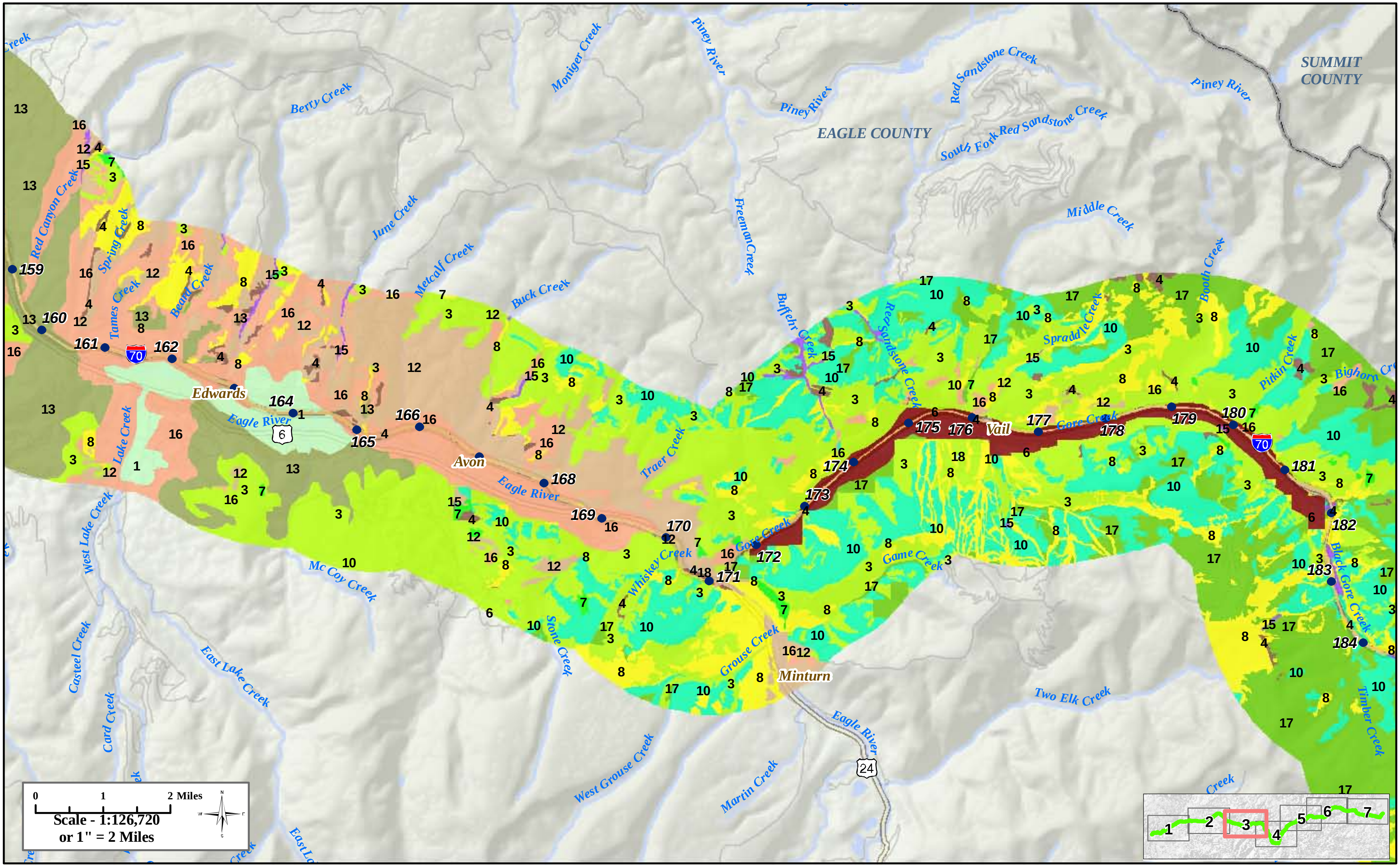
Vegetation

Map 2 of 7



Legend

- Mileposts
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- County Boundary
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Vegetation Types

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14	Ponderosa Pine Forest
15	Riparian Forest and Shrub
16	Sagebrush Shrubland
17	Spruce - Fir Forest
18	Wetland (general) / Water

I-70 Mountain Corridor PEIS

T e c h n i c a l R e p o r t s

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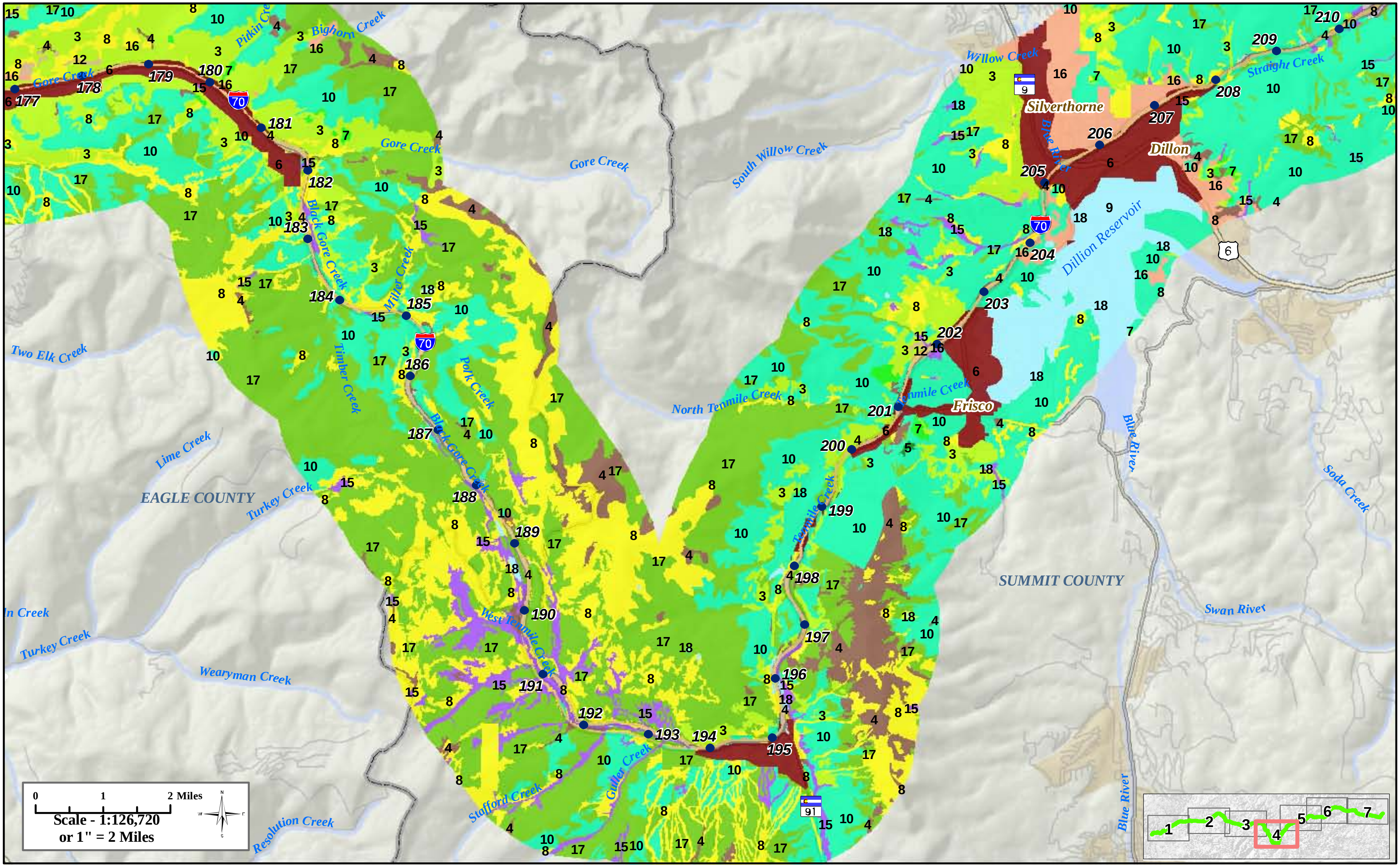
Vegetation

Map 3 of 7



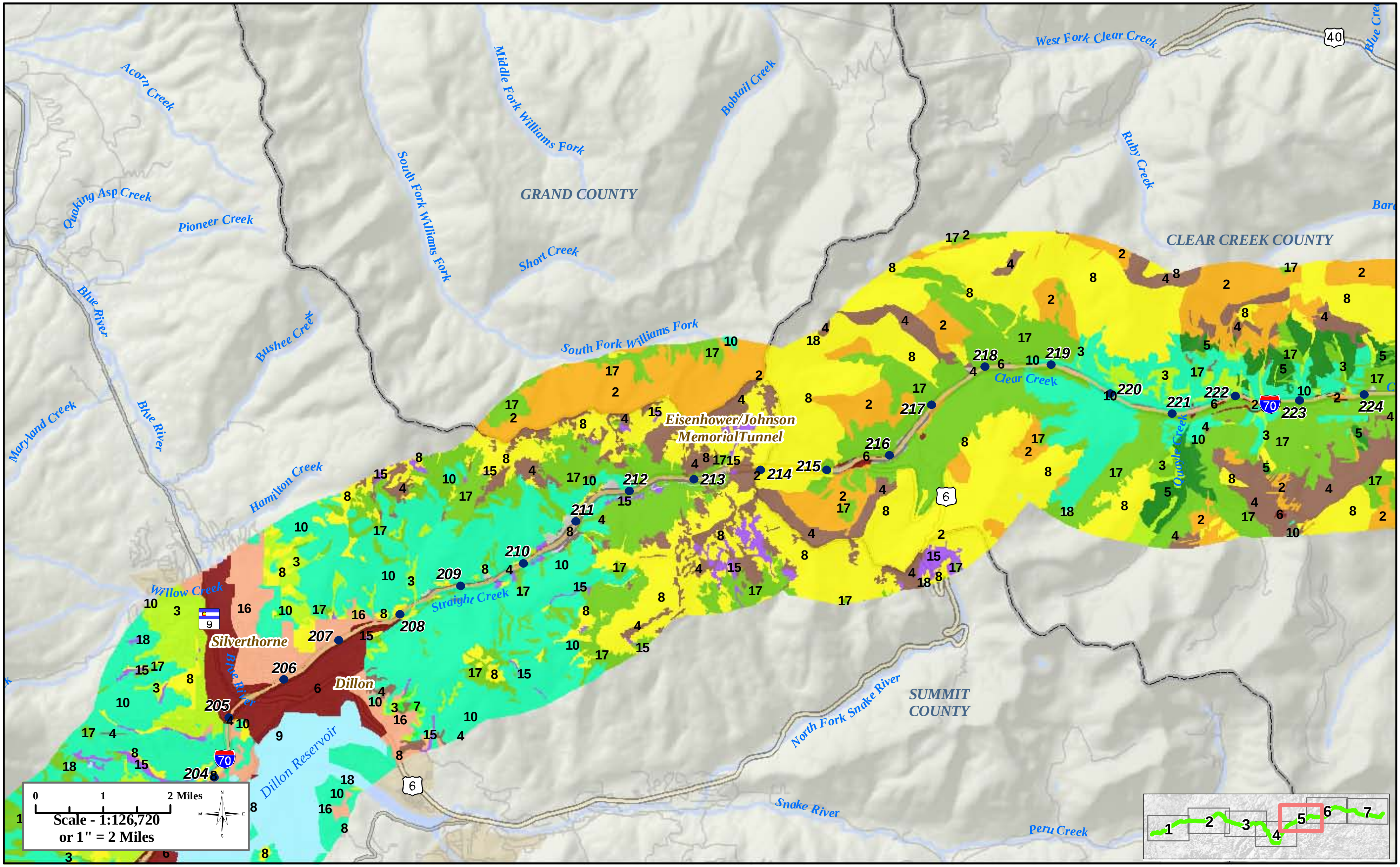
Legend

- Mileposts
- Limited Access Highways
- Major Highways
- Highways
- Lakes
- County Boundary
- Urban Areas
- USFS Land
- BLM Land

Vegetation Types

1	Agricultural
2	Alpine Meadows-Tundra
3	Aspen Forest
4	Barren Land
5	Bristlecone - Limber Pine Forest
6	Developed
7	Douglas-Fir Forest
8	Grass / Forb Meadows
9	Lakes & Ponds
10	Lodgepole Pine Forest
11	Mixed Forest
12	Mountain Shrubland
13	Pinyon-Juniper Woodland
14	Ponderosa Pine Forest
15	Riparian Forest and Shrub
16	Sagebrush Shrubland
17	Spruce - Fir Forest
18	Wetland (general) / Water

Vegetation



Legend

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17 Spruce - Fir Forest
18 Wetland (general) / Water

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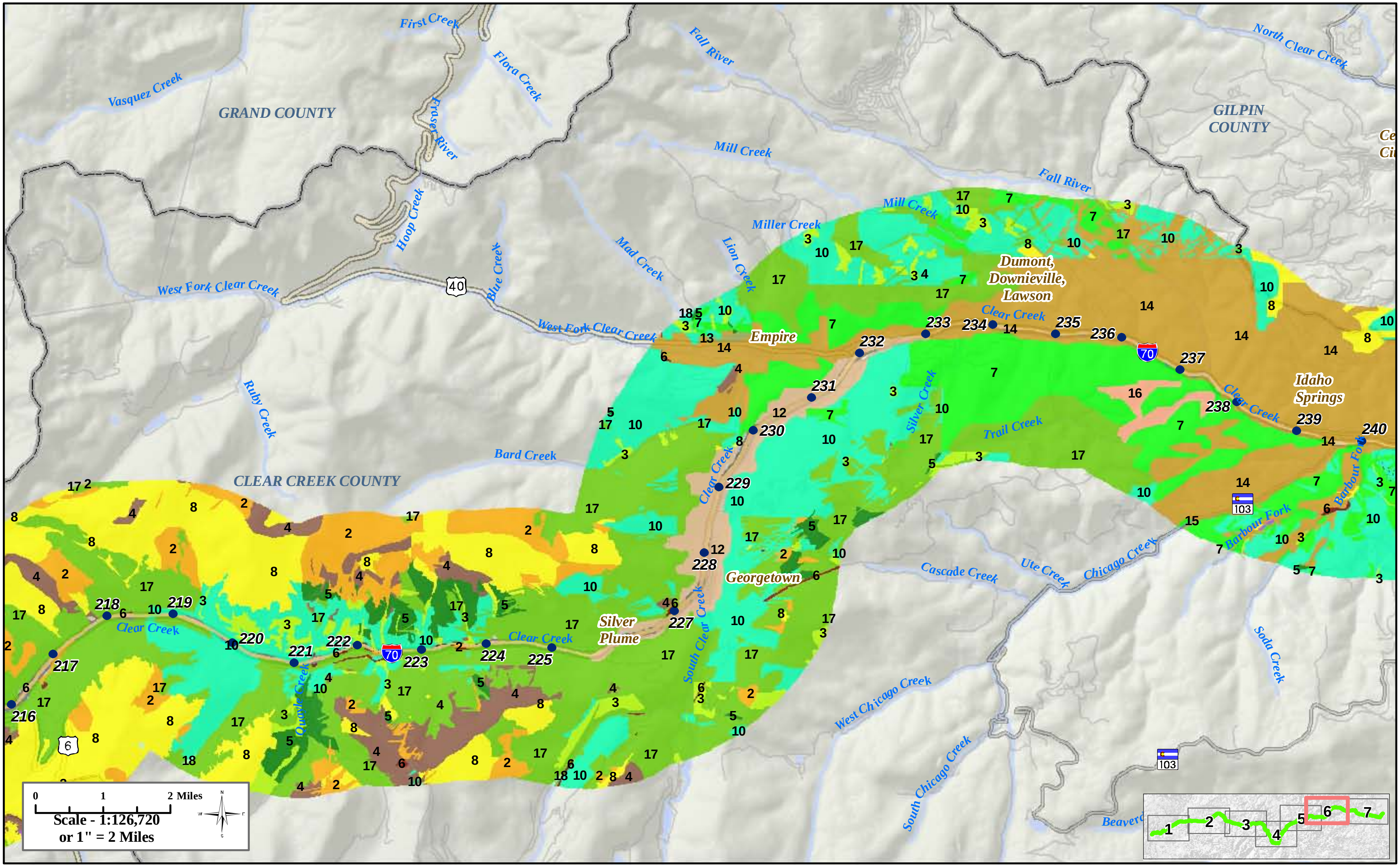

Legend

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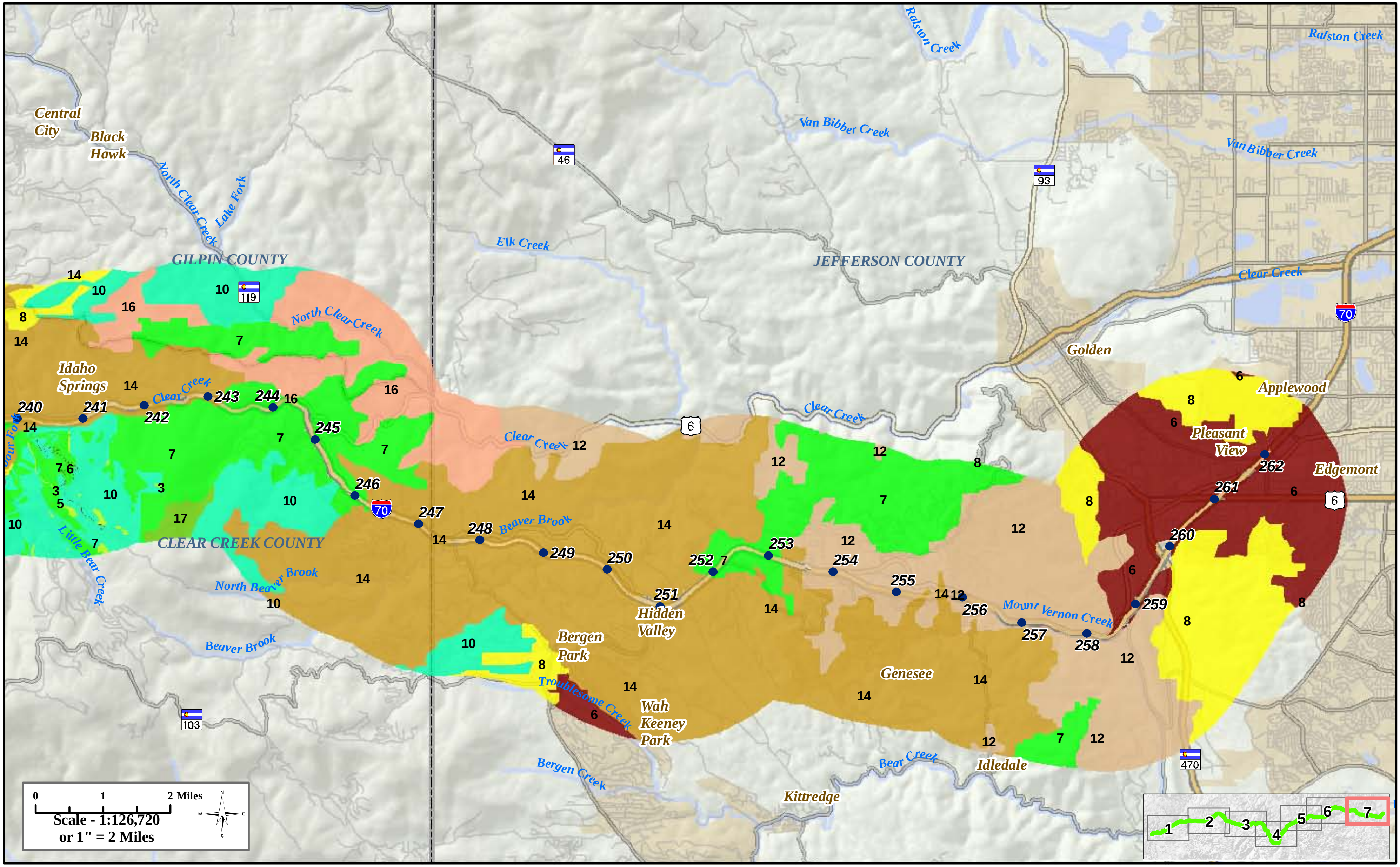
Vegetation

Map 6 of 7



Legend

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Table BR - 6. Direct Impacts on Lynx Habitat and Lynx Linkage Areas within WRNF: Preferred Alternative Eagle Valley, Ten Mile, and Blue River LAUs (acres and percent)

Habitat Type (total acres)	Minimum Program		Maximum Program	
	Specific Highway Improvements with AGS		Combination 6-Lane Highway with AGS	
	55 mph	65 mph	55 mph	65 mph
Impacts within Eagle Valley LAU				
Winter Forage (18,895)	3.0 0.02%	2.4 0.01%	3.0 0.02%	2.4 0.02%
Denning (14,245)	1.6 0.01%	1.6 0.01%	1.6 0.01%	1.6 0.02%
Other (17,536)	3.6 0.02%	3.6 0.02%	3.6 0.02%	3.6 0.06%
Lynx Linkage Areas (8,448)	104.4 1.24%	97.3 1.15%	104.4 1.24%	97.3 1.15%
Impacts within Ten Mile LAU				
Winter Forage (10,073)	0.4 0.00%	0.4 0.00%	0.4 0.00%	0.4 0.00%
Denning (5,314)	0.0 0.00%	0.0 0.00%	0.0 0.00%	0.0 0.00%
Other (10,884)	0.8 0.00	0.8 0.00	0.8 0.00	0.8 0.00
Lynx Linkage Areas (5,034)	50.3 1.00%	50.3 1.00%	50.3 1.00%	50.3 1.00%
Impacts within Blue River LAU				
Winter Forage (16,133)	0.1 0.00%	0.1 0.00%	0.1 0.00%	0.1 0.00%
Denning (18,956)	0.7 0.00%	0.7 0.00%	0.7 0.00%	0.7 0.00%
Other (34,484)	2.7 0.00	2.7 0.00	2.7 0.00	2.7 0.00
Lynx Linkage Areas (7,382)	50.7 0.69%	50.7 0.69%	50.7 0.69%	50.7 0.69%

Table BR - 7. Direct Impacts on Lynx Habitat and Lynx Linkage Areas within WRNF (Eagle Valley, Ten Mile, and Blue River LAUs) (acres and percent) updated

Habitat Type (total acres)	Minimal Action	Rail with IMC	AGS	Dual-Mode Bus in Guideway	Diesel Bus in Guideway	Six-Lane Highway 55 mph	Six-Lane Highway 65 mph	Reversible/ HOV/HOT Lanes	Combination Six-Lane Highway with Rail and IMC	Combination Six-Lane Highway with AGS	Combination Six-Lane Highway with Dual-Mode	Combination Six-Lane Highway Diesel Bus in Guideway
Impacts within Eagle Valley LAU												
Winter Forage (18,895)	2.3 0.01%	1.7 0.01%	1.9 0.01%	2.7 0.01%	2.7 0.01%	2.3 0.01%	0.5 0.00%	2.3 0.01%	3.1 0.02%	3.0 0.02%	3.1 0.02%	3.1 0.02%
Denning (14,245)	0.9 0.01%	1.9 0.01%	1.0 0.01%	0.7 0.00%	0.7 0.00%	0.9 0.01%	0.9 0.01%	0.9 0.01%	2.6 0.02%	1.6 0.01%	1.4 0.01%	1.4 0.01%
Other (17,536)	2.3 0.01%	3.8 0.02%	1.7 0.01%	0.3 0.00%	0.3 0.00%	2.3 0.01%	2.2 0.01%	2.3 0.01%	6.0 0.03%	3.6 0.02%	2.7 0.02%	2.7 0.02%
Lynx Linkage Areas (8,448)	86.9 1.03%	69.7 0.83%	46.2 0.55%	98.7 1.17%	98.7 1.17%	86.9 1.03%	74.6 0.88%	86.9 1.03%	126.7 1.50%	104.4 1.24%	128.3 1.52%	128.3 1.52%
Impacts within Ten Mile LAU												
Winter Forage (10,073)	0.4 0.00%	3.1 0.03%	0.4 0.00%	2.3 0.02%	2.3 0.02%	0.4 0.00%	0.4 0.00%	0.4 0.00%	3.1 0.03%	0.4 0.00%	2.3 0.02%	2.3 0.02%
Denning (5,314)	0.0 0.00%	0.1 0.00%	0.0 0.00%	0.1 0.00%	0.1 0.00%	0.0 0.00%	0.0 0.00%	0.0 0.00%	0.1 0.00%	0.0 0.00%	0.1 0.00%	0.1 0.00%
Other (10,884)	0.8 0.00%	1.4 0.00%	0.8 0.00%	1.3 0.00%	1.3 0.00%	0.8 0.00%	0.8 0.00%	0.8 0.00%	1.4 0.00%	0.8 0.00%	1.3 0.00%	1.3 0.00%
Lynx Linkage Areas (5,034)	5.0 0.10%	101.9 2.02%	50.3 1.00%	88.6 1.76%	88.6 1.76%	5.0 0.10%	5.0 0.10%	5.0 0.10%	101.9 2.02%	50.3 1.00%	88.6 1.76%	88.6 1.76%
Impacts within Blue River LAU												
Winter Forage (16,133)	0.1 0.00%	0.3 0.00%	0.0 0.00%	0.1 0.00%	0.1 0.00%	0.1 0.00%	0.1 0.00%	0.1 0.00%	0.4 0.00%	0.1 0.00%	0.2 0.00%	0.2 0.00%
Denning (18,956)	0.0 0.00%	1.0 0.01%	0.3 0.00%	0.7 0.00%	0.7 0.00%	0.7 0.00%	0.7 0.01%	0.7 0.00%	0.7 0.00%	0.7 0.00%	0.7 0.00%	0.7 0.00%
Other (34,484)	1.0 0.00%	2.5 0.00%	0.9 0.00%	1.8 0.00%	1.8 0.00%	2.6 0.00%	2.6 0.00%	2.7 0.00%	3.2 0.00%	2.7 0.00%	2.9 0.00%	2.9 0.00%
Lynx Linkage Areas (7,382)	0.0 0.00%	79.7 1.08%	38.1 0.52%	72.2 0.98%	72.2 0.98%	16.8 0.23%	16.8 0.23%	15.7 0.21%	87.2 1.18%	50.7 0.69%	72.2 0.98%	72.2 0.98%

Table BR - 8 and **Table BR -** 9 provide the estimated direct impacts on potential lynx winter forage, denning, other habitat, and linkage areas on the ARNF from project alternatives. No impacts on lynx denning areas are anticipated to occur under implementation of any of the project alternatives on the ARNF. The greatest impacts on lynx winter forage, other habitat, and lynx linkage areas are associated with the Combination Alternatives. Specifically, direct impacts on other habitat and lynx linkage areas are greater under the Combination Six-Lane Highway with Rail and Intermountain Connection, the Maximum Program at 55 mph (which is the same as the Combination Six-Lane Highway with Advanced Guideway System), and the Maximum Program at 65 mph.

Table BR - 8. Direct Impacts on Lynx Habitat and Lynx Linkage Areas within ARNF: Preferred Alternative Clear Creek LAU (acres and percent)

Habitat Type (total acres)	Minimum Program		Maximum Program	
	Specific Highway Improvements with AGS		Combination 6-Lane Highway with AGS	
	55 mph	65 mph	55 mph	65 mph
Winter Forage (26,222)	2.7 0.01%	2.7 0.01%	2.3 0.01%	2.3 0.01%
Denning (10,008)	0 0%	0 0%	0 0%	0 0%
Other (3,466)	0.3 0.01%	0.3 0.01%	1.9 0.05%	1.9 0.05%
Lynx Linkage Areas (2,585)	14.2	14.2	71.8	71.8

Table BR - 9. Direct Impacts on Lynx Habitat and Lynx Linkage Areas within ARNF (Clear Creek LAU) (acres and percent) updated

Habitat Type (total acres)	Minimal Action	Rail with IMC	AGS	Dual-Mode Bus in Guideway	Diesel Bus in Guideway	Six-Lane Highway 55 mph	Six-Lane Highway 65 mph	Reversible/ HOV/HOT Lanes	Combination Six-Lane Highway with Rail and IMC	Combination Six-Lane Highway with AGS	Combination Six-Lane Highway with Dual-Mode	Combination Six-Lane Highway Diesel Bus in Guideway
Winter Forage (26,222)	1.6 0.01%	5.6 0.02%	0.8 0.00%	1.2 0.00%	1.2 0.00%	1.5 0.01%	1.4 0.01%	2.2 0.01%	3.7 0.01%	2.3 0.01%	2.4 0.01%	2.4 0.01%
Denning (10,008)	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%
Other (3,466)	0.3 0.01%	0.3 0.01%	0.1 0.00%	0.2 0.01%	0.2 0.01%	0.5 0.1%	0.5 0.01%	0.9 0.03%	2.6 0.08%	1.9 0.05%	1.9 0.05%	1.9 0.05%
Lynx Linkage Areas (2,585)	9.3 0.36%	17.9 0.69%	12.8 0.50%	35.6 1.38%	35.6 1.38%	61.9 2.40%	62.0 2.40%	66.3 2.56%	74.1 2.87%	71.8 2.78%	69.9 2.70%	69.9 2.70%

To quantify potential impacts on lynx linkage areas, project alternatives were overlaid onto the linkage area maps, and linear distance (in miles) was calculated for each alternative. **Table BR - 10** and **Table BR - 11** document the estimated linear distances for project alternatives. On the WRNF, all alternatives, except the Minimal Action and the Highway Alternatives, traverse the Castle Peak, Dowd Junction, Herman Gulch, Loveland Pass, Officer's Gulch, and Vail Pass lynx linkage areas. The Minimal Action and Highway Alternatives traverse less distance than the Rail with Intermountain Connection and Advanced Guideway System Alternatives but include 10 miles of auxiliary lanes along Vail Pass through the Vail Pass lynx linkage area.

On the ARNF, all action alternatives, including the Minimal Action Alternative (auxiliary lane), traverse the entire length of the Herman Gulch lynx linkage area in close proximity to the existing I-70 alignment.

Table BR - 10. Direct Impacts on Lynx Linkage Areas (miles): Preferred Alternative

Habitat Type (total acres)	Minimum Program		Maximum Program	
	Specific Highway Improvements with AGS		Combination 6-Lane Highway with AGS	
	55 mph	65 mph	55 mph	65 mph
Castle Peak	8.4	8.4	8.4	8.4
Dowd Junction	0.6	0.6	0.6	0.6
Vail Pass	11.3	11.3	11.3	11.3
Officer's Gulch	5.1	5.1	5.1	5.1
Loveland Pass	6.2	6.2	6.2	6.2
WRNF Total	31.7	31.7	31.7	31.7
ARNF Total (Herman Gulch)	3.9	3.9	3.9	3.9
Total	**35.52**	**35.52**	**35.52**	**35.52**

Table BR - 11. Direct Impacts on Lynx Linkage Areas (miles) updated

Habitat Type (total acres)	Minimal Action	Rail with IMC	AGS	Dual-Mode Bus in Guideway	Diesel Bus in Guideway	Six-Lane Highway 55 mph	Six-Lane Highway 65 mph	Reversible/ HOV/HOT Lanes	Combination Six-Lane Highway with Rail and IMC	Combination Six-Lane Highway with AGS	Combination Six-Lane Highway with Dual-Mode	Combination Six-Lane Highway Diesel Bus in Guideway
Castle Peak	0.5	0.5	8.4	8.4	8.4	0.5	0.5	0.5	0.5	8.4	8.4	8.4
Dowd Junction	0.6	0.6	0.6	0.6	0.6	0.6	0.0	0.6	0.6	0.6	0.6	0.6
Vail Pass	7.3	11.3	11.3	11.3	11.3	7.3	7.3	7.3	11.3	11.3	11.3	11.3
Officer's Gulch	0.3	5.1	5.1	5.1	5.1	0.3	0.3	0.5	5.1	5.1	5.1	5.1
Loveland Pass	0.0	6.2	6.2	6.2	6.2	0.6	0.6	0.6	6.2	6.2	6.2	6.2
WRNF Total	8.7	23.7	31.7	31.7	31.7	9.3	8.7	9.5	23.7	31.7	31.7	31.7
ARNF Total (Herman Gulch)	3.6	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9
Total	12.3	27.6	35.5	35.5	35.5	13.1	12.6	13.3	27.6	35.5	35.5	35.5

While the impacts on lynx linkage areas are the same for each alternative traversing the ARNF, the impacts on lynx linkage areas vary greatly on the WRNF. The reasons for these variations are primarily related to the variation termini of project alternatives, as well as the specific locations of lynx linkage areas throughout the Corridor.**Figure BR - 1** illustrates the termini and Minimal Action components associated with each project alternative, as well as the locations of lynx linkage areas. The following describe key differences among alternative termini:

- Minimal Action components are made up of localized improvements throughout the Corridor and do not result in physical improvements across the entire Corridor. The Minimal Action components of each alternative vary with alternative; see **Figure BR - 1**.
- Transit Alternatives
  - The Rail with Intermountain Connection Alternative includes physical improvements between the Minturn interchange and C-470 (milepost 168 to milepost 260). It is important to

note that an existing rail bed is used between Eagle Airport and the Minturn interchange (milepost 142 to milepost 168), which is referred to as the Intermountain Connection. This portion of existing rail bed is not considered new impact on lynx linkage area.
- The Advanced Guideway System Alternative includes physical improvements between the Eagle Airport interchange and C-470 (milepost 142 to milepost 260).
- The Bus in Guideway Alternatives include physical improvements between Eagle Airport interchange and C-470 (milepost 142 and milepost 260), with localized Minimal Action components beyond these termini.

- Highway Alternatives
  - The Six-Lane Highway Alternatives include physical improvements at Dowd Canyon (milepost 170 to milepost 173) and between the Continental Divide and Floyd Hill (milepost 215.3 to milepost 247), with localized Minimal Action components, such as the Vail Pass climbing lanes beyond these termini.
- Combination Alternatives
  - The Combination Six-Lane Highway with Rail and Intermountain Connection Alternative has the same termini as the Rail with Intermountain Connection single-mode alternative.
  - The Combination Six-Lane Highway with Advanced Guideway System alternative has the same termini as the Advanced Guideway System single-mode alternative.
  - The Combination Bus-in-Guideway alternatives have physical improvements between the Eagle Airport interchange and C-470 (milepost 142 to milepost 260).

Indirect Effects

The I-70 Corridor, along with associated communities and roadways, constitutes a major source of habitat fragmentation, effectively dividing large home ranges and disrupting wildlife movements from north to south (USDA, 2002b). As wide-ranging predators, lynx are especially susceptible to fragmentation impacts, and the Corridor crosses known historical lynx habitat (for example, Vail Pass area) and intersects eight areas considered by federal agencies to be lynx linkage zones. In 2002 and 2004, two reintroduced lynx were killed on I-70 near the top of Vail Pass (milepost 188) and one east of EJMT near Bakerville (milepost 220), and with the species increasing in numbers, more AVCs are likely. Also, the linkage interference zone adjacent to the ARNF at milepost 247 to milepost 258 had the highest rate of AVCs (2.4/mile/year). However, the three lynx killed between milepost 188 and milepost 220 were in linkage interference zones where few or no AVCs were previously reported for any wildlife species (D. Lowry pers. comm. with D. Solomon, 2006b).

The Lynx Conservation Assessment and Strategy (LCAS) identifies more than 4,000 vehicles per day on a roadway as a serious threat for wildlife mortality and habitat fragmentation (Ruediger et al., 2000). Travel on I-70 throughout the Corridor currently greatly exceeds 4,000 vehicles per day. The lowest traffic volumes recorded by automated CDOT traffic counters occurred in the winter in Glenwood Canyon and were approximately three times higher than this threshold.

Most of the alternatives increase the indirect barrier effect of I-70. For example, the Advanced Guideway System Alternative requires a 3-foot-tall barrier to prevent oncoming traffic from colliding into the piers. Additional highway lanes also do not in themselves create physical barriers as compared to the Rail with Intermountain Connection, Bus in Guideway, and Combination Alternatives, but additional lanes of traffic increase the barrier effect during high traffic volumes. The ALIVE Committee has developed measures to reduce the barrier effect and AVCs. As documented in Chapter 3, Section 3.2 of the 2004 Draft PEIS, existing barriers identified by the ALIVE Committee that are encountered by the Preferred Alternative will be mitigated. Existing barriers not encountered will be mitigated only through partnering opportunities with other stakeholders. Proposed mitigation of existing barriers includes placing an overpass or underpass at key locations in linkage interference zones that allow animals to more easily cross I-70, and installing, repairing, and maintaining wildlife fencing that reduce contact with vehicles and help channel wildlife to crossing structures. Barrier effects will be reduced in accordance with the ALIVE Memorandum of Understanding, but only if it is implemented.

Alternatives that extend through the greatest length of the Corridor (for example, Rail with Intermountain Connection, Bus in Guideway, Advanced Guideway System, Combination Six-Lane Highway with Rail and Intermountain Connection, Combination Six-Lane Highway with Advanced Guideway System, and Combination Six-Lane Highway with Bus in Guideway) offer the greatest opportunities to mitigate the existing barrier effects in the linkage interference zones. Therefore, the longer an alternative, the more existing barriers will be mitigated. If an alternative does not encounter an existing barrier, then the barrier will be altered only through partnering opportunities with other stakeholders. The No Action Alternative has the greatest impacts on wildlife crossings because it is assumed that the existing conflict areas will not be addressed.

Locations where lynx linkage zones intersect with I-70 are described as lynx linkage interference zones. (Note: Fifteen linkage interference zones identified along the Corridor apply to wildlife in general, with 10 of these applicable specifically to lynx).

All project alternatives are projected to stimulate growth as a result of the increased access and mobility opportunities in the Corridor. However, if changes in population exceed these anticipated projections for the Corridor, that excessive growth is considered to be "induced."

Possible induced growth in travel demand associated with all action alternatives, except the Minimal Action Alternative, is expected to lead to an increase in recreational use in the Corridor during winter. Expansion of ski areas, snowshoeing, and snowmobile use compact snow and increase the frequency of human presence. Increased snow compaction affords other carnivores (such as coyotes or mountain lions) the ability to access deep snow areas that are typically hunted only by lynx. This increase in competition for resources may be detrimental to the lynx. Road effect zone-related disturbance and habitat fragmentation due to increased human activity also likely affect lynx. These impacts could potentially have population-wide effects, as well as affect individuals. The Combination alternatives are associated with the greatest possible induced growth in Eagle and Summit counties, as well as the greatest chance for increased visitation in WRNF and ARNF. Highway alternatives are associated with possible moderate induced growth in Eagle County and possible increased visitation to ARNF and WRNF, including increased dispersed winter recreation. Transit alternatives might induce growth near urban areas and increase visitation to developed recreation areas in ARNF and WRNF such as ski areas.

Cumulative Effects

Cumulative impacts include direct impacts of action alternatives, impacts from forest management activities on both forests, impacts from induced growth, and impacts from planned development. The greatest cumulative impact on Canada lynx is likely to result from the action alternatives and future development that is planned for areas outside National Forest System Lands, primarily in Eagle County. The larger human population in areas adjacent to National Forest System Lands and the transport of people through the Corridor would increase the amount of disturbance in lynx linkage areas and in the recreational use of National Forest System Lands, which, in turn, would increase the disturbance factor.

There are currently approximately 13,000 acres of developed land in Eagle County. Planned urban development areas have been proposed for approximately 39,000 acres and planned rural development areas for approximately 48,000 acres. In addition to these planned development areas of 87,000 acres, analysis for the Corridor indicates there could be approximately 45,000 acres of induced land development as a result of increased access and mobility resulting from the Corridor alternatives (see Chapter 4 of the Draft PEIS). A large portion of the induced growth also would be expected in Eagle County. Planned development and induced growth have the potential cumulative effect of more people intruding into lynx habitat. The result to lynx would likely be displacement from existing habitat into more distant or more remote habitat that might be of lesser quality to meet the needs of lynx hunting and denning. However, it must be noted that the planned and induced growth would first occur at lower elevations in open areas of more gentle terrain, thus avoiding the steeper, more densely vegetated terrain that lynx may use as habitat. Therefore, much of the planned and induced growth would not occur in lynx habitat.

No Action Alternative

Impacts on lynx would be expected to increase with the No Action Alternative from increased traffic volumes and growth already occurring. The I-70 Corridor, as currently configured through the mountains, is not designed to promote linkage between lynx habitat on either side of I-70. Furthermore, no commitment to mitigating this existing barrier is being made under the No Action Alternative.

Cumulative Effects

Cumulative impacts include impacts from forest management activities on both forests and from planned development. Future development that is planned for areas outside National Forest System Lands, primarily in Eagle County, will result in habitat loss and fragmentation. Such planned and induced growth could amount to 130,000 acres in and adjacent to the Corridor by 2025 (see Chapter 4 of the Draft PEIS). The larger human population in areas adjacent to National Forest System Lands and the transport of people through the Corridor would increase the amount of disturbance in lynx linkage areas and, which in turn, would increase the disturbance factor. However, it must be noted that the planned and induced growth would first occur at lower elevations in open areas of more gentle terrain, thus avoiding the steeper, more densely vegetated terrain that lynx may use as habitat. Therefore, much of the planned and induced growth would not occur in lynx habitat.

Determination of Effects and Rationale

All action alternatives: **May affect, likely to adversely affect.**

This determination is based on the consideration that although limited lynx habitat would be affected directly, the barrier effect of any additions to the Corridor may further restrict lynx movements, and construction could temporarily disturb individuals in the area. Three reintroduced lynx have been killed recently along I-70 by AVCs. These direct impacts are anticipated to continue as the reintroduced population increases and the traffic volume continues to rise. It is not expected that these impacts would likely affect population viability. Impacts may be alleviated in subsequent years as lynx find and learn to use the new crossing structures provided.

No Action Alternative: **May affect, likely to adversely affect.**

This determination is based on the consideration that direct effects on lynx movements (the Corridor serving as a barrier between linkage areas, and AVCs) would continue under the No Action Alternative. The I-70 Corridor, as currently configured, is not designed to promote linkage between lynx habitat on either side of I-70 AVCs would continue or increase with increased population and traffic.

BR.3.1.2 Birds

Least Tern (Sterna antillarum), E

The least tern is a member of the order Charadriiformes, the family Laridae, and the genus *Sterna*. It is not known or suspected to occur on National Forest System Lands, but it may occur in the planning area vicinity of the ARNF. The interior population of the least tern was listed as endangered on May 28, 1985 (50 FR 21784-21792).

Distribution

In Colorado, least terns are known to nest at Horse Creek Reservoir, Adobe Creek Reservoir, and Neenoshe Reservoir, all three of which are in southeastern Colorado in the Arkansas River drainage (Kingery, 1998). The species is being considered within this biological report based on the potential for the action alternatives to create water depletions downstream on the Platte River system in Nebraska. Outside Colorado, the interior least tern is recorded to nest along rivers and lakes in the Mississippi, Ohio, Missouri, and Arkansas River drainages, as well as several rivers in Texas. The bird overwinters in South America.

Natural History

Adult birds are 8.27 to 9.45 inches long and typically have wingspans of 20 inches. The birds breed at 2 years old. The least tern nests in simple scrapes made on sparsely vegetated sandbars of rivers or islands, and on salt flats along the shoreline of lakes and reservoirs. These birds form nesting colonies of perhaps as a many as 75 nests (USFWS, 2005). Egg laying is typically accomplished in late May to early August. This nesting strategy is later than most migrant birds and is timed to match receding water levels. Typical clutch size is 2 (Ehrlich et al., 1988). The eggs are incubated approximately 20 days, and the chicks fledge after another 20 days. Interior least terns feed solely on small fish, thus limiting their nesting to water bodies with adequate fish populations (Kingery, 1998). Critical habitat has not been designated for the least tern.

Environmental Baseline

Suitable habitat does not exist within the Corridor for this species; however, habitat occurs downstream of the Corridor. The interior population of the least tern is listed under the ESA as an endangered species and an uncommon summer resident along the Platte River drainage in Nebraska around reservoirs. Previous census data documented approximately 5,000 interior least terns (USFWS, 1990b).

Direct, Indirect, and Cumulative Effects of Alternatives

Action Alternatives

Construction of the action alternatives would occur well out of known least tern range; therefore, no direct effects will be caused by this project.

Water needs for the action alternatives are not known at this time, but there is a limited potential for construction of the action alternatives to cause the indirect effect of water depletions on the Platte River drainage downstream in Nebraska, where this species does occur. Some degree of water depletions would likely be necessary during the construction of all action alternatives for activities such as dust suppression, materials handling, or washing. The specific water needs and impacts will be examined during Tier 2 analysis and pre-construction stages.

According to USFWS, any depletion to the Platte River basin (roughly defined as the Palmer Divide north and the Continental Divide east in Colorado) constitutes an action that may affect and is likely to adversely affect TES species that depend on the river for their existence. To comply with the SPWRAP, an analysis of effects on ESA species downstream in Nebraska resulting from the Preferred Alternative is required in the BA. These effects will be examined during Tier 2 processes and will be submitted to USFWS for streamlined Section 7 consultation under the ESA. CDOT is coordinating with USFWS on this matter for documentation in the BA.

Cumulative Effects

Cumulative effects on this species would include existing and planned development in addition to construction and operation of alternatives in the I-70 Mountain Corridor, which reduce instream flows and/or water quality of the Platte River system. Possible induced growth is not associated with any of the action alternatives in the Platte River watershed.

Cumulative effects on this species on nonfederal lands would include existing and planned development in addition to construction and operation of alternatives in the I-70 Corridor, which reduce instream flows and/or water quality of the Platte River system.

No Action Alternative

Current threats to populations of the interior least tern include elimination of nesting habitat due to control of rivers by upstream dams/reservoirs. Control of spring flooding has eliminated scouring effects that formerly eliminated undesirable buildup of vegetation on sandbars and also has limited the amount of alluvium available for sandbar or island formation. Human disturbance in the form of recreational usage of interior least tern habitat has also had a negative effect on the species' survival by lowering reproductive success (Mayer and Dryer, 1988; and Smith and Renken, 1990).

Cumulative Effects

Cumulative effects on this species would include existing and planned development, which could reduce instream flows and/or water quality of the Platte River system.

Cumulative effects on this species would include planned development on nonfederal lands, which could reduce instream flows and/or water quality of the Platte River system.

Determination of Effects and Rationale

All action alternatives: **May affect, likely to adversely affect.**

This determination is based on the consideration that no direct impacts on habitat for the least tern are expected with construction of any of the action alternatives. However, any water depletions may affect this Platte River basin species.

No Action Alternative: **No effect.**

This determination is based on the consideration that the No Action Alternative would occur well out of least tern range in Colorado. No water depletions or direct impacts on habitat for this species are expected to occur as a result of implementation of the No Action Alternative.

Piping Plover (*Charadrius melodus*), T

The piping plover is a shorebird. It is a member of the order Charadriiformes, the family Charadriidae, and the genus *Charadrius*. Other North American members of this genus include the semipalmated plover (*Charadrius semipalmatus*), Wilson's plover (*Charadrius wilsonia*), snowy plover (*Charadrius alexandrinus*), killdeer (*Charadrius vociferous*), mountain plover (*Charadrius montanus*), and Mongolian plover (*Charadrius mongolus)*. The piping plover is not known or suspected to occur on National Forest System Lands, but it may occur in the planning area vicinity of the ARNF. The piping plover was listed by USFWS as threatened on December 11, 1985.

Distribution

The piping plover is currently designated as endangered in the Great Lakes watershed in the states of Illinois, Indiana, Michigan, Minnesota, New York, Ohio, Pennsylvania, and Wisconsin, and in Canada (Ontario). Outside the listing of critical habitat, the piping plover is well represented in states east of the Rocky Mountains. The piping plover winters along the Gulf Coast of Texas.

U.S. Fish and Wildlife Service designated certain habitats in Minnesota, Montana, North Dakota, South Dakota, and Nebraska as critical habitat for the Northern Great Plains population of piping plover.

In Colorado, all nesting records are from the southeastern part of the state. Nesting sites have been recorded at four sites for the time period 1987 to 1995. Locations included the Great Plains Reservoirs in Kiowa County, Adobe Creek Reservoir, and John Martin Reservoir (Kingery, 1998).

Total population estimate is approximately 4,200 birds in three distinct populations in North America (Kingery, 1998).

Natural History

Piping plovers return from their wintering grounds in late April. Pairs begin nesting in early May. One brood is raised per year. If nests fail, piping plovers may renest in favorable years. Several nest sites are constructed by the males and are typically simple scrapes on the ground far from cover. The female will choose one of the scrapes to lay a clutch of 3 to 4 cryptically colored eggs. Incubation is shared and lasts an average of 26 days in Colorado. Fledging takes approximately 28 to 31 days (Kingery, 1998).

Piping plovers nest on riverine sandbars and at inland lakes and reservoirs in areas with wide open, sandy, sparsely vegetated beaches. Some of the lakes/reservoirs may be alkaline, with beaches that may be salt-encrusted, or feature islands that provide some isolation for nesting. Their nests are often in association with other shorebirds' nests and are benefited by the more aggressive behavior toward predators shown by other species (Kingery, 1998). Diet for these birds consists of marine worms (*Sipunculus nudus*), crustaceans, mollusks, and eggs of marine invertebrates (Ehrlich et al., 1988).

This designation includes 183,422 acres of habitat and 1,207.5 river miles. Designated areas of critical habitat include prairie alkali wetlands and surrounding shoreline; river channels and associated sandbars and islands; and reservoirs and inland lakes and their sparsely vegetated shorelines, peninsulas, and islands. These areas provide primary courtship, nesting, foraging, sheltering, brood-rearing, and dispersal habitat for piping plovers. USFWS has also designated additional critical habitat in Minnesota, Wisconsin, Michigan, Illinois, Indiana, Ohio, Pennsylvania, and New York for the Great Lakes breeding population of piping plover, but these habitats cannot legitimately be considered for effects from this project's action alternatives.

Environmental Baseline

Suitable habitat does not exist within the Corridor for this species; however, habitat occurs downstream of the Corridor. This small shorebird is listed as threatened by both the ESA and Colorado. It is a rare migrant in the state known to nest in only a few locations along the sandy beaches of reservoirs in eastern counties (Arkansas River drainage).

Piping plover populations originally experienced sharp declines due to hunting pressure. The chief threats are loss of habitat from development and recreation, with vehicles often destroying nests (Ehrlich et al., 1988).

Direct, Indirect, and Cumulative Effects of Alternatives

Action Alternatives

Construction of the action alternatives would occur well out of piping plover range in Colorado. No direct impacts on habitat for this species are expected to occur as a result of implementation of any of the action alternatives.

Water needs for the action alternatives are not known at this time, but it is anticipated that there is a limited potential for construction to cause the indirect effect of water depletions on the Platte River drainage downstream in Nebraska, where this species does occur. Some degree of water depletions would likely be necessary during the construction of the action alternatives for activities such as dust suppression, materials handling, and washing. The specific water needs and impacts will be examined during Tier 2 process and pre-construction stages.

According to USFWS, any depletion to the Platte River basin (roughly defined as the Palmer Divide north and the Continental Divide east in Colorado) constitutes an action that may affect, and is likely to adversely affect, TES species that depend on the river for their existence. To comply with the SPWRAP, an analysis of effects on ESA species downstream in Nebraska resulting from the Preferred Alternative is required in the BA. These effects will be examined during Tier 2 processes and will be submitted to USFWS for streamlined Section 7 consultation under the ESA. Colorado Department of Transportation is coordinating with USFWS on this matter for documentation in the BA.

Cumulative Effects

Cumulative effects on this species would include existing and planned development in addition to construction and operation of alternatives in the I-70 Corridor, which reduce instream flows and/or water quality of the Platte River system. Possible induced growth is not associated with any of the action alternatives in the Platte River watershed.

Cumulative effects on this species on nonfederal lands would include existing and planned development in addition to construction and operation of alternatives in the I-70 Corridor, which reduce instream flows and/or water quality of the Platte River system.

No Action Alternative

The No Action Alternative would occur well out of piping plover range in Colorado. No water depletions or direct impacts on habitat for this species are expected to occur as a result of implementation of the No Action Alternative.

Cumulative Effects

Cumulative effects on this species would include existing and planned development, which could reduce instream flows and/or water quality of the Platte River system.

Cumulative effects on this species would include planned development on nonfederal lands, which could reduce instream flows and/or water quality of the Platte River system.

Determination of Effects and Rationale

All action alternatives: **May affect, likely to adversely affect.**

This determination is based on the consideration that no direct impacts on habitat for this species are expected to occur as a result of implementation of any of the action alternatives. However, any water depletions may affect this Platte River basin species.

No Action Alternative: **No effect.**

This determination is based on the consideration that the No Action Alternative would occur well out of piping plover range in Colorado. No water depletions or direct impacts on habitat for this species are expected to occur as a result of implementation of the No Action Alternative.

Whooping Crane (*Grus americana*), E

The whooping crane is in the order Gruiformes and the family Gruidae. The other North American species in the genus *Grus* is the sandhill crane (*Grus canadensis*). The whooping crane is an endangered species that is not known or suspected to occur on National Forest System Lands; however, it may occur in the planning area vicinity of the ARNF.

Distribution

The historic range of the whooping crane extended from the Northwest Territories of Canada to the Gulf Coast and Atlantic Coast in the U.S., and south into Mexico. Whooping cranes were extirpated from the central U.S. in the 1890s.

The whooping crane was listed as endangered on March 11, 1967 (32 FR 4001). It is known to occur in Kansas, Montana, North Dakota, Nebraska, Oklahoma, South Dakota, and Texas; there are experimental populations in Wisconsin and Florida. There was also a Rocky Mountain non-essential experimental population (XN) that used habitat within the lower San Luis Valley of Colorado. The Rocky Mountain non-essential experimental population has been extirpated (NatureServe, 2006).

USFWS designated critical habitat for the whooping crane (Fed. Reg., Vol. 43, No. 94, p. 20938 –20942) on May 15, 1978. These habitats were identified as Monte Vista National Wildlife Refuge (NWR), Colorado; Alamosa NWR, Colorado; Grays Lake NWR and vicinity, Idaho; Cheyenne Bottoms State Waterfowl Management Area, Kansas; Quivira NWR, Kansas; Platte River Bottoms between Lexington and Dehman, Nebraska; Bosque del Apache NWR, New Mexico; Salt Plains NWR, Oklahoma; and Aransas NWR and vicinity, Texas.

Currently there is only one wild population of the birds. This population winters at the Aransas NWR in Texas and nests in the Northwest Territories (Aransas/Wood Buffalo Population). An aerial census flown on November 22, 2006, over the Aransas NWR and surrounding areas found a wild population of 182 adults and 42 chicks (USFWS, 2006b). There were four captive populations with approximately 130 birds, as of 1997 (62 FR 38933).

Natural History

The whooping crane is the tallest bird in North America, measuring approximately 4.92 feet and weighing 14 to 16 pounds at adulthood. The adult birds are white with black primaries. The average life span of this species is 22 to 24 years in the wild (62 FR 38933). Whooping cranes are monogamous, pairing for life. Mate selection is accomplished on the species wintering grounds or during migration. They arrive on the breeding grounds in late April, and southward migration begins from mid-September to mid-October. Most birds arrive on the wintering grounds by mid-November. Whooping cranes reach sexual maturity from four to six years of age. The female typically lays two eggs in late April to early May. Incubation of the eggs takes 29 to 34 days and is carried out by both adults. Young birds fledge between 78 and 90 days, but they continue to be fed by the adults until the following spring. Only one chick usually survives. Whooping cranes feed on crabs, clams, shrimp, snails, frogs, snakes, grasshoppers, larval and nymph forms of flies, beetles, water bugs, birds, and small mammals. They have also been observed to eat 58 species of fish (Lewis, 1995).

Whooping cranes breed and nest along lake margins, marshes, and wet meadows dominated by sedges, rushes, bulrushes, and cattails. Standing water in these habitats may be as much as 18 inches deep. The birds prefer sites that are not disturbed by humans and that are wet enough to avoid terrestrial predators.

The potential predators of whooping cranes include black bear (*Ursus americanus*), wolverine (*Gulo gulo*), gray wolf (*Canis lupus*), coyote (*Canis latrans*), red fox (*Vulpes vulpes*), lynx, and ravens (*Corvus corax*). Whooping cranes use wetlands, river bottoms, and agricultural lands along their migratory route (Lewis, 1995).

Environmental Baseline

Suitable habitat does not exist within the Corridor for this species; however, habitat occurs downstream of the Corridor. Migratory range in Colorado is fairly limited to the San Luis Valley (CDOW, 2004). Whooping cranes are occasional spring and fall migrants through the Platte River Valley in Nebraska between Lexington and Grand Island (Nebraska Game and Parks Commission, 2004). Clear Creek, a major stream in the I-70 Corridor, which flows into the South Platte River, is part of this watershed.

These cranes use croplands adjacent to the Platte River for foraging, usually within 30 miles of the river. Migration habitat usually consists of wet areas with good horizontal visibility, water depth of 12 inches or less, and minimum wetland size of 0.1 acre for roosting (NatureServe, 2004).

Whooping cranes cannot tolerate much human disturbance. This is especially true during nesting and during flightless molt (May to mid-August). Disturbance may include draining of wetlands, fencing, plowing, tour boats passing, waterfowl hunting, clamming, and fishing in proximity to these birds (Lewis, 1995).

Direct, Indirect, and Cumulative Effects of Alternatives

Action Alternatives

Construction for all action alternatives would occur well out of suitable whooping crane range. This species was evaluated because of the possibility of action alternatives causing water depletions to rivers that drain to the Platte River (for example, Clear Creek), thereby potentially affecting whooping crane migratory habitat downstream in Nebraska. Some degree of water depletions would likely be necessary during the construction of the action alternatives for activities such as dust suppression, materials handling, or washing. The specific water needs and impacts will be examined during Tier 2 process and pre-construction stages.

According to USFWS, any depletion to the Platte River basin (roughly defined as the Palmer Divide north and the Continental Divide east in Colorado) constitutes an action that may affect, and is likely to adversely affect, TES species that depend on the river for their existence. To comply with the SPWRAP, an analysis of effects on ESA species downstream in Nebraska resulting from the Preferred Alternative is required in the BA. These effects will be examined during Tier 2 processes and will be submitted to USFWS for streamlined Section 7 consultation under the ESA. CDOT is coordinating with USFWS on this matter for documentation in the BA.

Cumulative Effects

Cumulative effects on this species would include existing and planned development in addition to construction and operation of alternatives in the I-70 Corridor, which may reduce instream flows and/or water quality of the Platte River system. Possible induced growth is not associated with any of the action alternatives in the Platte River watershed.

Cumulative effects on this species on nonfederal lands would include existing and planned development in addition to construction and operation of alternatives in the I-70 Corridor, which may reduce instream flows and/or water quality of the Platte River system.

No Action Alternative

The No Action Alternative would occur well out of whooping crane range in Colorado. No water depletions or direct impacts on habitat for this species are expected to occur as a result of implementation of the No Action Alternative.

Cumulative Effects

Cumulative effects on this species would include existing and planned development, which could reduce instream flows and/or water quality of the Platte River system.

Cumulative effects on this species would include planned development on nonfederal lands, which could reduce instream flows and/or water quality of the Platte River system.

Determination of Effects and Rationale

All action alternatives: **May affect, likely to adversely affect.**

This determination is based on the consideration that no direct effects are anticipated from any of the action alternatives on habitat for whooping crane, including river sandbars, agricultural areas, or reservoir mudflats within known whooping crane range. However, any water depletions may affect habitat of this Platte River basin species.

No Action Alternative: **No effect.**

This determination is based on the consideration that the No Action Alternative would occur well out of whooping crane range in Colorado. No water depletions or direct impacts on habitat for this species are expected to occur as a result of implementation of the No Action Alternative.

BR.3.1.3 Fish

Bonytail Chub (Gila elegans), E

The bonytail chub is a member of the order Cypriniformes, family Cyprinidae, and genus *Gila*. This genus is represented by 14 species. The bonytail chub was first listed as endangered on April 23, 1980 (45 FR 27710). There is no suitable habitat for this species on either Forest, but it is known to occur downstream of the APE in the Colorado River watershed and may be impacted by changes in water flow, timing, or quality (C. Hirsch pers. comm. with JFSA, 2006).

Distribution

The bonytail chub is currently designated as endangered over its entire range. Within the area covered by this listing, this species is known to occur in Arizona, California, Colorado, Nevada, and Utah. USFWS Mountain-Prairie Region (Region 6) is the region in charge of the listing for the bonytail chub.

This species is endemic to the Colorado River basin and is the rarest of the Colorado River fish. Declines in populations are due to habitat modification largely caused by dams. Historically, bonytail chub were present in the Colorado River system, including the Yampa, Green, Colorado, and Gunnison rivers. Today, there are no known populations in Colorado. The last Colorado specimen was taken in 1984 from the Black Rocks area of the Colorado River, west of Grand Junction (CDOW, 2005d). They still can be found in the Green River drainage in Utah and in the Mohave Reservoir on the Arizona-Nevada border.

Population augmentation is ongoing in Lake Mohave and Lake Havasu in Mohave and La Paz counties, Arizona. This species occurs in streams running through lands owned or managed by the Bureau of Reclamation (BOR); USFWS (Bill Williams, Cibola, and Havasu NWRs); National Park Service (Lake Mead National Recreation Area); Lake Havasu State Park; La Paz County Park; the Nature Conservancy (Hassayampa River Preserve); and private citizens.

Natural History

Little is known about bonytail chub habitat except that the species prefers eddies and deep pools near the main channel of larger rivers (NDIS, 2003).

During spawning, eggs are scattered over the bottom, and no parental care occurs. Spawning has been observed during May in Lake Mohave and in June and July in the upper Green River at water temperatures of about 64 degrees Fahrenheit (Minckley, 1973). Cold water released below dams precludes successful hatching of eggs (Bagley, 1989). In rivers, young bonytail chub eat aquatic insects, while adults primarily eat terrestrial insects, plant debris, and algae. In lakes, they apparently feed on algae and plankton.

USFWS has designated critical habitat for four Colorado River basin fish: bonytail chub, Colorado pikeminnow, humpback chub, and razorback sucker. USFWS designated 1,980 miles of rivers in the Colorado River basin as critical habitat for the four endangered species in portions of Colorado, Arizona, Utah, New Mexico, Nevada, and California. Three primary constituent elements for designated critical habitat have been identified for the Colorado River basin listed fish: (1) water, (2) physical habitat, and (3) biological environment (50 CFR Part 17, Vol. 59, No. 54).

The water element includes consideration of water quality and quantity. Water quality is defined by parameters such as temperature, dissolved oxygen, environmental contaminants, nutrients, and turbidity. Water quantity refers to the amount of water that must reach specific locations at a given time of year to maintain biological processes and to support the various life stages of the species.

The physical habitat elements include areas of the Colorado River system that are or could be suitable habitat for spawning, nursery, rearing, and feeding, as well as corridors between such areas. Habitat types include bottomland, main and side channels, secondary channels, oxbows, backwaters, and other areas in the 100-year floodplain and full-pool levels of reservoirs, which, when inundated, may provide habitat or corridors to habitat necessary for the feeding and nursery needs of the razorback sucker.

The biological environment elements include the living components of the food supply and interspecific interactions. Food supply is a function of nutrient supply, productivity, and availability to each life stage. Negative interactions include predation and competition with introduced non-native fish.

Environmental Baseline

Listed as endangered both under the ESA and by Colorado, the bonytail chub historically occurred throughout the Colorado River drainage. This species currently has a limited distribution in Utah, and the last known Colorado specimen was taken in 1984 from the Black Rocks area of the Colorado River, west of Grand Junction. The species historically preferred the warm, swift, turbid mainstem rivers of the Colorado River basin, but in Arizona, it is now restricted to the two reservoirs in the lower basin.

Decline of this species appears to be related to the effects of dams, as well as competition and predation from exotic fish.

Direct, Indirect, and Cumulative Effects of Alternatives

Action Alternatives

The bonytail chub does not occur in stream segments within the Corridor area, and thus, no direct impacts on this fish or its critical habitat are expected. Temporary indirect effects are possible if water depletions or water quality degradation from project construction was substantial enough to affect the Colorado River watershed downstream, where the fish occur. Some degree of water depletions would likely be necessary during the construction of the action alternatives for activities such as dust suppression, materials handling, and washing. The specific water needs and impacts will be examined during Tier 2 process and pre-construction stages.

The 1999 *Colorado River Programmatic Biological Opinion* addresses water depletions in the Colorado River and its tributaries above its confluence with the Gunnison River. Recovery actions outlined in the *Programmatic Biological Opinion* provide measures to avoid the likelihood of jeopardy and adverse modification of critical habitat. To offset the cost of implementing recovery actions, a one-time fee is required for new depletions greater than 100 AF/year. Other provisions of the *Programmatic Biological Opinion* are that nonfederal water users are required to sign a Recovery Agreement and federal agencies are requested to retain discretionary authority in the event that consultation is reinitiated. Construction activities for all action alternatives include a Tier 1 commitment to limit stream depletions to 100 AF/year.

Cumulative effects on this species would result from existing and planned development in the upper Colorado basin (including agriculture, land development, transportation), and possible induced growth (Combination, Transit, and Highway alternatives) in addition to construction and operation of alternatives in the I-70 Corridor. When development in the upper basin serves to reduce instream flows or degrade water quality of the Colorado River, the humpback chub may experience adverse effects. Combination alternatives would have the greatest impacts on water resources from possible induced growth (in both Eagle and Summit counties), followed by more moderate effects from the Transit and Highway alternatives (Eagle County only). Combination and Highway alternatives are associated with greater effects on water quality from increased I-70 winter maintenance activities.

Cumulative Effects

Cumulative effects on this species would include existing and planned development in addition to construction and operation of alternatives in the I-70 Corridor, which reduce instream flows and/or water quality of the Colorado River system. Possible induced growth is anticipated with all action alternatives, except the Minimal Action Alternative.

Cumulative effects on this species on nonfederal lands would include existing and planned development in addition to construction and operation of alternatives in the I-70 Corridor, which reduce instream flows and/or water quality of the Colorado River system. Possible induced growth is anticipated with all action alternatives, except the Minimal Action Alternative.

No Action Alternative

Impacts that currently affect this species would continue to apply. These include habitat loss or modification by impoundments, upstream projects that may have flow reductions or water quality effects, inter-species competition, and predation.

Cumulative Effects

Cumulative effects on this species would include existing and planned development, which could reduce instream flows and/or water quality of the Colorado River system.

Cumulative effects on this species would include planned development on nonfederal lands, which could reduce instream flows and/or water quality of the Colorado River system.

Determination of Effects and Rationale

All action alternatives: **May affect, likely to adversely affect.**

This determination is based on the consideration that no direct impacts on sensitive habitat for the bonytail chub are expected. However, any water depletions may affect this Colorado River basin species.

No Action Alternative: **No effect.**

This determination is based on the consideration that current levels of man’s activities in the upper Colorado River basin would continue and are expected to increase over time, including agriculture, land development, and industrial and transportation expansions. These activities are currently affecting the Colorado River flows and water quality. Without the Corridor alternatives, no additional impacts on the bonytail chub would be expected. Impacts on this species from inter-species competition and predation would continue unchanged.

Colorado Pikeminnow (*Ptychocheilus lucius*), E

The Colorado pikeminnow is a large minnow in the order Cypriniformes, family Cyprinidae, and genus *Ptychocheilus*, of which three species are recognized. Colorado pikeminnow was listed as endangered on March 11, 1967. There is no suitable habitat for this species on either Forest, but it is known to occur downstream of the APE in the Colorado River watershed and may be impacted by changes in water flow, timing, or quality (C. Hirsch pers. comm. with JFSA, 2006).

Distribution

The Colorado pikeminnow is currently designated as endangered in its entire range, except the Salt and Verde River drainages of Arizona. Within the area covered by this listing, this species is known to occur in Arizona, California, Colorado, Utah, and Wyoming. USFWS Mountain-Prairie Region (Region 6) is the lead region for this entity. On July 24, 1985, the Colorado pikeminnow was designated as an Experimental Population, Non-Essential in the Salt and Verde River drainages, Arizona. Historically, the pikeminnow occurred in great numbers throughout the Colorado River system from Green River in Wyoming to the Gulf of California in Mexico. In Colorado, they are currently found in the Green, Yampa, White, Colorado, Gunnison, San Juan, and Dolores rivers (CDOW, 2005e). Colorado pikeminnow populations were estimated during the early 1990s to be 4,000 to 17,000 adult fish in the mainstem of the Green River system, and another 1,000 in the upper mainstem of the Colorado (NatureServe, 2005e).

Natural History

Colorado pikeminnow may live as long as 50 years or more, weighing 80 pounds, and reaching a length of 6 feet (USFWS, 2005). The largest fish on record for the last 30 years in the upper Colorado River basin was 38-inches long and weighed approximately 25 pounds. They spawn between the ages of five and six. Spawning occurs between late June and early September. Reproducing adults choose faunally depauperate white-water canyons for deposition of gametes (Tyus, 1991). In the lower Yampa River, the Colorado pikeminnow spawn where there is a mix of large, deep pools and eddies intermingled with riffles and runs and cobble bars (Tyus and Karp, 1989; and Tyus, 1991). Spawning migrations are extensive, with documentation of a 409-mile event from White River to the spawning ground in the Yampa River (Irving and Modde, 2000).

Colorado pikeminnow young eat primarily insect larvae, while adults eat mainly other fish. Critical habitat and primary constituent elements are discussed under the text for bonytail chub, discussed previously in this report.

Environmental Baseline

The ESA lists Colorado pikeminnow as endangered, and the state of Colorado lists it as threatened. Present distribution of the fish is drastically reduced from its historical range, with current populations occurring only in the Upper Colorado River basin, specifically in the Green, White, Yampa, Gunnison, and Colorado rivers in Colorado and portions of Utah (NDIS, 2003).

Key reasons for decline may include dam construction that creates impoundments on formerly free-flowing rivers, causes much cooler stream temperatures, blocks migration, and reduces peak river flows. Another threat has been exotic fish, particularly red shiners (*Cyprinella lutrensis*) that compete for zooplankton eaten by young-of-the-year Colorado pikeminnow (Muth and Snyder, 1995).

Preferred habitat includes medium to large rivers. Young fish prefer small, quiet backwaters. The adult fish use a variety of habitats, including deep turbid strongly flowing water, eddies, runs, flooded bottoms, backwaters, and lowlands inundated during spring runoff. In the winter, these fish prefer ice-covered shoreline areas (Tyus and Karp, 1989).

Direct, Indirect, and Cumulative Effects of Alternatives

Action Alternatives

Colorado pikeminnow does not occur in stream segments within the I-70 Corridor, and thus, no direct impacts on this species or its critical habitat are expected. Temporary indirect effects are possible if water depletions or water quality degradation from construction of alternatives are substantial enough to affect the Colorado River downstream, where the fish occur. Some degree of water depletions would likely be necessary during the construction of the action alternatives for activities such as dust suppression, materials handling, and washing. The specific water needs and impacts will be examined during Tier 2 process and pre-construction stages.

The 1999 *Colorado River Programmatic Biological Opinion* addresses water depletions in the Colorado River and its tributaries above its confluence with the Gunnison River. Recovery actions outlined in the *Programmatic Biological Opinion* provide measures to avoid the likelihood of jeopardy and adverse modification of critical habitat. To offset the cost of implementing recovery actions, a one-time fee is required for new depletions greater than 100 AF/year. Other provisions of the *Programmatic Biological Opinion* are that nonfederal water users are required to sign a Recovery Agreement and federal agencies are requested to retain discretionary authority in the event that consultation is reinitiated. Construction activities for all action alternatives include a Tier 1 commitment to limit stream depletions to 100 AF/year.

Cumulative effects on Colorado pikeminnow include existing and planned development, and possible induced growth in the upper Colorado River basin in addition to construction and operation of alternatives in the I-70 Corridor, which serve to reduce instream flows and/or water quality of the Colorado River. Combination alternatives are associated with greatest possible induced growth impacts on water resources (in both Eagle and Summit counties), followed by more moderate effects from the Transit and Highway alternatives (Eagle County only). Combination and Highway alternatives are associated with greater effects on water quality from increased I-70 winter maintenance activities.

Cumulative Effects

Cumulative effects on this species would include existing and planned development in addition to construction and operation of alternatives in the I-70 Corridor, which reduce instream flows and/or water quality of the Colorado River system. Possible induced growth is anticipated with all action alternatives, except the Minimal Action Alternative.

Cumulative effects on this species on nonfederal lands would include existing and planned development in addition to construction and operation of alternatives in the I-70 Corridor, which reduce instream flows and/or water quality of the Colorado River system. Possible induced growth is anticipated with all action alternatives, except the Minimal Action Alternative.

No Action Alternative

Impacts that currently affect this species would continue to apply. These include habitat loss or modification by impoundments, upstream projects that may have flow reductions or water quality effects, and inter-species competition for food.

Cumulative Effects

Cumulative effects on this species would include existing and planned development, which could reduce instream flows and/or water quality of the Colorado River system.

Cumulative effects on this species would include planned development on nonfederal lands, which could reduce instream flows and/or water quality of the Colorado River system.

Determination of Effects and Rationale

All action alternatives: **May affect, likely to adversely affect.**

This determination is based on the consideration that no direct impacts on habitat for Colorado pikeminnow are expected. However, any water depletions may affect this Colorado River basin species.

No Action Alternative: **No effect.**

This determination is based on the consideration that current levels of man's activities in the upper Colorado River basin would continue and are expected to increase over time, including agriculture, land development, and industrial and transportation expansions. These activities are currently affecting the Colorado River flows and water quality. Without the Corridor alternatives, no additional impacts on the Colorado pikeminnow would be expected. Impacts on this species from inter-species competition for food would continue unchanged.

Humpback Chub *(Gila cypha),* E

The humpback chub is found in the order Cypriniformes, family Cyprinidae, and genus *Gila*. It may hybridize with the endangered bonytail chub, *Gila elegans*. The humpback chub is distinctive in having a pronounced hump behind its head. The species was first listed as endangered on March 11, 1967. There is no suitable habitat for this species on either Forest, but it is known to occur downstream of the APE in the Colorado River watershed and may be impacted by changes in water flow, timing, or quality (C. Hirsch pers. comm. with JFSA, 2006).

Distribution

The humpback chub is currently designated as endangered over its entire range and as threatened in Colorado. Within the area covered by this listing, this species is known to occur in Arizona, Colorado, and Utah. USFWS Mountain-Prairie Region (Region 6) is the lead region for this entity.

In Colorado, there is a concentration of these fish at the Black Rocks area of the Colorado River near the Colorado/Utah border (CDOW, 2005f). They are also found in the Colorado River in Westwater Canyon, Utah, and in Cataract Canyon, Arizona. The fish may also be found in the Desolation and Gray Canyons of the Green River, and in the Yampa and Whirlpool Canyons in Dinosaur National Monument of Colorado and Utah. Population estimates are available only for the Little Colorado River, where approximately 4,500 individuals were documented in the early 1990s (Douglas and Marsh, 1996).

Natural History

The humpback chub may grow to 20 inches long and may survive in the wild for 30 or more years (USFWS, 2005). The humpback chub eats insects, planktonic crustaceans, and algae. The humpback chub spawns in the spring, reportedly at water temperatures of 52.7 to 60.8 degrees Fahrenheit in Colorado, after peak flows. The humpback chub's movements are limited, averaging 1 mile or less (Douglas and Marsh, 1996).

Critical habitat and primary constituent elements are discussed under the text for bonytail chub, discussed previously in this report.

Environmental Baseline

The species historically ranged throughout the mainstem Colorado River basin, including the Yampa, Gunnison, and Green rivers. Currently, the only known occurrence of humpback chub in the state is in the Colorado Black Rocks area, downstream of Grand Junction (NDIS, 2003).

Current threats to the species' conservation include destruction and modification of habitat from the construction of impoundments. Impoundments typically lower water temperatures and reduce spring flows. The species also suffers from competition and predation from introduced fish, hybridization with bonytail chub and roundtail chub (*Gila robusta)*, and parasitism from the range expansion of the Asian tapeworm (*Taenia asistica*).

The species occupies large rivers using habitat such as deep, turbulent currents, shaded canyon pools, and areas under shady ledges in moderate current, riffles, and eddies (Federal Register 21 March 1994). Adults that have been taken usually come from shoreline eddies created by large boulders and rapids (Tyus and Karp, 1989).

Direct, Indirect, and Cumulative Effects of Alternatives

Action Alternatives

Because the humpback chub does not occur in stream segments within the action area, no direct impacts on this fish or its critical habitat are expected. Temporary indirect effects are possible if water depletions or water quality degradation from construction are substantial enough to affect the Colorado River watershed downstream where the fish occur. Some degree of water depletions would likely be necessary during the construction of the action alternatives for activities such as dust suppression, materials handling, and washing. The specific water needs and impacts will be examined during Tier 2 process and pre-construction stages.

The 1999 *Colorado River Programmatic Biological Opinion* addresses water depletions in the Colorado River and its tributaries above its confluence with the Gunnison River. Recovery actions outlined in the *Programmatic Biological Opinion* provide measures to avoid the likelihood of jeopardy and adverse modification of critical habitat. To offset the cost of implementing recovery actions, a one-time fee is required for new depletions greater than 100 AF/year. Other provisions of the *Programmatic Biological Opinion* are that nonfederal water users are required to sign a Recovery Agreement and federal agencies are requested to retain discretionary authority in the event that consultation is reinitiated. Construction activities for all action alternatives include a Tier 1 commitment to limit stream depletions to 100 AF/year.

Cumulative effects on this species would result from all manner of existing and planned development in the upper Colorado River basin (including agriculture, land development, transportation) in addition to construction and operation of alternatives in the I-70 Corridor. When development in the upper basin serves to reduce instream flows or degrade water quality of the Colorado River, the humpback chub may experience indirect effects. Combination alternatives are associated with the greatest impacts on water quality and quantity from possible induced growth in Eagle and Summit counties. Transit and Highway alternatives are associated with moderate impacts on water quality and quantity from possible induced growth in Eagle County. The Minimal Action Alternative is not associated with possible induced growth in the Corridor.

Cumulative Effects

Cumulative effects on this species would include existing and planned development in addition to construction and operation of alternatives in the I-70 Corridor, which reduce instream flows and/or water quality of the Colorado River system. Possible induced growth is anticipated with all action alternatives, except the Minimal Action Alternative.

Cumulative effects on this species on nonfederal lands would include existing and planned development in addition to construction and operation of alternatives in the I-70 Corridor, which reduce instream flows and/or water quality of the Colorado River system. Possible induced growth is anticipated with all action alternatives, except the Minimal Action Alternative.

No Action Alternative

Impacts that currently affect the humpback chub would continue to apply. These would include habitat loss or modification by impoundments, upstream projects that may have flow reductions or water quality effects, inter-species competition, predation, hybridization, and parasitism.

Cumulative Effects

Cumulative effects on this species would include existing and planned development, which could reduce instream flows and/or water quality of the Colorado River system.

Cumulative effects on this species would include planned development on nonfederal lands, which could reduce instream flows and/or water quality of the Colorado River system.

Determination of Effects and Rationale

All action alternatives: **May affect, likely to adversely affect.**

This determination is based on the consideration that no direct impacts on sensitive habitat for the humpback chub are expected. However, any water depletions may affect this Colorado River basin species.

No Action Alternative: **No effect.**

This determination is based on the consideration that current levels of man's activities in the upper Colorado River basin would continue and are expected to increase over time, including agriculture, land development, and industrial and transportation expansions. These activities are currently affecting the Colorado River flows and water quality. Without the Corridor alternatives, no additional impacts on the humpback chub would be expected. Impacts on this species from inter-species competition, predation, hybridization, and parasitism would continue unchanged.

Razorback Sucker (*Xyrauchen texanus*), E

The razorback sucker is classified as a bony sucker fish in the order Cypriniformes, family Catostomidae. It is the only member of the genus *Xyrauchen* (NatureServe, 2005c). The razorback sucker was listed under the ESA as endangered on October 23, 1991 (56 FR 54957). There is no suitable habitat for this species on either Forest, but it is known to occur downstream of the APE in the Colorado River watershed and may be impacted by changes in water flow, timing, or quality (C. Hirsch pers. comm. with JFSA, 2006).

Distribution

The razorback sucker is currently designated as endangered throughout its entire range. Within the area covered by this listing, this species is known to occur in Arizona, California, Colorado, New Mexico, Nevada, Utah, and Wyoming and in Mexico. Historically found throughout the Colorado River drainage, it currently occurs in the lower mainstem Colorado River, as well as the lower Gunnison and Yampa rivers. USFWS Mountain-Prairie Region (Region 6) is the lead region for this entity.

Historically, this species was once common to many of the rivers of the Colorado River basin, including the Colorado, Gila, Salt, Verde, and San Pedro rivers in Arizona, at elevations less than 5,000 feet. Due to lack of recruitment, the few isolated populations of this species remain small. Currently, in Arizona, as a result of impoundment of large rivers and other habitat alterations, natural adult populations exist only in

Lake Mohave, Lake Mead, Lake Havasu, and Horseshoe Reservoir (Mohave, La Paz, and Maricopa counties, Arizona, respectively). Only small isolated populations of razorback suckers are believed to still occur in the Gila River, Salt River, and Verde River basins of Arizona. Population estimates include 25,000 individuals in Lake Mohave (1995), 1,000 adult fish in the Green River basin (1980s), and smaller populations elsewhere within the range (USFWS, 1997).

Wild populations in Colorado have been reduced to a small number of individuals in the Yampa, Colorado, and Gunnison rivers. Reproducing populations remain in an off-channel pond in the Colorado River near Grand Junction. The razorback sucker is most often found in quiet, muddy backwaters along the river (CDOW, 2005c).

Natural History

Razorback suckers are long lived. Older individuals in Lake Mohave have been estimated at more than 40 years of age. They grow quickly in the first 5 to 7 years, with growth slowing or becoming nonexistent in old individuals. Both sexes are sexually mature by age 4. Spawning occurs from late winter through spring along gravelly shorelines or bays. Evidence suggests they migrated from larger rivers to smaller tributaries prior to spawning. Two to 12 males attend a single female, and the group moves in tight circles over the bottom. Spawning occurs when the group settles to the bottom and with a vibrating action release gametes. The eggs are adhesive and attach to the interstitial spaces within the gravel substrate. The young hatch within a few days and live along the shoreline. Females will spawn repeatedly with several males. Spawning coloration in breeding males includes changing to dark brown or black on the back, and the development of a russet to orange colored lateral band and yellow belly. Coarse sharp tubercles, which are hornlike outgrowths of skin, are developed on the anal, caudal, and pelvic fins, and on the caudal peduncle. Hatching success is highly dependent on water temperature with complete mortality in temperatures less than 50 degrees Fahrenheit. Razorback suckers are known to hybridize with flannelmouth suckers (*Catostomus latipinnis*) and Sonoran suckers (*Catostomus igsignis*). Hatchery propagation has been successful in raising juveniles and is being used for reintroduction programs. Algae, insect larvae, plankton, and detritus represent natural food items for razorback suckers (Marsh, 1987).

Critical habitat and primary constituent elements are discussed under the text for bonytail chub, discussed previously in this report.

The razorback sucker has five additional selection criteria for habitats required for reproduction and recruitment, as follows. These areas once met the habitat needs of the razorback sucker and may be recoverable with additional protection and management.

1. Presence of known or suspected wild spawning populations, although recruitment may be limited or nonexistent
2. Areas where juvenile razorback suckers have been collected or which could provide suitable nursery habitat (backwaters, flooded bottom lands, or coves)
3. Areas currently occupied or that were historically occupied that are considered necessary for recovery and that have the potential for re-establishment of razorback suckers
4. Areas and water required to maintain rangewide fish distribution and diversity under a variety of physical, chemical, and biological conditions
5. Areas that need special management or protection to ensure razorback sucker survival and recovery

Major threats to the conservation of this species include low recruitment (Minckley et al., 1991), change in river flow and temperature regimes (Clarkson and Childs, 2000), reduced flooding, competition and predation on larvae and juveniles by introduced fish (USFWS, 1990a) and crayfish (Lenon et al., 2002), small number of spawning adults, and hybridization with other suckers (Tyus and Karp, 1990; and Minckley et al., 1991).

Environmental Baseline

Habitat for razorback sucker includes slow-moving waters of medium to large rivers, such as backwater sloughs, quiet pools, and eddies (Minckley et al., 1991). Three of the four remaining populations are in large man-made reservoirs. The razorback sucker is often associated with sand, mud, and rock substrate in areas with sparse aquatic vegetation, with moderate to warm temperatures (Sigler and Miller, 1963). During the nonbreeding season, adult fish were observed most commonly in shoreline runs and along mid-channel sand bars in the mainstem of the Green River (Tyus and Karp, 1989).

Direct, Indirect, and Cumulative Effects of Alternatives

Action Alternatives

Although this species does not occur directly within the Corridor, it is present in the Colorado River approximately 100 miles downstream of proposed construction areas and susceptible to potential downstream effects. Because the razorback sucker does not occur in stream segments within the action area, no direct impacts on this fish or its critical habitat are expected. Temporary indirect effects are possible if water depletions or water quality degradation from project construction are substantial enough to affect the Colorado River downstream, where the fish occur. Some degree of water depletions would likely be necessary during the construction of the action alternatives for activities such as dust suppression, materials handling, and washing. The specific water needs and impacts will be examined during Tier 2 process and pre-construction stages.

The 1999 *Colorado River Programmatic Biological Opinion* addresses water depletions in the Colorado River and its tributaries above its confluence with the Gunnison River. Recovery actions outlined in the *Programmatic Biological Opinion* provide measures to avoid the likelihood of jeopardy and adverse modification of critical habitat. To offset the cost of implementing recovery actions, a one-time fee is required for new depletions greater than 100 AF/year. Other provisions of the *Programmatic Biological Opinion* are that nonfederal water users are required to sign a Recovery Agreement and federal agencies are requested to retain discretionary authority in the event that consultation is reinitiated. Construction activities for all action alternatives include a Tier 1 commitment to limit stream depletions to 100 AF/year.

Cumulative effects on this species would include existing and planned development throughout the upper Colorado River basin, possible induced growth associated with alternatives (Combination, Highway, and Transit), in addition to construction and operation of alternatives in the I-70 Corridor, which reduce instream flows and/or water quality of the Colorado River. Combination alternatives are associated with greatest possible induced growth impacts on water resources (in both Eagle and Summit counties), followed by more moderate effects from the Transit and Highway alternatives (Eagle County only). Combination and Highway alternatives are associated with greater effects on water quality from increased I-70 winter maintenance activities.

Cumulative Effects

Cumulative effects on this species would include existing and planned development in addition to construction and operation of alternatives in the I-70 Corridor, which reduce instream flows and/or water quality of the Colorado River system. Possible induced growth is anticipated with all action alternatives, except the Minimal Action Alternative.

Cumulative effects on this species on nonfederal lands would include existing and planned development in addition to construction and operation of alternatives in the I-70 Corridor, which reduce instream flows and/or water quality of the Colorado River system. Possible induced growth is anticipated with all action alternatives, except the Minimal Action Alternative.

No Action Alternative

Impacts that currently affect this species would continue to apply. These include habitat loss or modification by impoundments, upstream projects that may have water depletions or water quality effects, competition, predation, small numbers of reproducing adults, and hybridization.

Cumulative Effects

Cumulative effects on this species would include existing and planned development, which could reduce instream flows and/or water quality of the Colorado River system.

Cumulative effects on this species would include planned development on nonfederal lands, which could reduce instream flows and/or water quality of the Colorado River system.

Determination of Effects and Rationale

All action alternatives: **May affect, likely to adversely affect.**

This determination is based on the consideration that no direct impacts on habitat for razorback sucker are expected. However, any water depletions may affect this Colorado River basin species.

No Action Alternative: **No effect.**

This determination is based on the consideration that current levels of man's activities in the upper Colorado River basin would continue and are expected to increase over time, including agriculture, land development, and industrial and transportation expansions. These activities are currently affecting the Colorado River flows and water quality. Without the Corridor alternatives, no additional impacts on the razorback sucker would be expected. Impacts on this species from inter-species competition, predation, small numbers of reproducing adults, and hybridization would continue unchanged.

Pallid Sturgeon (*Scaphirhynchus albus*), E

The pallid sturgeon is in the order Acipenseriformes, family Acipenseridae, and genus *Scaphirhynchus*. It is a large bony fish, weighing as much as 80 pounds, up to 6 feet long, with a flat shovel-like snout. The pallid sturgeon was listed by USFWS on September 6, 1990. There is no suitable habitat for this species on either Forest, but it is known to occur downstream of the APE in the Missouri River watershed and may be impacted by changes in water flow, timing, or quality (C. Hirsch pers. comm. with JFSA, 2006).

Distribution

The pallid sturgeon is currently designated as endangered over its entire range. Within the area covered by this listing, this species is known to occur in Arkansas, Iowa, Illinois, Kansas, Kentucky, Louisiana, Missouri, Mississippi, Montana, North Dakota, Nebraska, South Dakota, and Tennessee. USFWS Mountain-Prairie Region (Region 6) is the lead region for this entity. The primary reason for pallid sturgeon decline is habitat modification and loss caused by construction of large dams and channelization. Pollution and past overfishing may also be significant factors in the species' decline (USFWS, 2005). It is distributed through the Missouri and Mississippi river systems, including the Platte River, with its headwaters in Colorado. As of the late 1990s, total population size was estimated as 6,000 to 16,000 fish. Of this total, 2,000 to 6,000 were believed to reside in the Missouri River system, with the rest in the Mississippi River system (NatureServe, 2005a). Recovery efforts have included captive breeding, with experimental stocking in the upper Missouri and lower Yellowstone Rivers begun in 1998 (USFWS, 2004).

Natural History

The pallid sturgeon spawns from July to August. The males become sexually mature in three to four years (Kallemeyn, 1981). The pallid sturgeon is a bottom feeder, using a toothless mouth positioned under the snout to suck small fish and other food items from the bottom surface. The pallid sturgeon eats aquatic insects, crustaceans, mollusks, annelid worms, eggs of other fish, and occasionally other fish (USFWS, 1989).

Environmental Baseline

Pallid sturgeon can be found in backwaters, side channels, sloughs, and the main channels (USFWS, 2004). Historically, the species was located throughout the Missouri River from Montana to the Mississippi River and then south to Louisiana. It requires large, turbid, free-flowing riverine habitat. It is typically associated with strong current over firm gravel or sandy substrate. It also occurs in reservoirs.

The nearest occurrence to the Corridor is in the Platte River in Nebraska, considerably downstream of potential project effects. Dams, reservoirs, and channelization have altered virtually all habitat for the pallid sturgeon.

Direct, Indirect, and Cumulative Effects of Alternatives

Action Alternatives

Construction for all action alternatives would occur well out of pallid sturgeon range. This species was evaluated because of the possibility of a project alternative requiring water depletions that may affect the Platte River watershed, thereby potentially affecting this species at downstream locations. Some degree of water depletions would likely be necessary during the construction of all action alternatives for activities such as dust suppression, materials handling, and washing. The specific water needs and impacts will be examined during Tier 2 process and pre-construction stages.

According to USFWS, any depletion to the Platte River basin (roughly defined as the Palmer Divide north and the Continental Divide east in Colorado) constitutes an action that may affect, and is likely to adversely affect, TES species that depend on the river for their existence. To comply with the SPWRAP, an analysis of effects on ESA species downstream in Nebraska resulting from the Preferred Alternative is required in the BA. These effects will be examined during Tier 2 processes and will be submitted to USFWS for streamlined Section 7 consultation under the ESA. CDOT is coordinating with USFWS on this matter for documentation in the BA.

Effects on this species include existing and planned development in addition to construction and operation of alternatives in the I-70 Corridor, which reduce instream flows and/or water quality of the Platte River system.

Cumulative Effects

Cumulative effects on this species would include existing and planned development in addition to construction and operation of alternatives in the I-70 Corridor, which reduce instream flows and/or water quality of the Platte River system. Possible induced growth is not associated with any of the action alternatives in the Platte River watershed.

Cumulative effects on this species on nonfederal lands would include existing and planned development in addition to construction and operation of alternatives in the I-70 Corridor, which reduce instream flows and/or water quality of the Platte River system.

No Action Alternative

The existing impacts on tributary streams in the upper reaches of the Platte River system would continue. These include effects from sedimentation, roadway contaminants, and runoff from urban areas.

Cumulative Effects

Cumulative effects on this species would include existing and planned development, which could reduce instream flows and/or water quality of the Platte River system.

Cumulative effects on this species would include planned development on nonfederal lands, which could reduce instream flows and/or water quality of the Platte River system.

Determination of Effects and Rationale

All action alternatives: **May affect, likely to adversely affect.**

This determination is based on the consideration that no direct impacts on habitat for pallid sturgeon are expected. However, any water depletions may affect this Platte River basin species.

No Action Alternative: **No effect.**

This determination is based on the consideration that the No Action Alternative would occur well out of the range of the pallid sturgeon. No water depletions or direct impacts on habitat for this species are expected to occur as a result of implementation of the No Action Alternative.

Greenback Cutthroat Trout (*Onocorhynchus clarki stomias*), T

The greenback cutthroat trout is a salmonid fish, in the order Salmoniformes, family Salmonidae, and genus *Oncorhynchus*. In addition to being federally listed, the greenback cutthroat trout is also a MIS for the ARNF for montane aquatic communities.

Distribution

The greenback cutthroat trout is listed as threatened, both under the ESA and by the state of Colorado, and sensitive by the USFS, Region 2. In Colorado, the species occurs primarily in headwater streams of the Arkansas and Platte river drainages (CDOW, 2004), and USFS has reported that this trout species occurs in Dry Gulch, Clear Creek, and Bard Creek, which are adjacent to the I-70 Corridor.

The following narrative on distribution of the greenback cutthroat trout is taken from the Greenback Cutthroat Trout Recovery Plan (USFWS, 1998).

Historic Distribution

The greenback cutthroat trout is native to the headwaters of the South Platte River and the Arkansas River drainages within Colorado and a small segment of the South Platte drainage within Wyoming. The greenback and the Rio Grande cutthroat trout (*Oncorhynchus clarki virginalis*) represent the easternmost limits of native trout distribution in the western U.S. (Behnke, 1984). The greenback cutthroat trout declined so rapidly in the 1800s that the original distribution of the subspecies is not known. Behnke and Zarn (1976) assumed the original distribution included all mountain and foothill habitats of the Arkansas and South Platte drainages. The greenback cutthroat trout was known to occur within these drainages at lower elevations than it occupies today; however, little is known of its exact historic lake and stream distribution and the range in elevation it once occupied. The only other trout thought to have occurred within the greenback cutthroat trout's native range was the yellowfin cutthroat (*Oncorhynchus clarki macdonaldi)* collected from Twin Lakes (Arkansas River drainage) in 1889 (Behnke, 1979). The yellowfin cutthroat became extinct in the early 1900s.

Decline from historic distribution was caused by diversion of water for irrigation, water pollution, sedimentation caused by mining and logging, and especially competition with introduced trout species. Recovery efforts are ongoing and have been successful thus far. The recovery measures include removal of brook trout (*Salvelinus fontinalis*) from the home range of the greenback cutthroat, creation of barriers in streams to limit the influx of new brook trout populations, and reintroduction of the greenback cutthroat trout within its range.

Current Distribution

The Colorado greenback cutthroat trout historically occurred in the sources of the South Platte River and Arkansas River in Colorado and in some headwater tributary streams in Wyoming that feed into the South Platte (CDOW, 2005g). There are thought to be 11 “historical” and 44 introduced populations existing now in Colorado. It is believed that the extant populations are approaching the delisting goal (NatureServe, 2005e). The USFS has reported that this trout species occurs in Dry Gulch, Clear Creek, and Bard Creek, each of which is adjacent to the Corridor east of the EJMT. The fish in Dry Gulch are a pure strain of greenback cutthroat trout, compared to downstream fish in Clear Creek that are probably all hybridized with rainbow trout (*Oncorhynchus mykiss*). Barriers to upstream movement have maintained this pure strain in Dry Gulch.

Natural History

Greenback cutthroat trout spawn in riffle complexes during the spring, sometimes into early summer at high elevations (Matthews and Moseley, 1990). Diet consists of aquatic insects. Adult fish typically measure 12 to 18 inches.

Environmental Baseline

Preferred habitat for the greenback cutthroat trout is cold, clear, well-oxygenated mountain streams with moderate gradients, rocky to gravelly substrates, and abundant riparian vegetation. Overhanging branches, undercut banks, and eddies behind rubble are also important constituents of greenback cutthroat trout habitat, providing feeding and resting stations. They may also occur in ponds and lakes in the high country.

Direct, Indirect, and Cumulative Effects of Alternatives

Action Alternatives

Action alternatives are unlikely to affect the greenback cutthroat trout populations in Dry Gulch because the habitat of these populations is at least 400 feet upstream of I-70. The restriction to upstream fish movement at the lower reach of Dry Gulch, near I-70, should be maintained to prevent immigration of non-native fish species into Dry Gulch. Additional data would be obtained and the connections between the Dry Creek populations of greenback cutthroat trout and the Clear Creek populations would be discussed more fully to determine if construction on I-70 would be likely to affect this species during Tier 2 processes.

The Clear Creek population is unlikely to be reproducing, may be affected by heavy metal contamination, and may exist due to greenback cutthroat trout migrating from Dry Gulch (B. Rosenlund pers. comm. with L. Hettinger, 2004). However, the greenback cutthroat trout populations in Clear Creek may also be affected indirectly by sediment and contaminants (fuel and solvents) during construction. The effects of sedimentation and roadway runoff material (for example, winter maintenance) on aquatic habitat during operations is anticipated to decrease with implementation of additional sediment control features that are designated as part of the action alternatives, as well as CDOT best management practices for construction projects. Combination, Highway, and Bus in Guideway alternatives are associated with increased effects on water quality associated with winter maintenance activities.

Restrictions that occur near Silver Plume on Clear Creek to non-native trout species should be maintained. **Table BR - 54** and **Table BR - 55** provide estimated direct impacts on potential trout habitat. Direct impacts were estimated based on impacts on the following mapped habitats: aquatic montane and other waters of the U.S. The greenback cutthroat trout does not occur on the WRNF. The greatest impacts on ARNF lands would be associated with the Combination Six-Lane Highway with Rail and

Intermountain Connection alternative; the least impacts would be associated with the Minimal Action, Advanced Guideway System, and Bus in Guideway alternatives.

The potential to improve greenback cutthroat trout habitat in upper Clear Creek occurs as part of the objectives of several entities, including USFS, Colorado Division of Wildlife, and CDOT. Increased growth of the areas adjacent to the Forest would likely result in increased recreational use of National Forest System Lands in general, and in increased use of upper Clear Creek and Dry Gulch by anglers. This increase could negatively affect the populations and require strict enforcement of angling (for example, catch-and-release) policies. All action alternatives, except the Minimal Action Alternative, are associated with possible increased visitation to ARNF and subsequent increased recreational activities that might affect greenback habitat. For the ARNF, Combination alternatives are associated with the greatest potential indirect impacts, followed by more moderate indirect impacts from Transit and Highway alternatives. Combination and Highway alternatives are associated with a greater possibility for dispersed recreational activities including fishing.

Cumulative Effects

Cumulative effects on this species would include existing and planned development in addition to construction and operation of alternatives in the I-70 Corridor, which reduce instream flows and/or water quality of the Platte River system. Possible induced growth is not associated with any of the action alternatives in the Platte River watershed.

Cumulative effects on this species on nonfederal lands would include existing and planned development in addition to construction and operation of alternatives in the I-70 Corridor, which reduce instream flows and/or water quality of the Platte River system.

No Action Alternative

The existing impacts on Clear Creek and on greenback cutthroat trout populations in the upper reaches of this system would remain. These include effects from sediment and roadway contaminants, especially the influx of winter maintenance materials, although objectives to improve capture of runoff are currently being evaluated. Similarly, the potential to improve the hydrology of cross-slope drainages and the down-cutting forces of high flows is less likely to be realized with the No Action Alternative.

Cumulative Effects

Cumulative effects on this species would include existing and planned development, which could reduce instream flows and/or water quality of the Platte River system.

Cumulative effects on this species would include planned development on nonfederal lands, which could reduce instream flows and/or water quality of the Platte River system.

Determination of Effects and Rationale

All action alternatives: **May affect, likely to adversely affect.**

This determination is based on the consideration that direct impacts on habitat for the greenback cutthroat trout may occur if Clear Creek is affected, especially in sensitive portions of the occupied habitat. However, any water depletions may affect this Platte River basin species (see the introduction to **Section BR.3, Downstream Water Depletion**, on page BR-28 of this report).

The action alternatives may affect individual greenback cutthroat trout as a MIS but are not likely to create a viability threat to the species. The local population in upper Clear Creek may be adversely affected but not to the point that the viability of the entire population would be threatened.

No Action Alternative: **No effect.**

This determination is based on the consideration that the No Action Alternative would not result in any new type of adverse impacts beyond what is already occurring.

BR.3.1.4 Plants

Ute Ladies'-Tresses Orchid (*Spiranthes diluvialis*), T

The Ute ladies'-tresses orchid is a flowering plant in the family Orchidaceae, Genus *Spiranthes*. There are two species of ladies'-tresses orchid in Colorado, the other species being the more common *Spiranthes romanzoffiana*.

Species Status and Distribution

The Ute ladies'-tresses orchid was first listed as threatened on January 17, 1992. It is currently designated as threatened over its entire range. Within the area covered by this listing, this species is known to occur in Colorado, Idaho, Montana, Nebraska, Utah, Washington, and Wyoming. USFWS Mountain-Prairie Region (Region 6) is the lead region for this entity.

Populations of the Ute ladies'-tresses orchid are documented from several areas in the western U.S. These areas include near the base of the Eastern Slope of the Rocky Mountains in central and northern Colorado; southwestern Wyoming; western Nebraska; the upper Colorado River Basin, especially from the Uinta Basin in Utah; the Bonneville Basin along the Wasatch Front and westward in the eastern Great Basin; north-central and western Utah; extreme eastern Nevada; and southeastern Idaho. It has also been documented in southwestern Montana and in Washington State in the Okanogan area and along the Columbia River.

The most current data regarding species status and distribution are presented in a recent thorough status review prepared for USFWS and the Central Utah Water Conservancy District (Fertig, Black, and Wolken, 2005). The total number of known sites and total number of plants have substantially increased since the 1980s. This is probably a result of increased survey intensities, and not necessarily increased number of plants over time. Monitoring data are insufficient and inconclusive to determine overall trend for the species, but, in general, the species seems to be maintaining populations across its range, and most sites appear to be maintaining plants without long-term reduction in plant numbers. Threats to the continued existence of the Ute ladies'-tresses orchid include several forms of water development projects, intense domestic livestock grazing, haying, exotic species invasions, habitat fragmentation, recreation use, and urbanization. The species may also be vulnerable in parts of its range due to the loss of pollinators.

The action area for this species is defined as the project Corridor area identified with the maximum direct disturbance potential, and all downstream areas containing known sites or suitable habitat potentially influenced by possible water depletions. This includes Clear Creek and the mainstem of the Platte River but does not include watersheds west of EMJT because they are not considered suitable habitat for this species. In the action area, this federally listed orchid has been recorded in two locations of Jefferson County along Clear Creek: one population near Golden (Colorado Natural Heritage Program EO-002), and another to the west of Golden in Clear Creek Canyon (Colorado Natural Heritage Program EO-023). Both of these populations are on private land and are within a few air miles of the I-70 Mountain Corridor (CNHP, 2002a). No other sites of this plant are considered within the action area. It is unlikely that undetected sites are present within the project Corridor or action area.

The Golden site was first reported in 1980, and it is the type site for the species. In 2004, 271 plants were observed, by far the most of any year, but monitoring data are insufficient to show conclusive trend. This is because the increased number may likely reflect a greater intensity of recent monitoring efforts and not necessarily a true increase in plants. Potential threats to the site have been identified as increased vegetation cover (possible competition), incidental recreation activities, and unmitigated road maintenance or improvements. Plants at the site in Clear Creek Canyon west of Golden were first observed in 1993, and last observed in 1994, with only 9 above-ground plants present. Repeated efforts to relocate this site have failed in recent years, and it is possible that the site has been extirpated. Even though more than 10 years has passed since the last observation, plants may still be present underground, and the site is considered extant for analysis purposes.

There is no designated critical habitat for this species in the action area.

Species Life History and Habitat Requirements

Ute ladies'-tresses orchid is a perennial, terrestrial orchid with stems 8 to 20 inches tall, arising from tuberous, thickened roots. The inflorescence is a 1.18- to 5.91-inch long spike with white petals and blooms July through September (Spackman et al., 1997). The plant occurs at altitudes below 6,800 feet in seasonally moist soils and wet meadows near springs, lakes, or perennial streams and their associated floodplains in certain areas along the Front Range in Colorado.

Typical habitats include old stream channels and alluvial terraces, sub-irrigated meadows, and other areas where the soil is saturated to within 18 inches of the surface at least temporarily during the spring or summer growing season (USFWS, 1995).

This species is typically associated with silty, sandy, gravelly, or cobbly soils, and occasionally highly organic soils or peat. It prefers well-drained soils with a high moisture content that may contain some gleying or mottling but that are not anaerobic or permanently saturated. Ute ladies'-tresses orchid occurs with grasses, sedges, rushes, and shrubs, or riparian trees such as willows. It rarely occurs in deep shade, preferring open glades or pastures and meadows in full sunlight. Commonly associated species in areas along the Front Range include horsetail (*Equisetum* spp.), milkweed (*Asclepias incarnata*), verbena, agalinis, lobelia (*Lobelia* L.), blue-eyed grass (*Sisyrinchuium angustifolium*), arrowgrass (*Triglochin maritime* L.), carpet bentgrass (*Agrostis stolonifera*), reedgrass (*Calamagrostis arundinacea*), and goldenrod (*Solidago* sp.) (USFWS, 1995).

Effects of the No Action Alternative and Rationale

Direct and Indirect Effects

Because no plant sites occur or are expected within the Corridor, there are no direct effects on this orchid from the presence and maintenance of I-70. Because no water depletions are associated with current I-70 operations, water depletion is not a contributory factor. Indirect effects on water quality associated with interstate operations and maintenance (that is, interdependent actions) are unknown but could be occurring. Changes in water quality or chemistry due to annual herbicide roadside applications for controlling noxious weeds, and winter sanding, salting, and deicing agents added to roadways could be affecting downstream orchid populations, but there is no evidence of this, and there are no studies upon which to base possible effects. It is unknown if potential water quality temporary or long-term impacts from annual activities (1) are reasonably foreseeable; (2) would be sufficient to reach and impact the two known downstream sites; (3) would affect growing conditions; or (4) would be positive, neutral, or negative. Because impacts from I-70 are not known or suspected to occur, and cannot be identified, there are no design criteria in the current operations to address potential impacts on this species at these sites.

Nonetheless, because the trend at the known extant site is not determined, a conservative approach to assessing possible impacts would be to presume that some small-scale adverse indirect impacts could be occurring, but that they are not substantial enough at this time to conclude that plants are decreasing at the extant site, or that the site is losing population viability or habitat integrity over time due to Interstate presence or activities. That is, impacts, if occurring, are assumed to be insignificant (that is, immeasurable).

Cumulative Effects (ESA)

There are no known or suspected measurable impacts from I-70 in the Corridor area; thus, there are no contributions to cumulative effects.

Cumulative Impacts (NEPA)

Because there is no evidence that adverse impacts are occurring and are significant, it is concluded that the presence of I-70 and its current operations are not contributing to a net loss or gain to viability of the species at known sites or across its range. There are no measurable direct or indirect effects, and thus no contributions to cumulative impacts.

Effects Determination

Under the No Action Alternative, for the reasons stated above, a determination of "**No Effect**" (NE) is warranted for Ute ladies'-tresses orchid.

Effects of the Action Alternatives and Rationale

Direct and Indirect Effects

Because construction and maintenance of the action alternatives, including the Preferred Alternative, would not occur in areas of known or suspected Ute ladies'-tresses orchid populations, no direct effects are anticipated.

Permanent water depletions from Clear Creek would not be expected to occur. Water quality changes over and above those associated with current Interstate maintenance practices would not be expected to occur. Maintenance practices, materials application rates, and material application techniques would be anticipated to remain the same or increase slightly over current conditions.

According to USFWS, any depletion to the Platte River basin (roughly defined as the Palmer Divide north and the Continental Divide east in Colorado) constitutes an action that may affect, and is likely to adversely affect, TES species that depend on the river for their existence. To comply with the SPWRAP, an analysis of effects on ESA species downstream in Nebraska resulting from the Preferred Alternative is required in the BA. These effects will be examined during Tier 2 processes and will be submitted to USFWS for streamlined Section 7 consultation under the ESA. CDOT is coordinating with USFWS on this matter for documentation in the BA.

Cumulative Effects (ESA)

No State or private activities are reasonably certain to occur within the action area; thus, there are no contributions from them to cumulative effects.

Cumulative Effects (NEPA)

Possible impacts from temporary water withdrawal could add to possible impacts from another federal action involving water depletions near the project area. The Guanella Reservoir water-holding facility has recently been constructed near Empire, along the West Fork of Clear Creek, a few miles upstream from where the West Fork tributary enters Clear Creek. Water is diverted from the West Fork into the holding facility to provide drinking water to the City of Golden. This permanent annual water diversion commenced in 2005 and typically draws water from West Fork at a rate of 1 to 5 cfs (A. Beierle electronic correspondence with K. Bayer, 2006), or up to a theoretical maximum of approximately 3,500 AF per year, assuming a 24-hour draw every day. Although Guanella Reservior is approximately 17 river-miles upstream from the Clear Creek Canyon orchid site and approximately 30 river-miles upstream from the orchid site near Golden, this amount of water depletion could adversely affect downstream plants by reducing water needed by the plants or by changing subsurface hydrology. The degree of impacts, if they are occurring, is unknown.

The numerous long-standing and ongoing water withdrawals and augmentations from the action area, including the recent Guanella Reservoir water depletions, could cumulatively be adversely affecting extant sites. According to USFWS, any depletion to the Platte River basin (roughly defined as the Palmer Divide north and the Continental Divide east in Colorado) constitutes an action that may affect, and is likely to adversely affect, TES species that depend on the river for their existence. To comply with the

SPWRAP, an analysis of effects on ESA species downstream in Nebraska resulting from the Preferred Alternative is required in the BA. These effects will be examined during Tier 2 analysis and will be submitted to USFWS for streamlined Section 7 consultation under the ESA. CDOT is coordinating with USFWS on this matter for documentation in the BA.

These orchid sites are considered “medium” (Golden) and “small” (Clear Creek Canyon) in overall size (Fertig, Black, and Wolken, 2005), and there are numerous other extant sites in Colorado, some with thousands of plants, which appear currently to be stable. The potentially affected sites are not believed to be critical pollinator vectors or otherwise genetically interchanging with other orchid sites. Therefore, even if both known sites in the action area were extirpated over time, the loss of these sites would not be anticipated to lead to extinction of the species in Colorado or range-wide.

No other actions, occurring or planned, are known or suspected to be adversely affecting this plant in the action area. Potential adverse impacts associated with the action alternatives could add to a cumulative loss of plants or sites range-wide, if plants at the sites were to be extirpated. Such loss could contribute to a decline in the species across its range. But, because many sites appear stable, some of which have conservation measures in place, and the total number of plants is increasing as new surveys are conducted and new sites are being documented, such loss would not be expected to likely jeopardize the continued existence of the species across its range.

Effects Determination

Under the action alternatives, for the reasons stated above, a determination of “**May Affect, Likely to Adversely Affect**” (MA, LAA) is warranted for Ute ladies’-tresses orchid.

Western Prairie Fringed Orchid (*Platanthera praeclara*), T

The western prairie fringed orchid is a perennial herb in the flowering plant family Orchidaceae, Genus *Platanthera*.

Species Status and Distribution

The western prairie fringed orchid was first listed as threatened on September 28, 1989. It is currently designated as threatened over its entire range. Within the area covered by this listing, this species is known to occur in Iowa, Kansas, Minnesota, Missouri, North Dakota, Nebraska, and Oklahoma and in Canada (Manitoba). USFWS Great Lakes-Big Rivers Region (Region 3) is the lead region for this entity.

This species is known from 172 extant occurrences in the western Central Lowlands and the eastern Great Plains of the U.S. and the Interior Plains of Manitoba, Canada. There are only four large populations, all of which are in the northern part of the range, and which feature 1,000 or more plants. All of the populations observed in Kansas, Missouri, and Oklahoma are smaller than 50 individual plants (NatureServe, 2005b). The species is not known to occur in Colorado.

The action area for this species is the project Corridor area of maximum direct disturbance potential, and all downstream areas containing known sites or suitable habitat potentially influenced by the possible water depletions. Downstream action areas include only the mainstem of the Platte River in Nebraska, and not any watersheds in Colorado or west of EMJT, because they are not considered suitable habitat for this species. The closest known site to the project area is a historic site documented in 1891on the mainstem of the Platte River near Kearney, Nebraska. The site, containing an unknown number of plants, has not been relocated since 1891, and its current status is unknown (Sather, 1996; and USFWS pers. comm. with S. Popovich, 2005). It is possible the site has been extirpated. This is the only population that would be considered to be potentially affected by this project. The mainstem of the Platte has been significantly altered hydrologically, and the potential for additional undocumented sites to exist along the Platte under the current habitat conditions is low (USFWS pers. comm. with S. Popovich, 2005).

Species Life History and Habitat Requirements

The western prairie fringed orchid is a tallgrass prairie species, growing as high as about 4 feet and arising from an underground tuber. The plant produces a showy inflorescence, with up to two dozen white flowers arranged in a spike, and featuring fringed petals and having the longest nectar spur of any North American orchid. The plant commonly grows on moist, calcareous or subsaline prairies and sedge meadows (NatureServe, 2005b).

Declines in the numbers of this plant may be attributed to the past loss of most of the native tallgrass prairie in North America and conversion to agricultural uses. Current threats may also include conversion of remaining prairie to croplands, overgrazing, intensive hay mowing, drainage, fire suppression, collecting, and use of herbicides (NatureServe, 2005b).

Effects of the No Action Alternative and Rationale

Direct and Indirect Effects

It is unknown if the historic site is located directly on the Platte River, or if the site is off the river and located on an upstream tributary that potentially may not be influenced by hydrology of the mainstem of the Platte (USFWS pers. comm. with S. Popovich, 2005). For analysis purposes, it is assumed that the site is still extant and is located directly on the Platte River.

As with Ute ladies'-tresses orchid, because no plant sites occur or are expected within the Corridor, there are no direct effects on this orchid from the presence and maintenance of I-70. Because no water depletions are associated with current I-70 operations, water depletion is not a contributory factor. Indirect effects on water quality associated with I-70 operations and maintenance (that is, interdependent actions) are unknown but could be occurring. However, any changes in water quality or chemistry due to annual herbicide roadside applications for controlling noxious weeds, and winter sanding, salting, and de-icing agents added to roadways are not considered to be measurable as far downstream as the mainstem of the Platte. Therefore, it is concluded that no measurable effects or adverse impacts on the Kearney site are believed to be occurring from current I-70 operations.

Cumulative Effects (ESA)

There are no known or anticipated direct or indirect effects from I-70 in the Corridor area; thus, there are no contributions to cumulative effects.

Cumulative Impacts (NEPA)

Because there is no evidence that adverse impacts are occurring and are significant, it is concluded that the presence of I-70 and its current operations are not contributing to a net loss or gain to viability of the species at known sites or across its range. There are no measurable direct or indirect effects, and thus no contributions to cumulative impacts.

Effects Determination

Under the No Action Alternative, for the reasons stated above, a determination of "**No Effect**" (NE) is warranted for western prairie fringed orchid.

Effects of the Action Alternatives and Rationale

Direct and Indirect Effects

Construction and maintenance of the action alternatives, including the Preferred Alternative, would not occur in areas of known or suspected western prairie fringed orchid populations; therefore, no direct effects are anticipated. Maintenance practices, and materials application rates and techniques, would be anticipated to remain the same or increase slightly over current conditions, and to be immeasurable as far downstream as the mainstem of the Platte.

According to USFWS, including an intra-service biological opinion (USFWS, 1996) of federal agency actions resulting in minor water depletions affecting the Platte River system, any depletion to the Platte River basin constitutes an action that may affect, and is likely to adversely affect, downstream threatened species, including this orchid, that depend on the river for their existence. Depletions to the Platte River system due to CDOT activities are addressed by the State of Colorado's participation in the SPWRAP through the MOA as described in paragraph 4.a. of the MOA. The State has made and continues to make financial and other contributions to the PRRIP. In addition, SPWRAP has created a "Class X-1" membership specifically for and limited to the State of Colorado for diversions and depletions by State agencies that are comparatively small. CDOT falls into this category because their typical depletive activities such as wetland creation and water quality ponds, as well as water used for compaction, concrete, and dust control do not generally require large amounts of water. According to the MOA, contributions previously made are deemed payment of all SPWRAP assessments for the Class X-1 membership for the duration of the First Increment of the PRRIP, which expires in 2020. However, because the FHWA is funding the project, Section 7 consultation is required to satisfy FHWA's obligation under the ESA.

An analysis of effects on federally listed species downstream in Nebraska resulting from the Project's Preferred Alternative will be completed during Tier 2 processes, as CDOT cannot anticipate depletions at the Programmatic level of design. CDOT, as a Colorado State agency and participant in the PRRIP, will also complete a PRRIP template biological assessment during Tier 2 processes and submit it to the Service for streamlined Section 7 consultation provided by participation in the PRRIP. CDOT is coordinating with the Service on this matter for documentation in the BA; following streamlined consultation and the Service's issuance of a biological opinion, project-level depletions will be monitored annually by CDOT and reported to the Service. In the interim, as concluded by the 1996 USFWS intra-service biological opinion, the temporary water depletions associated with the proposed action alternatives could be reasonably expected to possibly adversely affect the Kearney site, if it is extant.

Cumulative Effects (ESA)

No State or private activities are reasonably certain to occur within the action area; thus, there are no contributions from them to cumulative effects.

Cumulative Effects (NEPA)

As with Ute ladies'-tresses orchid, numerous long-standing and ongoing water withdrawals and augmentations from the action area, including the recent Guanella Reservoir water depletions, could cumulatively be adversely affecting the Kearney site. According to USFWS, any depletion to the Platte River basin (roughly defined as the Palmer Divide north and the Continental Divide east in Colorado) constitutes an action that may affect, and is likely to adversely affect, TES species that depend on the river for their existence. To comply with the SPWRAP, an analysis of effects on ESA species downstream in Nebraska resulting from the Preferred Alternative is required in the BA. These effects will be examined during Tier 2 processes and will be submitted to USFWS for streamlined Section 7 consultation under the ESA. CDOT is coordinating with USFWS on this matter for documentation in the BA.

Effects Determination

Under the action alternatives, for the reasons stated above, a determination of "**May Affect, Likely to Adversely Affect**" (MA, LAA) is warranted for the western prairie fringed orchid.

BR.4. USFS Biological Evaluation

This section of the BR presents the biological evaluation of sensitive species and MIS for the WRNF and the ARNF. Included are descriptions of the distribution; natural history; environmental baseline; direct, indirect, and cumulative effects of alternatives; and a determination of effects and rationale for each species of mammals, birds, fish, invertebrates, and plants. These discussions are based on the best available scientific information. The source of data for each species is set out in **Table BR - 12**.

Table BR - 12. Source of Mapping Data for Sensitive Species Evaluated

Species	Data Source	Vegetation Map Units* or NDIS Map Elements
Pygmy shrew	Vegetation Map Units	3,7,10,12,17
River otter	NDIS	Overall range
American marten	Vegetation Map Units	7,10,12,15,18
North American wolverine	Vegetation Map Units	2,10,17
Bighorn sheep	NDIS	Winter range Summer range Lambing areas
Northern goshawk	Vegetation Map Units	3,10,14
American peregrine falcon	NDIS	Nesting area Potential nesting area
White-tailed ptarmigan	None of the alternatives would have an impact on mapped alpine tundra vegetation.	
Boreal owl	Vegetation Map Units	3,10,12,13,16
Flammulated owl	Vegetation Map Units	3,7,10,14,17
Black swift	No GIS mapping available. Specific nesting habitat near waterfalls or in wet cave entrances.	
Brewer's sparrow	Vegetation Map Units	16
American three-toed woodpecker	Vegetation Map Units	7,10,14,17
Bald Eagle	NDIS	Nest sites Winter concentration Winter range Communal roosts Roost sites
Olive-sided flycatcher	Vegetation Map Units	3,7,8,10,14,17,18
Boreal toad (Also MIS)	NDIS	Current range
Northern leopard frog	Populations on WRNF well removed from the Corridor. No known populations on ARNF. No impacts calculated.	
Colorado River cutthroat trout (Also MIS)	NDIS	Impacts calculated to linear feet of the Blue and Eagle rivers.
Bluehead sucker	No disturbance by alternatives in the upper Eagle River (above Dowd Canyon) where bluehead suckers are present.	
Flannelmouth sucker	Alternatives would have no direct effect on wetlands and riparian areas in the mainstem of the Colorado River in Glenwood Canyon (below milepost 134), or in the Blue River above Lake Dillon where flannelmouth suckers are present.	

***Vegetation Map Unit Key:** 1 – Alpine meadows – tundra, 2 – Aspen forest, 3 – Barren land, 4 – Douglas-fir forest, 5 - Grass/forb meadows, 6 – Lodgepole pine forest, 7 – Mountain shrubland, 8 – Piñon-juniper woodland, 9 – Ponderosa pine forest, 10 - Sagebrush shrubland, 11 – Spruce-fir forest, 12 – Montane riparian areas and wetlands, and 13 – Montane aquatic environments*

***New Vegetation Map Unit Key:** 1 Agricultural, 2 Alpine Meadows – Krummholz , 3 Aspen Forest,4 Barren Land,5 Bristlecone - Limber Pine Forest,6 Developed,7 Douglas-Fir Forest,8 Grass / Forb Meadows,9 Lakes & Ponds,10 Lodgepole Pine Forest,11 Mixed Forest, 12 Mountain Shrubland,13 Pinyon-Juniper Woodland,14 Ponderosa Pine Forest,15 Riparian Forest and Shrub,16 Sagebrush Shrubland,17 Spruce - Fir Forest, 18 Wetland (general) / Water*

BR.4.1 Sensitive Species

This section discusses habitat, overall distribution, and potential for each species presented to occur in the Corridor. Only those USFS-sensitive species identified as likely to be present or be influenced by the project on National Forest System Lands in the Corridor APE are presented below. These discussions are based on the best available scientific information.

BR.4.1.1 Mammals

Pygmy Shrew (Microsorex hoyi montanus), FS

The pygmy shrew is a small mammal in the family Soricidae, genus *Microsorex,* because it is the smallest of the North American shrews in the genus *Sorex*. The fur of Colorado specimens is dark brown with an indistinctly bicolored and relatively short tail. Their weight averages between 2 and 5 grams (Brown, 1966; and Armstrong, 1972). The pygmy shrew is currently documented to occur on ARNF lands. On WRNF lands, the species or habitat is suspected to occur but unconfirmed. Although the pygmy shrew is rated as globally secure (G5), its distribution in Colorado is restricted, and its state ranking is imperiled (S2).

Distribution

The pygmy shrew is distributed through most of boreal Canada and Alaska with populations in the contiguous U.S. limited to the northern Rocky Mountains, Great Lakes Region, and New England. Disjunct populations extend into the Southern Rockies (for example, northern Colorado) and the Appalachians (widespread and locally abundant in Virginia) (NatureServe, 2006).

Before 1961, this species was not known to occur south of Montana (Fitzgerald et al., 1994). Distribution in Colorado is a discontinuous population that occurs from the central southern Rocky Mountains north to just across the Wyoming border and is restricted to elevations above 9,600 feet. This discontinuous population may represent relict holdovers from the glacial periods (Fitzgerald et al., 1994).

Pygmy shrews have been documented in Grand, Gunnison, and Larimer counties in Colorado (NatureServe, 2006). The first pygmy shrew specimens in Colorado were from a small sphagnum bog in a coniferous forest, at 9,700 feet in elevation (Pettus and Lechleitner, 1963). Since that time, pygmy shrews have been documented on Rabbit Ears Pass in northwestern Grand County (Vaughan, 1969), near Gothic in Gunnison County (DeMott and Lindsey, 1975), and west of Fort Collins (USFS, USDA, 2005a). All captures to date have been above 9,600 feet in elevation. However, there is no documentation of pygmy shrew occurrence in the I-70 Corridor.

Given the wide range of habitats used by pygmy shrews, the Corridor could include potential pygmy shrew habitat in riparian areas, wetlands, and moist lodgepole pine, spruce-fir, and aspen habitats. Lack of information about this species in Colorado makes it difficult to estimate the current population size or trend for this species (NatureServe, 2006). Because the species seems to use many types of moist habitats, the habitat trend on the WRNF, the ARNF, and the higher elevation Corridor in general is expected to be stable. This may be a reasonable premise because the more kinds of habitats used by a species, the less likely that the loss of one kind of habitat would cause a viability risk to the species overall. For example, the elk is also a habitat generalist. On a global scale, there is little reason to believe that a significant decline has occurred (NatureServe, 2006).

Natural History

Pygmy shrews use a variety of moist habitats, preferring grassy openings within a boreal forest matrix (NatureServe, 2006). The species has been found in subalpine forests and parklands, clear-cut and selectively logged forests, forest-meadow edges, boggy meadows, willow thickets, and aspen-fir forests. Pygmy shrews build runways under stumps, fallen logs, and litter. The species breed once per season in the warmer months and may have up to eight young in the litter. Diet is mainly insects and other invertebrates (NatureServe, 2006; and Fitzgerald et al., 1994). Little is known about its natural history; however, like other shrews (*Sorex* spp.), it eats a wide variety of insects and carrion and has a voracious appetite (Fitzgerald et al., 1994).

Environmental Baseline

The pygmy shrew is a sensitive species of the Rocky Mountain Region of the USFS. Areas of the Corridor above 9,600 feet that might contain suitable, moist, forested habitat include the Vail Pass area (milepost 185 to Frisco at milepost 200) and the Continental Divide area (milepost 210 near Dillon to near Silver Plume at milepost 225).

Pygmy shrew habitat within the Corridor includes aspen forest, Douglas-fir forest, lodgepole pine forest, mountain shrubland, and spruce-fir forest. These vegetation types are illustrated on **Figure BR - 3** (Maps 1-7).

Direct, Indirect, and Cumulative Effects of Alternatives

Action Alternatives

Impacts from alternatives in higher elevation, moist, forested habitats would have the potential to directly and indirectly affect pygmy shrews in habitats where they occur. The pygmy shrew appears to occur only in forested habitats at elevations above 9,600 feet in Colorado. All action alternatives would affect some potential habitat areas on either side of the EJMT and on Vail Pass above 9,600 feet elevation, and could directly affect some individual shrews. The Minimal Action Alternative would not involve construction of a third bore at EJMT and, therefore, is expected to have the least impacts. However, because little is known about the distribution of pygmy shrews in Colorado (Fitzgerald et al., 1994), it is difficult to estimate the impact of habitat loss at population levels.

All action alternatives could have direct impacts on habitat in the Vail Pass (WRNF lands) and Continental Divide (WRNF and ARNF lands) segments of the Corridor. **Table BR - 13** and **Table BR - 14** provide the estimated direct impacts on potential pygmy shrew habitat. Impacts of the Preferred Alternative on WRNF lands would range from 10.8 acres for the Minimum Program 65 mph and Maximum Program 65 mph to 11.3 acres for the Minimum Program 55 mph and Maximum Program 55 mph. Impacts of the Preferred Alternative on ARNF lands would range from 3.1 acres for the Minimum Program (55 or 65mph) to 6.5 acres for the Maximum Program (55 or 65mph).

Of all of the alternatives, Combination Six-Lane Highway with Rail and Intermountain Connection would have the most direct impacts on pygmy shrew habitat from construction footprint and support activities for the total Corridor on the WRNF and on the ARNF. The Minimal Action and Six-Lane Highway 65 mph alternatives would have the least direct impacts on the WRNF, whereas the Advanced Guideway System alternative would have the least impacts on the ARNF.

Table BR - 13. Direct Impacts on Pygmy Shrew Habitat (acres): Preferred Alternative

	Minimum Program		Maximum Program	
	Specific Highway Improvements | with AGS		Combination 6-Lane Highway with AGS	
	55 mph	65 mph	55 mph	65 mph
WRNF	11.3	10.8	11.3	10.8
ARNF	3.1	3.1	6.5	6.5

Data provide the minimal to maximum impacts for the Preferred Alternative.

Table BR - 14. Direct Impacts on Pygmy Shrew Habitat (acres): Action Alternatives Evaluated in the Draft PEIS

	Minimal Action	Rail with IMC	AGS	Dual-Mode Bus in Guideway	Diesel Bus in Guideway	Six-Lane Highway 55 mph	Six-Lane Highway 65 mph	Reversible/ HOV/HOT Lanes	Combination Six-Lane Highway with Rail and IMC	Combination Six-Lane Highway with AGS	Combination Six-Lane Highway with Dual-Mode Bus in Guideway	Combination Six-Lane Highway Diesel Bus in Guideway
WRNF	5.3	15.7	6.7	9.5	9.5	7.6	5.8	7.6	19.0	11.3	12.7	12.7
ARNF	2.1	5.3	0.9	1.4	1.4	2.9	3.0	4.6	8.7	6.5	6.3	6.3

Road effect zone-related impacts such as noise, the barrier effect of the highway, potential for roadkill, and winter maintenance activities would not appreciably affect this species; the reason being that their home range is so small due to the individuals being so small. Indirect effects from all action alternatives, except the Minimal Action Alternative, could affect habitat of the pygmy shrew by possible increased Forest visitation. Public use of trails within suitable habitat could contribute to the threat of shrew trampling.

The Combination alternatives are associated with possible induced growth in Summit and Eagle counties. The Transit and Highway alternatives are associated with possible induced growth in Eagle County. However, most induced development would occur below 9,600 feet in elevation, and for Transit alternatives, induced growth is expected to occur near urban areas. Possible increased visitation to the WRNF and ARNF is associated with all alternatives except the Minimal Action Alternative. Combination alternatives would have the greatest potential for increased visitation, followed by Transit alternatives. Transit alternatives are expected to increase visitation to developed recreation areas such as ski resorts, while Highway alternatives are expected to increase dispersed recreation activities such as hiking. The effect of this greater visitation is the greater potential for trampling individual shrews, creating new trails that may have barrier effects, and packing winter snow that could delay shrew activity in the spring.

Cumulative effects on pygmy shrews could result from a mountain pine beetle epidemic in lodgepole pine. Effects of such an epidemic could include the loss of mesic coniferous habitats within the project area due to reduced canopy cover and increased understory exposure. Certain forest management activities might affect pygmy shrews including harvest activities where overhead cover and forest floor vegetation are disturbed; construction of forest roads that remove habitat, compact soil surfaces, and possibly create barriers for dispersal; trail construction; and construction of new recreational facility sites and ski-related resorts. Reduction in potential habitat, compacted soil and snow, and potential dispersal barriers are the overall possible outcomes from these forest management activities. However, no measurable impact on the Forest populations of pygmy shrews are expected as a result of indirect and cumulative impacts from any of the action alternatives since this species seems to be a generalist that has adapted to many habitat types and conditions.

No Action Alternative

The No Action Alternative is associated with increased traffic and congestion on I-70, and possible reduction of forest visitation. The No Action Alternative would not cause any further impacts on pygmy shrew habitat, but other activities, such as forest management, a mountain pine beetle epidemic, or the potential for roadkill could still affect the shrew.

Determination of Effects and Rationale

Action Alternatives

All action alternatives possibly **may adversely impact individuals**. However, because the species is a generalist that uses many different habitat types and conditions, prefers habitat above 9,600 feet elevation, and has been documented in four counties that are not Corridor counties, the action alternatives **are not likely to result in a loss of viability in the planning area, nor cause a trend to federal listing**. While there may be site-specific differences by alternatives, there would be no measurable differences among the action alternatives on Forest populations of the shrews. The action alternatives would affect habitat and possibly individuals on both the WRNF and the ARNF.

No Action Alternative

The No Action Alternative would not directly impact potential WRNF or ARNF habitat. However, the barrier effect of I-70 would remain. Therefore, this alternative **may adversely impact individuals but not likely to result in a loss of viability in the planning area, nor cause a trend to federal listing.**

River Otter (*Lontra canadensis*), FS

A large mustelid, otters are found in riverine habitat with low to moderate gradients. They also are found in forested, herbaceous scrub/shrub wetlands and riparian areas. They are active in winter, even in fresh, deep snow and may be active at any time of day (NatureServe, 2006). River otters are known to occur on the ARNF, are considered likely to occur on the WRNF, and are classified as a sensitive species on both forests.

Distribution

The river otter has a large range in much of North America north of Mexico; the population trend is relatively stable; reintroductions and management efforts have improved conservation status (NatureServe, 2006).

A population density of 1 per 2.2 miles has been recorded in Michigan (Baker, 1983). In Idaho, density was 1 family group and 1 to 3 subadults or nonbreeding adults per 9.3 miles of waterway, plus 1 breeding adult male for each 12 to 18 miles of waterway (NatureServe, 2006).

The river otter once occupied most of the major river drainages in Colorado but was extirpated. Beginning in 1976, Colorado initiated restoration efforts (USDA, 2005a). Otters were first introduced into Cheesman Reservoir on the South Platte River. Other introductions have occurred in the Gunnison, Piedra, and Dolores rivers and in the headwaters of the Colorado River. Reproduction appears successful in the Rocky Mountain National Park population, and colonization is occurring outside the park (USDA, 2005a). Overall, from 1976 through 1991, 107 river otters trapped in several states and Canada were released into Colorado streams. The outcome of Colorado's river otter reintroduction program is considered uncertain (USDA, 2005a).

Natural History

Home range typically is linear; 20 to 30 miles for a pair or males; less for females with young. Otters may hunt over as much as 50 to 60 miles of stream during the course of 1 year (NatureServe, 2006).

Implantation of eggs is delayed 8 months or more. Gestation, including delayed implantation, lasts 9 to 12 months. In many areas, births peak in late winter to early spring. Litter size is 1 to 6 (with an average of 2 to 3), with 1 litter per year. Young may first enter the water at about 7 weeks, are weaned at about 3 months, and stay with the mother for approximately 1 year. Males may rejoin the family after young leave the den (NatureServe, 2006).

When inactive, they occupy hollow logs, space under roots or overhang, abandoned beaver lodges, dense thickets near water, or burrows of other animals. Such sites also are used for rearing young. They use traditional haul-out sites along the banks of aquatic habitats and may travel long distances over land, particularly in snow (NatureServe, 2006).

Otters feed opportunistically on aquatic animals, particularly fish (mostly slow-moving, mid-size species), frogs, crayfish, turtles, insects, and sometimes birds and small mammals (NatureServe, 2006).

Environmental Baseline

There is potential habitat for otters in the Corridor APE. There was a sighting in the Eagle River near Dowd Canyon several years ago (K. Giezentanner pers. comm. with D. Solomon, 2006a). Because otters are present in the Colorado River headwaters, their possible presence in the Eagle River is not unreasonable. All populations of otters on the ARNF occur in drainages other than the Clear Creek drainage where the Corridor is located.

Direct, Indirect, and Cumulative Effects of Alternatives

Action Alternatives

River otters would be susceptible to direct impacts from habitat loss, degradation of water quality, water depletions, construction activities, and possibly from an expanded road effect zone. The areas of potential habitat most susceptible to these effects and that also have a good potential for otters to be present would include the Eagle River from Dowd Canyon downstream to the confluence with the Colorado River.

Table BR - 15 and **Table BR - 16** provide the estimated direct impacts on potential river otter habitat. The Preferred Alternative is anticipated to have no impact on river otter habitat in the WRNF or in the ARNF.

Among all of the alternatives, the Rail and Intermountain Connection, Bus in Guideway, Combination Six-Lane Highway with Rail and Intermountain Connection, and the Combination Six-Lane Highway with Bus in Guideway alternatives would have the most direct impact on river otter habitat from construction footprint and support activities on the WRNF. Other alternatives would not be anticipated to have any impact on river otter habitat on the WRNF. Increased inputs of highway runoff and winter maintenance runoff into aquatic habitats may have a negative impact on river otters, and these effects would be greatest with the Combination Six-Lane Highway with Bus in Guideway alternatives.

No impacts on river otter habitat are anticipated to occur on the ARNF.

The resultant effect on otters from these potential impacts is to reduce the amount of habitat and force the otters to range farther afield to obtain cover and breeding sites. If water quality is degraded, prey species for the otter may be decreased, forcing the otters to migrate to different streams where foraging may be better. In both of these cases, individual otters would be at increased risk to be able to meet their food, cover, and breeding requirements. Otters do move over land from one drainage to another, but this is usually high in the drainages and the potential for roadkill should be low.

Table BR - 15. Direct Impacts on River Otter Habitat (acres): Preferred Alternative

	Minimum Program		Maximum Program	
	Specific Highway Improvements with AGS		Combination 6-Lane Highway with AGS	
	55 mph	65 mph	55 mph	65 mph
WRNF	0.0	0.0	0.0	0.0
ARNF	0.0	0.0	0.0	0.0

Data provide minimal to maximum impacts for the Preferred Alternative.

Table BR - 16. Direct Impacts on River Otter Habitat (acres): Action Alternatives Evaluated in the Draft PEIS

	Minimal Action	Rail with IMC	AGS	Dual-Mode Bus in Guideway	Diesel Bus in Guideway	Six-Lane Highway 55 mph	Six-Lane Highway 65 mph	Reversible/ HOV/HOT Lanes	Combination Six-Lane Highway with Rail and IMC	Combination Six-Lane Highway with AGS	Combination Six-Lane Highway with Dual-Mode	Combination Six-Lane Highway Diesel Bus in Guideway
WRNF	0.0	2.1	0.0	1.8	1.8	0.0	0.0	0.0	2.1	0.0	1.8	1.8
ARNF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Indirect effects on river otter habitat are numerous and include any effects on wetlands and riparian areas that would contribute sediment, change water quality or chemistry, alter hydrology, or change the existing vegetative cover at an occupied site. Possible induced growth could affect wetlands and aquatic habitats that could potentially affect river otters. As areas develop along the Corridor, the potential for water quality to be affected by increased runoff from paved surfaces, disturbed construction sites, and landscaping inflows (such as golf courses, homes, and commercial areas) would become greater. The greatest potential for induced growth would be associated with the Combination alternatives in the Eagle River watershed. The Combination alternatives are projected to induce the greatest amount of growth in Eagle County and moderate growth in Summit County. Indirect effects resulting from any water withdrawals for construction would be short term and temporary and should not have any effect on downstream populations.

Cumulative effects on river otters may include loss of wetland habitat, loss or degradation of wetland function, or loss of habitat connectivity between wetlands in areas where future developments are planned, along with possible induced growth and visitation.

No Action Alternative

Effects on river otters and their habitat associated with the No Action Alternative may include similar levels or even gradual increases of road maintenance solutions runoff and sediment loading of aquatic habitats and wetlands. This assumes no additional construction of drainage or water quality mitigation for the Corridor.

Determination of Effects and Rationale

Action Alternatives

The action alternatives would directly disturb some wetland and riparian habitat, but there can be no net loss of wetlands under USACE regulations, and other wetland areas may have to be enhanced. Due to the high level of concern for sensitive species habitat, WRNF Standards and Guidelines were developed to greatly restrict management-related disturbance around wetlands and riparian areas. Similar goals on the ARNF (# 4 and #7 under Biodiversity, Ecosystem Health and Sustainability) will direct management to maintain and improve habitats for sensitive species. The Standards and Guidelines were designed to achieve the goals of perpetuating water-related values and sustaining riparian areas. Differences among alternatives are not measurable forest-wide and would vary only at the project level. Potential habitat for river otters subject to project disturbance is restricted to approximately 37 miles of the lower Eagle River. Therefore, the determination is that all action alternatives **may adversely impact individuals, but not likely to result in a loss of viability in the planning area, nor cause a trend to federal listing.**

No Action Alternative

The No Action Alternative would have no additional effects beyond current conditions. Effects from current trends including riparian habitat degradation would continue. The road effect zone of I-70 would remain in place. This alternative **may adversely impact individuals, but not likely to result in a loss of viability in the planning area, nor cause a trend to federal listing**.

American Marten (*Martes americana*), FS

The American marten, often called the pine marten, is a medium-sized carnivorous mammal in the family Mustelidae, genus *Martes*. It is weasel-like and smaller than an average house cat with a pointed face and conspicuous, rounded ears. The long bush tail accounts for about one-third of the animal's total length. The long, glossy, relatively stiff guard hairs and dense, silky underfur made the marten a target of furtrappers prior to 1996 when trapping was halted. Marten average 1.1 to 2.6 pounds (Strickland and Douglas, 1987). The species is currently documented to occur on ARNF and WRNF lands.

Distribution

Martens occur throughout Canada, Alaska, and the lower 48 states except for the Midwest and the South. Natural re-establishment and reintroduction programs have contributed to a moderate comeback in some areas of the northern U.S. (NatureServe, 2006). In Colorado, they occur in most areas of coniferous forest habitat in the high mountains (Fitzgerald et al., 1994). Only the subspecies, *Martes americana origenes*, is found in Colorado (Fitzgerald et al., 1994). Martens have been isolated in Colorado from other marten metapopulations to the north by the Green River-Wyoming basin complex (Ruggiero et al., 1994).

The American marten is listed as a sensitive species in USFS Region 2 due to its dependency on a specific habitat. Actual population numbers have rarely been determined. The marten is a Forest Sensitive species with documented occurrences in both WRNF and ARNF. On the WRNF the marten population located on the eastern White River Plateau may be isolated from other marten populations of Colorado (Ruggiero et al., 1994). The Colorado River might serve as a barrier to connectivity within the WRNF. Suitable habitat is present in montane forest areas of the Corridor. The American marten has a state heritage status rank of S4, apparently secure in Colorado (NatureServe, 2006).

Adequate population data are unavailable for much of the species' range other than harvest records, but it is considered stable throughout its range. Adequate population data are unavailable for much of the range, but the total population size is at least several hundred thousand and the species can be regarded as secure (NatureServe, 2006).

Winter track surveys (January and February 2003 and 2004) in the Williams Fork LAU on the ARNF detected marten in multiple locations: 248 individual tracking stations detected marten in the Keyser Creek and Kinney Creek drainages (Sulphur District files) (USDA, ARNF, 2004).

Problems that normally affect isolated populations (including the population in Colorado), such as inbreeding, genetic drift, allele effects, and stochastic events, are not thought to be factors affecting these isolated populations because they are so large. This suggests that sufficient habitat exists in these isolated populations to outlast the processes that push isolated populations to extinction (Ruggiero et al., 1994).

Natural History

The American marten inhabits subalpine spruce-fir and lodgepole pine forests and is usually associated with older and multi-aged stands with a high degree of forest floor structure. Marten foraging habitat occurs within all structural stages of spruce-fir forest, lodgepole pine, and high-elevation riparian forest, as well as mature and late-successional Douglas-fir habitat. The marten needs high canopy closures, usually greater than 30 percent, and coarse woody debris and other forest floor objects such as rock piles, slash, and stumps, to provide denning sites, access to prey, and protection from predators. Martens consume various prey, but voles (*Microtus* spp.) and mice (*Peromyscus* spp.) constitute the majority (Fitzgerald et al., 1994). Voles and other mice constitute 60 to 88 percent of a pine marten's diet, but martens will also eat shrews, insects, and vegetable matter in Colorado (Gordon, 1986). Pine martens usually hunt at night and are active year round (Buskirk et al., 1989).

Extremely dense stands of conifers are not suitable for marten occupation due to limited primary production and resultant low small mammal populations. Riparian woodland areas are used for both foraging and resting (Ruggiero et al., 1994). Martens den in tree cavities, logs, rock piles, and burrows. Breeding occurs most commonly between late July and early September. The young martens are partly furred. Their ears open at approximately three weeks, and their eyes open at slightly more than one month of age. At approximately one and a half months, they can leave the nest, and they become very active soon after that. The young are approximately adult size at three months (Fitzgerald et al., 1994).

Past logging and trapping for pelts led to extirpation in some areas. Populations are susceptible to decline if over-harvested when food supplies are low. Loss/degradation of habitat due to timber harvest remains a threat in some areas. Martens are tolerant of nondestructive intrusion such as hikers (NatureServe, 2006).

Environmental Baseline

Marten habitat in the Corridor consists of spruce-fir forest, Douglas-fir forest, lodgepole pine forest, aquatic montane habitat, and riparian habitat. These vegetation types occur throughout the Corridor as illustrated on **Figure BR - 3** (Maps 1-7). Marten foraging habitat occurs within all structural stages of spruce-fir forest, lodgepole pine, and high-elevation riparian forest, as well as mature and late-successional Douglas-fir habitat. Maintaining multi-storied, late-successional stands is important to healthy marten populations (Fitzgerald et al., 1994).

In general, the isolated populations of marten in Colorado are thought to be quite susceptible to human actions. Problems facing marten populations today include the following: logging in late-successional habitat causes habitat perforation and habitat loss; and reduction or elimination of dead and down structural components interferes with hunting and denning (Ruggiero et al., 1994). Martens have been documented on both the WRNF and the ARNF, but no concerted effort to date has tried to document the extent of the population. The Rocky Mountain states, including Colorado, maintain healthy and apparently stable populations (Ruggiero et al. 1994), but population trends on the National Forests are unknown.

Direct, Indirect, and Cumulative Effects of Alternatives

Action Alternatives

Table BR - 17 and **Table BR - 18** provide the estimated direct impacts on potential American marten habitat. The impacts on American marten habitat in the WRNF of the Preferred Alternative would range from 13.9 acres (Minimum Program 65 mph and Maximum Program 65 mph) to 15.4 acres (Minimum Program 55 mph and Maximum Program 55 mph). In the ARNF, the impacts would range from 3.5 acres for the Minimum Program (55 or 65mph) to 11.1 acres for the Maximum Program (55 or 65mph).

For the WRNF, the least impacts among all alternatives would be associated with the Advanced Guideway System and Six-Lane Highway 65 mph alternatives, while the greatest impacts would be associated with the Combination Six-Lane Highway with Rail with Intermountain Connection alternative. For the ARNF, the least impacts would be associated with the Advanced Guideway System, Bus in Guideway, and Minimal Action Alternatives, while the greatest impacts would be associated with the Combination Six-Lane Highway with Rail and Intermountain Connection, the Maximum Program 55 or 65mph, and the Combination Six-Lane Highway with Advanced Guideway System alternatives. Total estimated acreage of suitable habitat on WRNF and ARNF is 986,800 and 806,000, respectively.

Table BR - 17. Direct Impacts on American Marten Habitat (acres): Preferred Alternative

	Minimum Program		Maximum Program	
	Specific Highway Improvements with AGS		Combination 6-Lane Highway with AGS	
	55 mph	65 mph	55 mph	65 mph
WRNF	15.4	13.9	15.4	13.9
ARNF	3.5	3.5	11.1	11.1

Data provide minimal to maximum impacts for the Preferred Alternative.

Table BR - 18. Direct Impacts on American Marten Habitat (acres): Action Alternatives Evaluated in the Draft PEIS

	Minimal Action	Rail with IMC	AGS	Dual-Mode Bus in Guideway	Diesel Bus in Guideway	Six-Lane Highway 55 mph	Six-Lane Highway 65 mph	Reversible/ HOV/HOT Lanes	Combination Six-Lane Highway with Rail and IMC	Combination Six-Lane Highway with AGS	Combination Six-Lane Highway with Dual-Mode	Combination Six-Lane Highway Diesel Bus in Guideway
WRNF	9.6	17.8	8.4	12.9	12.9	12.1	8.9	12.1	24.6	15.4	17.2	17.2
ARNF	2.4	5.8	1.1	1.6	1.6	5.3	5.3	7.6	13.9	11.1	10.6	10.6

In general, critical habitat for marten includes mature forest stands and/or secluded subalpine areas often protected by wilderness status. The primary source of negative project-related effects for marten would occur if the barrier effect of the highway were increased. Indirect impacts such as those associated with vehicle collisions would include road effect zone-related disturbance and habitat perforation due to possible induced growth. However, development activities in areas of old-growth forest are highly unlikely.

Alternative-specific impacts on marten would include possible induced growth, associated with all action alternatives, except the Minimal Action Alternative, which is expected to lead to increased recreational uses in the Corridor during winter, resulting in expansion of ski areas, snowshoeing, and snowmobile use, all of which compact snow and increase frequency of human presence. Increased snow compaction affords other carnivores the ability to access deep snow areas that are typically hunted only by marten. This increase in competition for resources may be detrimental to the marten. Road effect zone-related disturbance and habitat perforation due to increased human activity also would likely affect marten. These impacts could potentially have population-wide effects, as well as effects on individuals. The Combination alternatives would be associated with the greatest possible induced growth in Eagle and Summit counties, as well as the greatest chance for increased visitation in the WRNF and the ARNF. The Highway alternatives would be associated with possible moderate growth in Eagle County and possible increased visitation to the WRNF and the ARNF, including increased dispersed winter recreation. Transit alternatives might induce growth near urban areas and increase visitation to developed recreation areas in WRNF and ARNF, such as ski areas.

The barrier effect of I-70 would have the potential to affect marten in habitats at elevations above 9,000 feet. Spruce-fir and lodgepole pine stands occur on both sides of the highway from approximately milepost 175 to milepost 220. Evidence suggests that the existing highway's barrier effect would impede traditional marten movement between areas north and south of the highway. Martens are relatively small animals, and guardrails and cement barriers could be significant barriers. The end result on marten is that the population (and their gene pool) may be fragmented. If this is the case, then the separated populations may experience lowered reproductive vitality compared to a single, larger population. Lowered reproductive vitality could possibly lead to a decline in the fragmented population.

Linkage zones are rated most susceptible to impact by the Combination Six-Lane Highway with Rail and Intermountain Connection alternative, followed by the Combination Six-Lane Highway with Advanced Guideway System and the Rail with Intermountain Connection alternatives. Each of these alternatives would have more than 250 acres of linkage area affected. Similar but lower levels of impacts on linkage areas would result from the other Transit alternatives and the Highway alternatives. The Minimal Action Alternative would have the least effect on linkage areas, and the No Action Alternative would have no additional effect.

Cumulative impacts would include possible direct impacts on habitat, barrier effects of the transportation corridor, and road effect zone-related disturbance and habitat fragmentation from possible induced growth (Combination and Highway alternatives only), possible induced Forest visitation (Combination, Transit, and Highway alternatives), and planned growth in the Corridor watersheds. Marten also would probably be sensitive to impacts occurring in lynx linkage areas (as identified previously in Environmental Baseline), as these zones represent connections between large blocks of undeveloped forest habitat that is important to both species. Impacts could potentially have population-wide, as well as individual, effects until animals find and use the safe crossing structures planned.

Cumulative effects within the Corridor area also would include the infestation of mountain pine beetles causing significant mortality of mature and late-successional lodgepole pine. Lodgepole pine in this portion of the WRNF is expected to experience stand replacement due to the mountain pine beetle epidemic, with all large trees killed. As such, these stands will no longer function as late-successional stands and will be, in effect, early seral stages. The late-successional stand value for foraging by marten will have been removed.

Other cumulative impacts on National Forest System Lands would include vegetation management of habitat, especially interior forests. The main action that would affect interior habitat is timber management. Vegetation treatments that change mesic, forested habitats to xeric openings or to low density forest, would result in a shift in primary forage species (voles and red squirrel) to deer mice, which would subsequently result in decreased habitat capabilities for marten. Clearcuts that are small in size (1 to 7 acres), and limited to less than 300 feet in width, would reduce some of the negative impacts on this species. Ski area and other recreation development may affect some marten habitat, but because these types of development are restricted from development in wetlands, the acreages affected from these actions would be small. Other impacts can occur, such as wildfire and infestations or disease, but these impacts are expected to be minor and generally not measurable forest-wide.

The 2002 WRNF Plan Standards and Guidelines will likely provide adequate habitat to maintain marten distribution across the Forest. Forest-wide Standards and Guidelines for retaining and managing dead and down wood components provide the structure needed for meeting subnivean access requirements (Water and Riparian Resources Standard #4 and Guideline #1; Soils Standard #7; Biodiversity Standards #2 and #3) (USDA, 2002a). A requirement for retention of late-successional/old-growth spruce-fir, lodgepole, and Douglas-fir habitats provides for a distribution across the forest of this important community and structural forest type (Biodiversity Standard #4) (USDA, 2002a).

In addition, MA 5.5 management prescriptions reduce the impact on this important forest type by eliminating spruce-fir from the timber base, requiring that a wildlife prescription determine the process for altering the spruce-fir habitat components, thereby benefiting this conifer cover type and marten before any harvest activities occur.

No Action Alternative

The current effects of I-70 on marten, including the barrier effect of the highway, would remain under the No Action Alternative because no additional crossing structures would be built, except possibly one near the top of Vail Pass. This overpass structure is currently in the planning process independent of the proposed project alternatives.

Determination of Effects and Rationale

Action Alternatives

All action alternatives would directly affect marten habitat to some degree, and all action alternatives would have barrier effects in marten/lynx linkage areas, but the extent of such impacts would depend on mitigation activities considered during Tier 2 studies. All action alternatives (except the Minimal Action Alternative) are likely to have indirect and cumulative effects due to planned and possible induced growth in the Eagle and Blue River watersheds. Combination alternatives would have the greatest cumulative effects from possible induced growth in Eagle and Summit counties and from induced visitation in the ARNF and the WRNF. Combination and Highway alternatives would be associated with possible increased dispersed development and increased dispersed recreation activities. Transit alternatives would be more closely associated with induced growth in existing urban areas and increased developed recreation and would have fewer effects on marten habitat. All action alternatives **may adversely impact individuals, but not likely to result in a loss of viability in the planning area, nor cause a trend to federal listing.**

No Action Alternative

The No Action Alternative would have no direct impacts on marten habitat. However, barrier effects and roadkills associated with increasing traffic and congestion on I-70 would continue to affect individuals. No project mitigation measures, including crossing structures, would be associated with the No Action Alternative. Therefore, the No Action Alternative **may adversely impact individuals, but not likely to result in a loss of viability in the planning area, nor cause a trend to federal listing.**

North American Wolverine (*Gulo gulo luscus*), FS

The North American wolverine is a bear-like mustelid with massive limbs and long, dense, dark brown pelage, paler on the head, with two broad yellowish stripes extending from the shoulders and joining on the rump. Variable white or yellowish markings are often present on the throat and chest. The tail is bushy. The feet are relatively large (2.6 to 4.5 inches total length) with robust claws. Wolverines weigh between 15 and 70 pounds and range from 2.9 to 3.6 feet in length. Females average about 10 percent less than males in linear measurements and 30 percent less in mass (Hall 1981; Ingles 1965; Nowak 1991). The species or habitat is suspected to occur on ARNF lands but is unconfirmed. The species is historically documented to occur on WRNF lands but not in recent times. Andrews (1991) conducted a systematic field survey during winter 1990-1991 in Rocky Mountain National Park and in nearby portions of the ARNF. He found no evidence of wolverine and concluded that it was unlikely that a viable population of wolverine was present. In their monograph on the mammals of Colorado, Fitzgerald et al. (1994) stated that the status of wolverines in Colorado was “uncertain.”

The wolverine has been petitioned for listing as threatened or endangered throughout its range in the contiguous U.S. It is listed as threatened by the states of California and Oregon, endangered in Colorado, and protected in Wyoming (Ruggiero et al. 1994). USFS lists the wolverine as sensitive species in Regions 1, 2, 4, and 6. The WRNF has identified it as a species of viability concern on the Forest. The ARNF considers the wolverine a sensitive species with individuals or habitat suspected to occur on ARNF lands but without present confirmation.

Distribution

Much of the following information on distribution, habitat, natural history, and environmental baseline is directly from the WRNF (USDA, 2002a) and ARNF (USDA, 1997) Final EIS documents.

Wolverines range from boreal and tundra areas of Alaska and Canada south to the boreal forests in the Rocky Mountains to Arizona and New Mexico. They are less common in their southern distribution.

Presently wolverines are found in the Northern Rockies in western Wyoming, western Montana, northeastern Washington, and the Idaho Rockies. Montana has the most viable population of wolverines in the Rocky Mountains of the US (Hash, 1987).

Population densities of wolverines are low, even in optimal habitat conditions. Hash (1987) reported population densities ranging from one wolverine/80 sq. miles in Canada to one wolverine/25 sq. miles in Montana. In Idaho, wolverine population densities were estimated at one wolverine/76 sq. miles (Copeland, 1996).

Wolverine population numbers in Colorado are not currently known. It is possible that wolverines have been extirpated from the state. Nead et al. (1995) speculate that population numbers were never very high in Colorado and that a viable population does not presently exist in the state. Historic wolverine sightings that have been verified by physical evidence such as the skin or a skull come from contiguous forested montane areas from Rocky Mountain National Park to Telluride. Historical wolverine sightings have been given ratings of A, B, C, or F, depending on the degree of certainty to which the animal was indeed a wolverine. "A" ratings are positive wolverine identifications, "B" ratings are probable identifications, "C" ratings are possible identifications, and "F" ratings are negative (Byrne, 1995). There have been five wolverine sightings in Colorado in the past 20 years (since 1980) with an "A" rating. These were in Larimer, El Paso, Park, and Arapahoe counties. Of the 23 "B" rated sightings in Colorado in the past 20 years, only three were in the WRNF; two were in Eagle County, and one was in Gunnison County. Some of the "A" rated wolverine identifications are confounded by the fact that six wolverines escaped from the Cheyenne Mountain Zoo in Colorado Springs from 1966 to 1986, and two were released near Aspen in 1979 (Byrne, 1995).

Since 1982, there have been four "B" rated sightings on or near the ARNF (CDOW, 2005 in USDA, 2005). Three of them were in Grand County and one in Larimer County. The most recent of these sightings was 1992.

Although wolverine sightings have been reported regularly in Colorado's northern and central mountains, this species' recent presence is unconfirmed in the state (NDIS, 2004). Abundance of this mammal in Colorado also is unknown, but populations were never high (Fitzgerald et al., 1994). Because they actively avoid areas of human activity, threats to this species include increased human activity from recreational activities associated with trail use, ski areas, and other resorts, and fragmentation caused by roads and development (USFS, 1999). Population trends in some parts of the species range are decreasing, but the trends in the southern Rocky Mountains and Colorado are unknown (there is possibly no reproducing population in Colorado).

Hornocker and Hash (1981) reported that in Montana, 70 percent of all wolverine telemetry relocations were in large areas of "medium or scattered mature timber." More specifically, they were relocated most frequently in areas of subalpine fir (*Abies lasiocarpa*). They were seldom found in areas of dense, young timber, burned over, or wet meadow areas. Specific habitat preferences of wolverines in Colorado are not known; however, most of the sightings within the past 20 years in Colorado were located in spruce-fir and alpine habitats.

Habitat fragmentation poses a serious threat to wildlife, especially for sensitive species such as the wolverine. A land bridge is one way to mitigate the barrier effect of a highway corridor. A land bridge currently exists where the EJMT passes underneath the Continental Divide. Proposals have been made to construct other land bridges over the Corridor in the high country. Wildlife crossing structures including overpasses and underpasses, in conjunction with wildlife fencing, are a demonstrated way to reduce AVCs and maintain landscape connectivity. Overpasses with vegetation are quite effective for a large spectrum of animals ranging from insects and amphibians to carnivores and ungulates.

Habitat

According to the WRNF 2002 Final EIS, no specific acreages for wolverine habitat are known because so little specific quantifiable definitions of habitat are available, but it is assumed that at least most of the alpine and subalpine areas of the Forest is habitat, along with some lower elevation areas. Trends for habitat throughout the species range are not known but are decreasing in some parts of its range due to vegetation management activities. Habitat quality and quantity trends in Colorado and on the Forest are not known because little is known about wolverine habitat in the southern Rocky Mountains and what is known has not been monitored.

According to the ARNF 1997 Final EIS, wolverines are a low-density species throughout their range and maintain a solitary existence. They mostly use subalpine coniferous forests and deciduous stands, with hunting forays taking them into vanous meadow and shrub communities. They are considered mostly a boreal species. The wolverine is an inhabitant of remote wilderness areas where development is unlikely to occur, and although it is considered that they follow their prey to lower winter elevations, their large home range and diversity in diet allow them to avoid conflicts with humans. Wolverines are believed to eat mostly carrion and are opportunistic hunters (Ruggiero et al., 1994). They do not hibemate. Only one individual has been positively identified in Colorado in the last 20 to 30 years and was near the Utah border.

Natural History

The North American wolverine occurs in the boreal forests and tundra of Canada and the northern U.S. Wolverines tend to avoid areas with human activity. Banci (1994) quotes Kelsall (1981) as stating that wolverine “habitat is probably best defined in terms of adequate year-round food supplies in large, sparsely inhabited wilderness areas, rather that in terms of particular types of topography or plant associations.” Specific preferred cover types tended to be associated with areas of high prey abundance or avoidance of high temperatures and humans (studies cited in Banci, 1994). In the Rocky Mountains, wolverines are found in coniferous forests. Ecotones with marshes, lakes, cliffs, as well as habitat type transitions, and elevational gradients also appear to be important habitat components (Hash, 1987).

The wolverine typically occurs at low numbers and has low reproductive rates with delayed sexual maturity. Trapping may have influenced the local distribution and abundance of wolverines in certain areas of their range. Fragmentation may play a role in determining the ability of transient wolverines to colonize areas that are suitable but unoccupied. Human impact at natal sites has been identified as a factor affecting the reproductive success of wolverines. This effect has a bearing on whether populations are stable, increasing, or decreasing, thereby affecting the long-term survival of this species throughout its range.

Wolverines typically breed from late spring to early fall. Young are typically born from January to April. The use of natal dens typically begins between early February and late March, and females may use multiple dens prior to weaning (Copeland, 1996). Wolverine dens are typically found in protected areas such as caves, root wads, burrows, or snow tunnels (Hash, 1987).

Environmental Baseline

Potential American wolverine habitat on National Forest System Lands includes alpine meadows/tundra, lodgepole pine forest, and spruce-fir forest. The Corridor includes high-elevation habitat thought to be suitable wolverine habitat. Both the WRNF and the ARNF contain high-elevation, rugged lands in the Corridor between Vail and Silver Plume, where elevations range from 9,000 feet to 12,600 feet. These areas are considered potential habitat due to elevation and presence of mature coniferous forest. Lodgepole pine stands with a minor component of aspen occur at the lower elevations up to about 10,000 feet, and dense spruce and fir stands cover the area up to approximately 11,500 feet.

Wolverines characteristically shun all human contact, including visual and noise intrusions. While there were three “B” rated sightings (probable) on the WRNF, two were in Eagle County and one in Gunnison County, from mountainous areas, not in the Corridor. There have been five “A” rated sightings in Colorado in the past 20 years (USDA, 2002b), only one of which was in a Corridor county (Larimer). That sighting was considerably north of the Corridor. None of the other “A” rated sightings were in a Corridor county. No specific information on the presence of wolverine in the Corridor has been documented.

Direct, Indirect, Cumulative Effects of Alternatives

Action Alternatives

Major risk factors for the species have been mortality through trapping (illegal since 1997) disturbance to individuals through human interactions, and fragmentation of habitat through vegetation management. Relatively small amounts of additional wolverine habitat would be directly affected by any of the alternatives because the Corridor intersects only minor amounts of mature forest stands. The existing I-70 highway already bisected some mature forest stands. A land bridge over the EJMT would allow wolverine to access habitat on both sides of the Corridor. Habitat in the Vail Pass area is also bisected, but no safe corridor crossing opportunities exist in that area.

Table BR - 19 and **Table BR - 20** provide estimated direct impacts on potential American wolverine habitat. In general, important habitat for wolverine includes mature forest and/or secluded areas, often protected with wilderness status. Therefore, the primary source of negative project-related effects for wolverine would be the barrier effect of the highway. Impacts on American wolverine habitat in the WRNF from the Preferred Alternative would be 8.4 acres for both the Minimum Program (55 or 65 mph) and the Maximum Program (55 or 65mph). On the ARNF, these impacts would range from 3.1 acres for the Minimum Program (55 or 65 mph) to 6.5 acres for the Maximum Program (55 or 65 mph).

For the WRNF, the greatest potential for effects on wolverine among all alternatives would result from the Combination Six-Lane Highway with Rail and Intermountain Connection alternative. The least amount of habitat disturbance for an action alternative would result from the Minimal Action and Advanced Guideway System alternatives. For the ARNF, the greatest potential for effects would also result from the Combination Six-Lane Highway with Rail and Intermountain Connection alternative, while the fewest impacts would result from the Advanced Guideway System alternative.

Table BR - 19. Direct Impacts on American Wolverine Habitat (acres): Preferred Alternative

	Minimum Program		Maximum Program	
	Specific Highway Improvements with AGS		Combination 6-Lane Highway with AGS	
	55 mph	65 mph	55 mph	65 mph
WRNF	8.4	8.4	8.4	8.4
ARNF	3.1	3.1	6.5	6.5

Data provide the minimal to maximum impacts for the Preferred Alternative.

Table BR - 20. Direct Impacts on American Wolverine Habitat (acres): Action Alternatives Evaluated in the Draft PEIS

	Minimal Action	Rail with IMC	AGS	Dual-Mode Bus in Guideway	Diesel Bus in Guideway	Six-Lane Highway 55 mph	Six-Lane Highway 65 mph	Reversible/ HOV/HOT Lanes	Combination Six-Lane Highway with Rail and IMC	Combination Six-Lane Highway with AGS	Combination Six-Lane Highway with Dual-Mode Bus in Guideway	Combination Six-Lane Highway Diesel Bus in Guideway
WRNF	3.2	11.4	4.5	5.6	5.6	5.5	5.5	5.6	14.1	8.4	8.5	8.5
ARNF	2.1	5.2	0.9	1.4	1.4	2.9	3.0	4.6	8.6	6.5	6.3	6.3

Indirect effects would include road effect zone-related disturbance and habitat fragmentation due to induced growth. However, action alternatives would include developing crossing structures into the design.

USFS actions that may affect wolverine populations include timber management, fire management, recreation, developments, utility corridors, ski areas, and large resorts. Because little detailed information is known about the specifics of wolverine habitat needs, habitat management prescriptions that encompass the life needs of lynx and American marten (*Martes americana*) also will benefit wolverines at the stand level (Banci, 1994). The 2002 WRNF Plan directs management for lynx, including maintaining denning and other habitat, and limiting or restricting actions that may result in disturbance or habitat alterations, such as ski area developments, winter recreational use, and vegetation management. While these Standards and Guidelines are not specifically designed for wolverine management, they will likely provide many of the habitat and solitude requirements for wolverines. Recreation poses a significant risk factor for wolverines especially in the late winter to early summer during denning and kit rearing seasons. Copeland (1996) found that wolverines abandoned their dens as a result of contact with field personnel.

The WRNF includes approximately 754,000 acres of wilderness, about one-third of the Forest. All of these eight wilderness areas include most of the alpine and subalpine areas of the Forest and represent the majority of the possible wolverine habitat on the Forest. These wilderness areas allow no vegetation treatments (except for prescribed fire) or motorized or mechanized recreational use. Some of these areas receive considerable hiking and horse riding use in the summer, but these activities generally occur only along established trails. Very few activities occur in these areas in the winter. Because the acres of wilderness area do not change by alternative, potential impacts would generally be the same for all alternatives.

Eight wilderness areas have been designated on the ARNF, representing 295,572 acres, or approximately 23 percent of the Forest. Of those acres, 78 percent is in alpine, spruce-fir, and spruce-fir-lodgepole pine stands. Forest Plan management emphasis will be to allow natural processes to be maintained or improved within wilderness, while identifying unacceptable impacts created by human use. Recreational use will be more intensely managed and may result in the loss of some types of opportunities (USDA, 1997). Wilderness use close to the Front Range population is increasing slightly, while more remote areas on the ARNF have stable or decreasing use. With a projected population increase of one-half million people in Colorado's Front Range by the year 2010, it is expected that wilderness use will continue to show some moderate increases (USDA, 1997). Any increases in wilderness use may serve to decrease the suitability of the area as wolverine habitat.

Additionally, the ARNF contains 38 roadless areas totaling 330,230 acres. These large, unroaded tracts provide the Forest with opportunities to manage for potential wilderness areas and effective wildlife habitat, among other uses (USDA, 1997). To the degree these areas are managed for wilderness and wildlife habitat, they have a greater potential to serve as wolverine habitat.

Forest Plans will maintain linkages and corridors between refugia/suitable habitats. Transient and dispersing wolverines may play an important role in maintaining viable wolverine populations (Banci, 1994). Forested landscape linkage areas were identified to provide areas for landscape scale movement, migration, and dispersal of forest carnivores and other wide-ranging wildlife species between forested landscapes across the Forest. Human use and management activities are restricted in these areas.

Guidelines and standards in the ARNF Forest Plan include protecting landscape linkage areas that facilitate multidirectional movement of species among important habitats such as late-successional forests, high-elevation tundra, meadows and forests, lower-elevation forests, shrublands, and prairies (Guideline 40). One Standard (50) in the Plan is to manage activities to avoid disturbance to sensitive species, which would result in a trend toward federal listing or loss of population viability. Special attention is given to breeding, young-rearing, and other time periods that are critical to survival of both flora and fauna. Another Standard (51) requires the closing of areas to activities to avoid disturbing threatened, endangered, and proposed species during breeding, young-rearing, or other times critical to survival (Guideline 40).

During the life of the WRNF Plan, it is difficult to predict the habitat trend because events such as catastrophic fire and insect epidemics are unknown, and very little is known about the specific habitat requirements of wolverines. Because most of what is considered wolverine habitat is in wilderness areas, it is anticipated that the overall trend for habitat quality and quantity will be stable. Even though habitat quality and quantity are expected to be stable during the life of the 2002 Forest Plan, impacts on the trends of existing or future populations is not known. It is unlikely that any change in wolverine numbers on the Forest will be measurable during the life of the 2002 Forest Plan because populations would be very low if any individuals were present.

Wolverine would also probably be sensitive to impacts occurring in lynx linkage areas on both forests, as these zones represent connections between large blocks of undeveloped forest habitat that is important to both species. These impacts could potentially have population-wide, as well as individual effects, until animals find and use the safe crossing structures planned. In addition, increased use of the Forest by a large human population base has the potential to displace wolverine from key habitats or essential parts of their ranges. Efforts also would be made to avoid or minimize impacts on wolverine by constructing wildlife crossing structures and improvements to existing structures to reduce the barrier effect of I-70. This would occur in areas in the Corridor that are especially important linkage zones for mammals.

No Action Alternative

No amount of new habitat disturbance would occur with this alternative. The current effects of I-70 on wolverine, including the barrier effect of the highway and potential for roadkill, would remain because no new crossing structures would be built, except possibly one near the top of Vail Pass. This overpass structure is currently in the planning process independent of the proposed action. Wolverine travel over great distances and the existing land bridge at the EJMT is currently the only safe area for passage by wolverine traveling in a north-south direction. Given the sensitive and reclusive nature of the wolverine, their potential to approach the highway or use a crossing structure must remain speculative.

Determination of Effects and Rationale

Action Alternatives

The Six-Lane Highway alternatives would disturb the greatest amount of potential wolverine habitat and the Bus in Guideway alternatives would disturb the least. The Six-Lane Highway alternatives may result in marginally more noise than other alternatives and thus would have a marginally greater intrusion on the solitude element of wolverine-preferred habitat. While there may be site-specific differences among alternatives, there would be no measurable differences among any of the alternatives on the wolverine population on the Forest. The action alternatives **may adversely impact individuals, but not likely to result in a loss of viability in the planning area, nor cause a trend to federal listing.**

No Action Alternative

The No Action Alternative would have no direct impacts on potential wolverine habitat. However, barrier effects and the potential for roadkill associated with increasing traffic and congestion on I-70 would continue to impact individuals. No project mitigation measures, including crossing structures, are associated with the No Action Alternative. Therefore, the No Action Alternative **may adversely impact individuals, but not likely to result in a loss of viability in the planning area, nor cause a trend to federal listing.**

Bighorn Sheep (*Ovis canadensis*), FS, MIS

Bighorn sheep are large mammals in the family Bovidae, genus *Ovis*. The average bighorn sheep measures 73 inches in length and weighs 330 pounds. Bighorn sheep are primarily active during daylight hours (diurnal).

In addition to being a Forest Sensitive species, the bighorn sheep are MIS on the ARNF for openings within and adjacent to the Forest. This species, however, occurs in open habitats on and near rocky cliffs and outcrops above tree line and also in such habitats at lower elevations through the Montane Zone. Habitat evaluation was conducted by mapping alpine meadows, barren lands, grass/forb meadows, mountain shrublands, Douglas-fir, and ponderosa pine. These habitats were mapped on lands on and near ARNF lands along I-70 from EJMT down to east of Idaho Springs beyond Forest lands.

Distribution

The distribution for bighorn sheep once covered much of western North America, from central British Columbia, south to Baja, California, and from the Sierra Nevada in California to the badlands of the Dakotas and Nebraska (Armstrong, 1987).

In Colorado, the species is present in the Corridor counties of Clear Creek, Summit, Eagle, and Garfield, as well as most other mountainous counties in the state (Fitzgerald et al., 1994). They are frequently observed alongside the I-70 Corridor from the Idaho Springs vicinity (milepost 240) to near Floyd Hill (milepost 245). In Colorado, bighorn sheep occupy montane shrublands, montane and subalpine forests, and alpine tundra habitats. They prefer habitat with high visibility, dominated by grasses, low shrubs, and rock cover, with good escape terrain and topographic relief (Fitzgerald et al., 1994). Bighorn sheep habitat has been reduced by fire suppression and the encroachment of trees and shrubs on grasslands (Lindsay, undated).

Natural History

Mating season varies throughout the range, July to January, as females are probably seasonally polyestrous. Rutting season is usually in November in the northern ranges (Shackleton et al., 1999). Gestation lasts about 175 days (Geist, 1971; and Shackleton et al., 1999). Lambing generally peaks in May (occasionally April or June) (Krausman et al., 1999; and Shackleton et al., 1999). Litter size is usually one lamb and, rarely, two (Geist, 1971; and Turner and Hansen, 1980). Young are weaned in 4 to 6 months.

Lamb-to-ewe ratios of the Georgetown herd average 59:100, although the ratios varied widely over a 7-year monitoring period. Declining populations often are caused by high lamb mortality, possibly from lungworm-induced pneumonia, but lamb mortality also occurs from weather and from predation by coyotes, bobcats, mountain lions, and golden eagles (*Aquila chrysaetos*) (Fitzgerald et al., 1994).

Populations typically migrate between an alpine or montane summer range and a lower elevation winter range (Shackleton et al., 1999), and may occupy as many as five separate ranges during a year (Geist, 1971). This vertical migration is probably a response to the increasing abundance of nutritious new vegetative growth at higher elevations as spring and summer progress (Shackleton et al., 1999). The downward migration is motivated by snow accumulation in the high-elevation summer ranges (Shackleton et al., 1999).

Sheep almost exclusively eat grass and grass-like forbs with some browse, although browse often becomes a more prominent part of winter diets, especially at lower-elevation winter ranges (Fitzgerald et al., 1994).

Environmental Baseline

Habitat for bighorn sheep includes alpine meadows, tundra, aspen forest, barren land, grass/forb meadows, lodgepole pine forest, mountain shrubland, ponderosa pine forest, and spruce-fir forest.

The project area occurs through several bighorn sheep summer and winter ranges and lambing areas. Winter and summer range on the ARNF occurs on the south-facing slopes above I-70 from near Herman Gulch (milepost 222) to near Floyd Hill (milepost 245), and lambing areas occur west of Georgetown (milepost 228 to milepost 230). Population trends of the Georgetown herd have been relatively stable since 1997, although a low was observed in 2003 (see **Table BR - 21**). ARNF and Colorado trends have varied between 1997 and 2008, decreasing somewhat over that time (12.0 and 9.1 percent, respectively) (see **Table BR - 21**).

Table BR - 21. Bighorn Sheep Post-hunt Population Estimates in and near ARNF (CDOW, Big Game Statistics, 2008)

Herd Name	GMUs in and near ARNF	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Poudre River	S1	150	120	120	120	115	105	95	95	65	55	55	60
Mount Evans	S3	240	200	200	200	200	160	125	125	175	100	90	80
Rawah	S18	**	40	40	40	30	30	45	45	20	15	15	15
Never Summer Range	S19	175	100	100	50	50	50	50	25	25	25	25	25
Georgetown	S32	350	350	450	450	450	400	250	300	300	400	400	375
St. Vrain	S37	***	80	80	80	80	100	100	100	100	100	50	50
Big Thompson	S57	140	60	50	50	60	80	80	80	80	80	85	100
Lower Poudre	S58	60	40	40	40	30	30	30	30	25	25	20	15
Rocky Mtn. National Park	N/A	130	130	400	350	350	350	450	450	375	375	375	375
In and near ARNF Totals		**1245**	**1120**	**1480**	**1380**	**1365**	**1305**	**1225**	**1250**	**1165**	**1175**	**1115**	**1095**
Statewide Totals		7720	7245	7455	7535	7590	7495	7465	7365	7275	7330	7040	7015

*** Lumped with S1.*

****Lumped with S57.*

Summer and winter range on the WRNF occurs north of I-70 from just east of Glenwood Springs (milepost 120 to milepost 128) and in the Vail area (milepost 177 to milepost 182). Population trends of the herds within the WRNF have been relative stable, although the Snowmass West herd has declined in recent years. WRNF bighorn population trends overall show a modest decrease of 8.3 percent (see **Table BR - 22**).

Table BR - 22. Bighorn Sheep Post-hunt Population Estimates in and near WRNF (CDOW, Big Game Statistics, 2008)

Herd Name	GMUs in and near ARNF	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Gore-Eagle's Nest	S2	80	80	80	100	100	100	100	100	100	100	100	80
Snowmass East	S13	100	100	100	100	75	75	115	115	110	110	110	70
Clinetop Mesa	S14	20	20	10	10	10	10	10	10	5	5	5	5
Battlement Mesa	S24	25	25	25	25	20	20	20	20	20	25	30	50
Snowmass West	S25	125	125	125	125	125	125	125	125	125	125	75	67
Basalt	S44	75	85	85	100	100	100	100	100	100	100	100	100
Derby Creek	S59	65	65	80	115	115	115	115	115	90	90	90	90
Flattops (S. Fork White River)	S67	75	75	75	60	60	60	60	60	40	40	40	40
Glenwood Canyon	S74	15	15	15	15	15	15	15	15	35	35	35	30
In and near WRNF Totals		**580**	**590**	**595**	**650**	**620**	**620**	**660**	660	625	630	585	532
Statewide Totals		7720	7245	7455	7535	7590	7495	7465	7365	7275	7330	7040	7015

Direct, Indirect, and Cumulative Effects of Alternatives

Action Alternatives

In addition to the potential for key and MIS habitat losses, I-70 restricts bighorn sheep from moving between seasonal ranges, and in some cases, restricts daily movements to attain full habitat usage such as feeding, hiding, and finding bedding cover. Alternatives would have the potential to exacerbate this barrier effect and effectively block movement and migration corridors, which would have serious consequences for many of the herds along the Corridor. Major sources of impacts on bighorn sheep mobility throughout the Corridor include the following:

- Road effect zones
- Barrier effect and animal-vehicle collisions (AVCs)

Direct Effects

Increases in road effect zone disturbances (additional noise, traffic volume, and human presence) would be likely to affect bighorn sheep to some extent along I-70. Bighorn sheep, however, currently are acclimated to traffic on I-70, often foraging along the shoulders of the road. Escape and flight behavior usually occurs if a vehicle stops and occupants get out to view the animals.

Key summer and winter ranges lie adjacent to the Corridor in a number of areas within the WRNF and the ARNF. The extent to which sheep attempt to cross the highway seems to be limited along the Corridor. However, sheep do frequent the edge of the highway to lick salts and to access water, and they are occasionally struck by vehicles. AVCs were documented over the period 2000 to 2004 along I-70. The average rate of AVCs was 1.2 collisions per mile per year, but the range of AVCs at different locations ranged from 0.4 to 4.4. The data indicated that linkage interference zones with AVCs of 1.4 or less could be considered "normal" and AVCs greater than 1.4 could be considered a trouble spot where animals were frequently trying to cross I-70. Of the 15 linkage interference zones, the greatest rate of AVCs (4.4) was in Linkage Interference Zone 13, Mount Vernon Canyon. The second highest AVCs (2.95) were reported for Linkage Interference Zone 4 in the Avon area. While the linkage interference zones for the Empire and Dowd Canyon areas had AVCs of 2.0 and 1.6, respectively, all other linkage interference zones had AVCs below 1.0. The ALIVE Committee has suggested placing cement barriers at the edge of the shoulder as a means of reducing AVCs to bighorn sheep.

Any increase in connectivity between habitats would also benefit the populations as a whole. Therefore, the action alternatives that would extend along the greatest length of the Corridor and cross the most linkage interference zones would have the greatest potential to improve habitat connectivity for elk and to reduce AVC frequencies on the ARNF. Out of the four linkage interference zones east of the Continental Divide, one is within the ARNF near Herman Gulch, and two are near and between blocks of the ARNF (at Empire and Fall River). The Mount Vernon Canyon linkage interference zone is farther removed from the ARNF but interferes with the same sheep herds that also use ARNF lands.

West of the Continental Divide, one linkage interference zone is just east of the WRNF in the Dotsero area near Glenwood Canyon. While not within the WRNF, this linkage interference also interferes with the same sheep herds that also use WRNF lands.

Key Habitat Change

Table BR - 23 and **Table BR - 24** provide estimated direct impacts on potential bighorn sheep habitat. There would be no impacts on bighorn sheep habitat in the WRNF from the Preferred Alternative. On the ARNF, these impacts would range from 1.4 acres for the Minimum Program (55 or 65 mph) to 3.6 acres for the Maximum Program (55 or 65 mph).

For the WRNF, the greatest potential for effects on bighorn sheep among all alternatives would result from the Rail with Intermountain Connection and Combination Six-Lane Highway with Rail and Intermountain Connection alternatives (0.4 acres). The least amount of habitat disturbance for an action alternative would result from the Minimal Action, Advanced Guideway System, Highway, and Combination Six-Lane Highway with Advanced Guideway System alternatives, with no impacts. For the ARNF, impacts among all alternatives would range from 0.4 (Advanced Guideway System) to 4.8 acres (Combination Six-Lane Highway with Rail and Intermountain Connection).

Table BR - 23. Direct Impacts on Key Bighorn Sheep Habitat (acres): Preferred Alternative

	Minimum Program		Maximum Program	
	Specific Highway Improvements with AGS		Combination 6-Lane Highway with AGS	
	55 mph	65 mph	55 mph	65 mph
WRNF	0.0	0.0	0.0	0.0
ARNF	1.4	1.4	3.6	3.6

Data provide the minimal to maximum impacts for the Preferred Alternative.

Table BR - 24. Direct Impacts on Key Bighorn Sheep Habitat (acres): Action Alternatives Evaluated in the Draft PEIS

	Minimal Action	Rail with IMC	AGS	Dual-Mode Bus in Guideway	Diesel Bus in Guideway	Six-Lane Highway 55 mph	Six-Lane Highway 65 mph	Reversible/ HOV/HOT Lanes	Combination Six-Lane Highway with Rail and IMC	Combination Six-Lane Highway with AGS	Combination Six-Lane Highway with Dual-Mode Bus in Guideway	Combination Six-Lane Highway Diesel Bus in Guideway
WRNF	0.0	0.4	0.0	0.3	0.3	0.0	0.0	0.0	0.4	0.0	0.3	0.3
ARNF	0.6	3.4	0.4	0.8	0.8	1.6	1.6	2.7	4.8	3.6	3.3	3.3

Population Change

Population changes from habitat losses would be unlikely. Indirect impacts that would occur during construction may force sheep to move farther from the road. The extent to which this could affect populations is unknown and will be addressed specifically in Tier 2 processes. Restricting sheep from highway shoulders and travel lanes would slightly increase population levels by reducing AVCs. Construction effects on key bighorn sheep habitat are unlikely to change population trends of bighorn sheep in the ARNF, as the amount of habitat lost would be small (0.003 percent) in relation to the 158,716 acres available within the ARNF (Colorado Division of Wildlife WRIS data, winter range, summer range, and lambing).

Indirect and Cumulative Effects

In Clear Creek County, induced traffic from alternatives would not be expected to induce growth, based on past growth trends. Susceptibility to changes in population due to induced or suppressed travel demand would be limited to Eagle and Summit counties, outside National Forest System Lands. Clear Creek County is not expected to experience growth-inducing effects from project alternatives (see Chapter 3, Section 3.9 of the Draft PEIS).

Planned population growth in areas outside the ARNF is expected to increase human recreational use of areas that are important sheep habitat, including lambing areas. Thus, additional forest restrictions of human use may be required in certain areas and during parts of the year that are critical to this species. Continued human population growth and associated developments would have the potential to increase human intrusion into bighorn sheep traditional winter and summer ranges and lambing areas, which could affect herd dynamics on the ARNF. A larger human population probably would increase the recreational use of the Forests, which, in turn, would increase the disturbance factor and may require strict enforcement of use restrictions near lambing areas and winter ranges.

Other actions, such as fire/fuel management and ski area development on ARNF lands, may cause cumulative impacts on bighorn sheep habitat by reducing or fragmenting existing habitat. Other cumulative effects include snowmobile and ATV use within the ARNF, which could affect bighorn sheep habitat. The Combination and Highway alternatives would be associated with possible increased dispersed recreation activities that would include snowmobile and ATV use.

Determination of Effects and Rationale

Action Alternatives

All of the action alternatives would have the potential to increase the road effect zone (increased noise and traffic activities) in bighorn sheep habitat. Conversely, the alternatives would also provide opportunities to reduce the AVCs by restricting wildlife access to traffic lanes. Induced growth would probably result in increased recreation on the ARNF and an increase in human intrusion into key sheep habitats. Thus, USFS may need to restrict recreation in key habitats during certain times of the year.

Based on the analyses conducted, there is no viability risk (the potential for populations to substantially decrease) for this species in Colorado, and none of the alternatives being considered for this project would threaten the viability of bighorn sheep within the project area of influence or change population trends on the ARNF or throughout the sheep range. The action alternatives **may adversely impact individuals, but not likely to result in a loss of viability in the planning area, nor cause a trend to federal listing.**

No Action Alternative

The No Action Alternative would not affect bighorn sheep habitat, as the roadway template will remain as is. Increases in traffic volumes, however, would be anticipated to increase road effect zone and AVC effects on sheep. Therefore, the No Action Alternative **may adversely impact individuals, but not likely to result in a loss of viability in the planning area, nor cause a trend to federal listing.**

BR.4.1.2 Birds

Bald Eagle (Haliaeetus leucocephalus), FS

The bald eagle is a very large diurnal raptor, which belongs to the order Falconiformes and the family Accipitridae, and is the only member of the genus *Haliaeetus* in North America. The bald eagle is a threatened species that is currently documented to occur on National Forest System Lands, in both the ARNF and the WRNF. Delisting of the bald eagle from its formerly federally threatened status became effective August 8, 2007.

Distribution

The current range of the bald eagle includes all of the U.S. and much of Canada. It is especially common in areas with extensive aquatic habitat (USFWS, 2005). In Colorado, bald eagles may be found nesting in trees lining reservoirs on the Eastern Plains and in cottonwood (*Populus deltoides*) or pine trees along the major rivers of the Western Slope.

There were 51 nesting pairs in Colorado in 2000 and approximately 1,000 bald eagles winter in the state as well (CDOW, 2001). There are 87 described bald eagle nest sites in Colorado, 79 of which are considered active. A site is considered active if it has had known occupancy in the last 5 years. Because approximately 75 percent of known active sites are occupied in any given year, it is believed that approximately 60 sites are currently occupied in Colorado. The breeding bald eagle population has increased substantially over the last 30 years, and the increase appears to be continuing. In 1974, there was one known nesting pair within the state. By 1989 the number of nesting pairs had increased to 10 and then to 14 by 1994. In the following 5 years, the known breeding number doubled to 29 in 1999 and has doubled again since then. The number of known breeding sites has increased by 16 in the past 3 years. Approximately one-third of the breeding sites are found east of the Continental Divide within the South Platte River watershed. Other breeding concentrations include the Yampa River upstream of Craig, the White River in the vicinity of Meeker, the Colorado River upstream of Kremmling, the Colorado River near Rifle, along the Roaring Fork River, and in La Plata and Montezuma counties. Colorado Division of Wildlife monitors the outcome at greater than 40 nests yearly. The recent success rate of monitored nests is near 70 percent, with 1.19 young fledged per occupied site, and 1.72 young fledged per successful site (CDOW, 2005b).

Colorado Division of Wildlife has conducted aerial midwinter counts of bald eagles since 1981. The number of wintering eagles increased steadily through the 1980s from the low count of 418 eagles in 1981 to the early 1990s. Since 1992, the number of wintering eagles has varied substantially but has not shown any apparent trend, averaging 887 eagles, ranging from a high count of 1,235 in 1994 to a low count of 595 in 2001 (CDOW, 2005b).

Approximately 75 percent of the Colorado nests are in plains or narrowleaf cottonwood (*Populus angustifoia*) trees, while the remaining 25 percent are in conifers. The Colorado Breeding Bird Atlas does not record evidence of breeding bald eagles in Eagle, Summit, or Clear Creek counties. There is documentation of a minimum of four breeding pairs in Garfield County in 2006 (K. Giezentanner pers. comm. with L. Hettinger, 2006b) and from the southwestern portion of Jefferson County (Kingery, 1998). Bald eagles primarily feed on fish, although they also eat small mammals, carrion, birds, various turtles, and snakes. Eagles are also opportunistic and will steal food from other raptors, including other eagles (Ehrlich et al., 1988). Because fish and waterfowl are an important part of their diet, they primarily choose habitats near water.

Throughout its range, the bald eagle has suffered population declines from habitat loss, mortality from shooting and poisoning, and reduced reproductive success from ingestion of contaminants (such as DDT). As a result, the bald eagle was federally listed as endangered on March 11, 1967 (32 FR 4001). Although bald eagles face numerous threats throughout the 48 states, they have recovered from dramatic population declines over the past several decades. Consequently, delisting of the bald eagle became effective on August 8, 2007. The bald eagle continues to receive protections under the Migratory Bird Treaty Act (MBTA), under the Bald and Golden Eagle Protection Act (BGEA), and through the state. In addition, USFWS is in the process of developing a permitting system to authorize take of bald eagles under the BGEPA.

There are no documented winter roosts on the WRNF, but nests and winter roosts are adjacent or near the Forest (USDA, 2002c), and one historic osprey nest on the WRNF was attended by a pair of bald eagles in 2006. No eggs or incubation has been documented for this pair (K. Giezentanner pers. comm. with D. Solomon, 2006a).

Natural History

The average lifespan of bald eagles is 15 to 20 years. Bald eagles become sexually mature at 4 to 5 years of age. Breeding pairs mate for life (Ehrlich et al., 1988). Generally, clutch size is two to three eggs. The laying rate is approximately 2 to 5 days after the first egg is laid, and incubation follows laying of the first egg. Incubation lasts 35 days (Harrison, 1979). The nestling stage lasts 77 days, and first flight occurs around day 112. If the first clutch fails, the female may lay a second clutch after 4 or more weeks. Both parents feed the eaglets, but one parent remains in constant attendance of the nest for the first 2 weeks. Eaglets generally leave the nest around 13 weeks but usually return to the general region of their birth at ages 1 to 3 years (Palmer, 1988). In Colorado, bald eagles tend to build large stick nests in the forks of large, mature cottonwoods or pines that allow them a wide field of vision as part of their critical habitat.

Bald eagles that spend the winter in Colorado tend to return to breeding grounds in Saskatchewan and Manitoba from January to March (Harmata and Stahlecker, 1993).

Environmental Baseline

Known winter range and roosting habitats in the Corridor include areas along the Colorado, Eagle, and Blue river valleys (BLM, 2001). Potential habitat of the bald eagle is grasslands, forb meadows, wetlands, springs/fens, and riparian areas. For the purposes of this study, any impacts on these areas within the Corridor were quantified as impacts on bald eagle habitat.

Surveys have not documented any bald eagle nests within the Corridor (K. Giezentanner pers. comm. with L. Hettinger, 2005; and W. Andree pers. comm. with D. Solomon, 2006). The Colorado Division of Wildlife Natural Diversity Information Source (NDIS) also indicates that no known nests occur within the Corridor (**ndis.nrel.colostate.edu**).

Colorado Division of Wildlife confirmed that there are no documented nests along the Corridor in Eagle County (W. Andree pers. comm. with D. Solomon, 2006). There are no active nests in Summit County, but the Blue River corridor and especially the area near the river inlet into Dillon Reservoir is used for summer roosting and winter foraging (Schwab, 2006). Nesting records of bald eagle on the Sulphur

District of the ARNF show four active nest sites from 1995 to 2004. These nest sites are on water bodies approximately 30 miles north of the Corridor.

Direct, Indirect, and Cumulative Effects of Alternatives

Action Alternatives

No documented nesting sites are within one-fourth mile of any of the alternatives (K. Giezentanner pers. comm. with L. Hettinger, 2005); therefore, no direct impacts on bald eagle nesting would occur from the action alternatives.

Table BR - 25 and **Table BR - 26** provide the estimated direct impacts on bald eagle nest sites, winter concentration, winter range, communal roosts, and roost sites. Known roost sites along the Eagle River between milepost 57 and milepost 58 may or may not be close enough to construction activities in the Corridor that roosting eagles could be disturbed.

The Preferred Alternative would affect 2.6 acres of bald eagle habitat in the WRNF. No impacts are anticipated from the Preferred Alternative on the ARNF.

Impacts from all alternatives on the WRNF would result from highway components. The Advanced Guideway System and Bus in Guideway alternatives would not be anticipated to affect any bald eagle habitat. Because there are no documented nesting sites within one-fourth mile of any of the alternatives, no direct impacts on bald eagle nesting would occur from the action alternatives. The minimal direct impact on bald eagle habitat associated with construction of action alternatives is not likely to affect sources of carrion or other prey species.

No impacts are anticipated to result from any alternatives on the ARNF. Nesting records of bald eagle on the Sulphur District of the ARNF show four active nest sites from 1995 to 2004. The bald eagle nests are approximately 30 miles north of the Corridor and would not be affected by project activities. Bald eagles are observed at many locations on the ARNF along the Front Range, but eagle presence in the Corridor is expected to be incidental.

Table BR - 25. Direct Impacts on Bald Eagle Habitat (acres): Preferred Alternative

	Minimum Program		Maximum Program	
	Specific Highway Improvements with AGS		Combination 6-Lane Highway with AGS	
	55 mph	65 mph	55 mph	65 mph
WRNF	2.6	2.6	2.6	2.6
ARNF	0.0	0.0	0.0	0.0

Data provide minimal to maximum impacts for the Preferred Alternative.

Table BR - 26. Direct Impacts on Bald Eagle Habitat (acres): Action Alternatives Evaluated in the Draft PEIS

	Minimal Action	Rail with IMC	AGS	Dual-Mode Bus in Guideway	Diesel Bus in Guideway	Six-Lane Highway 55 mph	Six-Lane Highway 65 mph	Reversible/ HOV/HOT Lanes	Combination Six-Lane Highway with Rail and IMC	Combination Six-Lane Highway with AGS	Combination Six-Lane Highway with Dual-Mode	Combination Six-Lane Highway Diesel Bus in Guideway
WRNF	2.6	0.0	0.0	0.0	0.0	2.6	2.6	2.6	2.6	2.6	2.6	2.6
ARNF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

The primary indirect impact from action alternatives would be potential disruption of bald eagle activities using traditional winter range. There are documented roosts and winter range in the Eagle River Valley, outside National Forest System Lands (NDIS, 2006), and these areas could be negatively affected by induced growth associated with action alternatives. All action alternatives, except the Minimal Action Alternative, would be associated with some degree of possible induced growth in Eagle County.

Direction in the 2002 Forest Plan for developing and implementing plans and prohibiting activities that may disturb nesting or winter roosting eagles will be implemented, if necessary, to protect roosting sites. Consultation with USFWS will be initiated for any nests or winter roosts that are found on or near the WRNF. Activities on the WRNF may affect bald eagle foraging behavior and habitat since some of these areas occur on or adjacent to the Forest. Recreation management activities could affect the foraging behavior of bald eagles at some of the lakes, reservoirs, or rivers that provide forage fish. Eagles using these areas are likely accustomed to the existing levels of disturbance from boating, fishing, and other uses.

Forest-wide impacts for both ARNF and WRNF would be minimal because direct impacts on bald eagle habitat are negligible in comparison with total habitat on the Forests and indirect impacts from alternatives are not expected to affect overall populations with the implementation of forest management activities. There are no nesting sites on National Forest System Lands within the APE, and all potential impacts are associated with winter range habitat on ARNF and WRNF. In addition, other protection measures for individuals and habitat are being implemented with all action alternatives as required by USFWS and by Colorado Division of Wildlife.

No documented nesting sites are within one-fourth mile of any of the alternatives; therefore, no direct impacts on bald eagle nesting would occur from the action alternatives. Roosting sites along the Eagle River may or may not be close enough that eagles could be disturbed. Direct impacts on foraging habitat are estimated to be minimal. Increased human activities and land development in the Eagle River Valley may potentially decrease aquatic habitat quality and the number of prey species available to eagles.

Combination alternatives would be associated with the greatest degree of possible induced growth, followed by Highway alternatives. Transit alternatives would be associated with the least possibility for induced growth that would negatively affect eagles because growth would be centered on existing urbanized areas.

Cumulative Effects

Cumulative impacts would include planned growth and possible induced growth associated with alternatives. An increase in human activities and development in the Eagle River Valley could lead to a decrease in aquatic habitat quality and, in turn, a decline in fish and waterfowl that bald eagles use as prey. In addition, activities on the WRNF near these nests and roosts include recreation, road use, vegetation management and possibly special uses, which could possibly disturb individuals that are nesting and winter roosting near the Forest.

Cumulative effects may occur when livestock, timber, and other management activities result in alteration to fish habitat (such as water quality and riparian vegetation), but 2002 Forest Plan Standards and Guidelines directing the protection and maintenance of fish habitat and water quality (Chapter 2, Water and Riparian Resources) are likely to maintain the quality of fish habitat and to maintain the available fish as forage for bald eagles in the WRNF.

Cumulative impacts would include planned growth and possible induced growth associated with alternatives. One result of increases in planned development and induced growth is that they can lead to an increase in sediment and contaminants running off into receiving streams. If such runoff contributes to a decrease in water quality or aquatic habitat quality, an end result may be a decline in fish and waterfowl that bald eagles use as prey.

No Action Alternative

Impacts such as general noise disturbance may be expected to increase with the No Action Alternative from increased traffic volumes. The No Action Alternative is not anticipated to create any additional effects on bald eagles.

Determination of Effects and Rationale

All action alternatives **may adversely impact individuals, but not likely to result in a loss of viability in the planning area, nor cause a trend to federal listing.**

This determination is based on the consideration that no documented nesting sites are within one-fourth mile of any of the alternatives; therefore, no direct impacts on bald eagle nesting would occur from the action alternatives. Direct impacts on foraging habitat are estimated to be unmeasurable on National Forest System Lands. Increased human activities and land development in the Eagle River Valley may potentially decrease aquatic habitat quality and the number of prey animals available to eagles. Combination and Highway alternatives would be associated with the greatest impact from possible induced growth. The Minimal Action Alternative would not be associated with possible effects from induced growth; therefore, it would have the least induced growth impacts on the bald eagle.

No Action Alternative: **No impact.**

This determination is based on the consideration that although impacts such as general noise disturbance may be expected to increase with the No Action Alternative from increased traffic volumes, the No Action Alternative is not anticipated to create any additional effects on bald eagles.

Northern Goshawk (*Accipiter gentilis*), FS

The northern goshawk is a diurnal raptor that is the largest and heaviest bodied of the three North American accipiters. They are part of the order Falconiformes, the family Accipitridae, and the genus *Accipiter*. They have long, broad wings; a long, rounded tail; and stout legs and feet (Squires and Reynolds, 1997). They typically measure 21 inches long, with a wingspan of 41 inches, and weigh 2.1 pounds. The females tend to be larger than the males (Sibley, 2000). The species is currently documented to occur on ARNF and WRNF lands.

Distribution

The northern goshawk has a holarctic distribution and occupies a wide variety of boreal and montane forest ecosystems from the boreal forests of north-central Alaska to Newfoundland and south to the southwestern montane forests of the U.S., including the eastern foothills of the Rocky Mountains (Squires and Reynolds 1997).

In North America they breed throughout Canada and the northern and western U.S., and south into Mexico. In Colorado, the northern goshawk is moderately widespread throughout the western 50 percent of the state and has been documented throughout most of the Western Slope counties, except for the extreme northwestern corner of the state. Confirmed breeding sites across the state indicate a very patchy distribution with most concentrated in the north-central and southwestern portions of the Western Slope. Breeding populations usually were found in western Colorado including Park, Chaffee, and Gilpin counties although the northern goshawk probably breeds in forest habitats around the state. The species conservation assessment indicates that winter sightings included Arapahoe, Jefferson, Eagle, Boulder, Garfield, and Clear Creek counties (Kennedy, 2003). The Colorado Breeding Bird Atlas documents confirmed breeding occurrence in Garfield, Summit, and Clear Creek counties. At least 22 goshawk nests/territories have been documented on the WRNF in the Biological Evaluation for the Forest Plan (USDA, 2002a). The goshawk is a sensitive species on both the WRNF and ARNF.

In Colorado, goshawks occur at elevations of 7,500 to 11,000 feet (NatureServe, 2006; and Kennedy 2003) and 64 percent of Breeding Bird Atlas observations occurred in coniferous forests. In

Grand County, goshawks occur uncommonly year-round within aspen and coniferous forests and also in riparian, wetland, and meadow habitats. Goshawks have been documented to breed primarily in upland conifer and aspen forest in Colorado (Kingery, 1998). Areas of the Corridor within the elevation range of the goshawk extend from milepost 150 (east of Eagle) to milepost 255, near Genesee, except for the EJMT area, which is above their elevation range.

USFS Southwest, Rocky Mountain, and Intermountain regions have listed this species as a sensitive species, and USFWS has been petitioned twice to list the northern goshawk as threatened or endangered. The Rocky Mountain Region does not have specific direction for the management of goshawks. There are some indications that populations have declined due to timber management activities on National Forest System Lands. USFWS stated (FR Vol. 63, No. 124, June 29, 1998) that listing was not warranted because there is no evidence that the goshawk population is declining in the western U.S., that habitat is limiting the overall populations, that there are no significant areas of extirpation, or that significant curtailment of the species' habitat or range is occurring.

Population trends are difficult to determine due to the paucity of historic quantitative data and because of biases inherent in the various methodologies used to track bird populations. Recent data (1990s) from Routt National Forest depict declining goshawk breeding success, some of which was caused by logging activities but also may be due to natural fluctuations (Kingery, 1998). In the western U.S., clearcut logging of old-growth forests, fire suppression, and catastrophic fire are postulated to be reducing habitat and thus populations. However, conclusive data supporting the purported decline in the western U.S. are lacking (NatureServe, 2006). Christmas Bird Count (CBC) data (1959–1988), North American Breeding Bird Survey (BBS) data (1966–1996), and counts of migrants in the eastern U.S. (1972–1987) do not indicate any changes in populations (RMBO, 2005).

Natural History

Northern goshawks inhabit mature forests of various cover types including aspen, lodgepole and ponderosa pine, and spruce-fir. Individuals feed primarily on birds (small and medium-sized and grouse) and small mammals (red squirrels [*Tamiasciurus hudsonicus]*, ground squirrels [*Spermophilus parryii* spp.], rodents, and hares). They may use marshes, meadows, and riparian zones for foraging (NatureServe, 2006; and Kennedy, 2003). Regardless of the cover type, goshawks require large blocks of forest for nesting and foraging. Goshawks tend to select nest trees on shallow slopes, flat benches in steep country, and fluvial pans on small stream junctions. Nest sites are often associated with small (less than 1 acre) openings (Kingery, 1998).

In the western U.S., goshawks characteristically nest in coniferous forests including those dominated by ponderosa pine, lodgepole pine, or mixed species forests dominated by various conifers including fir, cedar, spruce, and hemlock (Hayward and Escano, 1989; and USFS, 1995). Although the species is thought to favor coniferous forest, on the WRNF, nests are mostly found in mixed aspen stands. In addition, all WRNF nests occurred above 7,500 feet in elevation (WRNF, 2002). Migrants and winter residents are found in all types of coniferous and riparian forests and occasionally in shrublands (Andrews and Righter 1992). The clutch size is 2 to 4 eggs with an incubation period of approximately 32 days. The male feeds the female while she incubates the eggs. The young leave the nest at 5 to 6 weeks. They are independent from the adults at about 70 days. Nests are generally greater than 1.2 miles apart.

Existing databases (CNHP, 2002a; and USFS, 1999) indicate that there are no known nest sites for goshawks in the Corridor. In 2004, an adult goshawk was observed flying up out of sagebrush habitat at the southern Forest Boundary (USDA, 2005a). Extensive goshawk surveys were conducted in 2003 in the Simpson, Cook, Keyser, Kinney, and Mule Creek areas of the ARNF as part of the Crimson Allotment vegetation management project. Those surveys failed to detect goshawks in the area, although some suitable habitat is present in areas of lodgepole pine and lodgepole/aspen mix (USDA, 2005a).

Environmental Baseline

Goshawks have been documented to breed primarily in upland conifer and aspen forest in Colorado (Kingery et al. 1998). Areas of the Corridor within the elevation range of the goshawk extend from milepost 150 (east of Eagle) to milepost 255, near Genesee, except for the EJMT area, which is above their elevation range. Potential habitat of the goshawk within the Corridor is aspen, lodgepole pine, and ponderosa pine. Goshawks are likely to forage in all forested and nonforested areas throughout the Corridor, as they are habitat generalists.

The habitat trend is likely stable on the WRNF and ARNF based on goshawks' utilization of all structural stages of Douglas-fir, lodgepole pine, ponderosa pine, and aspen habitats for foraging year-round. Suitable cover habitat includes spruce-fir, mature lodgepole pine, and all structural stages of mature and late-successional aspen and Douglas-fir habitat. These habitats are present in the Corridor APE on the ARNF. Surveys in 2003 on the Sulphur District of the ARNF failed to detect goshawks although some suitable habitat is present in areas of lodgepole pine and lodgepole-aspen mix (USFS, ARNF, 2005).

According to NatureServe (2006), threats to the goshawk include timber harvest, fire suppression, grazing, and insect and tree disease outbreaks that can result in the deterioration or loss of nesting habitat. The goshawk is considered vulnerable in Colorado (NatureServe, 2006). The population trend is suspected to be stable or increasing in Colorado (Gross, 1998).

Direct, Indirect, and Cumulative Effects of Alternatives

Action Alternatives

Table BR - 27 and **Table BR - 28** provide estimated direct impacts on potential goshawk habitat. In the WRNF, impacts from the Preferred Alternative would range from 5.1 acres (Minimum Program 65 mph and Maximum Program 65 mph) to 5.8 acres (Minimum Program 55 mph and Maximum Program 55 mph). In the ARNF, impacts from the Preferred Alternative on potential goshawk habitat would range from 0.6 (Minimum Program [55 or 65mph] to 1.1 acres (Maximum Program [55 or 65mph]).

For the WRNF, the greatest impacts among all alternatives would be associated with the Combination Six-Lane Highway Rail with Intermountain Connection alternative. The least impacts would be associated with the Six-Lane Highway 65 mph alternative. For the ARNF, the greatest impacts would be associated with the Rail with Intermountain Connection and Combination Six-Lane Highway with Rail and Intermountain Connection alternatives. The least impacts would be associated with the Advanced Guideway System, Bus in Guideway, and Minimal Action Alternatives. Impacts on WRNF and ARNF habitat would be considered negligible based on total acreages of suitable habitat on the Forests of 682,900 and 682,000, respectively.

Table BR - 27. Direct Impacts on Northern Goshawk Habitat (acres): Preferred Alternative

	Minimum Program		Maximum Program	
	Specific Highway Improvements with AGS		Combination 6-Lane Highway with AGS	
	55 mph	65 mph	55 mph	65 mph
WRNF	5.8	5.1	5.8	5.1
ARNF	0.6	0.6	1.1	1.1

Data provide the minimal to maximum impacts for the Preferred Alternative.

Table BR - 28. Direct Impacts on Northern Goshawk Habitat (acres): Action Alternatives Evaluated in the Draft PEIS

	Minimal Action	Rail with IMC	AGS	Dual-Mode Bus in Guideway	Diesel Bus in Guideway	Six-Lane Highway 55 mph	Six-Lane Highway 65 mph	Reversible/ HOV/HOT Lanes	Combination Six-Lane Highway with Rail and IMC	Combination Six-Lane Highway with AGS	Combination Six-Lane Highway with Dual-Mode	Combination Six-Lane Highway Diesel Bus in Guideway
WRNF	3.9	6.7	3.3	5.4	5.4	3.9	2.2	3.9	9.7	5.8	7.2	7.2
ARNF	0.3	2.1	0.1	0.2	0.2	0.4	0.4	0.8	2.0	1.1	1.0	1.0

The primary impact source for this species would be road effect zone-related disturbance and loss of nesting habitat due to vegetation management and possible induced growth (from Combination, Transit, and Highway alternatives) and planned development. Combination and Highway alternatives would be associated with induced growth in rural areas of Eagle County. Combination alternatives would be associated with the greatest impacts from induced growth in both Eagle and Summit counties. Induced growth is not expected with any alternatives east of the Continental Divide. Other cumulative impacts would include the current mountain pine beetle epidemic that has caused significant mortality of mature and late-successional lodgepole pine, producing an abundance of snags. This would potentially allow for the expansion of aspen habitats across the landscape. Vegetation management activities in the WRNF and ARNF also affect possible nesting habitat of goshawks. Timber management, especially overstory removal, may alter stand structure sufficiently to eliminate the necessary structure for nesting. However, these impacts are not expected to affect prey availability.

Forest Plans for WRNF and ARNF include direction and standards (such as WRNF Wildlife Standard #5) that will likely maintain adequate forested areas that have goshawk nest site and post-fledgling habitat characteristics. According to the WRNF Biological Evaluation, there may be actions that disturb nesting goshawks, which may have an impact on their reproductive success, but it is anticipated that only a few individuals or pairs would be affected by the implementation of any of the project alternatives over the next 10 years.

No Action Alternative

No direct impacts on goshawk habitat would be associated with the No Action Alternative. Impacts that occur currently, such as forest management activities and ongoing development, would remain and may include actions that reduce nesting habitat.

Determination of Effects and Rationale

Action Alternatives

All action alternatives would have possible direct impacts on habitat areas on National Forest System Lands. Combination alternatives would be associated with the greatest potential impacts on habitat areas due to possible induced growth in combination with planned development, followed by more moderate impacts from the Highway alternatives. The Minimal Action Alternative would not include impacts from possible induced growth. Because there would be some impacts on suitable habitat, but adequate nesting, post-fledgling, and foraging habitat would likely be maintained throughout National Forest System Lands, all action alternatives **may adversely impact individuals, but not likely to result in a loss of viability in the planning area, nor cause a trend to federal listing.** This determination would apply to both the WRNF and the ARNF.

No Action Alternative

The No Action Alternative would not directly affect goshawk habitat and would not contribute additional indirect or cumulative impacts on individuals or the population. Therefore, the No Action Alternative would have **no impact** on the northern goshawk species.

American Peregrine Falcon (*Falco peregrinus anatum*), FS

The American peregrine falcon is a fairly large diurnal raptor with pointed wings and a short tail. It is in the family Falconidae, and the genus *Falco.* This very swift falcon typically measures 16 inches long, with a wingspan of 41 inches and a weight of 1.6 pounds. Adult female birds are larger than adult males (Sibley, 2000). The species is currently documented to occur on ARNF and WRNF lands.

Distribution

In North America, breeding populations are found from interior Alaska east to Labrador and south to Baja, California, and northern New Mexico. Migration patterns vary depending on the falcon's breeding area. Those falcons found at northern latitudes will migrate to Central and South America, while those that breed in southern latitudes exhibit variable migration and some are nonmigratory (USFWS 1999).

The regional population is currently increasing, and recovery objectives have been met in most areas (NatureServe, 2006). The population trends are significantly upward at larger geographic scales (USDA 2003) and appear to be increasing on the WRNF.

In Colorado, nesting areas are distributed throughout the central and western portions of the state. On the ARNF, several falcons were located along the foothills of the Front Range, but nesting does not occur on the Pawnee National Grasslands (USDA, 2003). The highest nesting concentrations were observed in the river valleys and canyons of the Western Slope (Craig, 1991, 1993, 1994), where the Dolores and Colorado River canyons and Dinosaur National Monument contained the highest concentrations of peregrine falcons.

Once locally common, the peregrine was all but extirpated from Colorado by DDT magnification through food chains, which thinned eggshells in raptors through the 1950s and 1960s. The species has rebounded as a result of restrictions on DDT and restoration efforts and occurs in most western counties of Colorado. Peregrine nest sites are known in the vicinity of the Corridor (CNHP, 2002a).

As of the 2004 breeding season, there are 10 known peregrine nest sites on, or within 2 miles, of ARNF lands. Six are on ARNF, one on Routt National Forest, one on BLM, one in Rocky Mountain National Park, and one on private land. The average occupancy rate over the 11 years from 1994 to 2004 was 74 percent. Average success rate was 87 percent for the 45 breeding attempts for which the outcome was determined. On average, 1.44 young were fledged per occupied site, with the average fledged brood size being 2.24 young (ARNF unpublished files, 2004).

On WRNF lands, there are at least two recently occupied peregrine nesting areas adjacent to the Corridor. One additional occupied aerie is within the Corridor but along a portion of the highway where no other development is planned. Several other pairs nest in areas that would include portions of the Corridor within their foraging territories (K. Giezentanner pers. comm., 2006c).

Natural History

The peregrine falcon is making a successful recovery across the U.S. and currently occurs in areas of high cliffs in mountains and foothills at elevations from 4,500 to above 9,000 feet (Kingery, 1998). Peregrines have also been successfully introduced into cities with tall buildings where they subsist on pigeons for prey.

Peregrines typically nest on ledges of vertical, rocky cliffs, commonly with a sheltering overhang. Locally, nests can occur on riverbanks, tundra mounds, open bogs, large stick nests of other species, tree hollows, and man-made structures, for example, ledges of city buildings (Cade, 1982). Typically, cliffs are surrounded by either piñon-juniper woodlands or ponderosa pine forests (Kingery, 1998). The falcons hunt within these ecosystems primarily for birds (medium-size passerines up to small waterfowl) and rarely for small mammals, lizards, fishes, and insects (Skaggs et al., 1986).

The female lays 3 to 4 eggs in late March into April on the WRNF, and the incubation period lasts 32 to 35 days. The fledging period is 39 to 46 days. Both adults incubate and care for the young, but the male is responsible for most of the hunting (Palmer, 1988).

Environmental Baseline

The peregrine falcon is a Forest Service Sensitive Species with documented occurrences in both the WRNF and the ARNF. Occurrences in Colorado are noted in several Corridor counties including Clear Creek, Eagle, Garfield, Summit, Park, and Jefferson (NatureServe, 2006). Watershed occurrences include the Colorado, Blue, Eagle, Roaring Fork, and South Platte headwaters.

Peregrines nest sites are known in the vicinity of the Corridor (CNHP, 2002a). Habitat for peregrine falcon within the Corridor includes aspen forest, lodgepole pine forest, mountain shrubland, piñon-juniper, and sagebrush shrubland. Peregrines are likely to forage in all forested and nonforested areas throughout the Corridor, as they are habitat generalists.

Direct, Indirect, and Cumulative Effects of Alternatives

Action Alternatives

Temporary road effect zone-related effects may occur in peregrine falcon foraging areas in the Corridor, but no direct effects on important habitat are expected. Nest sites are distant from I-70, and enough foraging habitat is available that the raptors would be able to adjust their habits until construction is complete. No suitable nesting cliffs occur in the vicinity of the action alternatives. The closest alternative components associated with all action alternatives would consist of interchange modifications at milepost 116 (Glenwood Springs) and milepost 140 (Gypsum).

The presence of falcons has been documented on both sides of I-70 near Frisco, Colorado (CNHP 2006). The CNHP records were of presence only, not nesting. Of the six known nesting sites on the ARNF, none are close to the Corridor, but peregrine falcons could forage in the Corridor APE.

Table BR - 29 and **Table BR - 30** provide estimated direct impacts on potential American peregrine falcon habitat. In the WRNF, the Preferred Alternative would affect 0.8 acres. The Preferred Alternative is anticipated to have no impact on American peregrine falcon habitat for the ARNF.

On WRNF lands, the greatest impacts among all alternatives would be associated with the Rail and Intermountain Connection, Bus in Guideway, Combination Six-Lane Highway with Rail and Intermountain Connection, and Combination Six-Lane Highway with Bus in Guideway alternatives. The least impacts would be associated with the Minimal Action, Advanced Guideway System, Highway, and Combination Six-Lane Highway with Advanced Guideway System alternatives. Alternatives are anticipated to have no impact on American peregrine falcon habitat on the ARNF.

Table BR - 29. Direct Impacts on American Peregrine Falcon Habitat (acres): Preferred Alternative

	Minimum Program Specific Highway Improvements with AGS		Maximum Program Combination 6-Lane Highway with AGS	
	55 mph	65 mph	55 mph	65 mph
WRNF	0.8	0.8	0.8	0.8
ARNF	0.0	0.0	0.0	0.0

Data provide the minimal to maximum impacts for the Preferred Alternative.

Table BR - 30. Direct Impacts on American Peregrine Falcon Habitat (acres): Action Alternatives Evaluated in the Draft PEIS

	Minimal Action	Rail with IMC	AGS	Dual-Mode Bus in Guideway	Diesel Bus in Guideway	Six-Lane Highway 55 mph	Six-Lane Highway 65 mph	Reversible/ HOV/HOT Lanes	Combination Six-Lane Highway with Rail and IMC	Combination Six-Lane Highway with AGS	Combination Six-Lane Highway with Dual-Mode	Combination Six-Lane Highway Diesel Bus in Guideway
WRNF	0.8	3.7	0.8	3.1	3.1	0.8	0.8	0.8	3.7	0.8	3.1	3.1
ARNF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Possible indirect and cumulative effects could result from induced growth along the Corridor and from increased recreation activities, both of which intrude on foraging areas. The Highway alternatives are expected to induce slight amounts of growth in Eagle County according to existing trends. The Transit alternatives are expected to induce moderate growth in Eagle County concentrated near transit centers. The Combination alternatives are expected to induce the greatest growth in Eagle County, as well as moderate growth in Summit County.

No Action Alternative

Impacts that currently affect the peregrine falcon would remain, and as human population levels increase, increases in human intrusion into areas of the nest sites may negatively affect this species. Cumulative effects, which are likely to increase in the Corridor, would include impacts from increased human intrusion, increased development, and increased recreational pursuits. Such increases in human activity may reach a point where intrusion causes a nest to be abandoned, depending on the tolerance levels of individual birds.

Determination of Effects and Rationale

Action Alternatives

Because pergrine falcons forage in the Corridor and there are known nest sites in the Corridor, there is potential for indirect and cumulative effects on individuals for all action alternatives. Therefore, the determination is that all action alternatives **may adversely impact individuals, but not likely to result in a loss of viability in the planning area nor cause a trend to federal listing.** This determination would apply to both the WRNF and the ARNF.

No Action Alternative

Because the No Action Alternative would not create any new impacts, the alternative would have **no impact** on the peregrine falcon. This determination would apply to both the WRNF and the ARNF.

White-Tailed Ptarmigan *(Lagopus leucurus),* FS

The white-tailed ptarmigan is classified as an upland game bird, in the family Phasianidae, and the genus *Lagopus.* These birds are found on barren, rocky tundra most of the year. Ptarmigan use almost all alpine areas to feed on insects and plants during summer. The typical size is 12.5 inches long, with a wingspan of 22 inches and a weight of 13 ounces. The plumage is all white in winter months (Sibley, 2000). The species is currently documented to occur on ARNF and WRNF lands.

Distribution

The white-tailed ptarmigan occupies alpine areas from north-central New Mexico north into the Yukon and southern Alaska. In the contiguous U.S., they are located in the Rocky Mountains from northern New Mexico into Montana and the Cascade Mountains in Washington (Frederick and Gutierrez, 1992).

The white-tailed ptarmigan is distributed throughout all alpine regions of Colorado, except the Wet Mountains and the Spanish Peaks (Kingery, 1998). The population on Pikes Peak is due to a 1975 transplant project (Hoffman and Giesen, 1983). The species conservation assessment for the ptarmigan states that Colorado supports the most extensive distribution of ptarmigan in the U.S. outside Alaska and that the occupied range of the bird in Colorado encompasses 9,712 km^2 (Hoffman, 2006). However, there are no documented occurrences in the Corridor APE. Ptarmigan may use the alpine area above the EJMT in the summer and may use the land bridge over the tunnel in their movements to access lower areas with willow bottoms in the winter. Lack of information makes it difficult to assess population size and trends (NatureServe, 2006). In Colorado, breeding density in three populations free of hunting was 9.6 to 11.9/100 ha. After the breeding season, density was 15.7 to 23.4 (Frederick and Gutierrez 1992). In Colorado, winter home ranges of 17 females averaged 1.62 sq km; those of males averaged 0.44 sq km; winter density averaged 10 to 20 birds/sq km (Giesen and Braun, 19992).

The white-tailed ptarmigan is considered secure globally (G5) and apparently secure in Colorado (S4) (NatureServe, 2006).

Natural History

The white-tailed ptarmigan occurs primarily in alpine tundra but can be found at lower elevations in willow carrs, especially in winter (Kingery, 1998). Summer habitats in the Rocky Mountains consistently include moist, low-growing alpine vegetation and nests in rocky areas or sparsely vegetated, grassy slopes. Ptarmigans tend to search for vacant territory for natal areas and show a high fidelity to breeding territory in successive years (Andrews and Righter, 1992; and NatureServe, 2006). The female lays 4 to 7 eggs in early June and incubates them for 22 to 23 days. The young leave the nest within 6 to 12 hours after hatching to begin foraging on their own (Braun et al., 1993). The chicks will remain with the hen through the remainder of the summer (Kingery, 1998).

Environmental Baseline

The ptarmigan is listed as sensitive for both the WRNF and the ARNF. Suitable habitat in the Corridor APE would consist of alpine tundra and willow carrs in areas of the Corridor at Vail Pass, EJMT, and the U.S. 6 interchange. These birds are found on rocky tundra with low-growing alpine vegetation most of the year. Ptarmigan use almost all alpine areas to feed on insects and plants during summer.

Summer habitats in the Rocky Mountains consistently include moist, low-growing alpine vegetation (NatureServe, 2006). Year-round Colorado residents of mountainous areas, these upland birds move from tundra down a few hundred feet in elevation into willow bottoms for the winter to feed on buds of willows. Ptarmigan depend on willows for survival during winter. Reservoir and recreation development and overgrazing of willows by elk and livestock in the state are believed to have had an impact on ptarmigan populations (Kingery, 1998). Most of Colorado’s alpine regions remain inaccessible due to their remoteness. However, even where human impacts have altered the landscape, the ptarmigan retains a presence. The corvids that trail human disturbance pose a greater threat than the disturbance itself (Hoffman, 2006).

Direct, Indirect, and Cumulative Effects of Alternatives

Action Alternatives

Action alternatives would have little to no direct impact on the white-tailed ptarmigan because none of the alternatives would affect mapped alpine tundra vegetation. However, the action alternatives would affect some forested habitat around treeline near the EJMT and the U.S. 6 interchange. Mapping of alpine meadows (ptarmigan summer habitat) in a 4-mile-wide corridor centered on I-70 indicated there were approximately 5,647 acres. Because of the large amount of habitat available in the Corridor, any impacts from project construction are expected to be negligible. Additionally, ptarmigan habitat is primarily located on National Forest System Lands, which reduces the potential for possible induced growth and development associated with the Transit, Highway, and Combination alternatives. However, improved highway access (associated with the Highway and Combination alternatives) may contribute to increased levels of dispersed recreational activity, which could potentially disturb some nesting birds. Even though the Corridor is often adjacent to non-Forest land, induced forest visitation could affect this species.

Cumulative effects for white-tailed ptarmigan may include effects that result from high-altitude ski area development and alpine tundra may receive increased recreational usage as populations grow in the area. Combination and Transit alternatives would be associated with possible increased visitation to developed recreation sites such as ski areas.

No Action Alternative

The No Action Alternative would result in essentially negligible effects on the white-tailed ptarmigan.

Determination of Effects and Rationale

Action Alternatives

All action alternatives **may adversely impact individuals** because all action alternatives would involve some habitat disturbance above the treeline due to the construction of the third bore at EJMT or with construction of U.S. 6 interchange improvements in the same area. Additionally, increased visitation to ski areas (with possible disturbance to habitat), or increased dispersed recreation may adversely impact individuals. However, because there is little evidence of ptarmigan occurrences in the Corridor and habitat is generally protected, the action alternatives are **not likely to result in a loss of viability in the planning area, nor cause a trend to federal listing**. This determination would apply to both the WRNF and the ARNF.

No Action Alternative

The No Action Alternative would result in **no impact** on the white-tailed ptarmigan because it would not cause any additional direct or indirect impacts on habitat in alpine tundra or areas above the treeline. This determination would apply to both the WRNF and the ARNF.

Boreal Owl (*Aegolius funereus*), FS

The boreal owl is primarily a nocturnal raptor, belonging to the owl family Strigidae, and the genus *Aegolius*. The boreal owl is a small-bodied owl, but relative to overall body size, it has a large head, long wings, and a long tail. It measures 10 inches long, with a wingspan of 21 inches and a weight of 4.7 pounds (Sibley, 2000). This species is currently documented to occur on ARNF and WRNF lands.

Distribution

The boreal owl occurs throughout the Holarctic in boreal climatic zones and subalpine forests from Alaska across Canada to the Atlantic. In western North America, boreal owls are restricted to subalpine forests in the Rocky Mountains, Blue Mountains, and Cascade Mountains, with the southernmost records occurring in the mountains of northwestern New Mexico. Boreal owls occupy a circumpolar distribution in Northern Hemisphere forests. In North America, boreal forests in Colorado and northern New Mexico delineate the southernmost extent of their distribution. Widespread and relatively common in the northern portions of its range, this species is rated as globally secure but as imperiled in Colorado because there is a limited amount of suitable habitat (NatureServe, 2006).

In Grand County, boreal owls are rare summer breeders in coniferous habitats (Jasper and Collins, 1987) and are believed to remain within and around their home ranges through the winter (Hayward and Verner, 1994). Boreal owls in Colorado have been located in the Elk and San Juan Mountains and in nest boxes located on the Grand Mesa. The owl is designated as a sensitive species on both ARNF and WRNF, and suitable habitat is present in both Forests. Sixteen individuals have been documented throughout the WRNF. Late-successional forest is present in the vicinity of the Corridor in the Vail Pass and Continental Divide areas.

In Colorado, boreal owls mainly occur in stands of spruce-fir that are in the 150-year plus category commonly referred to as mature to older age (late-successional) forests. They have been known to use high-elevation lodgepole pine and aspen stands. There are approximately 315,000 acres of late-successional spruce-fir on the WRNF, some of which may be owl habitat. Habitat quality and quantity are currently likely stable on the Forest (WRNF, 2002 FEIS). There are approximately 170,400 acres of late-successional-mature and late-successional-old-growth coniferous forest on the ARNF (USDA, 1997), much of which may provide habitat for the boreal owl. These acres represent about 18 percent of the total coniferous forest on the ARNF (USDA, 1997).

BBS data (Kingery, 1998) indicate boreal owl occurrence (with possible breeding) south of the Muddy Allotment in the Williams Fork Valley on the ARNF. Boreal owl surveys in April 2004 found owls in mixed spruce-fir and lodgepole pine habitats east of the Muddy Allotment in Simpson Creek, Church Park, and Crooked Creek Valley. The Keyser/Kinney Creek area also was surveyed in spring 2004 with no responses. The Muddy Allotment was surveyed by road in late June 1996, and no owl responses were recorded (Sulphur District files). The Muddy Allotment is approximately 15 miles north of the Corridor.

Because the body of knowledge for this owl is small, both in Colorado and range-wide, it is difficult to assess population size and trends. Widespread and relatively common in the northern portions of its range, this species is rated as globally secure (G5). Populations have experienced declines in the past but are thought to be currently stable in Colorado (Gross, 1998). Although boreal owls are considered globally secure, their trend is unknown due to unreliable population estimates and nomadism caused by fluctuation in prey base abundance and distribution (NatureServe, 2006). Habitat quality and quantity are currently likely stable on the WRNF.

Natural History

Boreal owls are secondary cavity nesters, usually occupying cavities excavated by pileated woodpeckers (*Dryocopus pileatus*) or flickers. In Colorado, nests were initiated from mid-April to early June. In winter, boreal owls appear unselective of roost sites, while in summer thermal stress appears to drive selection of cool roost sites with high canopy cover, basal area, and tree density. Average home ranges are about 2,600 acres in the summer and 3,700 acres in winter (Hayward and Verner, 1994; and NatureServe, 2004).

Nest initiation generally begins around May 22 and can extend through June 30. Only five nests in natural cavities have been reported in Colorado, with an additional 26 nests occurring in artificial nesting boxes. Included in the natural cavity nesting report is the use of lodgepole pine cavities in Larimer County (1982). Summer home ranges have been reported to vary from 593 to 869 acres during late spring, with the ranges increasing during fall and winter to 1,961 to 3,631 acres. Many of the year-round ranges have overlapped by as much as 90 percent.

A major threat to boreal owls includes the direct and indirect effects of forest harvesting practices. Timber harvest may reduce primary prey populations, remove forest structure used for foraging and roosting, and eliminate nesting cavities. However, mountain pine beetle outbreaks, both current and future, may provide a significant increase in dead and down trees with cavities, or trees that can readily be excavated by the owls or other birds. Increases in tree cavities may serve to improve nesting success for the owls. Forest vegetation management affects many of the species habitat needs, including nesting sites (cavities) and roost sites. Regeneration harvest can result in reducing or eliminating the necessary boreal owl habitat components, mainly cavities, for many years before adequate structure begins to develop within regenerating stands.

Environmental Baseline

Boreal owls prefer wet habitats within late-successional forests where an abundance of small rodents occur. Late-successional forest is present in the vicinity of the Corridor in the Vail Pass and Continental Divide areas. Boreal owls have been known to inhabit Engelmann spruce, subalpine fir, lodgepole pine, ponderosa pine, aspen, and even piñon-juniper forests. These vegetation types occur throughout the Corridor as illustrated on **Figure BR - 3** (Maps 1-7). Suitable habitat for this species is present in the Vail Pass area and around the EJMT, but this owl is probably an uncommon breeder in both locations (Kingery, 1998).

WRNF and ARNF Forest Plans include measures for the protection of late-successional forest areas. Late-successional and old-growth are being designated to provide a distribution of this resource across the forest, providing contiguous blocks of spruce-fir forests that boreal owls can use (WRNF Biodiversity Standard #4) (USDA, 2002a). In addition, more than one-third of the WRNF occurs within wilderness, which prohibits timber harvest and restricts other activities such as prescribed fire. Standards also direct a minimum level of snags, including large snags (WRNF Biodiversity Standards #2 and #3) (USDA 2002a). ARNF Goal #3 states, "In Ponderosa pine and Douglas-fir forests, manage existing old-growth and mature forests to retain and encourage old-growth qualities." Additionally, Objective #2 states, "Manage acres of old-growth and acres of mature forest to retain or encourage development of old-growth (according to a table for retention, 10-year increase and 20-year increase)."

Areas that are designated as late-successional on the Forests are provided some level of protection, and it is likely that, under current Forest Management Plans, the habitat and the population of this species would increase. Considering all possible actions on and off the Forest that could affect boreal owl habitat, including the action alternatives, plus the fact that the WRNF currently has approximately 367,000 acres of Class 4A, B, and C, and Class 5 (mature and old-growth) spruce-fir habitat, population-wide effects on boreal owls are not expected. The ARNF contains approximately 248,000 acres of spruce-fir habitat, of which approximately 191,000 acres are between the ages of 80 and 220 years (USDA, 1997).

Direct, Indirect, and Cumulative Effects of Alternatives

Action Alternatives

The main impact on this species is the removal of forest structure for foraging and the elimination of nest cavities, mainly through timber management. Potential effects on boreal owl habitat are possible in a small area of late-successional forest in the Vail Pass area (WRNF). Other mapped late-successional forest is located both east and west of the Continental Divide (ARNF) and also is present south of I-70 and south of adjacent streams but would not likely be affected. However, because late-successional habitat in the Corridor largely would be avoided, direct impacts on boreal owls are expected to be relatively small.

Table BR - 31 and **Table BR - 32** provide the estimated direct impacts on potential boreal owl habitat. These direct impacts were estimated based on calculated impacts on aspen forest, lodgepole pine forest, ponderosa pine, spruce-fir, and piñon-juniper. Impacts on potential boreal owl habitat in the WRNF from the Preferred Alternative would range from 6.1 acres (Minimum Program 65 mph and Maximum Program 65 mph) to 6.6 acres (Minimum Program 55 mph and Maximum Program 55 mph). On the ARNF impacts would range from 0.6 acres (Minimum Program [55 or 65mph]) to 1.1 acres (Minimum Program [55 or 65mph] and Maximum Program [55 or 65mph]).

The greatest impacts on WRNF lands among all alternatives would be associated with the Combination Six-Lane Highway with Rail and Intermountain Connection alternative (11.4 acres). The greatest impacts on ARNF lands would result from the Rail with Intermountain Connection alternative (2.1 acres) and the Combination Six-Lane Highway with Rail and Intermountain Connection alternative (2.0 acres). The total acreages for these mapped habitats on the WRNF are 1,349,000 and on the ARNF, 938,000. However, acres of the owl's preferred habitat, late-successional forest, represent 502,500 acres on the WRNF and 170,400 acres on the ARNF. The largest potential impacts on Table BR - 32 represent 0.003 percent of old-growth on the WRNF and 0.001 percent of old-growth on the ARNF.

Table BR - 31. Direct Impacts on Boreal Owl Habitat (acres): Preferred Alternative

	Minimum Program		Maximum Program	
	Specific Highway Improvements with AGS		Combination 6-Lane Highway with AGS	
	55 mph	65 mph	55 mph	65 mph
WRNF	6.6	6.1	6.6	6.1
ARNF	0.6	0.6	1.1	1.1

Data provide the minimal to maximum impacts for the Preferred Alternative.

Table BR - 32. Direct Impacts on Boreal Owl Habitat (acres): Action Alternatives Evaluated in the Draft PEIS

	Minimal Action	Rail with IMC	AGS	Dual-Mode Bus in Guideway	Diesel Bus in Guideway	Six-Lane Highway 55 mph	Six-Lane Highway 65 mph	Reversible/ HOV/HOT Lanes	Combination Six-Lane Highway with Rail and IMC	Combination Six-Lane Highway with AGS	Combination Six-Lane Highway with Dual-Mode Bus in Guideway	Combination Six-Lane Highway Diesel Bus in Guideway
WRNF	4.8	8.1	3.5	5.5	5.5	4.8	2.9	4.8	11.4	6.6	8.1	8.1
ARNF	0.3	2.1	0.1	0.2	0.2	0.4	0.4	0.8	2.0	1.1	1.0	1.0

Indirect impacts from induced growth are unlikely since development is unlikely to take place in late-successional forest or other suitable habitat for owls. Because owls prefer moist/wet habitat, they may be affected by I-70 winter maintenance activities. The greatest impacts from winter maintenance would be from the Combination, Bus in Guideway, and Highway alternatives.

The most significant cumulative effect in the project area vicinity is the existing and expanding mountain pine beetle epidemic that is killing thousands of acres of mature lodgepole pine trees. This kind of habitat change would occur regardless of harvest management. Salvage of some areas of beetle-killed lodgepole pine trees may affect available, late-successional lodgepole pine habitat for this species. Available habitat for boreal owls within the larger geographic area is far greater than within the project area. Forest management activities also affect habitat including timber management activities; ski area development; prescribed fire; and insect and disease management. Ski area expansions may affect a very small portion of the older spruce-fir, but much of these lands are in areas that include alpine, barren, and grassland communities. Very little prescribed fire is expected to occur within the late-successional spruce-fir type in the next 10 years. According to the WRNF Forest Plan, because timber harvest activities may have a direct impact on nesting boreal owls, reproduction may be affected, but considering the limited actions in mature and old-growth spruce-fir that is planned, very few pairs would be affected in the next 10 years. Cumulative effects would also include snowmobile and ATV use within the geographic area. Combination and Highway alternatives would be associated with possible increased Forest visitation and increased dispersed recreational use (such as snowmobile and ATV use).

No Action Alternative

No additional impacts on boreal owl habitat or species would occur under the No Action Alternative. The areas that are designated as old-growth on the Forest are provided some level of protection, and it is likely that, under current Forest Management Plans, the habitat and the population of this species would increase.

Determination of Effects and Rationale

Action Alternatives

The boreal owl would most likely be affected by habitat loss, either directly or due to induced growth, and by an increase in road effect zone-related disturbance. Because old-growth habitat in the Corridor would be avoided, impacts on boreal owls are expected to be relatively small. Although some individuals may be displaced, population-wide effects would be unlikely. All action alternatives would likely have some limited indirect and cumulative effects due to planned and possible induced visitation to WRNF and ARNF. Therefore, all action alternatives **may adversely impact individuals, but not likely to result in a loss of viability in the planning area, nor cause a trend to federal listing.** This determination would apply to both the WRNF and the ARNF.

No Action Alternative

The No Action Alternative would not have an impact on the current condition and distribution of boreal owl habitat within the Corridor on the WRNF or the ARNF. Therefore, the No Action Alternative would have **no impact** on boreal owls**.**

Flammulated Owl (*Otus flammeolus*), FS

The flammulated owl is a small, primarily nocturnal bird of the family Strigidae, and the genus *Otus.* They typically measure only 6.75 inches long, with a wingspan of 16 inches and a weight of 2.1 ounces (Sibley, 2000). This species is currently documented to occur on ARNF and WRNF lands.

Distribution

Flammulated owls are limited in distribution to North and Central America, from southern British Columbia south and eastward to Guatemala and probably El Salvador and the Sierra Madre Oriental. During the winter, they are found in Mexico, southern Texas, Arizona, and California.

In Colorado, flammulated owls are restricted to montane forests during the breeding season and occur most commonly in the southwestern portion of the state (Andrews and Righter, 1992). Winn (1998) found flammulated owls in 71 montane blocks surveyed for breeding birds west of the Rocky Mountain escarpment, 40 percent in ponderosa pine habitat and 28 percent in aspen habitat. The Rocky Mountain Bird Observatory (RMBO) has initiated nocturnal surveys across Colorado and monitors 300 owl nest boxes on the Grand Mesa, Uncompahgre, and Gunnison National Forests in western Colorado.

The Colorado Breeding Bird Atlas observed owls on the Roan Plateau, in western Rio Blanco and Garfield counties, and in the Routt National Forest (Kingery, 1998). Kingery (1998) also confirmed breeding evidence for Eagle County, probable breeding evidence in Garfield and Jefferson counties, and possible breeding evidence in Clear Creek County. On the WRNF, the flammulated owl has been documented on the forest in aspen and aspen/conifer stands (Winn, 1998; and USDA, 2002a). Most likely the Forest is used only during the breeding season, with individuals migrating off the Forest for the winter. The Rocky Mountain Region TEPS list indicates the owl is known from both the WRNF and the ARNF.

Though the species occurs widespread throughout its range in appropriate habitat, the distribution is spotty (Gross, 1998). Total number of individuals is thought to be high, but population trends are thought to be declining or are unknown (Winn, 1998). The species may be the most common raptor of the montane pine forests of the western U.S. and Mexico. Fire suppression and logging of older forests may have decreased available habitat and possibly populations.

Population densities and trends are not available for the ARNF or for larger geographic regions due to lack of historic data (USDA, 2003). However, mean annual densities were studied at Manitou Experimental Forest during a 19-year study south of the ARNF and determined to be one breeding pair per 278 acres, and one unpaired male per 357 acres.

Natural History

The flammulated owl, a cavity-nesting owl, prefers open ponderosa pine forests for hunting insects and brush or dense foliage for roosting (Kingery, 1998). Flammulated owls also have been known to use flicker cavities that have been drilled in aspen for nesting. In northern Utah, this species successfully nested in nest boxes placed in montane deciduous forests dominated by aspen with some scattered firs (NatureServe, 2004).

Males show strong fidelity to breeding territories (Reynolds and Linkhart, 1987). In Colorado, some males appear on territories as early as the first week of May, and all territories are occupied by the third week of May (Reynolds and Linkhart, 1987). Flammulated owls raise a small clutch, ranging in size from 2 to 4 eggs per nest, incubation lasts 21 to 22 days, and fledglings depart the nest about 22 to 24 days after hatching or mid- to late-July (Reynolds and Linkhart, 1987). The species tends to migrate through lowlands in the spring and to migrate south primarily through mountains in the fall (Andrews and Righter, 1992). Prey availability appears responsible for the migratory behavior of this insectivorous species. Several authors noted that flammulated owls appear to form clusters of breeding pairs with areas of unoccupied habitat between clusters.

Environmental Baseline

Habitat for the flammulated owl in the Corridor was estimated using mapped areas of aspen, ponderosa pine, spruce-fir, lodgepole pine, and Douglas-fir vegetation. **Figure BR - 3** (Maps 1-7) illustrate the vegetation types that occur throughout the Corridor.

Primary nesting habitat for flammulated owls includes open ponderosa pine forests or forests with similar features, such as dry montane conifer or aspen (*Populus tremuloides*) forests, often with dense saplings, oak (*Quercus*), or other brushy under story. They are secondary cavity nesters, using natural cavities or more commonly old woodpecker holes that are often reused year after year. Most flammulated owl studies were conducted in ponderosa pine habitat, and the majority of scientific information available on habitat associations pertains to this habitat; however, a few recent studies were conducted in fir (*Abies* spp.) and mixed deciduous forests and in deciduous forests dominated by quaking aspen. Flammulated owls have not been documented as present on the WRNF within ponderosa pine stands found scattered across the Forest; however, they have been documented in several locations using pure aspen and aspen-conifer stands (Winn, 1998).

Direct, Indirect, and Cumulative Effects of Alternatives

Action Alternatives

Table BR - 33 and **Table BR - 34** provide the estimated direct impacts on potential flammulated owl habitat. Impacts on potential flammulated owl habitat on the WRNF from the Preferred Alternative would range from 10.6 acres (Minimum Program 65 mph and Maximum Program 65 mph) to 11.2 acres (Minimum Program 55 mph and Maximum Program 55 mph). On the ARNF impacts would range from 3.1 acres (Minimum Program [55 or 65mph]) to 6.5 acres (Maximum Program [55 or 65mph]).

The greatest impacts among all alternatives would be associated with the Combination Six-Lane Highway with Rail and Intermountain Connection alternative for the WRNF, while the least impacts would be associated with the Minimal Action Alternative. However, because old-growth habitat would be avoided in the APE, actual impacts on sensitive habitat are expected to be relatively small. For the ARNF, the greatest impacts would be associated with the Combination Six-Lane Highway with Rail and Intermountain Connection, while the least impacts would be associated with the Advanced Guideway System and Bus in Guideway alternatives. Total habitat acreage for old-growth in the various vegetation types on the ARNF and WRNF are 170,400 and 315,000, respectively. The maximum loss of habitat under the alternatives would represent 0.006 percent of total habitat on the WRNF and 0.005 percent on the ARNF.

Table BR - 33. Direct Impacts on Flammulated Owl Habitat (acres): Preferred Alternative

	Minimum Program		Maximum Program	
	Specific Highway Improvements with AGS		Combination 6-Lane Highway with AGS	
	55 mph	65 mph	55 mph	65 mph
WRNF	11.2	10.6	11.2	10.6
ARNF	3.1	3.1	6.5	6.5

Data provide minimal to maximum impacts for the Preferred Alternative.

Table BR - 34. Direct Impacts on Flammulated Owl Habitat (acres): Action Alternatives Evaluated in the Draft PEIS

	Minimal Action	Rail with IMC	AGS	Dual-Mode Bus in Guideway	Diesel Bus in Guideway	Six-Lane Highway 55 mph	Six-Lane Highway 65 mph	Reversible/ HOV/HOT Lanes	Combination Six-Lane Highway with Rail and IMC	Combination Six-Lane Highway with AGS	Combination Six-Lane Highway with Dual-Mode Bus in Guideway	Combination Six-Lane Highway Diesel Bus in Guideway
WRNF	5.2	14.3	6.5	9.5	9.5	7.5	5.8	7.6	18.1	11.2	12.6	12.6
ARNF	2.1	5.3	0.9	1.4	1.4	2.9	3.0	4.6	8.7	6.5	6.3	6.3

The flammulated owl would most likely be affected by habitat loss, either directly or as a result of induced growth, and an increase in road effect zone-related disturbance (noise, lights, contaminants, barrier to crossing, and AVCs). Although some individuals may be displaced, population-wide effects would be unlikely.

Vegetation management activities that affect possible nesting habitat are the major concern in the management of flammulated owls. The need for adequate canopy closure, nest cavity sites, and other structural characteristics may limit available nest sites. Vegetation management, especially timber management, may alter stand structure sufficiently to eliminate the necessary components for nesting.

On the WRNF, it is unlikely that timber management activities would have any measurable impact on the available nesting areas for flammulated owls. Current Forest Plan direction would likely maintain the existing condition of structural stages on the Forest, which, generally, is that forested areas are in the mid- to mature stages. This would likely maintain adequate forested areas on the Forest that have owl nest site habitat characteristics. Current Forest Plan direction would provide protection for known active and inactive nest sites (Chapter 2, Wildlife Standard #5), and for maintaining a minimum number of snags and large snags per acre (Chapter 2, Biodiversity Standards #2 and #3).

On the ARNF, timber management activities would not likely affect old-growth stands that have owl nest site habitat characteristics. The Forest would be managed to maintain and restore, where necessary, the compositional, structural, and functional element to perpetuate diversity (Chapter 1, Goal #34 for Biodiversity) and to protect, restore and enhance habitat for federally listed threatened, endangered, and regionally listed sensitive species (Chapter 1, Goal #45 for TES). The ARNF also has a goal to maintain aspen, even at the expense of spruce-fir or other late-successional stands (Goal #37 for Composition).

Corridor alternatives may have actions that disturb ponderosa or aspen stands with nesting owls, which may affect their reproductive success, but it is anticipated that very few individuals or pairs would be affected given the small acreages listed in **Table BR - 33** and **Table BR - 34**. None of these actions would likely measurably affect the flammulated owl population on the WRNF under any alternative.

No Action Alternative

No additional direct impacts on flammulated owl habitat would occur. Forest management for old-growth ponderosa pine forests would continue as at present.

Determination of Effects and Rationale

Action Alternatives

All action alternatives would disturb some habitat for flammulated owls (see **Table BR - 33** and **Table BR - 34**). Indirect impacts may also result in additional human presence in owl habitat. The end result of habitat loss and human intrusion is that owls may have to use more energy in foraging or they may be less successful in nesting. There would be more stress on the individuals, which could potentially cause a decline in the local population. The determination for these effects is that alternatives **may adversely impact individuals, but not likely to result in a loss of viability in the planning area, nor cause a trend to federal listing**. This determination would apply to both the WRNF and the ARNF.

No Action Alternative

The No Action Alternative would not disturb nesting owls, but the indirect and cumulative effects would still be present. This alternative **may adversely impact individuals, but not likely to result in a loss of viability in the planning area, nor cause a trend to federal listing**. This determination would apply to both the WRNF and the ARNF.

Black Swift (*Cypseloides niger*), FS

The black swift is the largest swift in North America. It is in the family Apodidae, genus *Cypseloides.* It typically measures 7.25 inches long, with a wingspan of 18 inches and a weight of 1.6 ounces. It features long, curved wings and a broad tail and tends to nest on cliffs near or behind waterfalls. This species is currently documented to occur on ARNF and WRNF lands.

Distribution

Black swifts have a scattered breeding distribution in western North America, from southeast Alaska to central Mexico (Kingery, 1998). Their winter range is poorly known with populations wintering in South America (Stiles and Negret, 1994). In the U.S., the distribution is southeast Alaska, western Canada, south to southern California, northwest Montana, Colorado, Utah, Northern New Mexico, and southeastern Arizona. Within Colorado, potential breeding pairs were located at scattered locations in central and western Colorado with the largest concentration of colonies in the San Juan Mountains. Smaller colonies were observed in the Sangre de Cristo, Flat Tops, Gore, and Front Ranges including a center of concentration in Rocky Mountain National Park (Wiggins, 2004a). They are very rare in foothills, in western valleys, in mountain parks, and on the Eastern Plains. Approximately 50 confirmed colonies are known in Colorado. Fifteen confirmed colonies were identified on the WRNF in 2001 (USDA, 2002c). The black swift is a rare to uncommon summer visitor on ARNF where it forages at high elevations over most montane and adjacent lowland habitats (USDA, 2005a).

The black swift's preferred habitat is relatively rare in Colorado. It is a migratory species that arrives in Colorado in June. The population trend throughout its range was declining for most of the 1900s, but it may be stable currently (some surveys may indicate a possible increase in populations, but this may result from increased survey efforts for this species). The trend on the WRNF is unknown (annual monitoring/surveying occurs on the Forest at known and potential sites, with reproductive activities varying by site and year). Colorado Bird Observatory (CBO, 1995) identified that a 26 percent to 50 percent loss of breeding habitat has occurred over the past 50 years. Factors attributing to the decline are increased recreational pressures around these unique sites. Recreational activities of rock climbing and spelunking have the potential to disturb delicate habitats associated with black swift nests. This species has been identified as one requiring more baseline information to determine viability on the WRNF.

This species has a natural heritage ranking of "apparently secure" at both the global and state level (G4, S4) (NatureServe, 2004). The Colorado Natural Heritage Program rates this species as S3, vulnerable in the state.

Natural History

The black swift has a restricted range because of its very narrow nest-site preference. It requires rocky shelves and outcrops on moist cliffs, usually behind active waterfalls or dripping caves. It forages for insects, sometimes far from nesting areas in a large variety of habitats. Black swifts are most common from 7,500 to 10,500 feet in elevation. They migrate north in May and leave the Forest in September. Nests are constructed from mud, mosses, or algae and are located on ledges under overhanging rocks, often behind a waterfall, or in caves. Other areas that may have habitat characteristics for black swifts (similar to the known sites in the state) likely exist on the WRNF.

Black swift lay a single egg and are suspected of raising only one brood per season (Ehrlich et al., 1988). Eggs are typically laid from June to July. Due to the specific nesting requirements for black swifts, they may have never been very abundant in Colorado. Although in areas they find suitable, they can congregate into colonies representing as many as 10 pairs at some sites. Only three sites have been documented in the state with this large number of pairs, one in the Ouray area, a site near Little Bear Peak in the Sangre de Cristo Mountains, and one colony of nine pairs on the WRNF in 2005. Statewide the population is not expected to be more than a few hundred pairs, although estimates from the Breeding Bird Atlas suggest a population of black swift from 700 to 800 pairs.

Environmental Baseline

Recent surveys conducted by the USFS and the RMBO inventoried more than 375 waterfalls in Colorado with more than 100 sites occupied by breeding black swifts (Wiggins, 2004a). Two of these waterfalls were recorded within 1 mile of I-70 (CNHP, 2002a).

The RMBO (Levad, 2006) reports several black swift sites in the vicinity of the Corridor, including one west of Georgetown discovered in 1994 and occupied in 2004, and four colonies east of Glenwood Springs, the lowest of which is just below Hanging Lake, approximately 1 mile from I-70. There are also at least three black swift colonies at small waterfalls east of Vail. These were first discovered in 1958, and the RMBO has observed swifts at each since surveys began in 2000. Each of the falls is perhaps 300 to 400 feet up the escarpment. Foraging birds range at high elevations over most montane and adjacent lowland habitats.

Direct, Indirect, and Cumulative Effects of Alternatives

Action Alternatives

Potential impact sources for the black swift would be water diversions that might affect their nesting sites, physical disturbance or human intrusion on nesting sites, and induced growth and development, especially in aspen, Douglas-fir, riparian forest, and spruce-fir habitats. It has not been ascertained whether water diversion practices are negatively affecting black swift on the ARNF (Wiggins, 2004a). However, stream flow is needed for their existence, and changes in stream flow could have direct, indirect, and cumulative effects on their habitat streams (USDA, 2005a). Whenever water withdrawals might be made for construction activities, the water would be procured as close to the construction site as possible and no water would be removed from higher elevation streams that might be supplying waterfalls where swifts could be nesting.

No impact table was prepared for the black swift because their foraging habitat for insects is at high elevation over most montane and adjacent lowland habitats. The determining factor for their foraging habitat is their very specific nesting habitat, that is, near waterfalls or in wet cave entrances, neither of which was subjected to GIS mapping.

The greatest risk factor (limiting factor) for black swift is the presence of hiking trails to the base or top of waterfalls where nesting is occurring, along with rock climbing (Partners in Flight, 2006). Recreational activities of rock climbing and spelunking also have the potential to alter habitat characteristics associated with black swift nesting sites. Because black swifts have a very narrow range of habitat conditions that they may use, disturbances at these specific habitats can eliminate the sites from further use. These activities are expected to occur at other black swift sites in Colorado and throughout its range. However, none of the known nest sites along I-70 are close enough to the construction disturbance zone or sensitivity zone that project alternatives would be expected to have any effect on the black swift. The nests identified in Glenwood Canyon would not experience any impacts from the implementation of any of the project alternatives because no construction activities are planned in the canyon.

The WRNF Plan (USDA, 2002a) strategies, standards, and guidelines provide direction for black swift management that will maintain the existing and any newly found colonies. This direction includes Forestwide Goals and Objectives and Strategies that direct the Forest to manage for Management Indicator, Sensitive, and species that need more baseline inventory and evaluation to determine status (Objective # 1b, Strategies 1b.3 and 1b.4; Objective # 1c, Strategy 1c.3); to manage for black swifts (Objective #s 1b.25 and 1b.26); to restrict disturbances at black swift nesting sites and habitat in general (Wildlife, Standard #1, #2, and #3).

The trend for habitat quantity on the WRNF should be stable under all alternatives because of implementation of the strategies, standards, and guidelines. Known populations of black swifts should be maintained throughout the areas where they currently exist. Population trends on the Forest for black swifts at known sites will likely be stable.

The ARNF Plan (USDA, 1997) has similar goals and standards designed to direct management of forest activities to maintain and enhance the environment for sensitive species. Included are goals to maintain, restore, and enhance elements of the Forest to perpetuate biodiversity (Goal #34); protect special habitats (Goal #41); restore, protect, and enhance habitats for TES and sensitive species (Goals 44 and 45); prepare biological evaluations for projects (Goal #46); prepare species management guides for local populations of sensitive species (Goal #47); and develop conservation strategies to direct management considerations to maintain viable populations of sensitive species (Goal #48). Forest Standards also have been defined, including analyzing newly discovered habitats to see if the management plans should be adjusted (Standard 49), avoiding areas where sensitive species have been observed to preserve the population viability (Standard 50), and closing areas to activities during time-critical activities of the sensitive species to maintain their viability (Standard 51).

Indirect effects that are occurring throughout the black swift range, including areas adjacent to the WRNF, mainly result from disturbance from recreational use. It is unknown what the trends for habitat and populations for black swift would be based on the potential impacts. But considering that current population trends are stable or increasing, and similar emphasis on black swift management is expected on other public lands, any changes in populations off the Forest should have no or only limited impact on the populations on the WRNF.

Cumulative effects are not likely to affect the black swift nesting habitat but may affect their broad use of the montane life zone in the Corridor for foraging habitat. Such effects are most likely to occur from increased residential and commercial land development in areas adjacent to National Forest System Lands in Eagle, Clear Creek, and Summit counties.

No Action Alternative

There would be no additional impacts on black swift habitat under the No Action Alternative beyond those already occurring, and Forest management measures would remain in effect.

Determination of Effects and Rationale

Action Alternatives

There is the potential for impacts on foraging habitat from induced growth and the potential for recreational activities to affect nest sites on the WRNF. For the ARNF, the only known occurrences of black swift are in or near Rocky Mountain National Park, which is more than 25 miles north of the Corridor. The determination is that the Corridor **may adversely impact individuals, but not likely to result in a loss of viability in the planning area, nor cause a trend to federal listing.**

No Action Alternative

The No Action Alternative would not cause any additional kinds of impacts in the Corridor, and the determination would be **No impact**.

Brewer's Sparrow *(Spizella breweri)*, FS

The Brewer's sparrow is a member of the family emberizidae, and the genus *spizella*. It normally measures 4.5 inches long and weighs 0.5 ounces. Brewer's sparrow is the smallest North American sparrow, with a long, notched tail and short bill, a finely streaked brown crown and rump, a complete white eye ring, and a uniformly drab color with no other distinct markings (Sibley, 2000). Brewer's sparrows are often the most abundant bird on sagebrush shrubland breeding grounds (Rotenberry et al. 1999). This species is currently documented to occur on ARNF and WRNF lands.

Distribution

Across their breeding range, Brewer's sparrows are shrubland specialists that prefer sagebrush shrubsteppe (Rotenberry et al., 1999). In Colorado, Brewer's sparrows have been noted in 8 shrubland vegetation classes, with almost 60 percent of occurrences in sagebrush (Lambeth, 1998). Distribution of the species in Colorado probably reflects changing patterns in the quality and distribution of sagebrush habitat (Kingery, 2005).

Natural History

During spring and fall migrations, this species uses shrubland habitats similar to their breeding habitats throughout Colorado's western valleys, foothills, and mountain parks, and riparian shrub corridors on the eastern plains, near foothills (Andrews and Righter, 1992). The Brewer's sparrow winter range consists of dry, shrubby, lowland habitats dominated by sagebrush or desert shrubs (Rotenberry et al., 1999).

Brewer's sparrows begin arriving on their breeding grounds in mid-April (Andrews and Righter, 1992) and they nest primarily in shrubs. Brewer's sparrows are not known to nest in forest habitats (Kingery, 2005).

Environmental Baseline

Brewer's sparrows prefer sagebrush shrublands but will also use other types of shrubby cover types including rabbitbrush (*Chrysothamnus* spp.), greasewood (*Sarcobatus vermiculatus*), hopsage (*Grayia spinosa*), and saltbush (*Atriplex canescens*) species in lower elevations or mountain mahogany (*Cercocarpus ledifolius*) and snowberry (*Symphoricarpos albus*) higher up (Kingery, 1998).

Potential habitat of the Brewer's sparrow within the Corridor is sagebrush shrubland. For the purposes of this study, any impacts on these areas within the Corridor were quantified as impacts on brewer's sparrow habitat. These vegetation types occur throughout the Corridor as illustrated on **Figure BR - 3** (Maps 1-7)**.**

This species is a common summer resident throughout the mesas and foothills of western Colorado. In the APE, they are most likely breeding in the western portions of Eagle County and into Garfield County. Although the Brewer's sparrow may be the most abundant bird species in appropriate sagebrush habitats, it has shown substantial declines throughout its range during the last 10 to 20 years in Colorado, Montana, Nevada, Oregon, and Wyoming. Only Utah currently contains an apparently stable population. Despite these known declines, lack of information makes it difficult to assess population size and trends. This species has a global natural heritage ranking of "secure" (G5) and a state ranking of "apparently secure" (S4; NatureServe, 2009).

Direct, Indirect, and Cumulative Effects of Alternatives

Action Alternatives

Table BR - 35 and **Table BR - 36** provide the estimated direct impacts on potential Brewer's sparrow habitat. On the WRNF, impacts from the Preferred Alternative would be 0.8 acres. No impacts on Brewer's sparrow habitat are anticipated to result from the Preferred Alternative on the ARNF.

On the WRNF, all Highway alternatives or alternatives with a Highway component are anticipated to affect 0.8 acres of Brewer's sparrow habitat. No impacts on this species' habitat are anticipated to result from any alternatives on the ARNF.

Table BR - 35. Direct Impacts on Brewer's Sparrow Habitat (acres): Preferred Alternative

	Minimum Program		Maximum Program	
	Specific Highway Improvements with AGS		Combination 6-Lane Highway with AGS	
	55 mph	65 mph	55 mph	65 mph
WRNF	0.8	0.8	0.8	0.8
ARNF	0.0	0.0	0.0	0.0

Data provide minimal to maximum impacts for the Preferred Alternative.

Table BR - 36. Direct Impacts on Brewer's Sparrow Habitat (acres): Action Alternatives Evaluated in the Draft PEIS

	Minimal Action	Rail with IMC	AGS	Dual-Mode Bus in Guideway	Diesel Bus in Guideway	Six-Lane Highway 55 mph	Six-Lane Highway 65 mph	Reversible/ HOV/HOT Lanes	Combination Six-Lane Highway with Rail and IMC	Combination Six-Lane Highway with AGS	Combination Six-Lane Highway with Dual-Mode Bus in Guideway	Combination Six-Lane Highway Diesel Bus in Guideway
WRNF	0.8	0.0	0.0	0.0	0.0	0.8	0.8	0.8	0.8	0.8	0.8	0.8
ARNF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Possible indirect and cumulative impacts on habitat would include possible induced growth in rural areas associated with the Combination and Transit alternatives. However, because of the large amount of sagebrush shrubland habitat available in the Forests, these impacts are expected to be relatively small. Cumulative impacts would include increased loss of foraging habitat from planned growth and development of areas adjacent to the Forests.

No Action Alternative

There would be no additional impacts on Brewer's sparrow habitat under the No Action Alternative beyond those already occurring, and Forest management measures would remain in effect.

Determination of Effects and Rationale

Action Alternatives

Habitat loss due to construction and induced development would be the effects most likely to affect this species. Additionally, I-70 may act as a barrier or increase vehicular collisions with Brewer's sparrows, as this species tends to fly low to the ground, where there is sagebrush habitat on both sides of the highway as in locations at the western end of the Corridor. Substantial losses of sagebrush habitat and the inability to move freely between habitat areas could potentially have population-wide, as well as individual, impacts on this species. Induced rural growth from Highway alternatives could also cause the loss of sagebrush habitat, directly affecting this sparrow.

All action alternatives **may adversely impact individuals, but not likely to result in a loss of viability in the planning area, nor cause a trend to federal listing.**

No Action Alternative

The No Action Alternative would not cause any additional kinds of impacts in the Corridor, and the determination would be **No Impact.**

American Three-Toed Woodpecker (Picoides tridactylus dorsalis) [also Northern Three-toed Woodpecker (Picoides tridactylus dorsalis)(also Picoides dorsalis)], FS

The three-toed woodpecker is a member of the family Picidae, and the genus *Picoides.* It normally measures 8.75 inches long, with a wingspan of 15 inches and a weight of 2.3 ounces. The species occupies boreal forest habitat, and they flake bark instead of excavating wood (Sibley, 2000). This species is currently documented to occur on ARNF and WRNF lands.

Distribution

Three-toed woodpeckers have a circumpolar distribution in boreal forest habitat. Globally, this species is considered stable, yet these woodpeckers are locally distributed and occur nowhere in abundance. Limited North American BBS data indicate a relatively stable population (NatureServe, 2006). The BBS (1987–

1995) indicated the woodpecker was breeding in all high-elevation mountain ranges in the state but with low abundance scores throughout (Wiggins, 2004b).

In Colorado, these woodpeckers occur in a scattered distribution of older spruce and fir forests with decadent trees (Kingery, 1998). Wiggins (2004b) mentions in the species conservation assessment that there have been strong decreases in abundance in the Southern Rocky Mountains of Colorado. In Grand County, three-toed woodpeckers are uncommon year-round residents in aspen and coniferous habitats, with breeding records in coniferous forests (Jasper and Collins, 1987). The three-toed woodpecker has been observed in Garfield, Eagle, and Summit counties (USDA, 1997). The WRNF reports that the woodpecker occurs throughout the Forest at elevations of 8,500 to 11,000 feet, in suitable habitat (USDA, 2002a).

Three-toed woodpeckers can reach their highest densities in recently burned forest, up to 1 bird for every 250 acres (USDA, 2003). ARNF also indicated that no discernable trends are present on the ARNF because counts are too low. This Forest Sensitive species occurs on both the WRNF and ARNF. Potential habitat in the Corridor would be in the montane and subalpine areas between Vail and Georgetown, where suitable spruce-fir habitat is present.

Surveys in 2003 on the ARNF just south of the Muddy Allotment in the Cook, Keyser, Bonham, and Kinney Creek drainages found numerous three-toed woodpeckers foraging in lodgepole pine and spruce-fir habitats. Abundance of woodpeckers in this area has probably increased as a result of mountain pine beetle infestations (USDA, 2005a). RMBO (2004) completed other monitoring surveys on the ARNF in the years 1998 through 2004. RMBO surveyed 26 transects (not every transect in every year) for a total of 121 sampling points. The results were 0.2 birds per transect per year on two of the transects. The averages on the two transects were 0.3 birds per year and 0.3 transects per year containing birds.

Evidence from the BBS throughout the species range in North America suggests a decline of 3 percent per year from 1980 to 2003. However, regional trends fluctuated widely, from an 11 percent decease in the southern Rocky Mountains, to an 8 percent increase in the northern Rocky Mountains. It is important to note that none of the trends are statistically significant because the two main tools typically used in assessing long-term population trends for birds (BBS and CBC surveys) do not adequately sample for American three-toed woodpeckers.

Natural History

Distributed throughout the subalpine in coniferous-forested regions, primary habitat of the three-toed woodpecker is spruce-fir forests, but the bird may also inhabit ponderosa pine, lodgepole pine, Engelmann spruce, and mixed conifer stands where insect populations are high and the tree bark is thin and flaky (Andrews and Righter, 1992; and Hoover and Wills, 1984).

Nesting occurs in May and June, and young can be found in the nest into mid-August in Colorado (Kingery, 1998). These woodpeckers stay on or near their home ranges throughout the year (Wiggins, 2004b).

Environmental Baseline

The basic habitat requirements of the species include mature and old-growth forests with abundant snags and diseased trees and recently burned areas. Wood-boring insect larvae and pupae extracted from beneath the bark of trees constitute the main diet for these woodpeckers.

Potential habitat of the three-toed woodpecker within the Corridor is lodgepole pine, ponderosa pine, Douglas-fir, and spruce-fir forests with decadent trees. For the purposes of this study, any impacts on these areas within the Corridor were quantified as impacts on three-toed woodpecker habitat. These vegetation types occur throughout the Corridor as illustrated on **Figure BR - 3** (Maps 1-7)

The woodpecker is uncommon but scattered throughout the forested regions of Colorado. The species is a confirmed breeder in Rio Blanco and Pitkin counties on the WRNF and has been observed in Garfield, Eagle, and Summit counties. The best data available for the ARNF come from unburned, old-growth spruce-fir habitats in the Indian Peaks Wilderness Area, where population estimates of 1 bird for every 250 acres were found (RMBO, 2005); but no population trends are currently discernable. Transect counts in and near the ARNF since 1998 are sparse and are consistent with the low-density findings in Indian Peaks Wilderness Area. Results of survey efforts suggest that population trends may be stable (RMBO, 2005). Wiggins (2004b) presented BBS abundance numbers of 0.61 birds per acre and CBCs of 0.39 birds per acre. The species has a state heritage status rank of S3, showing it is vulnerable to extirpation in Colorado.

Direct, Indirect, and Cumulative Effects of Alternatives

Action Alternatives

Table BR - 37 and **Table BR - 38** provide the estimated direct impacts on potential American three-toed woodpecker habitat. Impacts on the WRNF from the Preferred Alternative would be 8.4 acres for both the Minimum Program (55 or 65 mph) and Maximum Program (55 or 65mph). On the ARNF, impacts would range from 3.1 acres (Minimum Program [55 or 65mph]) to 6.5 acres (Maximum Program [55 or 65mph]).

On the WRNF, the greatest impacts among all alternatives would be associated with the Combination Six-Lane Highway with Rail and Intermountain Connection alternative, while the least impacts would be associated with the Minimal Action and Advanced Guideway System alternatives. On the ARNF, the greatest impacts would be associated with the Combination Six-Lane Highway with Rail and Intermountain Connection alternative, while the least impacts would be associated with the Advanced Guideway System and Bus in Guideway alternatives. Total habitat acreage in WRNF and ARNF is estimated at 907,600 acres and 886,000 acres, respectively. Road effect zone-related disturbance would also affect this species due to increased transportation activities associated with all action alternatives. Loss of occupied habitat would force the birds to find new habitat and likely spend more energy in doing so. The direct loss of habitat shown in **Table BR - 37** and **Table BR - 38** would represent approximately 0.002 percent and 0.001 percent of potential habitat available on the WRNF and ARNF, respectively.

Table BR - 37. Direct Impacts on American Three-Toed Woodpecker Habitat (acres): Preferred Alternative

	Minimum Program		Maximum Program	
	Specific Highway Improvements with AGS		Combination 6-Lane Highway with AGS	
	55 mph	65 mph	55 mph	65 mph
WRNF	8.4	8.4	8.4	8.4
ARNF	3.1	3.1	6.5	6.5

Data provide minimal to maximum impacts for the Preferred Alternative.

Table BR - 38. Direct Impacts on American Three-Toed Woodpecker Habitat (acres): Action Alternatives Evaluated in the Draft PEIS

	Minimal Action	Rail with IMC	AGS	Dual-Mode Bus in Guideway	Diesel Bus in Guideway	Six-Lane Highway 55 mph	Six-Lane Highway 65 mph	Reversible/ HOV/HOT Lanes	Combination Six-Lane Highway with Rail and IMC	Combination Six-Lane Highway with AGS	Combination Six-Lane Highway with Dual-Mode Bus in Guideway	Combination Six-Lane Highway Diesel Bus in Guideway
WRNF	3.2	11.4	4.5	5.6	5.6	5.5	5.5	5.6	14.1	8.4	8.5	8.5
ARNF	2.1	5.2	0.9	1.4	1.4	2.9	3.0	4.6	8.6	6.5	6.3	6.3

Indirect impacts on habitat would include possible induced growth in rural areas associated with the Combination and Transit alternatives. However, because of the large amount of spruce-fir, ponderosa pine, and lodgepole pine habitat available in the Forests, these impacts are expected to be relatively small.

Cumulative impacts would include increased loss of foraging habitat from planned growth and development of areas adjacent to the Forests. However, the most significant cumulative effect in the project area would be the existing and expanding mountain pine beetle epidemic that is killing thousands of acres of trees and is actually increasing the food source available to the woodpecker. Available suitable habitat for three-toed woodpeckers is extensive within the larger geographic areas.

No Action Alternative

Indirect and cumulative impacts on woodpecker habitat areas that currently occur within the road effect zone would remain. No additional kinds of impacts are expected to result from the No Action Alternative, but existing sources of impacts would continue (growth and forest visitation).

Determination of Effects and Rationale

Action Alternatives

Because three-toed woodpecker populations within the Corridor area and adjacent areas are expected to increase as a result of a mountain pine beetle epidemic, and because none of the action alternatives would affect the availability of cavity-nesting and foraging habitat within the high-elevation geographic area, all action alternatives **may adversely impact individuals, but not likely to result in a loss of viability in the planning area, nor cause a trend to federal listing**. This determination would apply to both the WRNF and the ARNF.

No Action Alternative

Because the No Action Alternative would not cause any direct changes to the existing condition of habitat, even though indirect and cumulative effects such as growth and dispersed recreation use would continue, the determination is that there will be **no impact** on three-toed woodpeckers. This determination would apply to both the WRNF and the ARNF.

Olive-Sided Flycatcher *(Contopus cooperi)*, FS

The olive-sided flycatcher is a large flycatcher in the family Tyrannidae, genus *Contopus*. It normally measures 7.5 inches long, with a wingspan of 13 inches, and weighs 1.1 ounces. This species is currently documented to occur on ARNF and WRNF lands.

Distribution

Olive-sided flycatchers breed in boreal forests from Alaska to Newfoundland and in the mountains of the western U.S. They winter from Mexico south to Peru and Bolivia. In Colorado, they winter in high mountain boreal forest inhabiting elevations from 7,000 to 11,000 feet (Andrews and Righter, 1992). On the WRNF, olive-sided flycatchers are mostly found in spruce-fir forests of the upper Montane Zone. Their distribution on the Forest is probably widespread due to the naturally patchy structure of the Forest (USFS, 2002a). On the ARNF, in Grand County, olive-sided flycatchers are considered fairly common summer visitors, using aspen and coniferous forest, meadows, and riparian areas (USDA, 2005a). Breeding records exist within coniferous forest (Jasper and Collins, 1987). BBS found 84 percent of olive-sided flycatcher habitat occurrences in coniferous forests (Kingery, 1998). Considered vulnerable both globally and in Colorado (NatureServe, 2004), this species is an uncommon summer resident in the Colorado mountains and is thought to be rare to uncommon locally in the lower mountains and foothills (Andrews and Righter, 1992).

The flycatcher is a Region 2 Forest Sensitive species with documented occurrence in both the ARNF and the WRNF. The flycatcher elevation range is present in most of the Corridor: in Glenwood Springs and from Eagle to the eastern terminus, except in the area of the Continental Divide that extends above 11,000 feet.

Causes of olive-sided flycatcher decline are not well known but may be due to habitat changes in the breeding range and/or in migration and wintering areas. BBS data indicate declines since 1966 across much of North America and an overall decline of 70 percent (3.6 percent per year) from 1966 to 1999 and 53 percent (3.7 percent per year) from 1980 to 1999. Declines are relatively similar across the range. The only state or province with a positive trend estimate for 1966–1999 is Alberta (3.1 percent); however, its trend estimate for 1980–1999 is negative (NatureServe, 2005d).

The Colorado BBS and other surveys indicate a decreasing trend in population of 3.9 percent per year, resulting in a drop of three-quarters of the population over the last 31 years. The factors affecting the change are not entirely clear because information is lacking about their natural history. As a neotropical migrant that may spend only three to four months of the year on its North American breeding grounds, the flycatcher is at risk from deforestation on its wintering grounds in Central and South America (USDA, 2005a). Pesticide applications to control black flies, mosquitoes, or injurious forest insects could have a severe local impact on the prey base of this flycatcher, both in North America and on its wintering grounds (USDA, 2005a). Populations have experienced declines in Colorado in the past, but it is thought that populations are currently stable (Gross, 1998).

Natural History

The olive-sided flycatcher breeds where two basic habitat components exist: snags and conifers. They most often occur at elevations from 7,000 to 11,000 feet, in areas with natural clearings, bogs, stream, and lakeshores with water-killed trees, forest burns, and logged areas with standing dead trees. Andrews and Righter (1992) contend that mature spruce-fir and mature Douglas-fir are the preferred breeding habitats. However, they will use aspen forests that are clear-cut in patches and have snags and spruce trees available. Habitat preference seems to be associated with open areas and edges that provide for foraging. Remnant snags and trees in burns and clearcuts may provide the necessary foraging and singing perches. Generally, nesting habitat does not have a high canopy closure. Nests are placed most often in conifers on horizontal limbs, from 5 to 30 feet above ground. Kingery (1998) suggests that forest structure is more important than tree species composition.

Most flycatchers consume some nonflying insects, but the olive-sided flycatcher feeds exclusively on flying insects, in particular honeybees, flies, moths, grasshoppers, and dragonflies (Kingery 1998).

Environmental Baseline

Habitat within the Corridor known to support olive-sided flycatchers includes aspen, riparian areas, coniferous forests, and meadows. These vegetation types occur throughout the Corridor as illustrated on **Figure BR - 3** (Maps 1-7). Colorado olive-sided flycatchers do not always stay near water and are recorded from streamsides to ridge tops (Kingery, 1998). Studies in western North America conclude that this species is more abundant in some types of logged forest than in unlogged stands. A preliminary study in western Oregon documented that nest success was substantially higher in post-fire habitat than in several types of harvested forests (USDA, 2005a). In Colorado, the species is considered a fairly common summer visitor, using aspen and coniferous forests, meadows, and riparian areas.

Direct, Indirect, and Cumulative Effects of Alternatives

Action Alternatives

The main risk factor for the flycatcher is the removal of perch snags and trees used for foraging and singing. Timber harvest activities may increase open areas and edge, but burned areas probably provide higher quality habitat for reproductive success. This species would most likely be affected by habitat loss, both directly and due to induced growth, as well as an increase in road effect zone-related disturbance. Loss of occupied habitat would force the birds to find new habitat, and they would likely spend more energy in doing so.

Table BR - 39 and **Table BR - 40** provide the estimated direct impacts on potential olive-sided flycatcher habitat. Impacts on the WRNF from the Preferred Alternative would range from 24.9 acres (Minimum Program 65 mph and Maximum Program 65 mph) to 27.8 acres (Minimum Program 55 mph and Maximum Program 55 mph). On the ARNF impacts would range from 3.1 acres (Minimum Program [55 or 65mph]) to 8.9 acres (Maximum Program [55 or 65mph]).

Of all the action alternatives, the Six-Lane Highway 65 mph alternative would disturb the least amount of flycatcher habitat on the WRNF. On ARNF lands, the least impacts would be associated with the Advanced Guideway System alternative. In both the WRNF and the ARNF, the most flycatcher habitat would be disturbed by the Combination Six-Lane Highway with Rail and Intermountain Connection alternative. Total flycatcher habitat on the WRNF represents 1,513,000 acres and 1,218,000 acres on the ARNF. Potential maximum direct habitat losses would represent approximately 0.003 percent of total available habitat on WRNF and 0.001 percent on ARNF lands.

Table BR - 39. Direct Impacts on Olive-Sided Flycatcher Habitat (acres): Preferred Alternative

	Minimum Program		Maximum Program	
	Specific Highway Improvements with AGS		Combination 6-Lane Highway with AGS	
	55 mph	65 mph	55 mph	65 mph
WRNF	27.8	24.9	27.8	24.9
ARNF	3.1	3.1	8.9	8.9

Data provide minimal to maximum impacts for the Preferred Alternative.

Table BR - 40. Direct Impacts on Olive-Sided Flycatcher Habitat (acres): Action Alternatives Evaluated in the Draft PEIS

	Minimal Action	Rail with IMC	AGS	Dual-Mode Bus in Guideway	Diesel Bus in Guideway	Six-Lane Highway 55 mph	Six-Lane Highway 65 mph	Reversible/ HOV/HOT Lanes	Combination Six-Lane Highway with Rail and IMC	Combination Six-Lane Highway with AGS	Combination Six-Lane Highway with Dual-Mode Bus in Guideway	Combination Six-Lane Highway with Diesel Bus in Guideway
WRNF	17.2	31.5	16.3	25.5	25.5	20.3	14.5	20.3	43.1	27.8	32.8	32.8
ARNF	2.1	5.3	0.9	1.4	1.4	4.4	4.4	6.3	11.2	8.9	8.5	8.5

Most of the action alternatives would affect the abundance of snags on the landscape and disrupt existing foraging opportunities for the species. Forest-wide Standards and Guidelines on both Forests require managing for special habitats such as snag and future snag (green trees) components. Because the olive-sided flycatcher catches all of its prey in the air, it is dependent on areas with abundant flying insects. This likely means riparian areas, meadows and edge habitats, and coniferous forests with open canopies. Because significant amounts of these habitats are available in the Corridor, habitat loss would be relatively small in scope, and the impacts are expected to be minor.

Cumulative effects within the Corridor area would include the mountain pine beetle epidemic, causing significant mortality of mature and late-successional lodgepole pine stands. Cumulative effects may affect the flycatcher's broad use in the Corridor for foraging habitat. Cumulative effects also may result from increased residential and commercial land development in areas adjacent to National Forest System Lands in Summit and Clear Creek counties and an increase in recreational use of the Forest. Such disturbance, while possibly affecting individuals and nesting pairs, is not likely to have effects on the population as a whole.

All of these activities may affect the reproduction of some pairs because of direct disturbance or destruction of nesting habitat. Similar actions are occurring outside the Forests, which may also affect reproduction or habitat with similar activities. None of the proposed alternatives would likely measurably affect the habitat or populations of this species under any alternative because habitat loss would affect approximately 0.0003 percent of available habitat on either Forest, there are management prescriptions to maintain snag habitats, and nesting habitat losses would affect the birds in only the one year when the disturbance occurred.

No Action Alternative

Because the No Action Alternative would not have any direct impacts on habitat, the current level of impacts on the species would remain.

Determination of Effects and Rationale

Action Alternatives

All action alternatives would have minor direct effects from actual removal of habitat ranging from 0.9 to 43.1 acres. Possible indirect effects from the alternatives could result in increased forest visitation (both forests) and possible increases in induced growth (Corridor west of the Continental Divide primarily). The Transit alternatives may increase visitation to developed recreation areas and induce additional growth near the transit centers. Combination alternatives could contribute the greatest amount of induced growth in Eagle County plus moderate growth in Summit County. The indirect effects would include increased disturbance resulting from human presence and may remove some foraging habitat for the birds.

*Because some actions in all alternatives may affect reproductive **success** of some pairs, the proposed actions of all alternatives may adversely impact individuals. Because little change in habitat is expected forest-wide, and possible impacts on the reproductive success of some pairs would be limited, the proposed actions of all alternatives **may adversely impact individuals, but not likely to result in a loss of viability in the planning area, nor cause a trend to federal listing.** While there may be site-specific differences, there will be no measurable differences among alternatives on the forest populations on either the WRNF and the ARNF.*

No Action Alternative

Because the No Action Alternative would not cause any direct changes to the existing condition of habitat, even though indirect and cumulative effects such as growth and dispersed recreation use would continue, the determination is that there would be **no impact** on olive-sided flycatchers. This determination would apply to both the WRNF and the ARNF.

BR.4.1.3 Amphibians

Boreal Toad (Bufo boreas boreas), FS, MIS

The boreal toad is in the family Bufonidae, genus *Bufo*. This toad is considered a subspecies of western toad (*Bufo boreas*). The females range from 3 to 4 inches in length, while the generally smaller males range from 2.4 to 3.2 inches (Keinath and McGee, 2005). In addition to being a Forest Sensitive species, the boreal toad is also an MIS species for the ARNF for the community of montane riparian and wetlands. This species is currently documented to occur on WRNF and ARNF lands.

Distribution

The boreal toad ranges from southern Alaska through the mountains and higher plateaus of Utah and portions of the mountains of Colorado. In 1995, USFWS determined that federal listing was warranted, but this population was precluded from listing due to the need for action on higher priority species (NatureServe, 2005e). On September 23, 2005, USFWS issued a final notice in the Federal Register stating that listing the boreal toad as endangered was not warranted because the Southern Rocky Mountain population (SRMP) does not constitute a species, subspecies, or distinct population segment, and the SRMP is withdrawn from the Candidate list.

The species conservation assessment (Keinath and McGee, 2005) noted the boreal toad was once widely distributed in Region 2. In the Southern Rocky Mountains, the boreal toad was historically found in the San Juan Mountains, Elk Mountains, Front Range, Park Range, Elkhead Mountains, Tenmile Range, Gore Range, Mosquito Ridge, Collegiate Peaks, Calebra Range Flat Tops, and Grand Mesa in Colorado. In southern Wyoming, it was found in the Medicine Bow, Sierra Madre, and Pole Mountains. In New Mexico, it was found in the Lagunita Mountains. The New Mexico populations are thought to be extirpated (Degenhardt, Painter, and Price, 1996). Within Colorado, the boreal toad is found in most high-elevation mountain ranges including the Front Range, Gore Range, Mosquito, and Tenmile Range, and the White River Plateau (Keinath and McGee, 2005).

Populations from the Southern Rocky Mountains are geographically separated from other populations by elevational and geographic barriers (Nesler and Goettl, 1994). The elevational range for this species within the Southern Rocky Mountains is between 7,000 and 12,900 feet (Nesler and Goettl, 1994). This population is unique from other North American populations in its precipitous, well-documented population decline over the past 15 to 20 years (Keinath and McGee, 2005).

The boreal toad was once widespread throughout its range. Downward population trends have been noted from the 1970s continuing through the 1990s. The boreal toad has undergone a precipitous decline in distribution and abundance in the Southern Rocky Mountains during the last 20 years. By the early 1980s, the boreal toad was still considered fairly common throughout its known range in Colorado (Nesler and Goettl, 1994 as cited in Keinath and McGee, 2005). However, since that time, many known populations throughout Colorado and southern Wyoming have become extirpated. Reasons for the widespread decline in toad breeding populations are not well defined. Though no one factor has been identified as the cause of the declines, more than one factor or the synergistic effects of two or more factors may contribute to documented population declines (Carey, 1993 as cited in Keinath and McGee, 2005). Chytrid fungus (*Batrachochytrium dendrobatidis*, known as Bd) has been associated with amphibian extirpations in Australia. Chytrid fungus has been found in the Southern Rocky Mountains in Colorado in western boreal toad in 1999. Recent evidence points to Chytrid fungus as a significant contributor to boreal toad population declines. It appears that a combination of host factors (niche specialization, low fecundity) and pathogen factors (prefers cool developmental temperatures) may predispose some montane species, such as boreal toads, to increased impacts (Danzak et al., 1999 as cited in Keinath and McGee, 2005). Little is known about the extent and severity of the outbreak in Colorado, but because of the potential consequences of the outbreaks on montane amphibians, it needs to be taken very seriously. Chytrid fungus may be the greatest threat to the viability of this species. It is not known how chytrid fungus moves through the environment and whether human activities may contribute to its spread.

Declines of boreal toads have also been attributed to redleg disease, a highly contagious bacterial infection caused by *Aeromonas*, which is more severe when populations are stressed (Nestler and Goettl, 1994 as cited in Keinath and McGee, 2005). The species' population decline is not isolated and is believed to be linked to other catastrophic die-offs of amphibians throughout portions of the world. Worldwide declines in amphibian populations are well described but poorly understood.

On the ARNF, there are currently 23 breeding populations with variable population numbers listed in tables from the Boreal Toad Recovery Team (USDA, 2008f). Of the current breeding sites, 15 are on the ARNF, 6 are in Rocky Mountain National Park, 1 is in Clear Creek County, and 1 is in Grand County (USDA, 2008a). All of the sites and the trend data for each are presented in **Table BR - 41**.

Table BR - 41. Boreal Toad Population Trend Data in and Near Arapaho and Roosevelt National Forests (Boreal Toad Recovery Team, 2008)

Year	Males/Females/ Egg Masses[1]	Recruitment[2]	Age Classes[3]	Comments
Boulder County – BO01 – Lost Lake (Middle Boulder Creek) - ARNF Bd: Negative (2001)				
1996	0/1/0	No	2(M,A)	Toadlets introduced
1997	0/1/0	No	3(M,1,A)	Toadlets introduced*
1998	0/2/0	No	3(1,2,A)	No breeding observed
1999	0/0/0	No	None	Minimal surveys done
2000	0/0/0	No	None	Adequate monitoring
2001	0/0/0	No	None	Adequate monitoring**
2002	0/0/0	No	None	Adequate monitoring
2003	0/0/0	No	None	3 visits
2004	0/0/0	No	None	2 visits
2005	0/0/0	No	None seen	Site visited 2 times
2006	0/0/0	No	None seen	Site visited once
2007	0/0/0	Unk	None	Site visited once
*Tadpoles observed, possibly from mating of a resident female and a translocated male toad. **PCR test results were negative for samples from 5 groups of sentinel tadpoles placed at Lost Lake in 2001.				
Clear Creek County – CC01 - Vintage Site (Clear Creek West Fork) – ARNF Bd: Not tested				
1994	?/?/?	Unk	Multiple	Little data available
1995	3/2/2	Unk	2(M,A)	Probably few metamorphs
1996	1/1/1	No	1(A)	No production
1997	1/1/1	No	1(A)	Eggs froze
1998	3/0/0	No	1(A)	No breeding observed
1999	3/0/0	No	1(A)	No breeding observed
2000	0/0/0	No	None seen	Minimal monitoring
2001	0/0/0	No	None seen	No breeding observed*
2002		No		Not monitored
2003	0/0/0	Unk	None seen	No evidence of breeding
2004		No		Not monitored
2005	0/0/0	No	None seen	No evidence of breeding
2006	0/0/0	No	None seen	Site is drying
2007	0/0/0	Unk	None seen	Site was dry at only visit
*All site visits in 2001, including night surveys, conducted in May.				
Clear Creek County – CC02 – Urad/Henderson (Clear Creek West Fork) – Henderson Mine Bd: Positive (2004)				
1995	131/19/19	Yes	4(M,1,S,A)	

Year	Males/Females/ Egg Masses[1]	Recruitment[2]	Age Classes[3]	Comments
1996	142/18/18	Yes	4(M,1,S,A)	Few metamorphs
1997	167/33/23	Yes	4+(M,1,S,A)	
1998	203/107/55	Yes	4(M,1,S,A)	Many metamorphs
1999	141/60/60	Unk	4(M,1,S,A)	Bd mortality
2000	34/34/34	Yes	2(M,A)	
2001	14/14/14	Unk	3(M,1,A)	Some egg mortality*
2002	25/22/22	Unk	2(M,A)	Several sites dry
2003	15/15/15	Yes	1(A)	
2004	10/16/16	Yes	3(M,A,1)	Several sites dried up
2005	2/12/12	Yes	2(M,A)	Poor hatching success
2006	2/1/4	Yes	4(M,1,S,A)	Some water level issues
2007	2/2/0	Unk	3(M,A,1)	
*Egg mass mortality due to a water fungus observed at the hesbo site; other sites had good egg mass survival.				
Clear Creek County – CC03 – Herman Gulch (Clear Creek) – ARNF Bd: Positive (2004)				
1993	?/?/?	Unk	2(M,A)	Breeding observed
1994	11/11/11	Unk	2(M,A)	
1995	52/12/12	Unk	3(M,S,A)	Good production
1996	20/12/12	No	1(A)	Poor larvae survival
1997	19/10/10	Unk	3(M,S,A)	Many metamorphs
1998	10/10/10	Unk	2(M,A)	Few metamorphs seen
1999	11/11/11	Yes	1(A)	High egg mortality
2000	9/5/5	Unk	3(1,S,A)	No metamorphs seen
2001	2/2/4	Unk	3(M,S,A)	<50 metamorphs
2002	0/1/0	Unk	1(A)	No evidence of breeding
2003	1/1/1	Yes	1(M)	<50 metamorphs
2004	4/4/4	No	2(1,A)	
2005	0/0/0	No	None seen	
2006	0/0/0	No	None seen	Site visited once
2007	0/0/0	Unk	None seen	Site visited twice
Clear Creek County – CC04 – Mount Bethel (Clear Creek) – ARNF Bd: Positive (2005/2006)				
1993	Yes	Unk	2(M,A)	Many metamorphs
1994	Yes	Unk	2(M,A)	
1995	4/1/1	No	2(S,A)	Few, if any metamorphs
1996	3/3/3	Unk	2(M,A)	Few metamorphs
1997	9/1/1	Unk	2(M,A)	
1998	11/3/3	Unk	2(M,A)	36 + metamorphs seen
1999	23/1/1	Yes	2(M,A)	500 + metamorphs
2000	29/3/3	Yes	4(M,1,S,A)	Many metamorphs seen
2001	28/6/5	Yes	4(M,1,S,A)	500+ metamorphs seen
2002	16/4/4	Yes	3(M,1,A)	Early metamorphosis
2003	7/7/7	Yes	3(M,1,A)	<50 metamorphs
2004	68/8/8	Unk	3(M,S,A)	<50 metamorphs
2005	33/6/6	Unk	2(M,A)	Tested Bd positive
2006	5/0/7	Unk	2(M,A)	Early breeding
2007	1/1/2	Unk	2(M,A)	4 site visits
Clear Creek County – CC05 – Bakerville (Clear Creek) – ARNF Bd: Not tested				
1994	1/1/1	Unk	2(M,A)	Limited data
1995	Unk	No	Unk	Site not monitored
1996	0/0/0	No	None seen	
1997	Unk	Unk	Unk	Site not monitored
1998	0/0/0	Unk	None seen	Inadequate monitoring

Year	Males/Females/ Egg Masses[1]	Recruitment[2]	Age Classes[3]	Comments
1999	0/1/0	No	1(A)	Inadequate monitoring
2000	0/0/0	No	None seen	Monitoring adequate
2001	3/0/0	Unk	1(A)	Inadequate monitoring
2002				Site not monitored
2003	1/1/1	No	1(A)	Few tadpoles found
2004	0/0/0	No	None seen	
2005	0/0/0	No	None seen	
2006	0/0/0	No	None seen	Site visited once
2007	0/0/0	Unk	None seen	Visited twice
Clear Creek County – CC06 – Silverdale (Clear Creek South) – ARNF Bd: Negative (2003)				
1993	?/?/0	Unk	Multiple	First survey of site
1994	?/?/0	Unk	Multiple	No metamorphs
1995	2/0/0	Unk	2(S,A)	No breeding observed
1996	5/0/0	No	1(A)	No breeding observed
1997	0/0/0	No	None	Inadequate monitoring
1998	1/1/0	Unk	2(S,A)	Monitoring marginal
1999	0/0/0	Yes	1(S)	41 subadults seen
2000	0/0/0	Unk	2(1,S)	Many subadults seen
2001	0/0/0	Unk	2(S,A)	65 subadults, 7 adults*
2002				Site not monitored
2003				Site not monitored
2004	0/0/0	No	None seen	
2005	0/0/0	No	1(A)	9 unsexed adults seen
2006	0/0/0	No	None seen	Site visited twice
2007	0/0/0	Unk	None seen	Visited once – poor visibility
*Breeding site used in 1990s apparently not being used at present, and location of current breeding site unknown.				
Clear Creek County – CC07 – Otter Mountain (Clear Creek South) – ARNF Bd: Negative (2003/2006)				
2003	1/1/1	No		200 tadpoles seen
2004	2/2/2	No	1(A)	50 tadpoles seen
2005	0/0/0	No	1(A)	1 adult seen
2006	2/2/2	No	1(A)	5 adults seen
2007	0/0/0	Unk	None	Sed fences may be barriers
Grand County – GR01 – Jim Creek (Winter Park) – ARNF Bd: Not tested				
1995	5/1/?	Unk	3+(S,A)	Substantial population
1996	?/?/0	Unk	3+(S,A)	Substantial population
1997	0/0/0	Unk	None	Monitoring inadequate
1998	0/0/0	Unk	None	Monitoring inadequate
1999	0/0/0	Unk	None	No night survey done
2000	0/0/0	Unk	None	Monitoring adequate
2001	0/0/0	Unk	None	No night survey done
2002	0/0/0	Unk	None	Not monitored
2003	0/0/0	Unk	None	Site visited 7 times*
2004	0/0/0	Unk	None	
2005				Not monitored
2006				Monitoring report not received
2007	0/0/0	Unk	None	Visited twice
*Breeding site constructed just downstream from original breeding area in 2003; this is the site that will be monitored in subsequent years.				
Grand County – GR02 – Pole Creek (Pole Creek) Bd: Positive (2002/2003)				
1995	5/3/3	Unk	2(M,A)	Numerous metamorphs
1996	3/3/3	Yes	2(M,A)	Few metamorphs
1997	10/4/2	No	2(1,A)	Few, if any, metamorphs

Year	Males/Females/ Egg Masses[1]	Recruitment[2]	Age Classes[3]	Comments
1998	5/2/2	Yes*	2(M,A)	Monitoring marginal
1999	5/5/5	Unk	2(M,A)	Metamorphs at #4
2000	6/2/2	Yes	3(M,S,A)	One clutch desiccated
2001	9/7/7	Yes	4(M,1,S,A)	>500 metamorphs
2002	14/6/6	Yes	4(M,1,S,A)	Metamorphs present**
2003	7/2/2	Yes	4(M,1,S,A)	>500 metamorphs
2004	2/2/2	Yes	3(M,S,A)	>150 metamorphs
2005	34/8/8	Yes	4(M,1,S,A)	>3000 metamorphs
2006	5/5/5	Yes	3(M,1,A)	35 adults seen
2007	12/4/0	Unk	3(A,1,S)	16 adults seen
This locality is on Pole Creek Golf Course, near holes 4 and 15. *Recruitment from 1998 production based on observations of subadult toads in 2000. **Metamorphs sampled on 9/23/02 Bd positive.				
Grand County – GR03 – Vasquez Creek (Vasquez Creek) – ARNF Bd: Not tested				
1999	1/1/1	Yes*	1(A)	Found late in the season
2000	0/0/0	No	None	Monitoring adequate
2001	0/0/0	No	1(S)	1 subadult seen*
2002	0/0/0	Unk	None	1site visit
2003				Site not monitored
2004	0/0/0	No	None	
2005	0/0/0	No	1(A)	1 adult seen
2006	0/0/0	No	None seen	
2007	0/0/0	Unk	None	Potential habitat searched throughout drainage
*16 toadlets from 1999 clutch were captive reared and released in Vasquez Creek drainage In 2000; the subadult observed in 2001 was observed at the release site. No toads were observed then or since at the 1999 breeding site (tire rut): both sites continue to be monitored.				
Grand County – GR04 – McQueary Lake (Upper Williams Fork) – ARNF Bd: Positive (2003)				
2001	2/3/3	Yes	2(1,A)	No metamorphs observed
2002	8/6/6	Unk	2(M,A)	<50 metamorphs
2003	2/2/2	No	2(S,A)	Desiccation and predation
2004	0/0/0	No	None	
2005	0/0/0	No	None seen	
2006	0/0/0	No	None seen	Possible adult sighting
2007	0/0/0	Unk	None	Also searched above lake to upper ponds
Grand County – GR05 – Upper Williams Fork (Upper Williams Fork) – ARNF Bd: Negative (2006)				
2001	2/2/2	Yes	3(A,M,1)	Metamorphs observed
2002	1/1/1	Yes	3(A,S,1)	No metamorphs seen
2003	1/2/1	Yes	4(M,1,S,A)	<50 metamorphs
2004	2/2/2	Yes	4(M,1,S,A)	Cold water temps
2005	2/1/1	Unk	2(1,S,A)	Metamorphs possible
2006	2/0/1	Yes	2(M,A)	
2007	2/1/0	Unk	3(M,A,1)	
Grand County – GR06 – Big Meadow (Big Meadow) – RMNP Bd: Positive (2004/2005)				
2004	1/1/0	Yes	3(M,1,A)	
2005	2/2/2	Unk	2(1,A)	
2006	0/0/2	Unk	1(S)	Pond dried
2007	1/1/0	Unk	2(A,S)	
Grand County – GR07 – South Fork (South Fork Williams Fork) – ARNF Bd: Unk				
2007	?/?/?	Unk	?	Found by DOW in September – only tadpoles seen

Year	Males/Females/ Egg Masses[1]	Recruitment[2]	Age Classes[3]	Comments
Larimer County – LR01 – Lost Lake (North Fork Big Thompson) – RMNP Bd: Positive (2000/2005)				
1990	?/?/22	Unk	1(A)	Incomplete data
1991	206/28/15	Unk	1(A)	No data on subadults
1992	143/23/23	Unk	1(A)	No data on subadults
1993	77/10/?	Unk	1(A)	Incomplete data
1994	110/35/35	Unk	Unk	No data on subadults
1995	122/32/32	Yes*	1(A)	No data on subadults
1996	43/15/152	No	1(A)	No data on subadults
1997	112/15/15+	No	3(M,2*,A)	15–20 egg masses
1998	106/12/12	Unk	2(M,A)	150+ metamorphs seen
1999	10/10/10	Unk	1(A)	Metamorphs possible
2000	3/3/3	Unk	1(A)	Bd positive
2001	0/3/0	Unk	1(A)	Only females observed
2002	0/1/0	Unk	1(A)	One female observed
2003	0/0/0	Unk	None	Surveys adequate
2004	0/0/0	Unk	None seen	Juveniles found along trail
2005	3/3/3	Unk	1(A)	Larvae seen
2006	0/0/0	Unk		Larvae seen
2007	0/2/2	Unk	2(A,S)	No breeding observed
*Recruitment in 1995 based on observation of 2-year-old toads in 1997				
Larimer County – LR02 – Kettle Tarn (North Fork Big Thompson) – RMNP Bd: Positive (2001/2005); Negative (2006)				
1990	?/?/13	Unk	1(A)	Incomplete data
1991	21+/23/23	Unk	1(A)	No data on subadults
1992	63/18/18	Unk	1(A)	No data on subadults
1993	54/25/25	Unk	2(M,A)	
1994	120/21/21	Unk	2(M,A)	
1995	210/24/24	Unk	2(M,A)	
1996	29/13/8	Unk	3(M,2,A)	
1997	15/11/0	No	1(A)	
1998	18/13/10	Unk	1(A)	
1999	15/8/2	Yes*	1(A)	No metamorphs seen
2000	13/5/3	Unk	2(1,A)	One 1 year old seen*
2001	2/4/3	Yes	3(M,S,A)	Metamorphs observed*
2002	2/2/2	Yes	3(M,1,A)	NASRF tadpoles released**
2003	3/3/3	Yes	3(M,1,A)	500+ metamorphs
2004	2/2/2	Unk	3(1,S,A)	Site dry by late July
2005	0/1/0	Unk	1(A)	Good water levels
2006	0/3/1	Unk	1(A)	Desiccation loss
2007	1/0/0	Unk	1(A)	No breeding observed
*Metamorphs observed but not estimated on monitoring form. **Tadpoles from NASRF released at site; it is unknown whether metamorphs observed in 2002 derived from naturally produced clutches for from these released tadpoles.				
Larimer County – LR03 – Spruce Lake (Big Thompson) – RMNP Bd: Negative (2003/2005/2006)				
1996	Unk	Yes	Unk	Reproduction presumed
1997	3/1/?	Unk	3(1,S,A)	Limited monitoring
1998	9/3/1	Unk	1(A)	Inadequate monitoring
1999	9/3/1	Yes	2(S,A)	Inadequate monitoring
2000	10/4/2	Unk	3(M,1,A)	Three 1-year old seen
2001	10/2/2	Unk	2(S,A)	Larvae observed*
2002	15/3/3	Unk	1(A)	No metamorphs observed
2003	12/1/1	Unk	1(A)	No larvae observed
2004	10/2/2	Unk	1(A)	No larvae observed

Year	Males/Females/ Egg Masses[1]	Recruitment[2]	Age Classes[3]	Comments
2005	7/5/5	Unk	1(A)	Larvae observed
2006	7/1/3	Unk	2(M,A)	Eggs collected from site
2007	0/8/2	Unk	1(A)	15 egg masses and 100 tadpoles observed
*Last site visit June 20, prior to time of metamorphosis.				
Larimer County – LR04 – Glacier Basin (Big Thompson) – RMNP Bd: Not tested				
1995	1/1/0	Unk	1(A)	
1996	1/1/1	Yes	1(A)	Translocation site
1997	0/1/0	No	2(1,A)	
1998	3/0/0	Unk	1(A)	No breeding activity seen
1999	3/0/0	Unk	1(A)	No night survey done
2000	0/0/0	Unk	None	Monitoring adequate
2001				Not monitored*
*This site will no longer be regularly monitored after 2000. Translocation appears unsuccessful (Muths et al. 2001).				
Larimer County – LR05 – Twin Lake (South Cache la Poudre) – ARNF Bd: Positive (2001)				
1998	1/1/1	Unk	1(A)	Tadpoles observed
1999	0/0/0	Unk	None	Site disturbed/dam work*
2000	0/0/0	Yes	None	Low water
2001	3/2/2	Yes	3(1,S,A)	No metamorphs seen
2002	1/1/1	Unk	2(S,A)	No metamorphs seen
2003	0/0/0	Unk	0	Site disturbed
2004				Not monitored
2005				Not monitored
2006				Not monitored
2007				Not monitored
*In 1999 there was temporary disturbance at this site due to testing of reconstructed dam.				
Larimer County – LR06 – Trout Creek (Trout Creek) – ARNF Bd: Negative (2004/2006)				
2004	2/2/2	Yes	1(A)	Site found 6/22/04
2005	0/0/0	Yes	None seen	
2006	0/0/3	Unk	3(1,S,M)	Good year at site
2007				Monitoring date not yet received
Larimer County – LR07 – Panhandle Creek (Panhandle Creek) – ARNF Bd: Negative (2006)				
2004	3/2/0	Yes	2(S,A)	Exact site not found
2005	0/0/0	Yes	None seen	
2006	5/0/1	Unk	4(M,1,S,A)	Exact site located
2007				Monitoring date not yet received
Larimer County – LR08 – Faye Lakes (Faye Lakes) – RMNP Bd: Negative (2005/2006)				
2004	4/4/0	Yes	2(M,A)	
2005	2/2/2	Yes	2(1,A)	
2006	3/2/0	Yes	3(M,1,A)	
2007	6/2/2	Unk	3(A,1,S)	

[1]*Males/Females/Egg Masses: This column shows the minimum number of breeding age males and females and number of viable egg masses at the locality in each year.*

[2]*Recruitment: A 'yes' entry means that one-year-old toadlets were observed at the site in the spring of the following year, or two-year-old toads were seen the second year.*

[3]*Age Classes: The first number in the entry indicates the minimum number of age classes observed/reported at a specific site. Numbers within parentheses indicate which age classes were observed: M=metamorphs (young of the year), 1=one-year-olds (new 'recruits'), S=subadults (generally two- or three-year-old toads), 2 or 3=subadults which were specifically identified as either two- or three-year-old toads, A=adult toads (generally 4 years old and older).*

As of 2007, there are 23 breeding sites on the Planning Area (see **Table BR - 42**). Although not part of the historic database, discovery of "new" breeding areas is probably just the first confirmation of boreal toad presence in areas not previously surveyed for boreal toads, but where they have been present for years. Of all 23 sites, 9 are Bd positive, 7 are Bd negative, and 6 have not yet been tested.

Table BR - 42. Breeding Sites on Planning Area

# Sites	Boulder County	Clear Creek County	Grand County	Larimer County
ARNF	1	6	5	3
RMNP	0	0	1	5
Private	0	1	1	0
Bd+	0	3 (2 neg: 2 unk.)	4 (3 unk.)	2 (5 neg: 1 unk.)

Despite the discovery of new sites (previously undetected sites) on the Planning Area, predominantly in Larimer County, and several others statewide, CNHP and other data clearly indicates a downward trend for boreal toad numbers at occupied sites in Colorado and on the Planning Area.

The WRNF has documented 14 boreal toad breeding populations on or near the Forest. Most of them are on National Forest System Lands, and some are on private land (in Vail, near Breckenridge, and in historic mining areas). **Table BR - 43** presents monitoring data from 1995 to 2004 for these sites.

Table BR - 43. Boreal Toad Population Trend Data in and near WRNF (CDOW, 2005)

Year	Males/Females/Egg Masses[1]	Recruitment[2]*	Age Classes[3]	Comments
Locality EA01 – Holy Cross City (Holy Cross City) Bd Status: Negative (2003)				
1996	1/1/1	Unk	1(A)	Predation & late season
1997	1/1/1	Unk	1(A)	Recruitment unlikely
1998	2/2/2	Unk	1(A)	Inadequate monitoring
1999	2/0/0	Unk	1(A)	Inadequate monitoring
2000	1/0/0	Unk	1(A)	Inadequate monitoring
2001	1/1/1	Unk	None seen	5 visits to site*
2002	2/1/1	Unk	1(A)	Breeding pond dried**
2003	2/1/1	Unk	1(A)	5 visits to site
2004	1/0/0	Unk	1(A)	No evidence of breeding
2005	1/0/0	Unk	1(A)	No evidence of breeding
2006	0/0/0	Unk	None seen	No evidence of breeding
2007	1/0/0	Unk	1(A)	No evidence of breeding
**Report of boreal toad tadpoles at this site in July 2001 by Bill Andree. **In 2002, the breeding pond dried, probably before tadpoles could metamorphose.*				
Locality EA02 – East Lake Creek (East Lake Creek) Bd Status: Negative (2004/2005/2006/2007)				
1996	1/1/1	Unk	3(M,S,A)	Site found 8/13/96
1997	Unk	Yes	Unk	Site not monitored
1998	3/0/0	Yes	2(1,A)	Inadequate monitoring
1999	4/4/4	Yes	3(M,1,A)	No night survey done
2000	2/2/2	Unk	3(1,S,A)	Minimal monitoring
2001	1/0/0	Yes	1(A)	Only one adult male seen*
2002	2/2/2	Yes	3(1,S,A)	14 adults seen (not sexed)
2003	2/2/2	Yes	3(M,S,A)	Likely many metamorphs
2004	2/2/2	Yes	4(M,1,S,A)	
2005	16/1/1	Yes	4(M,1,S,A)	
2006	5/0/1	Yes	4(M,1,S,A)	Tadpoles on first visit
2007	8/1/1	Unk	3(1,S,A)	Tadpoles on first visit
*Two closely associated breeding sites at this locality. *Successful breeding in 2001 assumed due to 2 one-year-olds observed in 2002.*				

Year	Males/Females/Egg Masses[1]	Recruitment[2]*	Age Classes[3]	Comments
Locality EA03 – East Vail (Vail) Bd Status: Negative (2004/2007); Positive (2005)				
1999	3/1/1	Yes	3(M,S,A)	Site found late July
2000	8/2/1	Unk	3(M,1,A)	Many metamorphs
2001	32/4/3	Yes	3(M,S,A)	15 metamorphs seen
2002	7/1/1	Yes	4(M,1,S,A)	Many subadults
2003	4/1/1	Yes	4(M,1,S,A)	50-100 metamorphs seen
2004	5/1/1	Unk	4(M,1,S,A)	300+ metamorphs seen
2005	8/2/2	Yes	4(M,1,S,A)	500+ metamorphs seen
2006	6/1/1	Yes	4(M,1,S,A)	High water levels
2007	2/2/2	Unk	4(M,1,S,A)	High water levels
This site is near a bike path and surrounded by development.				
Locality EA04 – Strawberry Lakes (Holy Cross City) Bd Status: Negative (2006)				
2003	1/1/1	Unk	1(A)	100-500 tadpoles
2004	1/1/1	Unk	3(M,S,A)	100-500 tadpoles
2005	0/2/0	Unk	1(A)	Likely metamorphs
2006		Yes		Monitoring report not received
2007	3/1/2	Unk	2(1,A)	
Locality SU01 – Cucumber Gulch (Breckenridge) Bd Status: Not tested				
1995	1/1/1	No	3+(M,S,A)	Mult. age classes seen
1996	?/?/0	No	2(S,A)	No breeding observed
1997	2/1/1	No	1(A)	Recruitment doubtful
1998	1/0/0	Unk	1(A)	Monitoring minimal
1999	1/1/1	Unk	1(A)	No metamorphs seen
2000	0/1/0	Unk	1(A)	Monitoring adequate
2001	0/0/0	Unk	None seen	Monitoring adequate
2002	0/0/0	Unk	None seen	5 site visits by CNHP
2003	0/0/0	Unk	None seen	4 site visits
2004	0/0/0	Unk	None seen	1 site visit, access issues
2005	1/1/0	Unk	1(A)	
2006				Not monitored
2007	0/0/0	Unk	None seen	
Locality SU02 – Montezuma (Snake River) Bd Status: Not tested				
1995	7/1/1	No	2(S,A)	Breeding unsuccessful
1996	9/?/0	No	1(A)	No breeding observed
1997	1/1/1	Unk	1(A)	New site, vs. 95 & 96
1998	0/0/0	Unk	None seen	Monitoring inadequate
1999	3/1/1	Unk	1(A)	Tadpoles observed
2000	0/0/0	Unk	None seen	No access to property*
2001				Not monitored
2002	0/0/0	Unk	None seen	2 site visits
2003				Not monitored
2004				Not monitored
2005				Not monitored
2006				Not monitored
2007				Not monitored
[4]*This site is on private property, and permission for ongoing access needs to be obtained.*				
Locality SU03 – Peru Creek (Snake River) Bd Status: Positive (2001/2003)				
1996	1/1/1	Yes	3(M,S,A)	Maybe>3 age classes
1997	6/2/2	Unk	4(M,1,S,A)	Good metamorphosis
1998	3/1/1	Unk	2(M,A)	Monitoring inadequate
1999	14/1/1	Unk	1(A)	Monitoring minimal
2000	19/1/1	Yes	1(A)	Tadpoles seen
2001	29/1/1	Unk	2(1,A)	Inadequate monitoring

Year	Males/Females/Egg Masses[1]	Recruitment[2]*	Age Classes[3]	Comments
2002	2/1/1	Unk	2(M,A)	>500 metamorphs
2003				Not monitored
2004	0/0/0	Unk	None seen	Low water levels
2005	0/0/0	Unk	None seen	Low water levels
2006	0/0/0	Unk	None seen	Better water levels
2007	0/1/0	Unk	1(A)	Water levels still good
**Disturbance from construction was observed in the wetland area, but not the breeding pond itself, on 6/15/01. Monitoring in 2001 did not occur around the time that metamorphosis would be expected.*				
Locality SU04 – Upper North Tenmile (North Tenmile Creek) Bd Status: Negative (2003/2004/2005/2007)				
1995	6/6/6	Unk	2(S,A)	Few, if any, metamorphs
1996	17/6/6	Unk	3(M,S,A)	Good production
1997	13/3/3	Unk	2(M,A)	Limited metamorphosis
1998	18/3/1	Yes	2(S,A)	Inadequate monitoring
1999	2/3/3	Unk	4(M,1,S,A)	Inadequate monitoring
2000	7/4/4	Unk	2(S,A)	Metamorphs likely
2001	8/2/2	Yes	1(A)	Larvae disappeared
2002	8/8/8	Yes	4(M,1,S,A)	No night survey
2003	1/1/1	Unk	1(A)	No larvae/metamorphosis
2004	5/1/1	Yes	2(S,A)	Late egg deposition
2005	2/2/2	Unk	2(1,A)	Poor hatching success
2006	0/1/0	Unk	1(A)	No evidence of breeding
2007	3/3/3	Unk	1(A)	Poor tadpole survival
Locality SU05 – Lower North Tenmile (North Tenmile Creek) Bd Status: Negative (2005/2006)				
1996	4/2/2	Yes	2(M,A)	Few metamorphs
1997	1/2/1	Unk	2(1,A)	Little or no reproduction
1998	5/5/5	Unk	3(M,S,A)	Inadequate monitoring
1999	3/2/1	Unk	1(A)	Inadequate monitoring
2000	5/3/2	Unk	2(M,A)	Monitoring adequate
2001	3/4/3	Yes	2(M,A)	100 metamorphs seen
2002	2/2/2	Yes	3(M,1,A)	No night survey
2003	2/2/2	Unk	2(1,A)	Likely many metamorphs
2004	1/1/1	Yes	1(A)	Likely many metamorphs
2005	4/4/4	Yes	3(M,1,A)	Likely many metamorphs
2006	2/0/0	Unk	2(S,1)	No evidence of breeding
2007	0/0/0	Unk	None seen	No evidence of breeding
Locality SU06 – Upper North Fork of Snake River (Snake River) Bd Status: Positive (2001); Negative (2003/2004/2005)				
1998	1/2/i	Unk	3(M,S,A)	1st survey mid-July
1999	1/1/1	Unk	2(S,A)	Some tadpoles seen
2000	1/1/1	Unk	2(M,A)	10-20 metamorphs seen
2001	1/1/1	Yes	2(1,A)	Inadequate monitoring
2002	1/2/1	Unk	2(1,A)	Inadequate monitoring
2003				Not monitored
2004	16/0/0	Unk	1(A)	Site visited 3 times
2005	20/0/0	Unk	1(A)	
2006	20/0/0	Unk	1(A)	No evidence of breeding
2007	0/0/0	Unk	None seen	
One male, one female, and 13 additional toads observed 5/24/01; About 100 tadpoles and 23 yearlings observed 7/20/01.				
Locality SU07 – Lower North Fork of Snake River (Snake River) Bd Status: Negative (2004)				
1998	1/2/1	Unk	3(M,S,A)	1st survey mid-July
1999	1/2/0	Unk	1(A)	No breeding observed
2000	1/1/0	Unk	1(A)	No breeding observed
2001	1/0/0	Unk	1(A)	Inadequate monitoring
2002	0/0/0	Unk	None seen	Three site visits
2003	Not monitored			

Year	Males/Females/Egg Masses[1]	Recruitment[2]*	Age Classes[3]	Comments
2004	1/0/0	Unk	1(A)	Site visited 3 times
2005	0/0/0	Unk	None seen	
2006	0/0/0	Unk	None seen	No evidence of breeding
2007	0/0/0	Unk	None seen	
Locality SU08 – Straight Creek (Snake River) Bd Status: Negative (2003)				
2003	1/1/1	Unk	3(M,S,A)	Site discovered 5/29/03
2004	0/0/0	Unk	None seen	Site visited 3 times
2005	0/0/0	Unk	None seen	
2006	0/0/0	Unk	None seen	
2007	0/0/0	Unk	None seen	Surveyed surrounding ponds
Locality PI01 – Conundrum Creek (Conundrum Creek) Bd Status: Positive (2001)				
1995	3/1/1	Yes	2+(S,A)	Minimal monitoring
1996	1/1/1	Unk	2+(S,A)	Many metamorphs
1997	2/2/2	Unk	2(2,A)	Poor production
1998	2/2/0	Unk	1(A)	Inadequate monitoring
1999	0/0/0	Unk	Unk	Site not monitored
2000	2/2/2	Unk	2(M,A)	Adequate monitoring
2001	3/9/3	Yes	2(M,A)	100 metamorphs seen
2002	1/1/1	Unk	2(M,1)	Many metamorphs*
2003	0/0/0	Unk	None seen	
2004	0/0/0	Unk	None seen	
2005	0/0/0	Unk	None seen	One site visit
2006	0/0/0	Unk	None seen	One site visit
2007	0/0/0	Unk	None seen	
**No adults seen during many site visits, but at least one egg mass produced, resulting in hundreds of metamorphs.*				
Locality PI02 – East Maroon Creek (Conundrum Creek) Bd Status: Negative (2003/2004/2005/2006/2007)				
2000	3/3/3	Yes	4(M,1,S,A)	Several ponds at site
2001	3/3/3	Yes	3(1,S,M)	Adults not observed
2002	3/3/3	Yes	4(1,M,S,A)	Breeding in 2 ponds
2003	3/3/3	Yes	3(M,S,A)	Numerous metamorphs
2004	7/1/1	Unk	3(1,S,A)	Possible metamorphs
2005	2/2/2	Yes	4(M,1,S,A)	Breeding in 2 ponds
2006	2/2/2	Yes	4(M,1,S,A)	Good year
2007	2/2/5	Unk	4(M,1,S,A)	
1n 2001, about 3 egg masses deposited although adults were not observed; 16 subadults and about 50 metamorphs seen.				

[1] *Males/Females/Egg Masses: This column shows the minimum number of breeding age males and females and number of viable egg masses at the locality in each year.*

[2] *Recruitment: A 'yes' entry means that one-year-old toadlets were observed at the site in the spring of the following year, or two-year-old toads were seen the second year.*

[3] *Age Classes: The first number in the entry indicates the minimum number of age classes observed/reported at a specific site. Numbers within parentheses indicate which age classes were observed: M=metamorphs (young of the year), 1=one-year olds (new 'recruits'), S=subadults (generally two- or three-year-old toads), 2 or 3=subadults which were specifically identified as either two- or three-year-old toads, A=adult toads (generally 4 years old and older)*

Natural History

In Colorado, boreal toad occupies forest habitats at elevations between approximately 7,500 and 12,000 feet (Campbell, 1970; Baxter and Stone, 1985; Hammerson, 1999; and Degenhardt et al., 1996) and is generally found at elevations between 8,000 and 11,000 feet.

Breeding habitat consists of shallow, quiet water in lakes, ponds, marshes, bogs, and wet meadows. Summer range includes use of upland montane forests and rocky areas, with an affinity for locations with seeps or springs (Jones, 1998). Over-winter refugia, or hibernation chambers, are reported to need a continuous flow of groundwater beneath the chamber floor to prevent freezing (Campbell 1970). Toads also use small rodent burrows and beaver lodges and dams. Toads emerge from hibernacula during May and June and return in late August and early September. Young toads are restricted in distribution and movements by available aquatic habitat, while adults can move up to several miles and take up residence in marshes, wet meadows, or forested areas (Nesler and Goettl, 1994).

Breeding begins late in spring as the winter snowpack begins to melt. Eggs are usually deposited in shallow pools or along lake margins in late May or early June. Tadpoles metamorphose during their first summer at elevations below 9,000 feet. At higher elevations, metamorphosis does not occur until the second summer. Tadpoles overwinter under the ice. Toads do not breed successfully every year at elevations above 11,000 feet (Campbell, 1972).

Environmental Baseline

Boreal toads occupy three types of habitat during the year: breeding ponds, summer range, and over-winter refugia. All of these specific habitats are associated with open water (ponds), wetlands, and riparian areas within lodgepole pine and spruce-fir forests (Campbell, 1970).

The boreal toad population data from ARNF (see **Table BR - 41**) indicate 23 populations on or near the Forest. Data from known breeding sites on Clear Creek collected by the Boreal Toad Recovery Team include sites within the Corridor APE (at least three ponds are within 100 meters of I-70). Suspected factors contributing to population declines include chytrid fungus (Loeffler, 2001; Jones, 1998; and CNHP, 2002b), redleg disease, and contaminants to the water supplies supporting toad habitat populations. Despite the discovery of new sites on the ARNF, and a few others statewide, Boreal Toad Recovery Team data (2005) indicate a downward population trend on the ARNF and in Colorado. The boreal toad also is a MIS for the ARNF.

There are 14 known boreal toad breeding populations on or adjacent to the WRNF: two near Independence Pass, three near Montezuma, two in the North Tenmile drainage, five in the North Fork Snake River drainage, and two in Eagle County (Lambert, Malleck, and Huhn, 2000). Five of the 14 known breeding populations on WRNF lands are within designated wilderness areas, two are in a tributary outside the Corridor, and all those in the Snake River drainage are outside the Corridor, leaving two breeding populations in the Corridor APE on or near the WRNF. The two sites are in east Vail (private land) and along Straight Creek east of Silverthorne.

Direct, Indirect, and Cumulative Effects of Alternatives

Action Alternatives

The boreal toad would be susceptible to impacts from habitat loss, an expanded road effect zone including downstream effects on habitats, and possibly induced growth. Not all toad habitat is breeding habitat, but numerous sites on both forests have been documented as breeding sites. Habitat loss, especially breeding habitat, would be a potentially serious effect. There are five breeding populations in the Corridor APE; one in east Vail (on private land), a historic location in Straight Creek (WRNF), and three in upper Clear Creek (ARNF). Only one of the five sites in the Corridor is projected to be disturbed by any action alternative. All alternatives except two (Dual-Mode Bus in Guideway and Diesel Bus in Guideway) would have the potential to affect the breeding habitat in East Vail. Construction activities are expected to be far enough away from the site in Straight Creek that breeding toad habitat would not be affected.

Because the three sites in upper Clear Creek (all between milepost 217.9 and milepost 221.2) are located in natural and man-made ponds that are within hundreds of feet of I-70, additional survey and analysis will be completed for Tier 2 proposals. Increasing habitat suitability at the Mount Bethel site and at possible new sites along Clear Creek (Barry property) is being considered as part of the I-70 construction plan. Moreover, the Forest Service is currently developing plans to construct boreal toad habitat in the Dry Gulch area. However, the toads depend on habitats with a high water table, and streamflow is not generally the main source of groundwater that supports most Forest wetlands and riparian areas (ARNF and PNG 2005). No project effects on groundwater have been identified in the Corridor.

Estimated direct impacts on boreal toad habitat are based on broad construction assumptions at this Tier 1 level of analysis. Construction procedures that cause habitat disturbance could include activities at water's edge that result in sedimentation, use of caissons to place concrete structures in streams or water bodies, use of structures to divert flowing water to allow construction, and other procedures that will be identified in Tier 2 projects. Tier 2 studies will further evaluate and identify permanent mitigation measures for specific issues including structural controls. Stream restoration measures might include creation of drop structures and/or bioengineering techniques.

Table BR - 44 and **Table BR - 45** provide the estimated direct impacts on potential boreal toad habitat. Habitat was defined using the vegetation-based categories of wetland vegetation and riparian areas, along with the wetlands category (channels, open water bodies, and fens). Boreal toads use open water for breeding and meadows and springs in spruce-fir and lodgepole forests for summer foraging. On the WRNF, the total acreage of open water and riparian areas is 88,900 acres. Potential impacts on all boreal toad habitat on the WRNF from the Preferred Alternative would be 8.4 acres for both the Minimum Program and the Maximum Program 55 mph and 7.1 acres for the Minimum and Maximum Program at 65 mph. Potential impacts for all alternatives would range from 4.2 acres (Six-Lane Highway 65 mph) to 12.9 acres (Combination Six-Lane Highway with Rail and Intermountain Connection), or about 0.01 percent of available open water and riparian habitat.

On the ARNF, montane riparian areas and wetlands also are considered MIS habitat. The ARNF includes approximately 100,400 acres of open water and riparian areas. Potential impacts on boreal toad from the Preferred Alternative would range from 0.7 acres (Minimum Program [55 or 65mph]) to 5.6 acres (Maximum Program [55 or 65mph]). Potential impacts from all alternatives, including loss of habitat for breeding, would range from 0.5 acres (Minimal Action) to 6.4 acres (Combination Six-Lane Highway with Rail and Intermountain Connection). The impact of 6.4 acres would represent approximately 0.007 percent of available habitat.

Table BR - 44. Direct Impacts on Boreal Toad Habitat (acres): Preferred Alternative

	Minimum Program		Maximum Program	
	Specific Highway Improvements with AGS		Combination 6-Lane Highway with AGS	
	55 mph	65 mph	55 mph	65 mph
WRNF	8.4	7.1	8.4	7.1
ARNF	0.7	0.7	5.6	5.6

Data provide the minimal to maximum impacts for the Preferred Alternative.

Table BR - 45. Direct Impacts on Boreal Toad Habitat (acres): Action Alternatives Evaluated in the Draft PEIS

	Minimal Action	Rail with IMC	AGS	Dual-Mode Bus in Guideway	Diesel Bus in Guideway	Six-Lane Highway 55 mph	Six-Lane Highway 65 mph	Reversible/ HOV/HOT Lanes	Combination Six-Lane Highway with Rail and IMC	Combination Six-Lane Highway with AGS	Combination Six-Lane Highway with Dual-Mode Bus in Guideway	Combination Six-Lane Highway Diesel Bus in Guideway
WRNF	7.4	8.5	5.3	8.9	8.9	7.6	4.2	7.6	12.9	8.4	10.4	10.4
ARNF	0.5	0.9	0.9	0.3	0.3	2.8	2.8	3.7	6.4	5.6	5.4	5.4

The analysis in **Table BR - 44** and **Table BR - 45** was done using the categories of riparian areas, wetland vegetation, and wetlands (open water, channels, springs and fens). In addition, a fine-scale analysis was conducted using different categories than were used **Table BR - 44** and **Table BR - 45**.

Categories for the fine-scale analysis included open water with adjacent meadows, in spruce-fir and lodgepole pine forests, with elevations greater than 8,000 feet. The results of this analysis indicate that the Minimum Program, Minimal Action and Advanced Guideway System alternatives would have no effect. The Bus in Guideway alternatives would disturb 0.11 acres. The Rail with Intermountain Connection and the Highway alternatives would each disturb from 0.44 to 0.42 acres. The Combination alternatives would disturb from 0.63 to 0.73 acres. The Maximum Program Preferred Alternative would affect .72 acres.

Increased inputs of contaminated runoff and sediment into aquatic habitats may also have a substantial negative impact on boreal toads in the Corridor. Sediment has been a factor in covering eggs and also toad food sources (Loeffler, 2001). In addition, contaminants can cause mortality of eggs and tadpoles. Impacts on wetlands and other riparian areas would be minimized as much as possible, but temporary downstream effects may occur. Induced growth that brings additional people into those areas for recreation could also affect this species.

It is conceivable that toads would attempt a crossing of I-70 to reach another water body, especially in areas where multiple ponds are present in the APE. No roadkills of amphibians have been reported for I-70. While their home ranges are relatively small (a few acres of wet meadow adjacent to water bodies), they have been documented to travel up to 3 miles (Boreal Toad Recovery Team, 2001). However, the potential for roadkill should be considered low.

Potential effects on known breeding sites would have greater effect on the population than impacts on nonbreeding sites. There are two known breeding sites in the Corridor APE on the WRNF. One is located along Straight Creek east of Silverthorne and the second site, near the WRNF, is on private land in Vail. None of the sites on the WRNF would be affected by any of the action alternatives. Although the resource protection measures outlined in the WRNF Plan are expected to foster habitat improvement and the potential for population expansion at all sites, concentrated disturbance in the area around breeding sites can affect adjacent habitat (relating to the potential for population expansion). Some suitable wetlands on WRNF lands are expected to be lost as discussed above, but resource protection measures are expected to minimize loss. Additional suitable wetlands may be created through habitat improvement projects, but unoccupied suitable habitat appears to be readily available.

There are 19 current or historic toad population sites in the Corridor APE on the ARNF. They are located in upper Clear Creek between milepost 217.9 and milepost 221.2, and all of them are within 200 feet of I-70. The aerial mapping, field investigation, and literature search characterized the 19 sites as three breeding sites, four man-made ponds, and 12 historic population sites. There is some overlap as the breeding population at Bethel slide is in a man-made pond. The four man-made ponds were either created as borrow pits by CDOT or have had sediments cleaned out by CDOT. The term "historic" means that toads have been in ponds in the past but not during the most recent observations. Action alternatives are projected to affect two of the four man-made ponds and four of the 12 historic sites. None of the breeding sites are expected to be disturbed. Resource protection measures in the ARNF Plan are expected to foster habitat improvement and the potential for population expansion at all sites. Some historic sites and some of the man-made sites on ARNF lands could be disturbed by the Combination alternatives, especially the Combination Six-Lane Highway with Rail and Intermountain Connection alternative, but resource protection measures are expected to minimize loss. Additional suitable wetlands may be created through habitat improvement projects, but unoccupied suitable habitat appears to be readily available.

A wide variety of land use practices may have indirect impacts on boreal toads. Because boreal toads are highly dependent on aquatic habitat, any action that changes water volume, water quality, aquatic vegetation, or the aquatic fauna can have significant negative impacts on the toads. Fish populations that are already established may preclude toad recolonization.

The Boreal Toad Conservation Plan and Agreement between Colorado Division of Wildlife, Wyoming Game and Fish Department, New Mexico Game and Fish, USFS, National Park Service, USFWS, BLM, CNHP, and U.S. Geological Survey establishes a framework for reintroduction of boreal toads, control of chytrid fungus (Bd), breeding pond surveys, and habitat protection recommendations. Suggested conservation recommendations are consistent with current Standards and Guidelines in the 1997 ARNF Plan (USDA, 1997). Potential effects from the project on boreal toad habitat are not expected to cause a viability risk to the species in the planning area or on the ARNF.

Due to the high level of concern for boreal toad viability, both the WRNF and ARNF will use their management Standards and Guidelines to greatly restrict management-related disturbance around known and historic boreal toad breeding sites. Although these additional restrictions will protect most individuals and habitat, occasional incidental mortality is still possible.

Cumulative effects on boreal toad may include loss of wetland habitat, loss or degradation of wetland function, or loss of habitat connectivity between wetlands and uplands in areas where future developments are planned. Decline in boreal toad populations is not well understood, and it could be that a suite of cumulative effects is at the core of this decline, with impacts as far ranging as climate change, lowered disease resistance, or other causes.

No Action Alternative

Effects on boreal toad and their habitat in the Corridor APE associated with the No Action Alternative may include similar levels or even gradual increases of road maintenance chemicals and sediments running off into wetlands. This assumes no additional construction of drainage or water quality mitigation for the Corridor.

Determination of Effects and Rationale

Action Alternatives

Implementation of Forest Standards and Guidelines for the protection of the boreal toad will accomplish that protection by directing management on Forest lands to avoid the loss of open water, riparian areas, and wet upland meadows in spruce-fir and lodgepole pine forests. Only one breeding site would be affected and it is on private land. No breeding sites would be affected on Forest lands. One breeding site disturbed out of 14 on or near the WRNF and 9 on the ARNF represents approximately 4 percent of the breeding sites on or near the Forests. Given the acres of potential boreal toad habitat directly affected (from 0.9 to 14.1 acres from **Table BR - 44** and **Table BR - 45**) and the fact that no breeding sites would be affected on Forest lands), the action alternatives **may adversely impact individuals, but not likely result in a loss of viability in the planning area, nor cause a trend to federal listing**. This determination would apply to both the WRNF and the ARNF.

No Action Alternative

The No Action Alternative would not cause any direct changes to the existing condition of habitat nor create any additional impacts. The barrier effect of I-70 with its potential for AVCs will remain in place. This alternative **may adversely impact individuals, but not likely to result in a loss of viability in the planning area, nor cause a trend to federal listing.** This determination would apply to both the WRNF and the ARNF.

Northern Leopard Frog *(Rana pipiens)*, FS

The northern leopard frog is a medium-sized spotted frog in the family Ranidae and the genus *Rana*. Adults are generally 5 to 9 cm in length and can reach up to 11 cm (NatureServe, 2006). This species is currently documented to occur on ARNF and WRNF lands.

Distribution

Western hemisphere distribution for this species ranges from Great Slave Lake and Hudson Bay, Canada, south to Kentucky and New Mexico (Stebbins, 1985; and Conant and Collins, 1991). The northern leopard frog is distributed widely across North America from the Great Basin eastward, including most of

Colorado and Wyoming below about 10,000 feet (Corn and Livo, 1989). Declines or extirpations of populations in Colorado have been observed recently in montane areas and plains habitats. Although extensive studies of midwestern populations have been conducted, ecological data from western populations are largely anecdotal (Corn and Livo, 1989). It has a rather spotty distribution in the west, where it has been introduced in many localities (NatureServe, 2006). At a continental scale, the frog is generally common with declines in a few areas (USDA, 2003). During the last several years, the ranid population has declined by an estimated 50 percent (USDA, 2002c).

This frog species occurs throughout much of Colorado, except for the southeastern and east-central portions of the state. They may be found from below 3,500 feet to more than 11,000 feet. They have been observed in Jefferson County along the South Platte River riparian area, Clear Creek County along Clear Creek, Summit County from a location on the Blue River upstream of Dillon Reservoir; Eagle County along the Eagle River, and Garfield County in habitat along the Colorado River (Hammerson, 1999). There have been no recent sitings on the ARNF, and this species may have been extirpated on the Forest (D. Lowry pers. comm., 2006b; and CNHP, 2002b).

There are two known populations of northern leopard frogs on the WRNF, and the sites are considerably north of the Corridor on the Rifle District. The only other sighting of a leopard frog on the Forest was in the Flat Tops Wilderness Area.

Surveys were done on the ARNF in Larimer County for the years 1975 to 1979 (CNHP, 2002b). One location had an estimated population of 2,103 in 1965 and 286 in 1976. A second location had populations of 283, 110, and 115 in the years 1977, 1978, and 1979, respectively. From 1973 to 1982, nine Larimer County populations were documented as extirpated from elevations of 7,760 to 8,265 feet (Hammerson, 1999). Six of the extirpations resulted from drying up of breeding ponds and the other three are unexplained. A population of leopard frogs in Boulder County declined severely after bullfrogs were established in the late 1970s.

Corn and Fogleman (1984) surveyed 40 sites on the ARNF from 1986 to 1988 but did not find any northern leopard frogs (CNHP, 2002b). Similarly, Livo (1995a, b) conducted amphibian surveys at 85 sites on the ARNF in 1994 and did not observe any northern leopard frogs. The northern leopard frog has a state heritage status rank of S3; vulnerable (NatureServe, 2006). Although still widespread and common in many areas, many populations have drastically declined, especially in the Rocky Mountains of Colorado, Wyoming, and Montana. Leopard frog records from Colorado occur from 3,500 to 11,000 feet but exclude southeastern Colorado (Hammerson, 1999).

Natural History

This species is highly dependent on aquatic habitats; however, adults will forage away from water given the right conditions of either moist vegetation or high humidity (Merril, 1977). During summer, adults prefer grassy areas, wet meadows, and swampy areas surrounding pools and marshes. Areas with 100 percent vegetative ground cover are preferred. Grassy areas 1 meter or more in height are seldom used, whereas grassy areas 5.9 to 11.8 inches are heavily used. Lack of oxygen in lake bottoms affects concentrations of frogs during winter, driving them to bottoms of well-aerated water spillways and rapidly flowing streams.

Leopard frogs typically overwinter in ponds, lakes, or streams. After emerging during early spring, they breed in shallow, nonflowing portions of permanent water bodies and in seasonally flooded areas adjacent to or contiguous with permanent water bodies (Merri,l 1977; and Hammerson, 1982). Egg laying typically occurs between late April and early June, depending on elevation and weather. Eggs are usually laid at night and attached to vegetation in 15.7 inches or shallower water on the north side of ponds. Aquatic vegetation (*Juncus*, *Carex*) is important in the breeding ponds for egg mass attachment. Water temperatures from 37.4 to 95 degrees Fahrenheit are tolerated during breeding. Eggs hatch in 15 to 20 days and larvae transform in 60 to 80 days. Tadpoles and young frogs likely eat vegetation for a short time and then become more carnivorous as metamorphosis approaches. Metamorphosis occurs between late-July and mid-September (Hammerson, 1999; and Corn and Fogelman, 1984). Adult frogs are able to forage away from water for invertebrates and are known to avoid vegetation more than 11.8 inches tall while foraging but use dense vegetation as escape cover (Merril, 1977).

Environmental Baseline

Typical habitats for the northern leopard frog include wet meadows and shallow areas of marshes, ponds, lakes, reservoirs, streams, and irrigation ditches. Usually, leopard frogs occur at the water's edge, but they may roam far from permanent water in wet meadows or during mild wet weather (Hammerson, 1999).

Northern leopard frog populations on the WRNF are well removed from the Corridor. One breeding population is in the Divide Creek watershed, west of Glenwood Springs. Another breeding population is in the White River watershed.

Currently, there are no known populations of northern leopard frogs on the ARNF (outside the Pawnee National Grasslands), and they seem to be declining in other parts of Colorado.

Direct, Indirect, and Cumulative Effects of Alternatives

Action Alternatives

If unknown populations of northern leopard frogs were present in the Corridor, they would be susceptible to direct impacts from habitat loss, an expanded road effect zone, and construction activities. The Combination alternatives would have the most direct impact on streams and riparian areas from construction footprint and support activities for the total Corridor and on the WRNF. The Combination Six-Lane Highway with Rail and Intermountain Connection would have the greatest direct effect on the ARNF. Increased amounts of highway runoff and winter maintenance runoff into aquatic habitats may have a substantial negative impact on leopard frogs, and these effects would be greatest with the Combination Six-Lane Highway with Bus in Guideway alternatives.

If unknown populations of leopard frogs were present in the Corridor, it is conceivable that frogs would attempt a crossing of I-70 to reach other water bodies because adults can move several miles when habitat conditions are wet enough. No roadkills of amphibians have been reported for I-70. For these reasons, the potential for roadkill should be considered low.

Indirect effects on leopard frog habitat are numerous and include any effects on wetlands and riparian areas that contribute sediment, change water quality or chemistry, alter hydrology, or change the existing vegetative cover at an occupied site. However, the frogs depend on habitats with a high water table, and streamflow is not generally the main source of groundwater that supports most forest wetlands and riparian areas (USDA, 2005d). No effects on groundwater have been identified in the Corridor. Possible induced growth could affect wetlands and aquatic habitats and might potentially also affect this species. The greatest potential for induced growth is associated with the Combination alternatives in the Eagle River watershed.

Cumulative effects on northern leopard frogs may include loss of wetland habitat, loss or degradation of wetland function, or loss of habitat connectivity between wetlands in areas where future developments are planned, along with possible induced growth and visitation. Any man-caused expansion of predator populations (fish and bullfrogs) also would constitute a cumulative effect on the frog. Decline in northern leopard frog populations is not well understood, and it could be that a suite of cumulative effects is at the core of this decline, with impacts as far ranging as climate change, lowered disease resistance, or other causes. Like many amphibians, leopard frog declines appear related to environmental changes that alter the frog's susceptibility to disease (NatureServe 2006; Hammerson 1999).

According to the WRNF Biological Evaluation, habitat quality at both known frog breeding sites is expected to increase as a result of restoration of these sites as directed in the Standards and Guidelines, and with general improvements in management of wetland and riparian areas associated with improving management practices. This is expected to cause an increase in habitat quality and population trend due to implementation of the resource protection measures. However, the rate of increase in population trend (frogs expanding into adjacent habitat) could vary. Quality of adjacent suitable habitat is likely to be influenced by the amount of disturbance.

Northern leopard frog populations on the WRNF are well removed from the Corridor. Currently, there are no known populations of northern leopard frogs in the Corridor on the ARNF. It is possible, however, that unknown populations could exist on both Forests.

No Action Alternative

Effects on northern leopard frogs and their habitat associated with the No Action Alternative may continue to include similar levels or even gradual increases of road maintenance solutions runoff and sediment loading of aquatic habitats and wetlands. This assumes no additional construction of water drainage or water quality mitigation for the Corridor.

Determination of Effects and Rationale

Action Alternatives

The action alternatives would directly disturb some wetland and riparian habitat, but there can be no net loss of wetlands under USACE regulations, and other wetland areas would be enhanced. Although Forest Standards and Guidelines are designed to protect most individuals and habitat, occasional incidental mortality is still possible. Differences among alternatives are not measurable forest-wide and would vary only at the project level. Because habitat for leopard frog is maintained more by groundwater than by surface water, indirect effects on surface water quality may be less important than previously thought. There are no known populations in the Corridor on either Forest, but there is a small possibility that an unknown population may exist. Therefore, the determination is that all action alternatives **may adversely impact individuals, but not likely result in a loss of viability in the planning area, nor cause a trend to federal listing**.

No Action Alternative

The No Action Alternative would have no additional effects beyond current conditions. Effects from current trends including riparian habitat degradation would continue. The barrier effect of I-70 with its potential for AVCs will remain in place. This alternative **may adversely impact individuals, but not likely to result in a loss of viability in the planning area, nor cause a trend to federal listing**.

BR.4.1.4 Fish

Colorado River Cutthroat Trout *(Oncorhynchus clarki pleuriticus)*, FS

The Colorado River cutthroat trout is in the family Salmonidae, genus *Oncorhynchus*. It is a subspecies of cutthroat trout (*Oncorhynchus clarki*). In addition to being a Forest Sensitive species, the Colorado River cutthroat trout is also an MIS species for both the WRNF and the ARNF for the montane aquatic communities. This species is currently documented to occur on ARNF and WRNF lands.

Distribution

The Colorado River cutthroat trout historically occupied portions of the Colorado River drainage in Wyoming, Colorado, Utah, Arizona, and New Mexico (Behnke, 1992). It is now restricted to headwater streams and lakes, but its original distribution probably included larger streams such as the Green, Yampa, White, Colorado, and San Juan rivers. Colorado River cutthroat trout have been eliminated from approximately 87 percent of their historic range, and the primary causes of this loss are competition and hybridization with non-native trout species (Hirsch, Albeke, and Nesler, 2006). Other factors attributed to this loss include impacts from livestock grazing, water diversions, mining, logging, roads, over-use, disease, and predation.

It was probably absent from the lower reaches of the larger rivers in the summer because of thermal barriers. Portions of the lower reaches may have been used in winter (Young, 1995). Most of the lotic populations are in isolated headwater reaches with flows of less than 30 cubic feet per second. Gradients are usually greater than 4 percent and the majority of populations are located above 7,500 feet elevation (USDA, 2005a).

As of 2002, there were 62 known Colorado River cutthroat trout populations on the WRNF. Some genetic analysis has been done on many of these populations; however, the Forest Service does not have minimum criteria for genetic purity; therefore, all populations are managed as “sensitive.” Presently, the WRNF manages all of these 62 populations as Sensitive. Of the 62 populations, 45 are cutthroat only, 9 are cutthroat and brook trout, and there is incomplete information on 8. Of the 45 cutthroat only populations, 16 are not protected by an adequate barrier, but the Forest is working to secure these populations. Of the 45 populations, 22 are in designated wilderness. There are 300 acres of cutthroat only lakes associated with the streams above. There are numerous other isolated lakes on the Forest with Colorado River cutthroat trout (USDA, 2002b).

Currently, small Colorado River cutthroat trout populations occur on the ARNF in tributaries of the Fraser River, Willow Creek, Williams Fork, and the Upper Colorado River drainages (USDA, 1997). Colorado River cutthroat trout also are known from at least eight smaller streams on the ARNF: Jim, Little Vasquez, Hamilton, Kinney, Kelly, Steelman, Cabin, and Little Muddy creeks. Populations have been monitored irregularly since 1992. Populations of Colorado River cutthroat trout have been observed ranging from 2 fish per mile on Jim Creek to 704 fish per mile on Cabin Creek (USDA, 2004). Colorado River cutthroat trout abundance in Little Muddy Creek has remained steady with 34 fish per mile in 1992 and 56 fish per mile in 2000; however, in Kelly Creek, Colorado River cutthroat trout abundance has declined from 184 fish per mile in 1992 to 26 fish per mile in 2000. Population trends for these streams were five upward, two downward, and one stable (USDA, 2005a). The overall trend for Colorado River cutthroat trout is considered stable on the ARNF and in Colorado, but effects of the current drought are unknown, and whirling disease continues to be a threat (USDA, 2003).

Natural History

The diversity of Colorado River cutthroat trout life histories is probably reduced from historic levels. Stocks moving between lakes and streams were once common but have largely been eliminated. Most remaining stocks are in streams or in lakes. Spawning begins after flows have peaked in spring or early summer and ends before runoff subsides (Quinlan, 1980; and Young 1995). Water temperature may be a cue for spawning. Colorado River cutthroat trout typically spawn in gravel substrate (Young, 1995). Spawning beds (redds) are generally located where the water is between 3.9 and 7.1 inches deep and velocity is 5.9 to 13.8 inches/second (Young, 1995). Emergence of fry generally occurs in late summer depending on elevation and annual climatic variation. Fry summer microhabitats are usually deeper than 1.18 inches and water velocity is slower than 2.4 inches/second. Woody debris, boulders, and root wads shelter these sites from higher flows.

Colorado River cutthroat trout reach maturity at age 3 and rarely live past age 6. Growth rates are among the lowest of all salmonids, probably due to the short growing seasons and colder temperatures at the higher elevations to which Colorado River cutthroat trout are currently confined. Lakes and streams with beaver ponds tend to have higher growth rates. Herger (1993) found most larger cutthroat trout in pools and found that trout density increased with pool depth.

Cutthroat trout, in some streams, do migrate. Adults often move upstream to spawn and then downstream to deeper waters following spawning. Lake populations move in and out of tributaries. It is common to find smaller cutthroat upstream and the larger fish downstream. Cutthroat may move from tributaries to larger river systems to overwinter. The influence of predatory species on Colorado River cutthroat trout is not known, but dippers, mink, and other predatory birds and mammals do feed on them.

Environmental Baseline

The Colorado River cutthroat trout is the only trout native to the Western Slope of Colorado. Its abundance and distribution have declined so much that calls have been made for federal listing (Behnke and Zarn, 1976; and Young, 1995). The WRNF, Routt National Forest, ARNF, BLM, and Colorado Division of Wildlife signed a Conservation Plan in 1992 (CDOW, 2001a). The *Conservation Plan for Colorado River Cutthroat Trout in Northwest Colorado* lists specific measures that will be taken to preserve and enhance existing populations of Colorado River cutthroat trout. The plan also lists the streams known or believed to contain Colorado River cutthroat trout. This plan was revised in 2001 and is now the C*onservation Agreement and Strategy for Colorado River Cutthroat Trout (Oncorhynchus clarki pleuriticus) in the States of Colorado, Utah, and Wyoming.* This document is a 5-year agreement (revised in 2006) signed by the three states involved, the USFS, BLM, USFWS, National Park Service, Ute Indian Tribes, and Trout Unlimited. The document has been changed and split into two separate documents: the agreement and the strategy.

As part of the WRNF Forest Plan Revision (USDA, 2002a), monitoring protocols were drafted in early 2003 and data collection began during the 2003 field season. The WRNF was divided into 10 management combinations based on Forest Plan land allocation and livestock grazing. One site from each management combination was randomly selected for monitoring each year for five years (50 sites total). The randomly selected sites will be resampled every five years to determine forest-wide trends. No forest-wide trend information is available because no repeat sampling has occurred. Nine sites were sampled in 2003, and 10 sites were sampled in 2004. These sites will be resampled when repeat sampling occurs starting in 2008. Additional information is presented in Section 0.

Introductions of non-native salmonids have had the greatest effect on Colorado River cutthroat trout. Stocking of non-native trout began before 1900 and has been very widespread. Rainbow trout and other cutthroat subspecies readily hybridize with Colorado River cutthroat trout and produce fertile offspring. More populations of Colorado River cutthroat trout have probably been lost through hybridization than through any other means (Behnke and Zarn, 1976). This species is well documented on the WRNF and the ARNF (see the previous Distribution discussion).

Habitat quality across the WRNF is generally increasing as watershed conservation practices and other habitat protection measures are applied to new and ongoing activities. However, areas with fewer disturbances are expected to improve faster than areas with ongoing disturbances. The Standards and Guidelines in the 2002 WRNF Plan include watershed conservation practices, which are designed to protect the streams from grazing damage. Additional Standards and Guidelines specific to cutthroat streams were added to address impacts from grazing and other management activities. It is the position of the WRNF to be very protective of occupied habitat to maximize the robustness of local populations to increase their chances of persistence.

Direct, Indirect, and Cumulative Impacts

Action Alternatives

The Colorado River cutthroat trout may be affected by impacts on Dillon Reservoir, Black Gore Creek, or Eagle River. Potential impacts would primarily be associated with construction that could cause sedimentation and the influx of materials (fuel, lubricants, and cement) that could affect water quality. Any water withdrawals for construction could have potential effects but would be short term and temporary and should not have any effect on downstream populations. All action alternatives (including the Minimal Action Alternative) are projected to disturb from 176 to 1554 linear feet of the Blue River. For the Eagle River, action alternatives are projected to disturb between 724 and 2,336 linear feet. The Combination Six-Lane Highway with Dual-Mode Bus in Guideway alternative would have the greatest disturbance (2,336 linear feet), followed closely by the Minimum Program 55 mph, Maximum Program 55 mph, and Combination Six-Lane Highway with Advanced Guideway System alternatives (2,137 linear feet). The Six-Lane Highway 65 mph alternative would have the least disturbance on the Eagle River (724 linear feet).

Indirect effects as development increases along the Corridor could include increased potential for water quality to be affected by increased runoff from paved surfaces, disturbed construction sites, landscaping inflows (from golf courses, homes, and commercial areas), and winter maintenance materials from I-70 and surface streets in residential and commercial areas. The Combination alternatives are projected to induce the greatest amount of growth in Eagle County and moderate growth in Summit County.

Another indirect effect is that Colorado River cutthroat trout are susceptible to over-fishing. Angling mortality is rarely heavy enough to reduce population viability, but it has the potential to change the age structure of fish populations (WRNF, 2002). Recreational fishing also could affect “conservation populations” of Colorado River cutthroat trout in some tributary streams entering the I-70 Corridor. Conservation populations are populations of pure strains of Colorado River cutthroat trout that are important in maintaining the genetic status of the species. State fishing regulations limit most of the populations on the forest to catch and release. If any action alternatives induce increased recreational use, it potentially could affect Colorado River cutthroat trout populations. Whirling disease is another indirect effect that could be exacerbated by increases in recreational use of National Forest System Lands. These potential indirect effects would be most likely to occur with the Highway and Combination alternatives.

Potential cumulative impacts on Colorado River cutthroat trout could include increased fishing pressure as the regional population grows, increased commercial use of the rivers, reduced water quality from increased land development both residential and commercial, induced growth and accelerated land use changes from increased transportation opportunities in the Corridor, whirling disease and water depletions from increased population. It is possible any increased fishing pressure indirectly caused by Corridor improvements could be mitigated by changes in fishing regulations administered by Colorado Division of Wildlife. Any water withdrawals necessary for any of the action alternatives would be short term and temporary and would occur significant distances downstream from Colorado River cutthroat trout habitat. Cumulatively, these effects could degrade riverine habitats over time or directly affect the trout and place additional stress on Colorado River cutthroat trout populations.

No Action Alternative

Colorado River cutthroat trout will continue to experience the threat of hybridization under the No Action Alternative. The species will remain susceptible to over-fishing. Effects on Colorado River cutthroat trout and their habitat associated with the No Action Alternative may include similar levels or even gradual increases of road maintenance materials runoff and sediment loading of aquatic habitats and wetlands. This assumes no additional construction of drainage or water quality mitigation for the Corridor.

Determination of Effects and Rationale

Action Alternatives

All action alternatives would create disturbance in the drainages that contain Colorado River cutthroat trout. Some alternatives may increase fishing pressure on the species as a result of induced growth in Eagle and Summit counties. Differences among action alternatives would not be measurable forest-wide, and even the variations at the project level would not have measurable differences for the trout habitat. Therefore, the determination is that all action alternatives **may adversely impact individuals, but not likely to result in a loss of viability in the planning area, nor cause a trend to federal listing**. Based on the above evaluations, none of the action alternatives would create any viability risk (the potential for populations to substantially decrease) for the Colorado River cutthroat trout within the planning area, on National Forest System Lands, or in Colorado.

No Action Alternative

The No Action Alternative would have no additional effects beyond current conditions. Effects from current trends including land use conversion and riparian habitat degradation will continue. The determination is that there will be **no impact**.

Bluehead Sucker (Catostomus discobolus discobolus), FS

The bluehead sucker belongs to the family Catostomidae, members of which are characterized by soft rays and a fleshy, subterminal, protractile mouth. The family includes 12 genera and 60 species in the U.S. and Canada (USDA, 2005e). *Catostomus discobolus* has two recognized subspecies, *C.d. discobolus* and *C.d. yarrowi. C.d. discobolus* occurs throughout the remainder of the range of bluehead suckers. Its maximum length is 10 to 16 inches (Ptacek, Rees, and Miller, 2005). This species is currently documented to occur on WRNF lands.

Distribution

The bluehead sucker usually occupies large rivers and mountain streams and is rarely found in lakes. They use a wide range of fluvial habitats ranging from swift, cold mountain streams to sluggish, warm rivers such as the Colorado River. The species prefers habitats with moderate to high water velocity and rocky substrates.

The bluehead sucker is native to the Colorado River basin and ancient Lake Bonneville in Idaho, Utah, and Wyoming. Within USFS Region 2, populations exist in western Colorado and south-central Wyoming. However, the species conservation assessment notes that the only populations documented on lands managed by the USFS are located on the WRNF and San Juan National Forest in southwestern Colorado (Ptacek, Rees, and Miller, 2005; and CDOW maps in 2006b).

Within the Colorado River basin, bluehead suckers are found in the Colorado, Dolores, Duchesne, Escalante, Fremont, Green, Gunnison, Price, San Juan, San Rafael, White, and Yampa rivers and numerous smaller tributaries (Ptacek, Rees, and Miller, 2005). The range of the bluehead sucker often overlaps that of other native suckers. In the Corridor APE, the bluehead sucker is found only in the Colorado River drainage in areas of swift water. Colorado Division of Wildlife maps show this species in the mainstem of the Colorado River in the Corridor and upstream to Rocky Mountain National Park, and in the Eagle River above Dowd Canyon.

Natural History

As the common name implies, the head of adult bluehead suckers often have a bluish tint. These suckers are omnivorous, bottom foragers with a unique mouth. The mouth of this species is lined with well-developed, hard ridges of cartilage that are used to scrape algae and invertebrates from rocks. Most studies have found this species to be relatively sedentary, moving only a few miles. Larvae of bluehead suckers are known to drift for various distances after emerging from the egg stage. This species spawns in the spring and early summer with water temperature being a primary determinant of the timing. Bluehead suckers are a long-lived species with maximum ages reported more than 20 years in the upper Colorado River basin. Hybridization with other sucker species occurs throughout the range of this species. They are known to hybridize with the native flannelmouth and mountain suckers (*Catostomus platyrhynchus*), as well as the non-native white sucker (*Catostomus commersoni*) (Ptacek, Rees, and Miller, 2005).

Environmental Baseline

The bluehead sucker is classified as G4 globally and S4 in Colorado (Ptacek, Rees, and Miller, 2005). Colorado Division of Wildlife has not given the bluehead sucker a special status, but the BLM on Colorado considers it a sensitive species. Research reported in the technical assessment found the bluehead sucker to be common to abundant at locations in the Yampa, Gunnison, and middle to upper Green and Colorado rivers in 1975. Others reported the percent of bluehead suckers in fish collections ranged between 7.8 and 28.0 at six sites on the Yampa between Dinosaur National Monument and

Hayden, Colorado (1979). Still other research in the technical assessment found the bluehead suckers among the most common fish species collected in tributaries of the San Juan River in 2000.

Recent work suggests that bluehead sucker populations are declining throughout their historic range (Ptacek, Rees, and Miller, 2005). Currently, they are found in only 45 percent of their historic range in the upper Colorado River basin. The reasons for this decline are most likely due to alteration of thermal and hydrologic regimes, degradation of habitat, and interactions with non-native species (Ptacek, Rees, and Miller, 2005).

Direct, Indirect, and Cumulative Impacts

Action Alternatives

Primary impacts on the bluehead sucker historically have resulted from water diversions that change the flow regimes in streams; construction of passage barriers that cause habitat fragmentation; introduction of non-native species, which increases predation on and competition with this species; the channelization of streams; and local land use changes, especially of riparian zones, that reduce the natural function of the stream ecosystem. Of these sources of potential impacts, the project alternatives could have short-term temporary withdrawals of water for construction purposes, but such withdrawals would be considered minor. Action alternatives are projected to disturb between 3.2 and 12.3 acres of wetland and riparian areas combined along the Eagle River. However, none of the disturbance to wetlands or riparian areas would occur in the upper Eagle River (above Dowd Canyon) where bluehead suckers are present, or in the mainstem of the Colorado in Glenwood Canyon (below milepost 134) where bluehead suckers are present. Therefore, potential for direct effects on the bluehead sucker would be considered minor.

Indirect effects could result from disturbance to wetlands and riparian zones and the potential for additional winter maintenance materials entering the Eagle River that could affect water quality downstream in the Colorado River where bluehead suckers are present. However, best management practices and construction monitoring are expected to greatly reduce the potential for water quality degradation from construction disturbance. Winter maintenance materials for use along the Eagle River, Gore Creek, and Black Gore Creek (milepost 133 to milepost 190) are projected to increase from 4.5 to 19 percent, depending on alternative (and not including the Combination alternatives). The lowest increase would result from the Bus in Guideway alternatives, followed by the Rail with Intermountain Connection and Advanced Guideway System alternatives (8 to 11 percent increase). Combination alternatives, including the Transit Preservation alternatives, could increase the use of winter maintenance materials from 29 to 96 percent over the entire Corridor.

If the Corridor induces additional growth and development, and additional dispersed recreation, these activities could also contribute to disturbance of wetland and riparian zones, water quality degradation, and additional fishing pressure. These kinds of indirect effects are expected to be greatest with the Combination alternatives, followed by the Transit alternatives, and then the Highway alternatives.

Cumulative effects on bluehead sucker could possibly result from land use changes on non-National Forest System Lands resulting from induced growth plus projected and planned growth. Land use conversions typically tend to increase runoff to streams with more urban and industrial contaminants. The Highway alternatives are projected to induce slight growth in Eagle County; the Transit alternatives would induce moderate growth; and the Combination alternatives could induce the greatest growth in Eagle County, as well as moderate growth in Summit County.

No Action Alternative

Indirect effects under the No Action Alternative would continue to include disturbance to wetlands and riparian zones and the potential for additional winter maintenance materials to enter the Eagle River that could affect water quality downstream in the Colorado River where bluehead suckers are present. Growth and development would continue under the No Action Alternative and result in additional dispersed recreation. These activities could contribute to disturbance of wetland and riparian zones, water quality degradation, and additional fishing pressure.

Determination of Effects and Rationale

Action Alternatives

All action alternatives would create disturbance in the drainage upstream of the Colorado River mainstem that contains bluehead sucker. Differences among action alternatives would not be measurable forest-wide, and even the variations at the project level would not have measurable differences for the sucker habitat. Therefore, the determination is that all action alternatives **may adversely impact individuals, but not likely result in a loss of viability in the planning area, nor cause a trend to federal listing**.

No Action Alternative

The No Action Alternative would have no additional effects beyond current conditions. Effects from current trends including land use conversion and riparian habitat degradation would continue. The determination is that there would be **no impact**.

Flannelmouth Sucker (*Catostomus latipinnis*), FS

The flannelmouth sucker belongs to the family Catostomidae, the members of which are characterized by soft rays and a fleshy subtermina, protractile mouth. The family includes 12 genera and 60 species in the U.S. and Canada, as presented in the species conservation assessment (Rees et al., 2005b). Adults have large fleshy lips, and young and adults feed primarily on bottom-dwelling aquatic invertebrates. Its maximum length is 20 to 30 inches (CDOW, 1994). This species is currently documented to occur on WRNF lands in the headwaters of the Colorado River and the Eagle River between Vail and Wolcott (CDOW, 2006b). The species or habitat is suspected to occur on ARNF lands but is unconfirmed.

Distribution

In Colorado, this species has been reported from the San Juan River and the following tributaries in the southern part of the state: Animas, Florida, La Plata, Los Pinos, Mancos, Navajo, and Piedra rivers, as well as McElmo Creek. Flannelmouth sucker are also present in the Colorado River and numerous tributaries, including the Gunnison River up to the Aspinall Unit reservoirs. They are also present in the Yampa River and are considered common in the White River above and below Kenney Reservoir. Flannelmouth sucker occur in the Uncompahgre River and associated irrigation canals. Colorado Division of Wildlife distribution maps show this sucker in the Corridor APE in the Blue River above Dillon, the mainstem of the Colorado River from Granby to the state line, the middle Eagle River, the Roaring Fork, West Divide Creek, and other tributaries to the Colorado River.

Natural History

Flannelmouth sucker typically spawn in the upper Colorado River basin between April and June. Females typically lay from 4,000 to 40,000 eggs each spring in the Colorado, Gunnison, Green, and Yampa rivers. After fertilization, eggs sink and adhere to the substrate for six or seven days before fry emerge. Juvenile flannelmouth sucker may reach maturity by age 4, but in most areas of the upper Colorado River basin, maturity is reached by age 5 or 6. Hybridization with other sucker species occurs throughout the range of this species. They are known to hybridize with the native bluehead and mountain suckers, as well as the non-native white sucker (Rees et al., 2005b).

Environmental Baseline

Flannelmouth sucker populations have declined in abundance and distribution throughout their historic range. Dam construction and the associated alterations of the thermal and hydrologic regimes have reduced sucker populations in both the lower and upper Colorado River basins. Studies are currently underway to determine if the flannelmouth sucker is declining in abundance and distribution. It is being considered as a candidate for federal listing as threatened or endangered. The flannelmouth sucker is classified as G3/G4 globally and S3 in Colorado.

Direct, Indirect, and Cumulative Impacts

Action Alternatives

Primary impacts on the flannelmouth sucker historically have resulted from water diversions that change the flow regimes in streams; construction of passage barriers that cause habitat fragmentation; introduction of non-native species which increases predation on and competition with this species; and local land use changes, especially of riparian zones, that reduce the natural function of the stream ecosystem. Of these sources of potential impacts, the project alternatives could have short-term temporary withdrawals of water for construction purposes, but such withdrawals are considered minor. Action alternatives are projected to disturb between 3.2 and 12.3 acres of wetland and riparian areas combined along the Eagle River. It is important to note that no direct effects on wetlands or riparian areas would occur in the mainstem of the Colorado River in Glenwood Canyon (below milepost 134). In addition, the action alternatives are projected to disturb from 5.17 to 9.5 acres of combined wetland and riparian areas along the Blue River. However, none of that projected disturbance would occur in the Blue River above Lake Dillon where flannelmouth suckers are present. Therefore, potential direct effects on the flannelmouth sucker are considered minor.

Indirect effects could result from disturbance to wetlands and riparian zones and the potential for additional winter maintenance materials to enter the Eagle and Blue rivers that could affect water quality in the Eagle River and downstream in the Colorado River where flannelmouth suckers are present in all three rivers. However, best management practices and construction monitoring are expected to greatly reduce the potential for water quality degradation from construction disturbance. Winter maintenance materials for use along the Eagle River, Gore Creek, and Black Gore Creek (milepost 133 to milepost 190) are projected to increase from 4.5 to 19 percent, depending on alternative (and not including the Combination alternatives). The lowest increase would result from the Bus in Guideway alternatives, followed by the Rail with Intermountain Connection and Advanced Guideway System alternatives (8 to 11 percent increase). Winter maintenance material usage is projected to increase into the Blue River as well, but all such winter maintenance would occur below Dillon Reservoir and would not have any indirect effect on flannelmouth suckers living above Dillon Reservoir. Combination alternatives, including the Transit Preservation alternatives, are associated with the greatest increase in the use of winter maintenance materials from 29 to 96 percent over the entire Corridor.

If the Corridor induces additional growth and development, as well as additional dispersed recreation, these activities also could contribute to disturbance of wetland and riparian zones, water quality degradation, and additional fishing pressure. These kinds of indirect effects are expected to be greatest with the Combination alternatives, followed by the Transit alternatives (moderate), and then followed by the Highway alternatives (slight).

Cumulative effects on flannelmouth sucker could possibly result from land use changes on non-National Forest System Lands resulting from induced growth plus projected and planned growth. Land use conversions typically tend to increase runoff to streams with more urban and industrial contaminants. The Highway alternatives are projected to induce slight growth in Eagle County; the Transit alternatives would induce moderate growth; and the Combination alternatives could induce the greatest growth in Eagle County, as well as moderate growth in Summit County.

No Action Alternative

Potential impacts on the flannelmouth sucker under the No Action Alternative would include predation on and competition from other non-native introduced species, and local land use changes, especially of riparian zones, that reduce the natural function of the stream ecosystem. The potential would continue for additional winter maintenance materials to enter the Eagle and Blue rivers that could affect water quality in the Eagle River and downstream in the Colorado River where flannelmouth suckers are present. Additional growth and development, as well as additional dispersed recreation, could continue, contributing to disturbance of wetland and riparian zones, water quality degradation, and additional fishing pressure.

Determination of Effects and Rationale

Action Alternatives

All action alternatives would create disturbance in the drainage upstream of the Colorado River mainstem that contains flannelmouth sucker, but below the upper Blue River where flannelmouth sucker occur. Disturbance of habitat for flannelmouth sucker is based on broad construction assumptions at this Tier 1 level of analysis. Procedures could include activities at water's edge that result in sedimentation, use of caissons to place concrete structures in streams or water bodies, use of structures to divert flowing water to allow construction, and other procedures that will be identified in Tier 2 projects. Tier 2 studies will evaluate and identify permanent mitigation measures for specific issues including structural controls. Stream restoration measures might include creation of drop structures and/or bioengineering techniques. Differences among action alternatives would not be measurable on a forest-wide basis. Therefore, the determination is that all action alternatives **may adversely impact individuals, but not likely to result in a loss of viability in the planning area, nor cause a trend to federal listing**.

No Action Alternative

The No Action Alternative would have no additional effects beyond current conditions. Effects from current trends including land use conversion and riparian habitat degradation will continue. Because of the potential for downstream effects, the determination is that this alternative **may adversely impact individuals, but not likely to result in a loss of viability in the planning area, nor cause a trend to federal listing.**

BR.4.1.5 Plants

Sensitive Plants Known or Suspected to Occur on the ARNF

Budding Monkeyflower (*Mimulus gemmiparus*)

Habitat

Budding monkeyflower is a Colorado Front Range endemic small annual plant that prefers granitic seeps, slopes, and open sites in alluvium within spruce-fir and aspen forests and occasionally in meadows, at elevations of 8,500 to 10,500 feet.

Environmental Baseline

Budding monkeyflower has records of occurrence for Boulder, Larimer, and Jefferson counties (near the Corridor) and Grand County (just outside the Corridor) on the Pike National Forest and ARNF (Spackman et al., 1997). Within the Corridor, marginal habitat occurs east of EJMT among roadside rock cliffs and terraces containing seepage areas. Surveys conducted in 2009 in all areas of suitable habitat in the APE revealed no plants, and absence is presumed.

Front Range or Rocky Mountain Cinquefoil (*Potentilla rupincola*)

Habitat

Rocky Mountain cinquefoil, a perennial herb, grows on granitic outcrops or thin, gravelly granitic soils with western or northern exposure, in ponderosa or limber pine forests between 6,900 and 10,500 feet above sea level (Spackman et al., 1997).

Environmental Baseline

Rocky Mountain cinquefoil is a Colorado Front Range species endemic to Clear Creek and three other Colorado counties. It is known from 23 occurrences with a total population size estimated to be

36,000 individuals or possibly even 100,000 individuals (Anderson, 2004). There are seven populations on the ARNF, and probably numerous additional unrecorded populations (A. Child pers. comm. with S. Popovich, 2005). Most populations of this species are protected from disturbance from recreationists, grazing, and management activities by the inaccessibility of their habitat (O'Kane, 1988; and A. Child pers. comm. with S. Popovich, 2005). Most populations appear to be stable in numbers based on casual observations (A. Child pers. comm. with S. Popovich, 2005). This species was recorded at two areas within 1 mile of the Corridor, one near the U.S. 40 junction with I-70, approximately milepost 232 (CNHP, 2002a) and the other near Georgetown (CNHP, 2002a). Within the Corridor, it could occur among roadside rock cliffs and terraces east of EJMT, in steep areas that are unsafe to survey, but the likelihood of occurrence within the APE is low. Extensive surveys have been conducted for this species in the APE in all areas safe to survey containing suitable habitat, and no plants were observed. However, because not all areas can be safely surveyed, the presence of at least some plants is nonetheless presumed for analysis purposes.

Selkirk's Violet (*Viola selkirkii*)

Habitat

Selkirk's violet, a small perennial herb, is known to occur from British Columbia east to Greenland, and down into the U.S. from Washington to New Mexico in cold mountain forests, moist woods, and thickets at elevations from 8,500 to 9,100 feet (Spackman et al., 1997). In Colorado, occurrence records exist for El Paso and Larimer counties, where it occurs in valley bottoms along drainageways and in cold air drainages.

Environmental Baseline

Suitable habitat may exist along the Corridor, especially in Douglas-fir and spruce-fir forests and certain drainageways. Because of its rarity, the likelihood of occurrence of this plant is low. Although limited surveys have been conducted for this species in the APE, no plants have been observed. This species is easily overlooked; however, the presence of at least some plants is presumed.

Sensitive Plants Known or Suspected to Occur on Both National Forests

Altai Cotton-Grass (*Eriophorum altaicum* var. *neogaeum*)

Habitat

Altai cotton-grass, a grass-like perennial herb, prefers cooler, wet places in the northern hemisphere, including Alaska, British Columbia, Utah, and Colorado. It is usually restricted in Colorado to fens or fen-like habitats.

Environmental Baseline

Altai cotton-grass has been recorded in high fens of the Elk and San Juan mountains in Colorado (Weber and Wittmann, 2001) usually at elevations from 9,500 to 14,000 feet. Records exist for six counties in Colorado, including Eagle and Gunnison counties, and in three wilderness locations on the WRNF (Cunningham et al., 2003). Extensive surveys have been conducted for this species in the APE in all fen and fen-like areas most likely to support the species, and no plants were observed. This plant is presumed to be absent.

Autumn Willow (*Salix serissima*)

Habitat

Autumn willow, a tall shrub, occurs in marshes or fens with other willow species and sedges at elevations between 7,800 and 9,300 feet (Spackman et al., 1997). Distribution includes Canada to New England to the northern Rocky Mountain states.

Environmental Baseline

In Colorado, autumn willow is known from Larimer, Park, and Routt counties. Marginally suitable habitat occurs in fens and fen-like areas of the Corridor near EJMT and Vail Pass. Extensive surveys have been conducted for this species in all suitable habitat in the APE. No plants were encountered, and it is presumed to be absent.

Baltic Sphagnum (Sphagnum angustifolium)

Habitat

Like sphagnum (*Sphagnum angustifolium)* (see discussion below), little is known about the distribution and abundance of Baltic sphagnum worldwide. It occurs in the same habitats as other sphagnum species.

Environmental Baseline

In Colorado this species is found in a handful of sites, none near the Corridor. It is unknown if additional undetected sites exist. The known sites in Colorado seem secure. Extensive surveys have been conducted for this species in the APE in all fen and fen-like areas most likely to support the species, and no sphagnum of any kind was observed. This plant is presumed to be absent.

Colorado Tansy-Aster (Machaeranthera coloradoensis)

Habitat

Colorado tansy-aster, a perennial composite herb, occurs on gravelly areas in mountain parks, slopes, and rock outcrops up to dry tundra at elevations from 8,500 to 12,000 feet (Spackman et al., 1997). This plant is endemic to south central Wyoming and Colorado. Soils often consist of limey-sandstone or shaley-gypsum.

Environmental Baseline

The Colorado tansy-aster has been recorded in nine counties in Colorado, including a Pitkin County location on the WRNF. Suitable habitat could occur in the Corridor as well. Suitable habitat is not thought to exist within the APE in the high-elevation areas of the Corridor at EJMT and Vail Pass, and its absence is presumed. Because suitable habitat is not believed to be present, only cursory surveys have been conducted for this species in the APE.

Dwarf Raspberry [Rubus arcticus var. acaulis (= Cylactis acaulis)]

Habitat

Dwarf raspberry, a small perennial herb, prefers boggy woodlands marshes and willow carrs at elevations from 8,600 to 9,700 feet. It also occurs in mossy willow thickets along mountain streams (Weber and Wittmann, 2001). The plant tolerates a wide variety of soils from sandy to clayey but requires moist conditions. Distribution ranges from Alaska to Canada and Minnesota, and the Rocky Mountains from Montana to Colorado.

Environmental Baseline

Dwarf raspberry is rare in Colorado, with a few records from mountainous areas in the northern part of the state. It occurs along Willow Creek on the ARNF in Grand County. That site was disturbed a few years ago in a small flood event, and about 1/4 to 1/3 of the known site and plants were washed away. In 2009, remaining undisturbed plants appeared stable. Suitable habitat is present within the APE. Extensive surveys have been conducted for this species in all suitable habitat in the APE. No plants were encountered, but it can be easily overlooked, and the presence of at least some plants is nonetheless presumed but, because of its rarity, the likelihood of occurrence of this plant is probably low.

Hall's Fescue (*Festuca hallii*)

Habitat

Hall's fescue, a perennial bunchgrass, occurs in alpine meadows, tundra, open woods, and dry subalpine grasslands at elevations from 11,000 to 12,000 feet (Spackman et al., 1997). Its distribution includes the northern Rocky Mountains and Canada.

Environmental Baseline

Hall's fescue reaches its southern limit in Colorado, and CNHP records show one population in Larimer County as of 1997 (Spackman et al., 1997), in an open meadow in the Rawah Mountains on the ARNF. This population occurs in patches on mature soils of relatively dry, but peaty, tundra (CNPS, 1997). A historical population occurs in Park County in South Park, but it has not been relocated. Suitable habitat is not thought to exist within the APE in the high-elevation areas of the Corridor at EJMT and Vail Pass, and its absence is presumed. Because suitable habitat is not believed to be present, only cursory surveys have been conducted for this species in the APE.

Harrington's Beardtongue (*Penstemon harringtonii*)

Habitat

Harrington's beardtongue is a Colorado endemic perennial herb that grows in association with mid-elevation (6,800 and 9,200 feet) sagebrush, oak brush, and other mountain shrub habitats including lower-elevation piñon-juniper woodlands. This penstemon species prefers level or slightly sloping sites with rocky loams and rocky clay loams derived from coarse calcareous parent materials (Spackman et al., 1997), but can also occur on steep slopes. Often, areas can be barren appearing. Harrington's beardtongue can somewhat tolerate sparsely vegetated sites, exposed ridges, and disturbances such as livestock grazing and road cuts (USFS, 1999).

Environmental Baseline

Suitable habitat for Harrington's beardtongue is confined to Colorado's Western Slope, in the Eagle River, Roaring Fork, and Colorado River valleys. Numerous small plant populations occur near the Corridor in Eagle County, from approximately milepost 140 (Eagle) to milepost 167 (Avon), and much suitable habitat exists along, but mostly outside, this portion of the Corridor. Ownership of occupied sites includes WRNF, BLM, State, and private land. Approximately 6 to 10 known populations or subpopulations occur close to the APE. Additional undetected populations may also occur. One population of up to 500 plants is known to occur within the Corridor, on private and BLM land immediately on both sides of the current Interstate roadway and within the median, in Red Canyon about 2.5 miles west of Wolcott. Scattered plants are known to occur in the Avon area on private property close to and perhaps just within the APE. This and the Red Canyon site are the only sites believed to contain plants within the APE. No plants are believed to occur within the APE on lands administered by the Forest Service although it is possible that some small sites or scattered plants may have escaped detection during surveys.

Surveys for this species were conducted in 1982, 1988, 1989, 1990, and with varying intensities in later years through 2009. They included surveys of historic sites and discovery of new populations. Extensive surveys have been conducted for this species in the APE in past survey years. As of 2003, BLM and CNHP Element Occurrence records show that there are 250 to 300 or more occupied sites across its range. One reference indicates there are 300,000 to 500,000 plants present on 55 sites within 132 acres of occupied habitat mapped in 1992; the total number of plants across all sites could be considerably more. Surveys continue to find new populations over time.

One source indicates populations of Harrington's beardtongue may peak every 4 to 5 years due to its short-lived perennial life-cycle. This may explain drastic differences in the number of individuals seen in different survey years. Population sizes seem to have declined from the early 1980s (USFS, 2003), but it is not known if the large numbers observed in recent years have been reliably compared. It has been noted that this decline might reflect a response to drought conditions in 1987 in western Colorado.

Many sites are located in areas unlikely to be threatened by management or development; these are mostly on BLM-administered land. However, the areas of occurrence of this species possibly within the APE are located around and near mountain ski towns. Development pressures are high in such sagebrush areas historically used for grazing. These areas are being converted to residential, commercial, and recreational developments. There is also some concern reported over the use of chemicals on sagebrush within the area of occurrences of Harrington's beardtongue. However, most people knowledgeable with this species agree that overall threats to this plant, based on revised presence and abundance known in 2009, are lower than previously believed, and that perhaps the plant in fact may no longer warrant special concern.

Hoary Willow (*Salix candida*)

Habitat

Hoary willow, a perennial shrub, occurs on hummocks in nutrient-rich fens, in thickets at the edges of moderately high-elevation ponds, and on river terraces at elevations from 8,800 to 10,600 feet (Spackman et al., 1997). Co-dominant plants include other willows and sedges, and distribution includes several northern states, Alaska, and Canada.

Environmental Baseline

Colorado is the known southern limit of hoary willow, and several counties have recorded the species, although none within the Corridor (Spackman et al., 1997). Marginaly suitable habitat occurs in fens and fen-like areas of the Corridor near EJMT and Vail Pass. Extensive surveys have been conducted for this species in all suitable habitat in the APE. No plants were encountered, and it is presumed to be absent.

Kotzebue's Grass-of-Parnassus (*Parnassia kotzebuei*)

Habitat

A small perennial herb, Kotzebue's grass-of-Parnassus occurs on subalpine and alpine wet, rocky ledges, moss mats, and in sandy soil at the edges of lakes, ponds, and streams (Spackman et al., 1997). It prefers high-elevation conditions, occurring at elevations from 10,000 to 12,000 feet.

Environmental Baseline

In Colorado, Kotzebue's grass-of-Parnassus occurs in a few scattered populations in several counties, including Clear Creek in the Corridor APE. The WRNF has documented the species in Summit County, west of Hoosier Pass. Extensive surveys have been conducted for this species in the APE in all areas most likely to support the species, and no plants were observed. The plant is presumed to be absent.

Lesser Bladderpod (*Utricularia minor*)

Habitat

Lesser bladderpod, a perennial aquatic herb, occurs in and near subalpine ponds in several northern states and California, and on the Eastern Slope of Colorado, including the Boulder watershed. It prefers shallow waters and wet soil. Habitats include fens, open bogs, sedge meadows, and marshes, often in calcium-rich soils.

Environmental Baseline

Marginal suitable habitat occurs along the Corridor along streams and in fens and fen-like wetlands. Extensive surveys have been conducted for this species in all suitable habitat in the APE. No plants were encountered, and it is presumed to be absent.

Lesser Panicled Sedge (*Carex diandra*)

Habitat

Lesser panicled sedge, a perennial grass-like plant, occurs in swamps, peat (*Sphagnum*) bogs, lake margins, and wet, often calcareous meadows at moderate elevations. The species is circumboreal in distribution.

Environmental Baseline

In Colorado, lesser panicled sedge occurs in willow carrs in subalpine areas (Weber and Wittmann, 2001). It has been documented on WRNF on the Garfield/Rio Blanco county line (outside the Corridor APE). Similar types of habitat occur along the Corridor, and extensive surveys have been conducted for this species in the APE in all areas most likely to support the species. No plants were observed, and because of its rarity, the likelihood of occurrence of this plant is probably low, but this species can be overlooked, and presence of at least some plants is presumed.

Livid Sedge (*Carex livida*)

Habitat

Livid sedge, a perennial grass-like plant, occurs in rich fens and grass-dominated mineral-rich wetlands at elevations between 9,000 and 10,000 feet (Spackman et al., 1997). Distribution includes Canada, northern states, and California, as well as Europe and Asia.

Environmental Baseline

In Colorado, livid sedge has been recorded in Jackson, Larimer, and Park counties, none of which is in the Corridor. The habitat in the fens and fen-like areas in the APE is the wrong type of habitat to support this species. Nonetheless, extensive surveys have been conducted for this species in the APE in all areas most likely to support the species, and no plants were observed. This plant is presumed to be absent.

Narrow-Leaved Moonwort (*Botrychium lineare*)

Habitat

Distribution of this rare moonwort, a primitive fern-like plant, includes Canada and northern states into Colorado. Less than 100 individuals are known to occur in a few sites in Colorado (Popovich 2004), and less than a few thousand occur across its range. However, plants are not always present above ground, and the actual numbers of plants occurring below ground at known and undetected sites could be significantly greater. Suitable habitat in Colorado appears restricted to upper montane and subalpine vegetation zones, and mostly occurs in historically disturbed open areas that are now stabilized. Suitable habitat is considered to be such areas as roadsides, ski slopes, transmission lines or other disturbance corridors, avalanche chutes, and old town sites (Popovich, 2004). Other preferred sites are grassy slopes with medium-height grasses, often along edges of forests and aspen stands near streams, and old mining sites. Elevations in Colorado range from about 8, 500 to 10,400 feet and possibly 10,750 feet (Popovich 2004).

Genetic analyses have shown that a moonwort previously believed to be a separate and new species, and identified with the provisional name *Botrychium* tax. nov. “furcatum,” is actually closely related to narrow-leaved moonwort and may not be a separate species. Plants corresponding to the “furcatum” entity are subsumed under *B. lineare* for the purposes of this report.

Environmental Baseline

This ½-ich tall plant does not show above-ground expression every year and is extremely difficult to detect in field surveys. It may very well be more common than believed. Recently, more sites have been located, and many sites seem secure. Because it seems to be able to colonize and persist in stabilized disturbed areas, threats to the species may be less than previously believed. In Colorado, this moonwort has been recorded only in Clear Creek (Empire area) and El Paso counties in recent years, but other known or unconfirmed sites have been reported (Popovich, 2004). A historical site on the ARNF in

Boulder County has not been relocated, but site descriptors are vague and the exact location is unknown. Suitable habitat occurs along the Corridor, especially in previously disturbed areas that are now stabilized, such as roadsides and borrow pits. Because of its rarity, the likelihood of occurrence of this plant could be low, but as it is known to occur nearby, the likelihood may also be medium to high. In 2009, thirty stops were made to survey for this plant and all other rare moonworts in areas exhibiting the most promising habitat in the APE, but no plants were observed. This species is easily overlooked, however, and the presence of at least some plants is presumed.

Paradox moonwort (Botrychium paradoxum)

Habitat

Distribution of the paradox moonwort, a primitive fern-like plant, includes eastern Washington, western Montana, southward through Idaho and Utah into Colorado. There is only one confirmed site of this plant in Colorado, discovered in 2008 near Crested Butte, with only a handful of plants observed. Another possible site near Grizzly Gulch near the APE is unconfirmed. Other sites may well exist. Suitable habitat in Colorado appears restricted to open meadows in the upper subalpine vegetation zone.

Environmental Baseline

Although more common in other parts of its range, it is rare on Colorado. Little is known about the habitat requirements in Colorado. The single known site is secure at this time. Various surveys have been conducted over the years for moonworts in the APE, but only relatively common moonworts have been encountered. This species is easily overlooked, however, and the presence of at least some plants is presumed.

Park Milkvetch (Astragalus leptaleus)

Habitat

Park milkvetch, an inconspicuous perennial herb, occurs in sedge-grass meadows, swales, and turfy hummocks on the edge of meandering brooks; it is also present along streamside willows. Elevations of sites are from 6,600 to 9,500 feet (Cunningham et al., 2003).

Environmental Baseline

Park milkvetch has been recorded in Summit County below Green Mountain Reservoir in the WRNF, north and upstream of the Corridor APE. Similar habitat occurs within the Corridor, and extensive surveys have been conducted for this species in the APE in many areas most likely to support the species. No plants were observed, and because of its rarity, the likelihood of occurrence of this plant is probably low, but this species is easily overlooked, and the presence of at least some plants is presumed.

Porter's Feathergrass (*Ptilagrostis porteri*)

Habitat

Porter's feathergrass, a perennial bunchgrass, is a Colorado endemic and occurs in peat hummocks in fens and willow carrs at elevations between 9,200 and 12,000 feet (Spackman et al., 1997). It occurs primarily in flat valleys exposed to the south and east (CNPS, 1997).

Environmental Baseline

Porter's feathergrass has been recorded in El Paso, Lake, Park, and Summit counties. Because of its global rarity, it was once considered for Candidate status under the ESA. The habitat in the fens and fen-like areas in the APE is the wrong type of habitat to support this species. Nonetheless, extensive surveys have been conducted for this species in the APE in all areas most likely to support the species, and no plants were observed. This plant is presumed to be absent.

Roundleaf Sundew (Drosera rotundifolia)

Habitat

Roundleaf sundew, a small carnivorous perennial plant, occurs on floating peat mats and on the margins of acidic ponds and fens (Spackman et al., 1997). Its distribution includes Eurasia, the northeast U.S., and several western states at elevations from 9,100 to 9,800 feet.

Environmental Baseline

In Colorado, roundleaf sundew has been recorded in Gunnison, Grand, and Jackson counties. The habitat in the fens and fen-like areas in the APE is the wrong type of habitat to support this species. Nonetheless, extensive surveys have been conducted for this species in the APE in all areas most likely to support the species, and no plants were observed. This plant is presumed to be absent.

Simple Kobresia (Kobresia simpliciuscula)

Habitat

Simple kobresia, a perennial grass-like plant of the western U.S., prefers moist gravelly tundra near the Continental Divide of the Front Range area of Colorado (Weber and Wittman, 2001), but it can also occur in fens. In Colorado, this plant is known in fens only from a handful of sites, none near the Corridor.

Environmental Baseline

Suitable habitat for this species exists in fens in the Vail Pass and EJMT areas. Extensive surveys have been conducted for this species in some but not all areas exhibiting the most promising habitat in the APE, revealing that one fen contains a small population of this plant somewhat beyond and slightly uphill from the outer edge of the APE near Vail Pass. Other areas within or near the APE may contain additional undocumented plants.

Slender Cotton-Grass (*Eriophorum gracile*)

Habitat

Slender cotton-grass, a perennial grass-like plant, occurs in fens, wet meadows, and on pond edges from elevations of 8,100 to 12,000 feet (Cunningham et al., 2003). The plant often prefers calcareous soils and can form large uniform stands.

Environmental Baseline

The WRNF records indicate distribution of slender cotton-grass as only in Park County. CNHP records include Jackson and Las Animas counties, and Weber lists the Elk and San Juan mountains, none of which are in the Corridor. Extensive surveys have been conducted for this species in the APE in all fen and fen-like areas most likely to support the species, and no plants were observed. This plant is presumed to be absent.

Sphagnum (Sphagnum angustifolium)

Habitat

Sphagnum is better known to most as “peatmoss.” Sphagnum is a small moss-like primitive plant of wet areas. It occurs across the globe in fens, bogs, and wet, cold areas. In Colorado, sphagnum species seem restricted to saturated water tables of fens or fen-like areas and pond margins.

Environmental Baseline

Little is known about the distribution and abundance of *Sphagnum angustifolium* worldwide. In Colorado it is found in a handful of sites, none near the Corridor. It is likely that additional undetected sites exist. The known sites in Colorado seem secure. Extensive surveys have been conducted for this species in the APE in all fen and fen-like areas most likely to support the species, and no sphagnum of any kind was observed. This plant is presumed to be absent.

Upswept moonwort (Botrychium ascendens)

Habitat

Distribution of this moonwort, a primitive fern-like plant, includes southern Alaska southeast to Nevada and Utah, and just reaching Colorado. In Colorado, it is known only from three sites, discovered in 2008 and 2009, but others may well exist. One site is in Park County, one site is above Georgetown toward Guanella Pass, and one site is within the APE between Vail Pass and Vail. Suitable habitat in Colorado appears restricted to the subalpine vegetation zone, and mostly occurs in historically disturbed open areas that are now stabilized. Suitable habitat is considered to be such areas as roadsides, ski slopes, transmission lines or other disturbance corridors, avalanche chutes, and old town sites.

Environmental Baseline

Although more common in other parts of its range, upswept moonwort is rare in Colorado. Because it seems to be able to colonize and persist in stabilized disturbed areas, threats to the species may be less than previously believed. Some of the plants at the site near Georgetown were extirpated in 2008 and 2009 by road improvement projects. The population in Park County seems secure but could be subjected to impacts if road or water development improvements were to occur nearby. Various surveys have been conducted over the years for moonworts in the APE, and mostly relatively common moonworts are encountered. This species can be easily overlooked, however, and additional undetected plants could exist within or near the APE. Currently, the species across these sites seems to be surviving.

Yellow Lady's-Slipper [Cypripedium parviflorum (=C. calceolus ssp. parviflorum)]

Habitat

Yellow lady's-slipper, a showy perennial orchid species, occurs in aspen groves and ponderosa pine/Douglas-fir forests at elevations from 7,400 to 8,500 feet in Colorado (Spackman et al., 1997), primarily on the Front Range.

Environmental Baseline

In Colorado, yellow lady's-slipper occurs in 16 counties. The largest populations occur in El Paso and Larimer counties, but scattered patches have been recorded in Clear Creek and Jefferson counties near the Corridor APE (CNPS, 1997). Extensive surveys conducted in 2009 in all areas of suitable habitat in the APE revealed no plants, and absence is presumed.

Mitigation Measures Common to All Action Alternatives

Plant Surveys and Tier 2 Projects for All Action Alternatives

Specific impacts from action alternatives are not known at this time. Plants or suitable habitat may be affected by the footprints of the project alternatives but would be avoided if feasible.

To better determine potential impacts, field surveys will be conducted at appropriate phenological times for species identification for all sensitive plant species that could occur in the APE or be affected by project activities as identified in **Table BR – 3**. Surveys are not needed for species that have already undergone extensive survey efforts and have been determined to be absent as identified in the species discussions. Surveys will occur within the growing season prior to final design of Tier 2 projects. Crews with team leaders or members who are trained botanists with field experience will conduct surveys for the target, or closely-related, species. Surveys will include mapping of populations encountered within the area of potential effects for each species potentially affected by the proposed Tier 2 project. This survey strategy will allow flexibility for impact avoidance, minimization, and mitigation efforts for species of concern.

Impacts on Plants

Harrington's Beardtongue (*Penstemon harringtonii*)

Effects of Alternatives

No Action Alternative

The population that occurs immediately adjacent to the existing roadway and in its median in Red Canyon could be experiencing direct adverse impacts on some individuals. This could result from localized crushing of plants if vehicles use the roadsides or median, or from routine maintenance work or noxious weed treatments. The changes in hydrology and site chemistry resulting from snow cleared from the highway and possibly placed on occupied road shoulder sites during the winter months are unknown but could be indirectly harming individuals. The majority of plants occur in areas beyond influence of these factors, however, and the overall site viability seems secure.

No other sites are known to be affected. Across the species range, sites may be subject to loss of individuals or local extirpation due to ongoing land development, especially on private property along the Corridor. The vast majority of sites occur on federal land that will not likely be developed or threatened, although some sites on BLM land may be developed for mining or other multiple use activities. Loss of these sites would add to a cumulative decrease over time, but long-term viability seems secure due to the large number of unthreatened sites and plants range-wide. The possible loss of a few plants at the roadside sites in Red Canyon and Avon (if plants occur within the APE there) would not be expected to contribute meaningfully to cumulative effects.

For the reasons discussed above, an effects determination of **"May adversely impact individuals, but not likely to result in a loss of viability on the planning area, nor cause a trend to federal listing"** is warranted for the No Action Alternative.

Action Alternatives

Impacts on this species are generally expected to be low, except for the Advanced Guideway System alternative, which may have a low to medium impact, depending on the number of plants disturbed. Potential impacts would be minimized and mitigated as feasible following plant surveys. Impacts on the Red Canyon site and Avon site (if occupied) would be expected to remain the same as those associated with the No Action Alternative or increase proportionally to the amount of occupied area that could be directly disturbed from each action alternative. If other sites found to occur near the roadway in the Corridor would become part of the project footprint area, they could be adversely affected as discussed under the No Action Alternative, or completely extirpated if the footprint and construction require their removal. The potential to affect plants would be relatively greater with those alternatives that disturb more area.

The possible loss of affected sites could contribute toward a cumulative loss of sites across the species range. Even if all sites within the APE were to be extirpated from implementation of the action alternatives, however, the species viability would be anticipated to remain secure because there would still be sufficient and large numbers of plants and sites across its range that remain unthreatened.

For the reasons discussed above, an effects determination of **"May adversely impact individuals, but not likely to result in a loss of viability on the planning area, nor cause a trend to federal listing"** is warranted for all action alternatives.

Narrow-Leaved Moonwort (*Botrychium lineare*), Paradox Moonwort (*Botrychium paradoxum*), Upswept Moonwort (*Botrychium ascendens*)

Effects of Alternatives

No Action Alternative

No sites are known to occur in the impact area, but presence is assumed for these species. Historically disturbed stabilized road cuts, former borrow pits, mountain meadows, and certain roadside shoulder areas are suitable habitat and could contain plants. Potentially occurring sites could be experiencing ongoing direct adverse impacts on some individuals. This could result from localized crushing of plants if vehicles use the roadsides or median, or from routine maintenance work or noxious weed treatments. The changes in hydrology and site chemistry resulting from snow cleared from the highway and possibly placed on occupied road shoulder sites during the winter months are unknown, as are impacts from possible soil disturbance, but these could be indirectly harming individuals or adversely altering habitat.

It is difficult to assess overall status of these species because sites do not exhibit above-ground expression each year and survival requirements are not known. Across the species range, sites may be subject to loss of individuals from incidental activities, competing vegetation, or habitat modification, but there is no evidence to suggest that sites are either threatened or not threatened. For narrow-leaved moonwort, the only site monitored for the species, in an undisturbed meadow near Pike's Peak, may be declining, but results are inconclusive. The nearby Empire area site is not being protected and could be adversely impacted or extirpated from future canal berm maintenance activities. In Colorado, the majority of known sites for this and other moonwort species occur on federal land that is currently being managed for and protected from disturbance. Habitat conditions of managed sites are being maintained but could be altered over time, which could affect plants. It is possible, but unknown, that numerous additional undetected sites occur across the species range for these moonworts. Undetected sites could be adversely affected by ongoing Forest activities such as physical disturbance associated with opening or closing historic roads, borrow pits, mining sites, logging skid trails, landings, or staging areas; road and ski slope maintenance, trailside use by recreationalists, and general forest management activities.

Anthropogenic disturbances may serve to increase suitable habitat that plants can then colonize over time, and it is possible that such disturbances have been and are currently contributing to a positive impact. For example, nearly all sites of narrow-leaved moonwort occur in formerly disturbed areas, and many individuals of related moonwort species have been found in the active ski runs of near Copper Mountain and Winter Park, but they do not occur in the adjacent forest edges.

Cumulative Effects. Because of the perceived global rarity of the narrow-leaved moonwort and rarity in Colorado of the other moonworts, and until more is known about these plants, a conservative assessment is to conclude that loss of any plants at a site could add to a potential cumulative decrease over time. The possible loss of a few plants at potential Corridor sites could be expected to contribute meaningfully to adverse cumulative effects. However, even though long-term viability across the species range remains unknown, evidence most suggests, and it is most probable at this time to conclude, that viability seems secure in the foreseeable future.

For the reasons discussed above, an effects determination of **"May adversely impact individuals, but not likely to result in a loss of viability on the planning area, nor cause a trend to federal listing"** is warranted for the No Action Alternative.

Action Alternatives

Additional disturbance above levels associated with the No Action Alternative near roads or in borrow pits that provide currently stabilized habitat may affect unknown moonwort populations and suitable habitat. Plant surveys for specific projects during Tier 2 processes may detect new populations. Potential impacts would be minimized and mitigated as feasible, including project design changes or possible transplanting of plants or occupied soil. The success of transplanting other moonwort species and occupied soil from another highway project on Forest-administered land at nearby Guanella Pass several years ago is being monitored and shows some success, but long-term results are not yet available. Transplant results in the Midwest with other moonwort species show limited success.

Direct and indirect effects on this species would be expected to remain the same as those associated with the No Action Alternative or increase proportionally to the amount of occupied area that could be directly disturbed from each action alternative. The potential to affect plants would be relatively greater with those alternatives that disturb more area. It is possible that disturbance could create suitable habitat that could be colonized over time, contributing to an overall net positive impact if the number of recruiting plants and suitable habitat areas created over time is greater than the number of plants and habitat areas lost during initial disturbance.

As part of implementation, the project would avoid the occupied site. While a few undetected individuals may exist near the main population and could be adversely impacted or killed by project implementation, most plants would be protected, and the population as a whole would be anticipated to remain viable.

Determination of effect: **May adversely impact individuals but not likely to result in viability in the planning area nor cause a trend to federal listing.**

Cumulative Effects. Even though long-term effects could be positive and contribute to a gain in plants and habitat, because of their perceived rarity in Colorado, and until more is known about these plants, a conservative assessment is to conclude that loss of any plants at a site could add to a potential cumulative decrease over time. The possible loss of a few plants at potential Corridor sites could be expected to contribute meaningfully to adverse cumulative effects. However, even though long-term viability across the species range remains unknown, evidence most suggests, and it is most probable at this time to conclude, that viability seems secure in the foreseeable future.

For the reasons discussed above, an effects determination of **“May adversely impact individuals, but not likely to result in a loss of viability on the planning area, nor cause a trend to federal listing”** is warranted for the action alternatives.

Plants of Fens and Riparian-Influenced Areas

- Altai cotton-grass (*Eriophorum altaicum* var. *neogaeum*)
- Autumn willow (*Salix serissima*)
- Baltic sphagnum (*Sphagnum balticum*)
- Budding monkeyflower (*Mimulus gemmiparus*)
- Dwarf raspberry [*Rubus arcticus* var. *acaulis* (= *Cylactis*)]
- Hoary willow (*Salix candida*)
- Kotzebue’s grass-of-Parnassus (*Parnassia kotzebuei*)
- Lesser bladderpod (*Utricularia minor*)
- Lesser panicled sedge (*Carex diandra*)
- Livid sedge (*Carex livida*)
- Park milkvetch (*Astragalus leptaleus*)
- Porter’s feathergrass (*Ptilagrostis porteri*)
- Roundleaf sundew (*Drosera rotundifolia*)
- Simple kobresia (*Kobresia simpliciuscula*)
- Slender cotton-grass (*Eriophorum gracile*)
- Spagnum (*Sphagnum angustifolium*)

Effects of Alternatives

No Action Alternative

Impacts on these species are generally expected to be nonexistent or low. Undetected populations of these species could occur in riparian areas and fens that could be experiencing impacts by current highway operations. Sand spillover of winter snow clearing operations from bridges crossing riparian areas (no organic fens supporting suitable habitat for sensitive fen species are crossed) could be physically crushing or smothering sensitive riparian plants, and preventing recruitment. There could also be indirect adverse impacts on individuals and habitat. Runoff (contaminants and sedimentation) from road maintenance and operations could have the potential to indirectly affect these species or downstream habitats. The changes in hydrology and water quality attributes, such as chemistry, salinity, nutrient loading, siltation, or pH resulting from spillover snow clearing sands, salts, and chemicals applied during the winter months are unknown, as are potential chemical residue impacts from roadside upland noxious weed treatments, but these could be indirectly harming individuals or adversely altering habitat by changing water quality status. The known site of simple kobresia does not seem to be adversely impacted by the current Corridor or related activities, and no dewatering to the sites is apparent or suspected. Possible impacts on additional undetected sites, if present, are unknown but would be anticipated to be of low magnitude and stabilized.

There are no other Forest, State, or private activities known to be adversely impacting these species, and none are foreseeable. It is possible other projects or uses are impacting individuals across the species range, possibly contributing to a cumulative loss of species. It is unlikely that potential populations in I-70 roadway impact areas would be expected to become extirpated over time. The possible loss of a few plants would not be expected to contribute meaningfully to cumulative effects.

For the reasons discussed above, an effects determination of **"May adversely impact individuals, but not likely to result in a loss of viability on the planning area, nor cause a trend to federal listing"** is warranted for these species for the No Action Alternative for dwarf raspberry, lesser panicled sedge, park milkvetch, and simple kobresia. For altai cotton-grass, autumn willow, Baltic sphagnum, budding monkeyflower, hoary willow, Kotzebue's grass-of-Parnassus, lesser bladderpod, livid sedge, Porter's feathergrass, roundleaf sundew, slender cotton-grass, and sphagnum, an effects determination of **"No impact"** is warranted because they are not known or suspected to occur in the APE.

Action Alternatives

Impacts on these species from the action alternatives are generally expected to be nonexistent or low, depending on the degree and number of sites disturbed. Potential impacts would be minimized and mitigated as feasible following plant surveys. Impacts would be expected to remain the same as with the No Action Alternative or increase proportionally to the amount of occupied area that could be disturbed from each action alternative. The potential to affect plants would be relatively greater with those alternatives that disturb more occupied area or allow greater visitor use to riparian areas.

Direct impacts on fens associated with construction and implementation activities above those associated with the No Action Alternative are assumed to be avoidable based on the update and the new fen inventory conducted in late 2009 by David Cooper, along the I-70 Corridor from milepost 130 to milepost 259 (Jones, Driver, Cooper, 2009). As with the No Action Alternative, runoff (contaminants and sedimentation), road operations, winter snow clearing, and weed treatment could have the potential to indirectly affect these species or downstream habitats, including fens. Water requirements for the alternatives are not known at this time, but temporary water depletions associated with construction could also affect plants or suitable habitat. If fens within the APE or fens hydrologically connected to the APE experience de-watering in the short- or long-term resulting from implementation of action alternatives, such de-watering could adversely impact undetected plants. Increases anticipated in recreational use levels could adversely affect individual plants by crushing or trampling them as people use riparian areas. The possible loss of affected plants could contribute toward a cumulative loss of plants across the species range. Even if affected sites were to be extirpated from implementation of the action alternatives, however, species viabilities would be anticipated to remain secure because there would still be sufficient numbers of plants and sites across their ranges that remain unthreatened.

For the reasons discussed above, an effects determination of **"May adversely impact individuals, but not likely to result in a loss of viability on the planning area, nor cause a trend to federal listing"** is warranted for all action alternatives for dwarf raspberry, lesser panicled sedge, Park milkvetch, and simple kobresia. For altai cotton-grass, autumn willow, Baltic sphagnum, budding monkeyflower, hoary willow, Kotzebue's grass-of-Parnassus, lesser bladderpod, livid sedge, Porter's feathergrass, roundleaf sundew, slender cotton-grass, and sphagnum, an effects determination of **"No impact"** is warranted because they are not known or suspected to occur in the APE.

All Other Sensitive Plants

- Colorado tansy-aster (*Machaeranthera coloradoensis*)
- Front Range or Rocky Mountain cinquefoil (*Potentilla rupincola*)
- Hall's fescue (*Festuca hallii*)
- Selkirk's violet (*Viola selkirkii*)
- Yellow lady's-slipper [*Cypripedium parviflorum* (=*C. calceolus* ssp. *parviflorum*)]

Effects of Alternatives

No Action Alternative

No adverse impacts on these species are anticipated to occur from highway maintenance, except possibly with Front Range cinquefoil. For this plant, impacts could occur to undetected sites from highway rock scaling. Recreational use associated with highway access could promote incidental trampling or picking of Selkirk's violet. The low levels of possible incidental impacts on individuals of these species would not be expected to affect their local-area viabilities and would not meaningfully contribute to cumulative effects.

For the reasons discussed above, an effects determination of **"May adversely impact individuals, but not likely to result in a loss of viability on the planning area, nor cause a trend to federal listing"** is warranted for Front Range cinquefoil and Selkirk's violet under the No Action Alternative. For Colorado tansy-aster, Hall's fescue, and yellow lady's-slipper, an effects determination of **"No impact"** is warranted because they are not known or suspected to occur in the APE.

Action Alternatives

Impacts on these species from the action alternatives are generally expected to be nonexistent or low, depending on the degree and number of sites disturbed. Potential impacts would be minimized and mitigated as feasible following plant surveys. Impacts would be expected to remain the same as with the No Action Alternative or increase proportionally to the amount of occupied area that could be disturbed from each action alternative or with increasing recreational visitor use. Plants or suitable habitat may be affected by the footprints of the project alternatives but would be avoided if possible. The potential to affect plants would be relatively greater with those alternatives that disturb more occupied area or allow greater visitor access.

Even with increased visitor use, the low probability and levels of possible incidental impacts on individuals of the above species would not be expected to affect their local area viabilities, and would not meaningfully contribute to cumulative effects.

For the reasons discussed above, an effects determination of **"May adversely impact individuals, but not likely to result in a loss of viability on the planning area, nor cause a trend to federal listing"** is warranted for Front Range cinquefoil and Selkirk's violet for all action alternatives. For Colorado tansy-aster, Hall's fescue, and yellow lady's-slipper, an effects determination of **"No impact"** is warranted because they are not known or suspected to occur in the APE.

Species of Local Concern

USFS has identified the following species as Species of Local Concern, a formal or informal designation (depending on Forest) that is made when species are of management concern because they may be locally rare, occur at the edges of their range, may be subject to viability issues in the future, or may need additional research, but for which a formal designation of Sensitive is not warranted at this time. The lists may be revised as new information becomes available.

Assessment of impacts on these species will be conducted during Tier 2 processes.

- Species of Local Concern for both Forests that may have suitable habitat or occur within the APE. All common names provided by USDA PLANTS Database (2010).
  - Crenulate moonwort (*Botrychium crenulatum)* – **known to occur in APE near Vail Pass**
  - Lanceleaf grapefern *Botrychium lanceolatum* ssp. n*ov. "viride")* (green-stemmed phenotype)
  - Leathery grapefern (*Botrychium multifidum)*
  - Pale moonwort *(Botrychium pallidum)*
  - Northern moonwort *(Botrychium pinnatum)*
  - Little grapefern (*Botrychium simplex)*
  - Grapefern *(Botrychium spathulatum)*
  - *Botrychium tunux X lineare (possible new specie)s* – **known to occur in APE near east side of Eisenhower-Johnson Memorial Tunnels**
  - Fairy slipper *(Calypso bulbosa)*
  - Bristlystalked sedge *(Carex leptalea)* **– known to occur in a fen near APE boundary near Vail Pass**
  - Peck'sedge (*Carex peckii)*
  - Rocky Mountain snowlover *(Chionophila jamesii)*
  - Northern golden saxifrage *Chrysosplenium tetrandrum)*
  - Purple marshlocks *(Comarum palustre)*
  - Bunchberry dogwood (*Cornus canadensi)*
  - Yellow coralroot *(Corallorhiza trifida)*
  - Spring coralroot (*Corallorhiza wisteriana)*
  - Clustered lady's slipper (*Cyprepidium fasciculatum)*
  - Tall cottongrass (*Eriophorum angustifolim)* – **known to occur a fen near APE boundary**
  - Ferns, all but brittle bladderfern (*Cystopteris fragilis)* – **Some ferns are known to occur within or near APE**
  - Lesser rattlesnake plantain (*Goodyera repens*)
  - Bog laurel (*Kalmia polifolia*)
  - Northern twayblade (*Listera borealis*) – **known to occur within or near the APE**
  - Broadlipped twayblade (*Listera convallarioides*)
  - Marsh felwort (*Lomatogonium rotatum*)
  - Stiff clubmoss (*Lycopodium annotinum*)
  - Stiff clubmoss (*Penstemon caythophorus*) – **known to occur near APE**
  - Arrowleaf sweet coltsfoot (*Petasites sagittatus*)
  - Whiteveined wintergreen (*Pyrola picta*)
  - Marsh arrowgrass (*Triglochin palustre*) – **known to occur near APE**

- Species of Local Concern for the White River National Forest that may have suitable habitat or occur within the APE. All common names provided by USDA PLANTS Database (2010).
  - Oneleaf onion (*Allium sibericum*)
  - Woodrush sedge (*Carex luzulina* var. *atropurpurea*)
  - Boreal bog sedge (*Carex paupercula*)
  - Slender spiderflower (*Cleome multicaulis*)
  - Thicksepal cryptantha (*Cryptantha crassisepala*)
  - Longflower cryptantha (*Cryptantha longiflora*)
  - Smooth draba (*Draba glabella*)
  - Fewseed draba (*Draba oligosperma*)
  - Arctic alpine fleabane (*Erigeron humilis*)
  - Featherleaf fleabane (*Erigeron pinnatisectus*)
  - Largeflower wild hollyhock (*Iliamna grandiflora*) – **known to occur near APE**
  - Manystem blazingstar (*Mentzelia multicaulis*) – **known to occur in APE**
  - Splitleaf groundsel (*Packera dimorphophylla* var. *inermedia*)
  - Alpine groundsel (*Packera pauciflora*)
  - Sparse-flowered bog orchid (*Plantanthera sparsifolia* var. *ensifolia*) – **known to occur in or near APE**
  - White princesplume (*Stanleya albescens*)
  - Hapeman's coolwort (*Sullivantia hapemanii*) – k**nown to occur in Glenwood Canyon**

BR.4.2 Management Indicator Species

The National Forest Management Act, 36 CFR 219.19, and Forest Service Handbook (FSM 2621) direct USFS to preserve and enhance plant and animal diversity, consistent with the overall multiple use objectives, and to maintain viability of all native and desirable non-native species on the National Forest. Species have been selected to serve as meaningful indicators of population-habitat relationships where management activities and habitat changes were likely to occur. Such species serve as management indicators (USDA, 2002c [WRNF Management Plan FEIS], USDA, 1997 [ARNF Revised Forest Plan FEIS]). Management indicators are defined as "plant and animal species, communities, or special habitats selected for emphasis in planning, and which are monitored during forest plan implementation in order to assess the effects of management activities on their populations" (Forest Service Handbook FSM 2620.5). MIS on the ARNF and on the WRNF have recently been evaluated through an environmental assessment, and their lists amended (USDA, 2005a and 2006, respectively). Certain TES species are also MIS and are labeled and discussed in preceding sections. MIS habitats were quantified from vegetation types by determining those appropriate to the MIS in question (See **Table BR - 46**). This information was used to determine the amount of each MIS habitat that would be affected by the footprint, construction disturbance zone, and sensitivity zone of each alternative within the WRNF and ARNF. Analyses in this section were conducted using the best available scientific information.

Forest-wide goals and objectives for MIS, as designated in Forest Plans (USDA, 2002a and 1997), are to maintain or improve habitats and include the following:

- Provide ecological conditions to sustain viable populations of native and desired non-native species and to achieve objectives for MIS and focal species
- Provide a range of sucessional stages of community types across the forests and grassland landscapes that maintain or improve habitats for management indicator species

Table BR - 46. Source of Mapping Data for Management Indicator Species for the White River and Arapaho and Roosevelt National Forests

Species/Community	Data Source	Vegetation Map Units* or NDIS Map Elements
White River National Forest		
Elk – MIS for young to mature forest structural stages and openings within/adjacent to forest	NDIS	Severe winter range Winter concentration Calving areas
Virginia's warbler – MIS for dense shrub	Vegetation Map Units	12,16,18
All trout – MIS for montane aquatic environments – Other waters of the U.S.	Vegetation Map Units	9
Aquatic macroinvertebrates – MIS for water quality and spring flow – Streams	Vegetation Map Units	9
Arapaho and Roosevelt National Forests		
Elk – MIS for young to mature forest structural stages and openings within/adjacent to forest	NDIS	Severe winter range Winter concentration Calving areas
Mule deer – MIS for young to mature structural stages and openings within/adjacent to forest	NDIS	Winter concentration Severe winter range
Bighorn sheep – MIS for openings within/adjacent to forest	NDIS	Winter range Summer range Lambing areas
Hairy woodpecker – MIS for young to mature forest structural stages	Vegetation Map Units	3,7,10,14,17
Pygmy nuthatch – MIS for existing and potential old-growth forest	Vegetation Map Units	7,10,14,17
Mountain bluebird – MIS for openings within/adjacent to forest	Vegetation Map Units	2,7,8,12,14,16
Warbling vireo – MIS for aspen forest	Vegetation Map Units	3
Wilson's warbler – MIS for montane riparian areas and wetlands	Vegetation Map Units	18
Boreal toad – MIS for montane riparian areas and wetlands	Vegetation Map Units	9,18
Brook trout – MIS for montane aquatic environments	Vegetation Map Units	9
Brown trout – MIS for montane aquatic environments	Vegetation Map Units	9
Greenback cutthroat trout – MIS for montane aquatic environments	Vegetation Map Units	9
Colorado River cutthroat trout – MIS for montane aquatic environments	Vegetation Map Units	9

Vegetation Map Unit Key: *1 Agricultural, 2 Alpine Meadows – Krummholz , 3 Aspen Forest,4 Barren Land, 5 Bristlecone - Limber Pine Forest,6 Developed,7 Douglas-Fir Forest,8 Grass / Forb Meadows,9 Lakes & Ponds,10 Lodgepole Pine Forest,11 Mixed Forest, 12 Mountain Shrubland,13 Pinyon-Juniper Woodland,14 Ponderosa Pine Forest,15 Riparian Forest and Shrub,16 Sagebrush Shrubland,17 Spruce - Fir Forest, 18 Wetland (general) / Water*

BR.4.2.1 WRNF Species

Elk (*Cervus elaphus*), MIS

Elk is a MIS primarily for semi-open forests and young to mature forest edges adjacent to parks, meadows, and alpine tundra (USDA, 2002b; and USDA 1997). However, they are habitat generalists and can be found on all terrestrial forest habitats except barren land. The objective of the WRNF is to maintain and improve habitats. Based on the WRNF Revised Forest Plan (WRNF, 2002), in addition to habitat quality in general, the management question is whether motorized and nonmotorized travel and recreation management result in effective use of habitat by elk.

Distribution

Elk are found throughout the western portions of North America. Elk range throughout the western two-thirds of Colorado, generally at elevations above 6,000 feet, and the entire project area falls within elk range. This species is classified as a game animal in Colorado, and Colorado Division of Wildlife closely manages it to maintain the health of existing herds.

The WRNF uses information compiled by Colorado Division of Wildlife (Big Game Statistics) within Data Analysis Units (DAUs) to identify population trends. DAUs include relatively large areas and a number of Colorado Division of Wildlife Game Management Units (GMUs). The DAUs adjacent to the Corridor are DAU E12 (north of I-70 from Vail Pass to Dotsero) and DAU E16 (south side of I-70 from Vail Pass to Glenwood Canyon).

DAU E12

Population trends in DAU E12 indicate steady growth (72 percent increase) from 1990 to 2003 when the population was at its maximum for the monitoring period. A population decrease from 2001 to 2002 was observed, however, and again from 2003 to 2004, partly in response to issuance of an increased number of cow tags. The population size has continued to decline and in 2008 was at a level below the herd size at the beginning of the monitoring period in 1990 (see **Table BR – 47**).

DAU E16

The population within DAU E16 was highest in 1990 and gradually decreased approximately 42 percent through 2004, with the exception of a slight increase from 1998 to 1999. Since 2004 the population has increased by 44 percent to 7,450 in 2008 (see **Table BR – 47**). A decrease in one DAU and an increase in the other may indicate movements across I-70 (for example, see trend data for 2003 in **Table BR – 47**).

The increasing population trend in DAU E12 does not reflect those in the other DAUs in the WRNF. Generally, populations, including that of DAU E16, have decreased since the 1990s. The populations of all the DAUs decreased from 2003 to 2004 (see **Table BR – 47**).

Elk populations in the WRNF increased appreciably since the early 1950s and peaked in the late 1980s. Fluctuations over the past 10 years probably reflect the active Colorado Division of Wildlife management to control herds that are considered to be over capacity objectives for particular DAUs. Hunting season lengths and tag opportunities have been increased as the principal means of reducing populations to meet these objectives. Changes in population estimates also may be due to modeling assumption changes.

Table BR – 47. Elk Post-hunt Population Estimates for Data Analysis Units on the WRNF (CDOW, Big Game Statistics)

	1990	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
DAU E12	4,165	4,690	5,076	5,700	5,977	6,970	6,048	7,041	6,292	6,130	5,230	4,760	4,080
DAU E16	8,967	8,273	8,494	8,823	7,716	7,915	6,907	5,841	5,178	6,760	5,950	7,700	7,450

Another population monitoring parameter and management trigger point is the cow/calf ratio of a particular DAU. This parameter was selected as an indicator of trend because there is a strong relationship between the number of calves produced and the overall herd health and reproductive potentials. Cow/calf ratios would be expected to decrease as populations approach carrying capacities. **Table BR – 48** shows the number of calves for each 100 cows from 2000 to 2008 in the DAUs adjacent to the Corridor.

Table BR – 48. Number of Calves/100 Cows by Data Analysis Unit, 2000 to 2008

Calves/100 Cows	DAU E12	DAU E16
2000	47.5	50.1
2001	45.7	44.5
2002	51.0	41.5
2003	37.0	34.5
2004	46.3	52.2
2005	48.3	40.3
2006	44.1	43.9
2007	39.3	40.4
2008	39.1	28.7
9-year average	44.3	41.8

The long-term trend for the calf/cow ratios appears to be down from the high values of the 1960s and 1970s when elk populations were significantly smaller than those found on the WRNF today (Colorado Division of Wildlife Draft and Final DAU Plans, as cited in USDA, 2005b). During the last nine recorded years (2000 to 2008), the calf/cow ratios appear to be stable in DAU E12, but in DAU E16 there is a marked decline in calf/cow, and DAU E12 and DAU E16 have slightly lower calf/cow ratios than the other DAUs on the WRNF. There are concerns, however, about an aging elk population, with older-aged cows that are less productive, arising from an inability to reduce the population sizes to the DAU objectives. Private lands that do not allow hunting create areas where elk can aggregate and escape hunter harvest, and also many hunters prefer to harvest a bull instead of a cow. Furthermore, winter range habitat loss due to residential and commercial development along the I-70 Corridor and elsewhere are restricting the available habitat for elk and deer. Therefore, these large elk populations that may have an older-age skew and that live on limited habitat are less productive and may be susceptible to a population crash if a severe environmental event (such as a severe winter, or an expansive wildfire) occurs.

Natural History

Elk are large mammals in the deer family Cervidae and the genus *Cervus*. Bull elk may stand 5 feet tall at the shoulder and weigh 750 pounds or more (Armstrong 1987). Fitzgerald et al. (1994) state that elk are generalist feeders (that is, both grazers and browsers). They tend to inhabit higher elevations during the spring and summer and lower elevations during the winter. Lengths of seasonal migration vary from about 3.7 to 37 miles. Elk require thermal cover and cover for hiding, resting, and escape. Effective hiding and escape cover adjacent to openings is most effective when forested stands are in high contrast to openings (vertical diversity). Forested ridges, saddles, riparian areas, and canyons are preferred for travel and escape routes. Elk are sensitive to human disturbance, especially during fall rut, during early summer calving, and on winter ranges (Fitzgerald et al., 1994).

The rut begins in autumn, typically in late September, heralded by the bugling of the bull elk. Bulls that are successful in acquiring a harem will then mate. The birthing of young typically occurs in June of the following year, following an approximate 250-day gestation period. Cows normally produce one offspring weighing an average of 30 pounds (Armstrong, 1987). On good quality range sites, a cow elk may live 15 years of more, while the life expectancy of a bull is somewhat shorter (Armstrong, 1987).

After numbers dwindled in the early 1900s, elk were successfully reintroduced and managed, and the recent state population was estimated to be 270,000 animals. Currently, the species is considered to be over carrying capacity in some areas (CDOW, 2001). Fitzgerald et al. (1994) indicated that mortality in Colorado is mainly from calf predation by black bears and coyotes, hunting, and winter starvation. Other threats to this species include disease, including chronic wasting disease (CWD) that has been detected in many of the GMUs that occur along I-70 (GMUs 36, 37, 28, 38, and 391 [west to east]: Chronic Wasting Disease Update # 6, Fall 2004, as seen on the Colorado Division of Wildlife website). Elk have also been affected by loss of, or disturbance to, critical habitats, such as calving grounds and winter range. In the Corridor, AVCs are a source of mortality, although their importance to long-term population trends is unknown. Roadkill is a factor on many Colorado mountain roads when elk graze along the roadside or when they cross the roadway during daily home range movements, during seasonal migrations, and during eruptive movements (such as during hunting season).

Environmental Baseline

Habitat for elk includes alpine meadows, tundra, aspen forest, Douglas-fir forest, grass/forb meadows, lodgepole pine forest, mountain shrubland, piñon-juniper, ponderosa pine forest, sagebrush shrubland, spruce-fir forest, riparian, and wetlands.

Key habitats of severe winter range, winter concentration, and calving areas occur in the Corridor in numerous locations within or near the WRNF (Avon to Dowd Canyon CDOW WRIS 2003; see Draft PEIS, Volume II Resource Map 3.2-3). Quality elk habitat is prevalent along I-70 on Vail Pass and on both sides of the EJMT.

Estimated Effects and Rationale

Action Alternatives

The potential for action alternatives to affect elk is based on the extent to which key habitats or MIS habitats are likely to be affected and whether the Corridor will continue to fragment habitat and act as a barrier to elk movement. In addition to impacts on MIS habitats, impacts on key elk habitats were assessed, including winter concentration areas, severe winter range, and calving areas. The amounts of applicable vegetation types that would be disturbed by the alternative were then tabulated to determine potential impacts on elk habitat.

Direct Effects

In addition to the potential for key and MIS habitat losses, I-70 restricts elk from moving between seasonal ranges, and in some cases, restricts daily movements to attain full habitat usage such as feeding, hiding, and finding bedding cover.

Project alternatives would have the potential to make this barrier effect worse and effectively block movement and migration corridors, which would have serious consequences for many of the herds along the Corridor. Major sources of impacts on elk mobility throughout the Corridor include the following concepts:

- Road effect zones
- Barrier effect and AVCs

Road Effect Zones. Road effect zones encompass a wide range of impacts but generally include (1) noise and general disturbance from construction activities and traffic and (2) roadway input of contaminants, such as winter deicing and traction material, that affect roadside vegetation, water bodies, and riparian habitats (Forman and Alexander, 1998; and Forman and Deblinger, 1998). The width of the road effect zone from noise and disturbance effects from traffic varies considerably depending on traffic volumes, terrain, vegetation structure, and sensitivity of the species (Singleton et al., 2002). In Colorado, both elk and mule deer were shown to avoid areas within approximately 600 feet of a road, with this effect appearing stronger in shrub cover types, as compared with forested habitats (Rost and Bailey, 1979). Studies also indicate that various carnivores such as grizzly bears (*Ursus arctos*) (McLellan and Shackleton, 1988), wolves (Thiel, 1985; and Mech et al., 1987), and bobcats (Lovallo and Anderson, 1996) avoid habitats adjacent to roads.

Estimating the impact of road effect zone-related disturbances, such as additional noise and human presence, is difficult because some elk populations adapt readily to disturbance, while others do not (LSA Associates 2003). Increases in road effect zone disturbances would be likely to reduce elk usage of some areas near I-70 and a negative impact would be likely for all alternatives as traffic volumes increase. However, some differences would be likely among alternatives. For example, noise analyses (see the Draft PEIS, Chapter 3, Section 3.12, Table 3.12-4) indicated that the increases in loudest hour noise levels would be greatest for Combination alternatives (3 to 5 decibels). Highway alternatives were predicted to increase noise levels 2 to 3 decibels, whereas Transit alternatives were predicted to increase noise levels by approximately 1 decibel. Thus, Combination alternatives would have the potential to affect elk the most by increasing the width or distance of the road effect zone from I-70 into adjacent habitats. The noise from the Six-Lane Highway 55 mph alternative was predicted to increase by 2 to 3 decibels. However, because it is unknown how an increase of 2 to 5 decibels would affect elk, and how numerous other factors such as adjacent terrain and vegetation would affect noise distribution, all of the alternatives are considered similar in terms of producing a negative effect.

Barrier Effect and AVCs. The barrier effect restricts movements between habitats that are important to certain aspects of the elk's life cycle. I-70 currently bisects a number of movement corridors, and increased transportation infrastructure and/or highway lanes associated with project alternatives are likely to increase the barrier effect. Similarly, increases in traffic volumes on I-70 would also increase the barrier effect and probably increase the frequency of AVCs.

AVCs were documented over the period 1988 to 1998 along I-70. The average rate of AVCs was 0.6 collisions per mile per year, but the range of AVCs at different locations was from 0.0 to 5.2. The data indicated that linkage interference zones with AVCs of 1.4 or less could be considered "normal" and AVCs greater than 1.4 could be considered a trouble spot where animals were frequently trying to cross I-70. Of the 15 linkage interference zones, the greatest rate of AVCs (2.4) was in Linkage Interference Zone 13, Mount Vernon Canyon. The second highest AVC (1.4) was reported for Linkage Interference Zone 1 near Dotsero. All other linkage interference zones had AVCs below 1.2, and two linkage interference zones had zero AVCs.

According to CDOT records, approximately 5,000 animals (mostly mammals) have been involved in collisions with vehicles on Colorado roads (Southern Rockies Ecosystem Project, 2006) during a 10-year period (1993 to 2003). These collisions resulted in seven deaths to people. Unless measures such as crossing structures and fencing are implemented to reduce the areas and the frequency of elk crossing I-70 at grade, animal, as well as human, fatalities are likely to increase as populations and roadway traffic volumes increase. The two linkage interference zones with high AVCs are in the Foothills life zone and low Montane life zone.

The ALIVE Committee identified a number of linkage interference zones where animal movement across I-70 is especially hindered and often reflected by high AVC frequencies. The Committee recommended that additional crossing structures and wildlife fencing be constructed in each linkage interference zone. Additional below-grade or above-grade crossing opportunities and the addition of wildlife fencing with I-70 projects could largely counteract expected impacts, and a positive effect from existing conditions would be realized. Thus, it is anticipated that elk would benefit from a greater frequency of crossing structures to access their habitats and seasonal ranges after the I-70 projects are built. Additionally, because elk are herd animals, they would have the opportunity to learn the new crossings from one another (Dodd et al., 2003). Elk commonly use the highway underpasses in Banff National Park in Canada (Clevenger, 1998) and open bridge structures in the US (Dodd et al., 2003).

Any increase in connectivity between habitats would also benefit the populations as a whole. Therefore, the action alternatives that would extend along the greatest length of the Corridor and cross the most linkage interference zones would have the greatest potential to improve habitat connectivity for elk and to reduce AVC frequencies on the WRNF. The ALIVE Committee identified 11 linkage interference zones west of the Continental Divide. Project alternatives would cross different numbers of linkage zones. For example, the Minimal Action Alternative would cross three linkage zones, whereas the Transit and Combination alternatives would cross seven. The alternatives contain proposed crossing structures as integral mitigation measures for each linkage area that is crossed.

In addition to the mitigation measures associated with the linkage interference zones, best management practices are being developed as part of the ALIVE program through a Memorandum of Understanding, which would offer additional opportunities to improve crossing structures wherever construction work is done. Such BMPs would apply to the linkage interference zones, as well as areas outside the linkage interference zones.

Key Habitat Change

No key habitats (calving areas, severe winter range, and winter concentration areas) within the WRNF would be directly affected by the construction of any of the action alternatives.

Management Indicator Habitat Change

Table BR - 49 and **Table BR – 50** provide the estimated direct impacts on potential MIS habitat for the elk on the WRNF. The Preferred Alternative will have no direct impact on elk habitat within the WRNF.

The other action alternatives would directly affect from 0 acres to 0.4 acres of MIS habitats within the WRNF. Because elk occur throughout the WRNF and use all of the major vegetated cover types at certain times of the year, these direct impacts on elk habitat on the WRNF are minute. Calving and winter use are critical periods for elk, which are not directly affected by any of the project alternatives.

Table BR - 49. Direct Impacts on MIS Elk Habitat (acres): Preferred Alternative

	Minimum Program		Maximum Program	
	Limited Highway Improvements		Combination 6-Lane Highway with AGS	
	55 mph	65 mph	55 mph	65 mph
WRNF	0.0	0.0	0.0	0.0

Data provide the minimal to maximum range of impacts for the Preferred Alternative.

Table BR – 50. Direct Impacts on MIS Elk Habitat (acres): Action Alternatives Evaluated in the Draft PEIS

	Minimal Action	Rail with IMC	AGS	Dual-Mode Bus in Guideway	Diesel Bus in Guideway	Six-Lane Highway 55 mph	Six-Lane Highway 65 mph	Reversible/ HOV/HOT Lanes	Combination Six-Lane Highway with Rail and IMC	Combination Six-Lane Highway with AGS	Combination Six-Lane Highway with Dual-Mode Bus in Guideway	Combination Six-Lane Highway Diesel Bus in Guideway
WRNF	0	0.4	0	0.3	0.3	0	0	0	0.4	0.0	0.3	0.3

Population Change

The loss of from 0 to 0.4 acres of MIS habitat on the WRNF is unlikely to change local elk populations within the two DAUs along I-70 because it constitutes a minute loss of the total MIS habitat on the WRNF (0.003 percent). The resultant effect on individual elk from loss of habitat would be increased difficulty in feeding and over wintering, possibly seeking new foraging areas. Increased difficulty in foraging would add stress to individuals but would not likely represent a viability risk to the species overall. Accordingly, no change in forest-wide or DAU-wide elk population trends is expected on the WRNF due to any project alternative.

Indirect and Cumulative Effects

Induced growth from Transit, Highway, and Combination alternatives may affect elk movement patterns, as well as their ability to access and use all aspects of their habitat. Induced growth is of greatest concern on private lands adjacent to the WRNF, where it may interfere with elk game trails and foraging areas. Most of the induced growth would occur in lower elevation valleys of the Corridor (Eagle and Summit counties) and would be most likely to affect elk wintering habitats. Population growth is likely to increase human intrusion into elk habitats from increased recreation activities.

Continued human population growth and associated developments, specifically in Eagle and Summit counties, would have the potential to force herds from some of the traditional winter and summer ranges and affect carrying capacities and herd dynamics on the WRNF. A larger human population probably would increase the recreational use of the Forests, which, in turn, would increase the disturbance factor and may require strict enforcement of use restrictions near calving areas and winter ranges. Moreover, vegetation management (timber sales and prescribed burns) and grazing will continue to occur on the WRNF and, although not necessarily occurring adjacent to I-70, such activities in other areas of the Forests, in combination with other developments and highway improvements, would have the potential to affect elk and how they are able to use habitats.

Effects of No Action

No habitat loss would occur from construction under the No Action Alternative. No new kinds of impacts would occur; however, habitat fragmentation, the barrier effect of I-70, and the potential for AVCs would continue and would probably worsen as traffic volumes increase. Few crossing structures would be built, and none of the existing structures would be improved in the linkage interference zones under this alternative. Fencing along the Corridor would remain as currently configured. Thus, elk herds in the vicinity of I-70 would continue to be negatively affected by the No Action Alternative. The vegetated wildlife overpass that is separately proposed by the Restore the Rockies organization and its partners may be constructed on Vail Pass in 2007. If constructed then, it could provide a possible benefit to elk and other wildlife in advance of the construction of any of the project alternatives.

Effects Summary

The objective for the MIS designation for elk is to demonstrate, within 15 years, a positive trend in habitat availability, habitat quality, or other factors affecting elk, and to determine if motorized and nonmotorized travel and recreation management result in effective use of habitat by elk.

Losses to MIS habitats would occur for all of the action alternatives (as shown in **Table BR – 50).** MIS habitat losses would generally be less than 30 acres, with the exception of the Combination Six-Lane Highway with Rail and Intermountain Connection, Combination Six-Lane Highway with Bus in Guideway, and Rail with Intermountain Connection, under which habitat losses would range from 35.7 to 49.1 acres. Because these losses would be a small fraction of the total of the MIS habitat type that occurs adjacent to the Corridor on the WRNF, the impacts from any of the alternatives would be minor or negligible and would be unlikely to appreciably affect elk populations on WRNF land. No impacts are anticipated on key elk habitat on the WRNF.

Integral design features in all of the action alternatives would provide opportunities to reduce the barrier effect, reduce AVCs, and improve habitat connectivity. However, the degree to which this can be realized is related to how far the alternative would extend through the Corridor and the number of linkage interference zones that would be intersected. The greatest opportunity to decrease the barrier effect of I-70 and to reduce AVCs through a combination of crossing structures and fencing would occur with the Transit and Combination alternatives, which would cross seven linkage interference zones in proximity to WRNF lands. The fewest number of opportunities (other than the No Action Alternative) would occur with the Minimal Action Alternative, which would cross three linkage interference zones in proximity to WRNF.

Based on the analyses presented, there is no viability risk for elk (the potential for populations to substantially decrease is unlikely), and none of the action alternatives would threaten the viability of elk within the project APE or the state (habitat effects are unmeasurable at the DAU or forest-wide level, and positive wildlife crossing effects are likely).

Virginia's Warbler (*Vermivora virginiae)*, MIS

The Virginia's warbler is a small song bird in the family Parulidae, genus *Vermivora*. Adults normally measure 4.7 inches in length and weigh 0.3 ounces. The species is active during daylight.

Virginia's warbler was selected as a Forest MIS to answer the question, "What are the effects of management on dense, mountain shrub communities?" The major risk factors identified for this species include prescribed burns that decrease the density of shrub habitats.

Distribution

The Virginia's warbler breeding range includes southeastern Idaho, northeastern Utah, and central Colorado south to southeastern California, southern Nevada, southeastern Arizona, and central New Mexico (AOU, 1983). The nonbreeding range includes southwestern Mexico (AOU. 1983).

In Colorado, these birds are commonly observed in the western quarter of the state, along the Eastern Slope foothills from the Wyoming line to New Mexico, and parallel to the Arkansas River drainage, between 6,500 and 8,000 feet in elevation. Breeding evidence was confirmed in Jefferson, Clear Creek, and Garfield counties (Kingery, 1998).

The North American BBS data show a negative trend in Colorado for both 1966 to 1996 (-0.8 percent average annual change) and 1980 to 1996 (-0.6 percent average annual change). A negative long-term trend also was evident for the southern Rockies physiographic region, 1966 to 1996 (-1.2 percent average annual change). Sample sizes are minimal for reliable trend analysis. Mapped trends show declines in

Colorado and northern New Mexico over the southern Rockies and increases in Utah, Arizona, and southern New Mexico for 1966 to 1996. Centers of abundance appear to be in western Colorado, northern New Mexico, and central Arizona (Sauer et al., 1997). Brawn and Balda (1988) suggest that populations have increased since presettlement times due to an increase in shrubby understories in ponderosa pine forests. The species is ranked secure (G5) globally and (S5) statewide (NatureServe, 2006).

Natural History

The Virginia's warbler is an insectivore. It forages on the ground in thick brush and flies into the air to catch insects. Virginia's warblers nest on the ground among dead leaves or in small depressions under cover of shrubs, tufts of grass, or other material. Well-concealed by vegetation, bark, grasses, roots, mosses, lichens, the rim of nest may be level with ground surface (Bent, 1953; and Griscom and Sprunt, 1979). Clutch size averages four eggs. Both parents care for the young. The young are fed on caterpillars and are in the nest when larvae are most abundant (Griscom and Sprunt, 1957). In Arizona, nesting territories ranged between 2.05 to 5.58 acres and were elongate (Fischer, 1978).

The Virginia's warbler migrates later than other warblers, arriving in Arizona in early April and in Nevada and Utah in late April/May. In Arizona, males establish breeding territories in May. The Virginia's warbler may disperse to lower elevations after breeding and before migration. These birds occur in mixed species flocks after breeding season (Fischer, 1978, and cited Martin and Olsen in press).

Environmental Baseline

The preferred habitat for the Virginia's warbler is dense shrubland. In the Corridor dense shrubland is largely distributed east of Glenwood Canyon, east of Avon, in the Georgetown area, and in Jefferson County.

Breeding habitat consists of arid montane woodlands, oak thickets, piñon-juniper forest, coniferous scrub, and chaparra (*Larrea divaricata*) (AOU, 1998). Virginia's warbler prefer brushy steep mountain slopes within or near dry coniferous woodlands (Dunn and Garrett 1997). In northwestern Colorado, a study of Virginia's warbler found that the birds preferred shrubby, Gambel oak (*Quercus gambelii*) covered slopes with high grass, forb, and shrub cover.

Estimated Effects and Rationale

Action Alternatives

The potential for action alternatives to affect Virginia's warbler is based on whether MIS habitats are likely to be affected.

Direct Effects

Key Habitat Change

Key habitat has not been specifically quantified for Virginia's warbler. All MIS habitat was evaluated for potential effects.

Management Indicator Habitat Change

Table BR - 51 and **Table BR - 52** provide the estimated direct impacts on potential MIS habitat for the Virginia's warbler on the WRNF. Impacts from the Preferred Alternative would range from 6.5 acres (Minimum Program 65 mph and Maximum Program 65 mph) to 7.8 acres (Minimum Program 55 mph and Maximum Program 55 mph).

Of all of the action alternatives, the Combination Six-Lane Highway with Rail and Intermountain Connection alternative would have the least potential for direct effects on Virginia's warbler habitat (1.7 acres). The Combination Six-Lane Highway with Bus in Guideway alternatives would have the greatest potential for direct effects (9.5 acres). The direct effect for the Combination Six-Lane Highway with Bus in Guideway alternatives (9.5 acres) would represent a loss of only approximately 0.005 percent of the MIS habitat estimated at 182,000 acres on the WRNF.

The resultant effect on individual Virginia's warblers from loss of forage and breeding habitat would be increased difficulty in nesting and rearing young. In response, individual pairs may have to find new breeding habitat that may not be as suitable, possibly causing them to fail in their attempts at reproduction. Increased difficulty in reproducing would add stress to the local population on up to 2.4 acres of potential habitat, and may cause a decline in the number of local individuals. These potential impacts would be unmeasurable on the WRNF due to the small acreage involved and would not cause a population decline on the WRNF, nor cause a viability risk to the species overall.

Table BR - 51. Direct Impacts on MIS Virginia's Warbler Habitat (acres): Preferred Alternative

	Minimum Program		Maximum Program	
	Specific Highway Improvements with AGS		Combination 6-Lane Highway with AGS	
	55 mph	65 mph	55 mph	65 mph
WRNF	7.8	6.5	7.8	6.5

Data provide the minimal to maximum impacts for the Preferred Alternative.

Table BR - 52. Direct Impacts on MIS Virginia's Warbler Habitat (acres): Action Alternatives Evaluated in the Draft PEIS

	Minimal Action	Rail with IMC	AGS	Dual-Mode Bus in Guideway	Diesel Bus in Guideway	Six-Lane Highway 55 mph	Six-Lane Highway 65 mph	Reversible/ HOV/HOT Lanes	Combination Six-Lane Highway with Rail and IMC	Combination Six-Lane Highway with AGS	Combination Six-Lane Highway with Dual-Mode Bus in Guideway	Combination Six-Lane Highway Diesel Bus in Guideway
WRNF	7.2	7.8	4.1	7.4	7.4	7.4	7.4	7.4	1.7	7.8	9.5	9.5

<u>Population Change</u>

The small amount of habitat loss (0.1 to 2.4 acres) is unlikely to affect Virginia's warbler populations. Indirect effects, such as increased growth and increased human intrusion, may affect some individuals and nesting pairs but also are unlikely to affect the population as a whole.

<u>Indirect and Cumulative Effects</u>

Induced growth from Transit and Highway alternatives may affect the Virginia's warbler's ability to access and use all portions of its habitat. Most of the induced growth would occur in lower elevation valleys of the Corridor (Eagle and Summit counties) and thus may adversely affect Virginia's warbler habitat where dense shrublands on WRNF lands lie adjacent to this new development. Population growth also would be likely to increase human intrusion into Virginia's warbler habitats from increased recreation activities.

Other actions, such as fire/fuel management and ski area development on WRNF lands, may cause cumulative impacts on Virginia's warbler dense shrubland habitat by reducing or fragmenting existing habitat. Population growth in areas of the Corridor adjacent to the WRNF would be likely to increase recreation, thus increasing human intrusion into Virginia's warbler habitats.

Effects of No Action

No nesting or foraging habitat would be directly affected by the No Action Alternative. No new impacts would be created beyond those already occurring. Population trends would not be affected.

Effects Summary

After evaluation, none of the alternatives would create trends for habitat or populations that would negatively affect achievement of Forest Plan MIS objectives or create viability concerns. This species would continue to be monitored across the WRNF using the protocols developed as a part of the Revised Plan.

Action alternatives may result in impacts on individuals due to the magnitude of indirect and cumulative effects of development in Eagle County, which might include development of up to 130,000 acres. The figure of 130,000 acres represents 13,100 acres of existing development in Eagle County, plus 39,300 acres of planned urban development, plus 47,600 acres of planned rural development, plus approximately 30,000 acres of induced development as a result of increased access opportunities from Corridor alternatives (see **Chapter 4** of the *I-70 Mountain Corridor PEIS* [CDOT, 2010]). However, there is no viability risk for Virginia's warbler (the potential for the population to substantially decrease is unlikely), and none of the project alternatives would threaten the viability of this species in the planning area or in the state.

All Trout Species, MIS

All trout species were selected as a MIS during the 2002 Forest Plan Revision (USDA, 2002b) for the WRNF. Trout were selected to answer the following question: "Does Forest management maintain or improve the physical habitat quality for salmonids in mountain streams?"

Distribution

The brook trout is native to most of eastern Canada from Newfoundland to the western side of Hudson Bay, south in the Atlantic, Great Lakes, and Mississippi River basins to Minnesota and (in the Appalachians) northern Georgia. The species was introduced in western North America and temperate regions in many other parts of the world (NatureServe, 2006). The brown trout is native to Europe and western Asia. It was introduced and established throughout much of the U.S. and southern Canada and is locally common (NatureServe, 2006).

Rainbow trout were introduced into Colorado streams in the early 1880s and have supplanted many of the native species in WRNF drainage systems. The greenback cutthroat trout is native to the headwaters of the South Platte River and the Arkansas River drainages within Colorado and a small segment of the South Platte drainage within Wyoming, and should not be present on the WRNF.

There are 62 known Colorado River cutthroat trout populations on the WRNF. Currently, the WRNF manages all of these 62 populations as Sensitive. Of the 62 populations, 45 are cutthroat only, 9 are cutthroat and brook trout, and there is incomplete information on 8. Of the 45 cutthroat only populations, 16 are not protected by an adequate barrier, but the Forest is working to secure these populations. Of the 45 populations, 22 are in designated wilderness. There are 300 acres of cutthroat only lakes associated with the streams above. There has been little or no genetic analysis done on the lake populations. There are numerous other isolated lakes on the WRNF with Colorado River cutthroat trout (WRNF, 2002).

Information from the USFS (2000) indicated that although conservation populations do not occur in the Corridor near the WRNF, conservation populations have been recorded in Berry, Polk, Booth, and Pitkin creeks within the Eagle Watershed, and in Meadow Creek within the Blue River watershed. Also individuals have been recorded at locations near the Corridor in Black Gore and Gore creeks in the Eagle River watershed, and in Dillon Reservoir in the Blue River watershed. Other Colorado River cutthroat trout records within 1 mile of the Corridor occur at Miller Creek (upper Gore Creek watershed).

Natural History

Generally, trout occupy clear, cool well-oxygenated creeks, and small to medium rivers and lakes. They may move from streams into lakes or seas to avoid high temperatures in summer. Trout usually spawn over gravel beds in shallow headwaters but also may spawn successfully in gravelly shallows of lakes if spring (groundwater) upwelling and moderate currents are present. Trout will feed opportunistically on various invertebrate and vertebrate animals, including terrestrial and aquatic insects, and planktonic crustaceans (in lakes) (NatureServe, 2005g).

Brook and brown trout spawn in the fall, while rainbow and cutthroat trout spawn in the spring. Eggs hatch from 47 to 165 days, depending on the temperature. Most species mature early with males typically spawning after their second year, and females usually after their third year (Moyle 1976). Some species can migrate over extensive stream and river networks. Some trout species were introduced into Colorado streams and have supplanted many of the native species, as well as other trout species in WRNF drainage systems.

Environmental Baseline

As part of the WRNF Forest Plan Revision (USDA, 2002a), monitoring protocols were drafted in early 2003 and data collection began during the 2003 field season.

Two aquatic management indicator species were selected to monitor water quality (aquatic macroinvertebrate communities) and habitat quality and availability (common trout) in streams and rivers across the WRNF. A sampling design was developed to select stratified random samples from across various types of management and livestock grazing types across the WRNF. Both common trout and aquatic macroinvertebrate communities were sampled from each site.

Five watersheds were randomly selected from each of the 10 management categories (50 sites total), with one site from each of the 10 management categories sampled each year over 5 years starting in 2003, with the rotation starting again in 2008. As such, in general, sites have each been sampled once to establish a baseline, but no repeat sampling has occurred. There are a few exceptions where a site was dropped for a variety of reasons (for example, there were no fish present at the site, the stream or river was too large or swift to be safely and effectively sampled with our equipment, or grazing had been discontinued at a site selected to monitor grazing). Most of the sites that were dropped for any of the above reasons have been replaced and baseline sampling has occurred, but there are a few exceptions. In addition, some sites have had macroinvertebrates sampled more than once. This is the case where these sites were needed to serve as Reference Sites for other projects across the WRNF and, therefore, tend to be sites within Wilderness areas.

A report is prepared for each site each year it is sampled. These reports are maintained on the WRNF server and are available on request. Fish sampling data are reported to the Colorado Division of Wildlife and maintained in the ADAMAS database in addition to being maintained in stream files on the WRNF.

At each site, a detailed physical survey is conducted as well as complete fish and macroinvertebrate data. **Table BR - 53** provides a limited presentation of some of the key information collected. Additional data collected at each site but not presented here includes a complete physical stream survey with each habitat feature quantified and summary data including the following:

- The types of habitat units present (such as punge pools, lateral scour pools, riffles, and cascades)
- A size distribution of the particles of the stream bed
- The condition of the banks (whether undercut or unstable)
- The wetted and bankfull widths
- Maximum, tail crest, and residual pool depths
- Average depth (across all habitat types)
- Shade
- Size and quantity of large wood in the channel
- Limited water temperature data

Fish information collected includes the species and length of each individual captured, population estimates of each encountered species of fish at least one year old, and a combined population estimate for all trout species at the site. No forest-wide trend information is available because of limited data. However, the information collected to date will be summarized.

Nine sites were sampled in 2003, and 10 sites were sampled in 2004. **Table BR - 53** presents sampling results from the first five years of the monitoring program.

Table BR - 53. Aquatic MIS Sites Sampled for Trout Communities From 2003 to 2007 on the WRNF

Year Sampled and Stream Name	Trout per 100 m	Species Present	Management
03 Avalanche Creek	24	Brook, brown, rainbow, and cutthroat trout, sculpin	Wilderness/no grazing
03 Bennett Gulch	24	Brown trout	Timber/no grazing
03 Big Fish Creek	66	Brook and rainbow trout, sculpin	Wilderness/cattle
03 Buck Creek	91	Brook trout	Recreation/sheep
03 Cottonwood Creek	3	Brook trout	Recreation/cattle
03 Crystal Creek	5	Cutthroat trout	Recreation/no grazing
03 East Canyon Creek	13	Cutthroat trout	Timber/sheep
03 East Miller Creek	140	Brown, brook, and hybrid cutthroat trout, sculpin	Timber/cattle
03 Piney River	24	Cutthroat and hybrid cutthroat	Wilderness/sheep
04 Beaver Creek**	9	Cutthroat trout	Recreation/cattle
04 Deep Creek (Rifle RD)	59	Cutthroat and brook trout	Timber/sheep
04 East Fork Crystal River	1	Cutthroat trout	Wilderness/sheep
04 Express Creek	4	Brook trout	Recreation/no grazing
04 Fourmile Creek**	0	Sculpin	Timber/cattle
04 Morapos Creek	35	Cutthroat trout, sculpin, dace	Recreation/sheep
04 North Barton Gulch	2	Brook trout	Timber/no grazing
04 Ripple Creek	59	Brook trout	Wilderness/cattle
04 Snowmass Creek	78	Rainbow and brook trout	Wilderness/no grazing
04 Two Elk Creek*	24	Brook and cutthroat trout	High development
05 Derby Creek	31	Trout	Timber/Cattle
05 East Brush Creek	52	Trout	Timber/cattle
05 East Elk Creek	28	Trout, sculpin	Timber/Cattle
05 Meadow Creek	40	Trout, sculpin	Wilderness/sheep
05 Milk Creek	5	Trout	Recreation/sheep
05 South Fork Fryingpan	128	Trout	Recreation/no grazing
05 South Fork Swan	23	Trout	Timber/no grazing
05 Turkey Creek	26	Trout	Timber/sheep
05 Upper Fryingpan	76	Trout	Wilderness/no grazing
05 West Tenmile Creek	71	Trout, sculpin	High development
06 Capitol Creek	54	Trout	Wilderness/cattle

Year Sampled and Stream Name	Trout per 100 m	Species Present	Management
06 Cattle Creek	75	Trout, sculpin	Timber/cattle
06 Deep Creek (Eagle RD)	136	Trout, sucker	Recreation/sheep
06 East Maroon Creek	79	Trout	Wilderness/no grazing
06 Keystone Gulch	40	Trout	High development
06 North Fork Piney River	45	Trout	Wilderness/sheep
06 Resolution Creek	42	Trout	Timber/sheep
07 Castle Creek	34	Trout, sculpin	High development
07 Chapman Gulch	60	Trout, sculpin	Recreation/no grazing
07 East Fork Fawn Creek	104	Trout	Recreation/sheep
07 Gypsum Creek	31	Trout	Recreation/cattle
07 Middle Thompson Creek	40	Trout, sculpin	Timber/Cattle
07 Miners Creek	54	Trout	Timber/no grazing
07 Snell Creek	14	Trout, sculpin	Recreation/cattle
07 South Fork White River	75	Trout	Wilderness/sheep
07 Three Forks Creek	29	Trout	Timber/sheep
07 West Grouse Creek	47	Trout	Timber/no grazing

** Fish in Two Elk Creek were sampled in 2003 as part of the Upper Eagle Watershed Assessment. Additional MIS data were collected in 2004.*

***These sites have or will be replaced and will not be continued. In some cases, physical data was not collected at these sites.*

Trout densities were varied, with three sites remaining the same or increasing slightly, three sites declining significantly, and one site increasing significantly. One of the declining sites had been dewatered by a ditch upstream at the time of the survey apparently influencing the results. High spring flows were common in many streams during spring 2008. It is possible that these flows depressed fish populations in many streams across the WRNF.

Estimated Effects and Rationale

Action Alternatives

The potential for action alternatives to affect trout is based on whether MIS habitats, both stream and open water, are likely to be affected. Open water is defined as ponds, lakes, or river oxbows that may contain trout.

Direct Effects

Key Habitat Change

All stream-habitat is key habitat for trout even though it is known that not all streams contain trout. Impacts on streams and open waters (nonstream) for each action alternative are quantified in the management indicator habitat discussion for all trout in **Table BR - 55** and **Table BR - 57**. It must be noted that not all open water may contain trout species.

Management Indicator Habitat Change

Table BR - 54 and **Table BR - 55** provide the estimated direct impacts on potential MIS habitat for all trout on the WRNF. Impacts from the Preferred Alternative would range from 1.4 acres (Minimum Program 55mph and Maximum Program 55 mph) to 1.7 acres (Minimum Program 65 mph and Maximum Program 65 mph).

All of the action alternatives except the Combination Six-Lane Highway with Rail and Intermountain Connection alternatives would affect 2 acres or less of open water habitat (nonstream) on the WRNF. The Combination Six-Lane Highway with Rail and Intermountain Connection would disturb the greatest amount of open water habitat (2.4 acres). These disturbance areas are very small (0.02 percent) relative to the total amount of open water on the WRNF (9,800 acres).

Table BR - 54. Direct Impacts on MIS All Trout Habitat (acres of open water): Preferred Alternative

	Minimum Program		Maximum Program	
	Specific Highway Improvements with AGS		Combination 6-Lane Highway with AGS	
	55 mph	65 mph	55 mph	65 mph
WRNF	1.4	1.7	1.4	1.7

Data provide the minimal to maximum impacts for the Preferred Alternative.

Table BR - 55. Direct Impacts on MIS All Trout Habitat (acres of open water): Action Alternatives Evaluated in the Draft PEIS

	Minimal Action	Rail with IMC	AGS	Dual-Mode Bus in Guideway	Diesel Bus in Guideway	Six-Lane Highway 55 mph	Six-Lane Highway 65 mph	Reversible/ HOV/HOT Lanes	Combination Six-Lane Highway with Rail and IMC	Combination Six-Lane Highway with AGS	Combination Six-Lane Highway with Dual-Mode Bus in Guideway	Combination Six-Lane Highway Diesel Bus in Guideway
WRNF	1.1	2.0	1.4	1.6	1.6	1.1	0.8	1.1	2.4	1.4	1.8	1.8

The I-70 Corridor project construction would create some direct disturbance along the streams that constitute trout habitat. The temporary construction disturbance near streams could include relocation of the channel or construction in the floodplain or creation of a barrier between flowing water and the construction. Proximity of construction to flowing water could vary from immediately in the channel to hundreds of feet away.

Table BR - 56 and **Table BR - 57** provide the estimated direct impacts in linear feet of stream on potential MIS habitat for all trout on the WRNF. Disturbance impacts could include, but are not limited to, temporary diversion of channels, rerouting of channels, removal of riparian vegetation, construction of stream crossings, crossing of streams with equipment, construction of foundations in a stream channel, construction of artificial stream channels, and other kinds of construction activities. Much of the disturbance would be temporary, but some construction may include permanent structures. The specific construction activities at a site will be detailed in the Tier 2 proposal for the site. Among all action alternatives, the least amount of disturbance would result from the Six-Lane Highway (65 mph) (900.5 linear feet). The greatest amount of disturbance would result from the Combination Six-Lane Highway with Rail and Intermountain Connection alternative (4,675.9 linear feet). It must be noted that trout species may not be in all areas of stream disturbance. It is a reasonable assumption that the WRNF has hundreds of miles of streams in several watersheds draining WRNF lands; therefore, the disturbance to 4,675.9 linear feet (0.9 mi) of stream would be a very small percentage of total streams on the WRNF.

Table BR - 56. Direct Impacts on MIS All Trout Habitat (linear feet of stream): Preferred Alternative

	Minimum Program		Maximum Program	
	Specific Highway Improvements with AGS		Combination 6-Lane Highway with AGS	
	55 mph	65 mph	55 mph	65 mph
WRNF	2346.2	2124.7	2346.2	2124.7

	Minimum Program		Maximum Program	
	Specific Highway Improvements with AGS		Combination 6-Lane Highway with AGS	
	55 mph	65 mph	55 mph	65 mph

Data provide the minimal to maximum impacts for the Preferred Alternative.

Table BR - 57. Direct Impacts on MIS All Trout Habitat (linear feet of stream): Action Alternatives Evaluated in the Draft PEIS

	Minimal Action	Rail with IMC	AGS	Dual-Mode Bus in Guideway	Diesel Bus in Guideway	Six-Lane Highway 55 mph	Six-Lane Highway 65 mph	Reversible/ HOV/HOT Lanes	Combination Six-Lane Highway with Rail and IMC	Combination Six-Lane Highway with AGS	Combination Six-Lane Highway with Dual-Mode Bus in Guideway	Combination Six-Lane Highway Diesel Bus in Guideway
WRNF	1680.5	3718.5	1581.1	3280.8	3280.8	1680.5	900.5	1680.5	4675.9	2346.2	3794.7	3794.7

Population Change

Although local populations may be reduced by project activities, population reductions across the WRNF are not expected to occur. Indirect effects that decrease habitat quality may affect some population segments. Reduction of these effects will be developed as part of the Preferred Alternative, which would help maintain and possibly increase population numbers. The resultant effect on individual trout from loss of aquatic habitat would be increased difficulty in rearing young and foraging. In response, trout may have difficulty finding new suitable breeding habitat, possibly causing them to fail in their attempts at reproduction. Increased difficulty in foraging and reproducing would add stress to the local population and may cause a decline in the local population, but may or may not cause a viability risk to the species overall.

In addition to direct habitat loss, all of the alternatives would be likely to increase the amount of indirect effects on streams and trout habitat. Such impacts would be associated with earthmoving activities and sedimentation that would occur in conjunction with construction and with roadway runoff materials from operations and winter maintenance. CDOT is currently evaluating measures to reduce the amount of winter maintenance material entering stream systems, even though with the addition of traffic lanes for the Highway and Combination alternatives, more material would be applied. Construction of alternatives, although directly affecting aquatic habitats, also would provide an opportunity in these areas to improve aquatic habitat and mitigate impacts that occurred during the original construction of I-70.

Indirect and Cumulative Effects

Continued human population growth and associated developments, especially in Eagle and Summit counties, have the potential to affect aquatic habitats from increased runoff rates and the amount of sedimentation and contamination that would occur in area streams. Rapid runoff rates also cause stream channelization, which, along with decreases in water quality, could reduce fishery habitat values.

Effects of No Action

Under the No Action Alternative, no construction-related effects would occur and no loss of stream habitat would occur. Conversely, fewer opportunities would be realized to increase the amount of road runoff captured and controlled and to improve stream habitat along the highway.

Effects Summary

The impacts on stream habitat and on trout would occur during construction activities. Increases of contamination and sedimentation, however, would also be likely to occur with the addition of lanes, transportation modes, and traffic volumes. Conversely, construction BMPs would provide an opportunity to reduce the current impact levels that occur from roadway runoff of contaminants and from winter maintenance materials, as well as to improve reaches of stream habitat that were negatively affected by the original I-70 construction.

Action alternatives may result in impacts on individuals due to the magnitude of indirect and cumulative effects of development in Eagle County (which might include development of a total of 130,000 acres). However, there is no viability risk for trout (the potential for the population to substantially decrease is unlikely), and none of the project alternatives would threaten the viability of these species in the planning area or in the state.

Aquatic Macroinvertebrates, MIS

Aquatic macroinvertebrates are invertebrates that spend at least part of their life cycle in water. Such organisms include worms, mollusks, mites, and insects, with the latter being the most common. Although most insect orders contain sensitive species, three orders include species that are especially sensitive to disturbances in water quality: Ephemeroptera (mayflies), Plecoptera (stoneflies), and Tricoptera (caddisflies). Macroinvertebrate population discussions frequently refer to these three orders as “EPT” taxa. Macroinvertebrates are designated as MIS species on the WRNF to answer the following questions: (1) “Does Forest management maintain or improve water quality (including chemical quality and sediment) such that aquatic faunal communities are similar between managed and reference sites?” and (2) “Is habitat being managed to provide for other aquatic species, including trout?”

The primary threats to macroinvertebrates include alteration and loss of suitable aquatic habitat from logging, fires, river impoundment, road and railroad construction, and land clearance for agriculture and human habitation.

Distribution

Aquatic macroinvertebrates are found throughout the Corridor in all types of aquatic environments including rivers, streams, lakes, ponds, irrigation ditches, and wetlands.

Natural History

Natural history data for aquatic macroinvertebrates are diverse and highly variable depending on the specific species under consideration. The three aquatic insect orders listed above (mayflies, stoneflies, and caddisflies) share some general characteristics. A very generalized life cycle for flying insects follows: adult insects mate and females deposit their eggs in the water where they drift to the bottom. The eggs hatch into an immature phase, such as a larvae or nymph. The immature stages feed on diatoms, algae, plankton, and animal debris. The immature stages are preyed upon by fish and play an important role in the food chain. The immature stages seal themselves into cases (like cocoons) to metamorphose into adults. The adults hatch from the cases, emerge from the water as flying insects typically with two pairs of wings, mate, and start the life cycle over again.

Environmental Baseline

Macroinvertebrate populations on the WRNF have been monitored as a MIS only since 2003, as part of the Forest Plan Revision (USDA, 2005b). Macroinvertebrate monitoring, however, has been conducted on the WRNF since 1989 in some streams, including Lost Creek, Cunningham Creek, and Coal Creek (USDA, 2005c). These sites were chosen to monitor individual projects and were not selected to be representative of the WRNF as a whole.

Table BR - 58. Aquatic MIS Sites Sampled for Macroinvertebrate Communities From 2003 and 2008 on the WRNF

Site (Management Code)	metric	2003	2004	2005	2006	2007	2008
Avalanche Creek (MA1 – no grazing)	# EPT	18		21			
	sed.sens.	8		9			

Site (Management Code)	metric	2003	2004	2005	2006	2007	2008
Big Fish Creek (MA1 – cattle grazing)	# EPT	23			26	18	19
	sed.sens.	9			9	5	7
East Maroon Creek (MA1 – no grazing)	# EPT				16	17	15
	sed.sens.				6	7	5
McCullough Gulch (MA3 – no grazing)	# EPT	11				13	
	sed.sens.	2				3	
Piney River (MA1 – sheep grazing)	# EPT		21	17			24
	sed.sens.		7	6			9
Ripple Creek (MA1 – cattle grazing)	# EPT		21		26	21	23
	sed.sens.		7		10	9	9
Snowmass Creek (MA1 – no grazing)	# EPT		17			23	21
	sed.sens.		6			7	7
Two Elk Creek (MA7)	# EPT		17	23			
	sed.sens.		6	9			

#EPT = the number of Ephemeroptera, Plecoptera, and Trichoptera taxa collected during macroinvertebrate sampling

sed.sens. = A WRNF specific metric of sediment sensitive macroinvertebrate taxa collected

Macroinvertebrate monitoring was also initiated in 2001 on Black Gore Creek and Gore Creek and in reference areas in the Eagles Nest Wilderness Area. Benthic Condition Index (BCI) was calculated for four sets of samples in Black Gore Creek and Gore Creek (Healy 2005). BCI is a measure of sedimentation; the higher the index, the more severe the filling of interstitial spaces. Three of the four groups of samples had BCIs worse than Forest Standards. Additionally, the BCIs were 56 percent higher (worse) than reference streams. EPT sampling of Gore Creek and Black Gore Creek also indicated that stream health is relatively poor in relation to reference streams (Healy 2005). These streams adjacent to I-70 and in the Vail Valley have almost no stonefly populations, reflecting substrate embeddedness and reduced dissolved oxygen that result from high sediment loads.

Table BR - 58 displays two key macroinvertebrate metrics from the eight sites that were sampled more than once. These sites were not randomly selected for repeat sampling (therefore, they are not representative) and were usually chosen to provide "reference" site data for analysis for various projects across the WRNF. Although there is insufficient data to determine trends, in general, sites seemed to support a more diverse community in later sampling. Using the number of taxa in the sensitive orders of Ephemeroptera, Plecoptera, and Tricoptera (EPT) as an indicator, the sites had approximately 18 EPT taxa in both 2003 (averaged 18.1) and 2008 (averaged 17.9). Individual sites each varied slightly. Four sites declined by 2 to 4 taxa, and four sites increased by 1 to 5 taxa.

Roads affect geomorphic process by four primary mechanisms (USDA, 2002b):

- Accelerating erosion from the road surface by both mass and surface erosion processes.
- Directly affecting channel structure and geometry.
- Altering surface flow-paths, leading to diversion or extension of channels onto previously unchannelized portions of the landscape.
- Causing interactions among water, sediment, and woody debris at engineered road-stream crossings.

Roads have three primary effects on water:

- They intercept rainfall directly by the road surface and road cutbanks and intercept subsurface water moving down the hill slope.
- They concentrate flow, either on the surface or in an adjacent ditch or channel.
- They divert or reroute water from flow-paths that it would otherwise have taken if the road were not present.

These physical effects lead to the following biological effects:

- Increased fine-sediment composition in stream gravel has been linked to decreased fry emergence, decreased juvenile densities, loss of winter carrying capacity, and increased predation of fishes.
- The effects of roads are not limited to those associated with increases in fine-sediment delivery to streams; they can include barriers to migration, water temperature changes, and alterations to stream-flow regimes.

Estimated Effects and Rationale

Action Alternatives

The potential for action alternatives to affect macroinvertebrates is based on whether MIS habitats, both steam and open water, are likely to be affected.

Direct Effects

Key Habitat Change

All stream habitat is key habitat for macroinvertebrates. Impacts on streams and open waters for each action alternative are quantified for the effects discussion on all trout and would equally apply to impacts on macroinvertebrates (see **Table BR - 55** and **Table BR - 57).**

Management Indicator Habitat Change

Action alternatives would result in direct disturbance along the streams that constitute macroinvertebrate habitat. As shown on **Table BR - 57,** the least amount of disturbance would result from the Transit alternative of Advanced Guideway System (1581.1 linear feet). The greatest amount of disturbance would result from the Combination Six-Lane Highway with Rail and Intermountain Connection alternative (4,675.9 linear feet).

These impacts on macroinvertebrate habitat are based on broad assumptions at this Tier 1 level of analysis. Implementation of project alternatives could include activities at water's edge that result in sedimentation, use of caissons to place concrete structures in streams or water bodies, use of structures to divert flowing water to allow construction, and other procedures that will be identified in Tier 2 proposals. Tier 2 processes will evaluate and identify permanent mitigation measures for specific issues including structural controls. Stream restoration measures might include creation of drop structures and/or bioengineering techniques.

The temporary construction disturbance near streams could include relocation of the channel or construction on the floodplain or creation of a barrier between flowing water and the construction. Proximity of construction to flowing water could vary from immediately in the channel to hundreds of feet away. When converted to something unsuitable for the species, habitat loss is considered total. The WRNF has approximately 3,000 miles of streams in several watersheds draining WRNF lands; therefore, the disturbance to 4,675.9 linear feet (0.9 miles) of stream would be a very small percentage of total streams on the WRNF.

Population Change

Any stream loss from construction is likely to eliminate the local macroinvertebrate populations. Such areas typically recolonize after stream conditions stabilize. Indirect effects that decrease water quality also may affect some local population segments. Reductions of these effects will be developed as part of the Preferred Alternative, which could minimize population decreases.

Indirect and Cumulative Effects

A large proportion of the effects would be indirect, occurring from road runoff (winter maintenance material) and as runoff contaminants and sedimentation, with possible effects as discussed previously. Additional lanes would probably increase the amount of winter maintenance material that is applied, which, in turn, would increase the amount of sediment in adjacent streams, such as Black Gore Creek and Gore Creek. Conversely, construction projects would offer the opportunity to improve mechanisms to control highway runoff and reduce the amount of traction sand that affects aquatic habitats. Means to reduce the effects of the highway on cross-slope drainages would also be included as part of the construction plans and would be designated as part of the measures to improve the continuity of cross drainage flows.

Water quality of stream systems has been affected by development throughout the Corridor and includes effects from increased runoff rates from either unvegetated or paved surfaces, which increase erosional forces of stream systems and, in turn, increases sedimentation and total dissolved solids in water. Runoff from developed areas also tends to increase the amount of contaminants in stream systems. These impacts would probably increase as development continues. Increased runoff rates also would cause streams to down-cut and to channelize, which would reduce the amount of suitable habitat for aquatic organisms.

Effects of No Action

Under the No Action Alternative, no construction-related effects and no loss of stream habitat would occur. Although measures to increase control of roadway runoff are currently being implemented through the SCAP program, fewer opportunities would be realized without large-scale construction projects to decrease the amount of road runoff and sediment that affects adjacent stream systems. Thus, many of the impacts on macroinvertebrates from road runoff, including sedimentation, would probably continue, along with general aquatic habitat deterioration.

Effects Summary

Impacts on stream habitat and on macroinvertebrates would occur during construction activities and during roadway operations. Construction-related impacts would probably include increased sedimentation during earthmoving operations and possible contamination from equipment fueling and maintenance. Increased contamination and sedimentation also would have the potential to increase with the addition of lanes, transportation modes, and traffic volumes. Conversely, project construction also would provide an opportunity to reduce the current impact levels that occur from roadway runoff of contaminants and winter maintenance materials, as well as to improve reaches of stream habitat that were negatively affected by the original I-70 construction. Therefore, because some improvements to macroinvertebrate habitats are anticipated with the action alternatives, impacts would not be expected to cause a change in macroinvertebrate populations on the WRNF. There is no viability risk for aquatic macroinvertebrates (the potential for the population to substantially decrease is unlikely), and none of the project alternatives would threaten the viability of these organisms in the planning area or in the state.

BR.4.2.2 ARNF Species

Elk (*Cervus elaphus*), MIS

A general discussion of elk natural history was presented previously for the WRNF in **Elk (Cervus *elaphus*), MIS** under **Section BR.4.2.1 WRNF Species**. The following information on distribution and environmental baseline is pertinent specifically to the ARNF. Elk are designated MIS on the ARNF to monitor progress toward the Forest Plan goal of maintaining or improving habitat for management indicator species.

Distribution

Two resident elk populations inhabit areas along the I-70 Corridor adjacent to the ARNF; one east of Vail Pass, east of Silverthorne to the south of Lake Dillon, and the other east of Floyd Hill to Genesee. Summer concentration areas include the west side of EJMT to the Williams Fork Mountain Range, from the Tenmile Mountain Range to Vail Pass, and at several smaller locations (refer to the Draft PEIS, Chapter 3, Section 3.2, Biological Resources). Elk populations currently are considered secure (state heritage status rank of S5) (NatureServe, 2004).

Environmental Baseline

Habitat for elk includes alpine meadows, tundra, aspen forest, Douglas-fir forest, grass/forb meadows, lodgepole pine forest, mountain shrubland, piñon-juniper, ponderosa pine forest, sagebrush shrubland, spruce-fir forest, riparian, and wetlands.

Key habitats of severe winter range and winter concentration occur within the Corridor in several locations near the ARNF (Herman Gulch and Idaho Springs; CDOW WRIS 2003; see Draft PEIS, Appendices, Resource Map 3.2-3). Quality elk habitat is prevalent along I-70 on Vail Pass and on both sides of the EJMT.

Colorado Division of Wildlife tracks population data according to GMUs. GMUs within ARNF that border the Corridor include numbers 37 (herd name Williams Fork, which also includes GMU numbers 28 and 371), and 38 (Clear Creek).

Numbers 37, 28, and 371 (Williams Fork)

Post-hunt population estimates for GMUs provided by Colorado Division of Wildlife (Big Game Statistics Post-Hunt Estimates) to the ARNF indicate the Williams Fork herd was at its highest level since 1998 in 2007, with 5,980 animals. The herd size decreased somewhat in 2008 to 5,220 animals but is still well above the average herd size from 1999 – 2005.

Number 38 (Clear Creek)

The Clear Creek herd was at its seven-year (1997 to 2003) high in 2002 (1,300 animals) and declined through 2004 (12 percent) (see **Table BR – 59**. ARNF population trends have been stable from 1997 to 2008. Colorado population estimates increased 40 percent from 1997 to 2000 but have slowly been decreasing since.

Table BR – 59. Elk Post-hunt Population Estimates for GMUs on ARNF (CDOW, Big Game Statistics, 2009)

Herd Name	Data Analysis Unit	GMUs in and near ARNF	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Poudre River	E4	7,8,9, 19, 191	4490	4390	4540	4240	4280	4210	3920	3890	3810	3770	3830	3750
Saint Vrain	E9	20	2670	2570	4140	4220	4370	3980	3810	4020	4100	3070	2360	2360
Clear Creek	E38	29,38	1240	1230	1280	1250	1290	1300	1180	1150	1190	1210	1130	1200
Mount Evans	E39	39, 46, 391, 461	2460	2620	3000	3170	3140	3220	3020	4090	3840	4200	3320	2590
Troublesome Cr	E8	18*, 181*	3640	4700	3560	3340	3590	4020	3590	3820	3030	2860	4150	3900
Williams Fork	E13	28*,37*, 371*	4770	5200	4160	3880	3490	3340	4200	3800	3300	3780	5980	5220

Herd Name	Data Analysis Unit	GMUs in and near ARNF	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
In and near ARNF Totals			**19270**	**20710**	**20680**	**20100**	**20160**	**20070**	**19720**	**20770**	**19270**	**18890**	**20770**	**19020**
Statewide Totals (rounded to 100)			218500	229400	264600	292600	305500	297500	278700	274900	258400	271800	292000	283200

*GMUs near I-70.

Estimated Effects and Rationale

Action Alternatives

The potential for action alternatives to affect elk is based on the extent to which key habitats or MIS habitats are likely to be affected and whether the I-70 Corridor will continue to fragment habitat and act as a barrier to elk movement. In addition to impacts on MIS habitats, impacts on key elk habitats were assessed, including winter concentration areas, severe winter range, and calving areas.

Direct Effects

In addition to the potential for key and MIS habitat losses, I-70 restricts elk from moving between seasonal ranges, and in some cases, restricts daily movements to attain full habitat usage such as feeding, hiding, and finding bedding cover. Alternatives would have the potential to exacerbate this barrier effect and effectively block movement and migration corridors, which would have serious consequences for many of the herds along the Corridor. Major sources of impacts on elk mobility throughout the Corridor include the following concepts:

- Road effect zones
- Barrier effect and AVCs

Road Effect Zones. Road effect zones encompass a wide range of impacts but generally include (1) noise and general disturbance from construction activities and traffic and (2) roadway input of contaminants, such as winter deicing and traction material, that affect roadside vegetation, water bodies, and riparian habitats (Forman and Alexander, 1998; and Forman and Deblinger, 1998). The width of the road effect zone from noise and disturbance effects from traffic varies considerably depending on traffic volumes, terrain, vegetation structure, and sensitivity of the species (Singleton et al., 2002). In Colorado, both elk and mule deer were shown to avoid areas within approximately 600 feet of a road, with this effect appearing stronger in shrub cover types, as compared with forested habitats (Rost and Bailey, 1979). Studies also indicate that various carnivores such as grizzly bears (McLellan and Shackleton, 1988), wolves (Thiel, 1985; and Mech et al., 1987), and bobcats (Lovallo and Anderson, 1996) avoid habitats adjacent to roads.

Estimating the impact of road effect zone-related disturbances, such as additional noise, and human presence, is difficult because some elk populations adapt readily to disturbance, while others do not (LSA Associates 2003). Increases in road effect zone disturbances would be likely to reduce elk usage of some areas near I-70, and a negative impact would be likely for all alternatives as traffic volumes increase. Some differences would be likely, however, among alternatives. For example, noise analyses (see the Draft PEIS, Chapter 3, Section 3.12, Table 3.12-4) indicated that the increases in loudest hour noise levels would be greatest for Combination alternatives (3 to 5 decibels). Highway alternatives were predicted to increase noise levels 2 to 3 decibels, whereas Transit alternatives were predicted to increase noise levels by approximately 1 decibel. Thus, Combination alternatives would have the potential to affect elk the most by increasing the width or distance of the road effect zone from I-70 into adjacent habitats. The noise from the Six-Lane Highway 55 mph alternative was predicted to increase by 2 to 3 decibels. However, because it is unknown how an increase of 2 to 5 decibels would affect elk and how numerous other factors such as adjacent terrain and vegetation would affect noise distribution, all of the alternatives are considered similar in terms of producing a negative effect.

Barrier Effect and AVCs. The barrier effect restricts movements between habitats that are important to certain aspects of the elk's life cycle. I-70 currently bisects a number of movement corridors and increased transportation infrastructure and/or highway lanes associated with project alternatives are likely to increase the barrier effect. Similarly, increases in traffic volumes on I-70 would also increase the barrier effect and probably increase the frequency of AVCs.

AVCs were documented over the period 1988 to 1998 along I-70. The average rate of AVCs was 0.6 collisions per mile per year, but the range of AVCs at different locations was from 0.0 to 2.4. The data indicated that linkage interference zones with AVCs of 1.4 or less could be considered "normal" and AVCs greater than 1.4 could be considered a trouble spot where animals were frequently trying to cross I-70. Of the 15 linkage interference zones, the greatest rate of AVCs (2.4) was in Linkage Interference Zone 13, Mount Vernon Canyon. The second highest AVC (1.4) was reported for Linkage Interference Zone 1 near Dotsero. All other linkage interference zones had AVCs below 1.2, and two linkage interference zones had zero AVCs.

According to CDOT records, approximately 5,000 animals (mostly mammals) have been involved in collisions with vehicles on Colorado roads (Southern Rockies Ecosystem Project website) during a 10-year period (1993 to 2003). These collisions resulted in seven deaths to people. Unless measures such as crossing structures and fencing are implemented to reduce the areas and the frequency of elk crossing I-70 at grade, animal, as well as human, fatalities are likely to increase as populations and roadway traffic volumes increase.

The ALIVE Committee identified a number of linkage interference zones where animal movement across I-70 is especially hindered, often reflected by high AVC frequencies, and the Committee recommended that additional crossing structures and wildlife fencing be constructed in each. Additional below-grade or above-grade crossing opportunities and the addition of wildlife fencing with I-70 projects could largely counteract expected impacts, and a positive effect from existing conditions would be realized. Thus, it is anticipated that elk would benefit from a greater frequency of crossing structures to access their habitats and seasonal ranges. Additionally, because elk are herd animals, they would have the opportunity to learn the new crossings from one another (Dodd et al., 2003). Elk commonly use the highway underpasses in Banff National Park in Canada (Clevenger, 1998) and open bridge structures in the U.S. (Dodd et al., 2003).

Any increase in connectivity between habitats would also benefit the populations as a whole. Therefore, the action alternatives that would extend along the greatest length of the Corridor and cross the most linkage interference zones would have the greatest potential to improve habitat connectivity for elk and to reduce AVC frequencies on the ARNF. Out of the four linkage interference zones on the east side of the Continental Divide, one is within the ARNF near Herman Gulch, and two are near and between blocks of the ARNF (at Empire and Fall River). The Mount Vernon Canyon linkage interference zone is farther removed from the ARNF but interferes with the same elk herds that also use ARNF lands.

In addition to the mitigation measures associated with the linkage interference zones, best management practices are being developed as part of the ALIVE program through a Memorandum of Understanding, which would offer additional opportunities to improve crossing structures wherever construction work is done. Such best management practices would apply to the linkage interference zones, as well as to areas outside the linkage interference zones.

Key Habitat Change

Table BR - 60 and **Table BR - 61** provide the estimated direct impacts on elk habitat on the ARNF. Impacts on habitat on the ARNF by the Preferred Alternative would range from 0.4 acres for Minimum Program 55 or 65mph to 5.4 acres for Maximum Program 55 or 65mph.

Impacts on elk habitat from the action alternatives would range from 0 acres for the Minimal Action Alternative to 6.7 acres for the Combination Six-Lane Highway with Rail and Intermountain Connection alternative. Impacts from the Preferred Alternative would fall within this range. Construction effects on elk habitat are unlikely to change population trends of elk herds in the ARNF, as the amount of habitat lost would be small (0.002 percent) in relation to the 428,047 acres available within the ARNF (CDOW WRIS data, elk winter concentration, severe winter range, and calving area). The resultant effects on individual elk from loss of these key habitats would be increased difficulty in feeding, over wintering, and calving, putting additional stress on their survival. These stresses would affect individuals but are not likely to cause a viability risk to the species overall.

Table BR - 60. Direct Impacts on Elk Habitat (acres): Preferred Alternative

	Minimum Program		Maximum Program	
	Specific Highway Improvements with AGS		Combination 6-Lane Highway with AGS	
	55 mph	65 mph	55 mph	65 mph
ARNF	0.4	0.4	5.4	5.4

Data provide the minimal to maximum impacts for the Preferred Alternative.

Table BR - 61. Direct Impacts on Elk Habitat (acres): Action Alternatives Evaluated in the Draft PEIS

	Minimal Action	Rail with IMC	AGS	Dual-Mode in Guideway	Diesel Bus in Guideway	Six-Lane Highway 55 mph	Six-Lane Highway 65 mph	Reversible/ HOV/HOT Lanes	Combination Six-Lane Highway with Rail and IMC	Combination Six-Lane Highway with AGS	Combination Six-Lane Highway with Dual-Mode	Combination Six-Lane Highway Diesel Bus in Guideway
ARNF	0.0	2.3	0.3	0.5	0.5	2.4	2.4	3.6	6.7	5.4	5.5	5.5

Population Change

The loss of habitat (0 to 6.7 acres) is not likely to cause a downward trend in elk populations on the ARNF. These losses are small when compared to the total that occurs near the Corridor and in the ARNF. This constitutes a minute loss of the total MIS habitat on the ARNF (0.002 percent). The resultant effect on individual elk from loss of habitat would be increased difficulty in feeding and over wintering, with elk possibly seeking new foraging areas. Increased difficulty in foraging would add stress to individuals but would not likely cause a viability risk to the species overall. Accordingly, no change in elk population trends is expected on ARNF due to any project alternative.

Effects of No Action

No habitat loss would occur from construction under the No Action Alternative. No new impacts would occur; however, habitat fragmentation, the barrier effect of I-70, and the potential for AVCs would continue and would probably worsen as traffic volumes increase. Few crossing structures would be built, and none of the existing structures would be improved in the linkage interference zones under this alternative. Fencing along the Corridor would remain as currently configured. Thus, elk herds in the vicinity of I-70 would continue to be negatively affected by the No Action Alternative.

Indirect and Cumulative Effects

Continued human population growth and associated developments, especially in Clear Creek County, would have the potential to force herds from some of the traditional winter and summer ranges and to affect carrying capacities and herd dynamics on the ARNF. A larger human population probably would increase the recreational use of the Forests, which, in turn, would increase the disturbance factor and may require strict enforcement of use restrictions near calving areas and winter ranges. Moreover, vegetation management (timber sales and prescribed burns) and grazing are expected to occur on the ARNF.

Although not necessarily occurring adjacent to I-70, such activities in other areas of the ARNF, in combination with other developments and highway improvements, would have the potential to affect elk and how they are able to use habitats.

Effects Summary

The management objective for the elk MIS is identified in the ARNF Plan, Goal #8 under Biodiversity, Ecosystem Health and Sustainability, that is, to provide a range of sucessional stages of community types across the Forest and Grassland landscapes that maintains or improves habitats for management indicator species.

Losses to habitat would occur for most of the alternatives under consideration, though habitat losses would generally be less than 7 acres. Key habitat losses would be a maximum of 6.7 acres lost by construction of the Combination Six-Lane Highway with Rail and Intermountain Connection alternative. Because these losses would be a small fraction of the total types that occur adjacent to the Corridor and in the ARNF, the impacts from any of the alternatives would be minor or negligible and would be unlikely to appreciably affect elk populations on the ARNF.

All of the action alternatives would provide opportunities to reduce the barrier effect and the AVCs and improve habitat connectivity. But the degree to which this can be realized is related to how far the alternative would extend through the Corridor and the number of linkage interference zones that would be intersected. Four linkage interference zones have been identified on or near the ARNF. All action alternatives would intersect all four linkage interference zones and there would not be any appreciable difference in benefit among the alternatives.

Based on the analyses presented, there is no viability risk to elk (the potential for populations to substantially decrease), and none of the action alternatives being considered would threaten the viability of elk within the Corridor or the state.

Mule Deer (*Odocoileus hemionus*), MIS

The mule deer is a large mammal in the deer family Cervidae, genus *Odocoileus*. The average length of an adult is 78 inches, and the average weight is 474 pounds. The species is typically active at dawn and dusk (that is, crepuscular) or at night in summer months, becoming more diurnal in winter (Fitzgerald et al. 1994).

The mule deer is a MIS for young to mature forest structural stages and openings within and adjacent to the Forest for the ARNF (USDA, 1997, 2005a). Mule deer are not a MIS for the WRNF.

Distribution

Mule deer are distributed from southeastern Alaska, south through Canada, and down through most of the western U.S. The species is also found on the Great Plains; in Baja, California (including some islands in the Sea of Cortez); and at the southern end of the Mexican Plateau (Sonora and northern Tamaulipas, according to Grubb [in Wilson and Reeder 1993]). Mule deer were introduced on Kauai, Hawaii, in the 1960s (population was 300 to 350 in 1981) (Tomich, 1986). They have also been introduced into Argentina.

In Colorado, mule deer occupy all major ecosystem types, from grasslands to tundra. They reach their greatest population densities in shrublands, in rough terrain with abundant browse and cover available (Fitzgerald et al., 1994). They are present in all counties transected by the I-70 Corridor.

Natural History

Breeding peaks mainly in late November to mid-December. Gestation lasts about 203 days. Young are born mostly in May and June in much of the range. Fawns usually number one or two, depending on age and condition of the female.

In mountainous regions, mule deer tend to migrate (up to 62+ miles) from high summer range to lower winter range. Home range size may be 74 to 593 acres or more, directly correlated with availability of food, water, and cover. Over much of Colorado, including much of the area bisected by I-70, the species is migratory, summering at higher elevations and moving down slope to winter range (USDA 1997, Revised Forest Plan, FEIS, Appendix G, page 10).

Mule deer are herbivores in coniferous forests, desert shrub, chaparral, and grasslands with shrubs. Often associated with successional vegetation, especially near agricultural lands. They may feed on agricultural crops. They also commonly consume mushrooms, especially in late summer and fall (Kucera, 1992).

Predators include mountain lions, black bears, brown bear (*Ursa arctos*), bobcats, coyotes, golden eagles, and domestic dogs (*Canis lupus familaris*) (Fitzgerald et al., 1994).

Environmental Baseline

Habitat for mule deer includes aspen forest, Douglas-fir forest, grass/forb meadows, lodgepole pine forest, mountain shrubland, ponderosa pine forest, and spruce-fir forest.

The project area occurs within mule deer winter and summer ranges, and several north-south mule deer migration corridors between Idaho Springs and Empire Junction (US 40) (CDOW WRIS 2003). **Table BR - 62** provides statewide, ARNF, and GMU population estimates. GMUs 37 and 371 occur adjacent to I-70.

Table BR - 62. Mule Deer Post-hunt Population Estimates (CDOW, Big Game Statistics, 2008)

Herd Name	Data Analysis Unit	GMUs in and near ARNF	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Redfeather	D4	7,8,9, 19, 191	12290	13810	11190	9730	9720	9070	8340	8650	8140	7320	5780	7570
Big Thompson	D10	20	7960	8240	5830	6320	6470	6120	6470	6430	5880	5410	2040	5670
Boulder	D27	29,38	7220	7400	8550	7890	7270	7080	7470	7000	7130	7370	7360	7560
Bailey	D17	39,46, 51, 391, 461	8330	6890	6750	7070	7570	8410	8420	8010	7880	7800	8790	8260
Middle Park	D9	18, 181, 27,28, 37,371	10150	11960	14180	10900	12250	13150	13240	13250	12030	9420	12800	12300
In and near ARNF Totals			**45950**	**48300**	**46500**	**41910**	**43280**	**43830**	**43940**	**43340**	**41060**	**37320**	**36770**	**41360**
In and near PNG Totals														
Table Lands	D5	87,88, 89,90, 93,95	1/	1/	1/	2110	1880	1600	1480	1450	1500	1810	2040	1870
In and near ARNF/PNG Totals						**44020**	**45160**	**45430**	**45420**	**44790**	**42560**	**39130**	**38810**	**43230**
Statewide Totals (rounded to 100)			516500	526400	528700	551600	565300	563700	602700	600900	614100	612800	538800	466800
1/ Not comparable at present scale. Prior to 2000, Table Lands data analysis unit included a larger area beyond PNG.														

Statewide, the mule deer population generally increased from 1997 to 2005 (19 percent). Populations then steadily declined through 2008 by 24 percent to levels below the population size at the beginning of the monitoring period in 1997. Pawnee National Grasslands (PNG) trend has declined yearly until 2005 but has since increased to levels close to 2000 levels. Combined ARNF/PNG trend has been generally stable since 2000, with population being lowest in 2007.

The Middle Park herd is adjacent to the I-70 Corridor. The population trend for the ARNF has varied since 1997, being highest in 1999 and lowest in 2006. For the GMUs in the ARNF, including numbers 37 and 371 that occur along I-70, the population numbers have fluctuated yearly, but have decreased 7 percent from 2003 to 2008 (see **Table BR - 62**). Forest-wide, early structural stages constitute 2 percent (19,600 acres) and natural vegetated openings constitute 16 percent (212,000 acres) of forested vegetation (USDA 1997 Revised Forest Plan). The Forest Plan objective is to increase grass-forb and shrub-seedling forest structural stages for mule deer (USDA 1997; FEIS, Appendix G, page 9).

Estimated Effects and Rationale

Action Alternatives

The potential for action alternatives to affect mule deer is based on the extent to which habitats are likely to be affected and whether the Corridor will continue to fragment habitat and act as a barrier to mule deer movement.

Direct Effects

The effects of the action alternatives on habitat for mule deer on the ARNF would be similar to those discussed for elk. However, the ramifications of the estimated habitat losses may have greater implications for mule deer than for elk because mule deer populations have been in decline over the last 40 to 50 years (Gill, 2001). The reasons for the decline are still being investigated but may be a combination of habitat deterioration, which is amplified by increasing elk numbers, and competition for forage. Potential direct effects, such as road effect zones, barrier effect, and AVCs for mule deer would be similar to those discussed in **Elk (Cervus *elaphus*), MIS** under **Section BR.4.2.2 ARNF Species** for elk.

AVCs were documented over the period 1988 to 1998 along I-70. The average rate of AVCs was 0.6 collisions per mile per year, but the range of AVCs at different locations was from 0.0 to 5.2. The data indicated that linkage interference zones with AVCs of 1.4 or less could be considered “normal” and AVCs greater than 1.4 could be considered a trouble spot where animals were frequently trying to cross I-70. Of the 15 linkage interference zones, the greatest rate of AVCs (2.4) was in Linkage Interference Zone 13, Mount Vernon Canyon. The second highest AVC (1.4) was reported for Linkage Interference Zone 1 near Dotsero. The two linkage interference zones with high AVCs are in the Foothills life zone or low Montane life zone. All other linkage interference zones had AVCs below 1.2, and two linkage interference zones had zero AVCs.

According to CDOT records, approximately 5,000 animals (mostly mammals) have been involved in collisions with vehicles on Colorado roads (Southern Rockies Ecosystem Project 2006) during a 10-year period (1993 to 2003). These collisions resulted in seven deaths to people. Unless measures such as crossing structures and fencing are implemented to reduce the areas and the frequency of elk crossing I-70 at grade, animal, as well as human, fatalities are likely to increase as populations and roadway traffic volumes increase.

Key Habitat Change

No direct impacts on key mule deer habitat, winter concentration, and severe winter range are anticipated to occur from the action alternatives on the ARNF.

Population Change

No downward changes to local mule deer populations from habitat losses would be expected because of the relatively small amount of habitat loss and because of reduced AVCs. Accordingly, no changes in forest-wide population trends are expected. The resultant effects on individual mule deer from loss of habitat would be increased difficulty in finding new feeding and shelter areas, possibly causing them to enlarge their foraging area or to seek other, new foraging areas. Increased difficulty in foraging and finding shelter would add stress to individuals but would not likely pose a viability risk to the species overall.

Indirect and Cumulative Effects

Potential indirect and cumulative effects for mule deer would be similar to those discussed under Elk. Continued human population growth and associated developments, especially in Summit County, would have the potential to force herds from some of the traditional winter and summer ranges, thereby lowering carrying capacities and herd dynamics on the ARNF. A larger human population probably would increase the recreational use of the Forests, which, in turn, would increase the disturbance factor and may require strict enforcement of use restrictions near calving areas and winter ranges.

Effects of No Action

No additional habitat would be directly affected by the No Action Alternative. No additional crossing structures would be built, existing structures would not be improved, and fencing along the Corridor would remain as currently configured. As traffic volumes increase over time, the barrier effect of the highway, as well as AVC frequencies, would likely increase, which would increase the fragmentation effect of I-70 on mule deer populations. Thus, deer herds in the vicinity of I-70 would be negatively affected by habitat fragmentation and increased frequencies of AVCs by the No Action Alternative.

Effects Summary

No direct impacts on mule deer habitat are anticipated to occur from the action alternatives on the ARNF. In addition, all of the project alternatives, except the No Action Alternative, would provide opportunities to reduce the barrier effect and AVCs and to improve habitat connectivity, but the degree to which these effects can be realized would be related to how far the alternative extends through the Corridor and the number of linkage interference zones that would be intersected within the ARNF. All of the action alternatives would occur in the four linkage interference zones that are within or near the ARNF. Therefore, construction of crossing structures, as well as fencing, would reduce the barrier effect on wildlife and also reduce AVCs.

Based on the analyses conducted, there is no viability risk (the potential for a population to substantially decrease) for mule deer. None of the alternatives being considered for this project would threaten the viability of mule deer in the Corridor area of influence, on the ARNF, or in Colorado.

Bighorn Sheep (*Ovis canadensis*), MIS

Rocky Mountain Bighorn Sheep is designated as a MIS for the ARNF, as well as a Region 2 Forest Service Sensitive Species. This species is a MIS on the ARNF for openings within and adjacent to the forest. This species, however, occurs in open habitats on and near rocky cliffs and outcrops above tree line and also in such habitats at lower elevations through the Montane zone. ARNF habitat evaluation was conducted by use of NDIS mapping of bighorn winter range, summer range and lambing areas overlaid on ARNF lands.

Effects Summary

Section BR.4 of this report should be referenced for habitat, environmental baseline (including population information in **Table BR - 21**), proposed project effects, and viability determination as a sensitive species. Bighorn sheep population trends on the ARNF are variable. Some sites showed peak populations in the late 1990s and some as recent as 2002. Some sites appear to have stable, but small, populations. However, the ARNF population appears to have a downward trend.

The amount of acreage of bighorn sheep habitat directly affected by the project (less than 5 acres) would represent approximately 0.003 percent of the 279,000 acres of alpine meadows, barren lands, grass/forb meadows and mountain shrubland on the ARNF.

The No Action Alternative would not affect bighorn sheep habitat, as the roadway template through such areas on the ARNF will remain as is. Increases in traffic volumes, however, would be anticipated to increase road effect zone and AVC effects on sheep. The No Action Alternative would not create a viability risk for the bighorn sheep population.

Hairy Woodpecker (*Picoides villosus*), MIS

The hairy woodpecker is a medium to large woodpecker in the family Picidae, genus *Picoides.* The adult birds typically measure 9.25 inches long, with a wingspan of 15 inches and a weight of 2.3 ounces (Sibley 2000). The hairy woodpecker is an MIS for young to mature forest with a snag component, including aspen, Douglas-fir, lodgepole, ponderosa, and spruce-fir forests.

Distribution

The hairy woodpecker occupies habitat including aspen forest, mixed conifer forest (Douglas-fir), ponderosa pine, and piñon-juniper (Kingery, 1998). The breeding distribution for the hairy woodpecker includes western and central Alaska to northern Saskatchewan and Newfoundland, south to northern Baja, California, the highlands of Middle America, the Gulf Coast, southern Florida, and the Bahamas. The winter distribution is generally throughout the breeding range, with more northern populations partially migratory (NatureServe, 2006).

In Colorado, the hairy woodpecker breeds throughout the mountains and some scattered locations on the Eastern Plains.

Natural History

Hairy woodpeckers nest from late May to early August in Colorado (Kingery, 1998). Clutch size is three to six eggs (usually four). Incubation lasts 11 to 12 days, with both sexes taking part. The young leave the nest at 28 to 30 days, then rely on parents for about 2 more weeks.

The northernmost breeding populations are partially migratory. They may migrate between higher and lower elevations in mountainous regions. The female spends the entire year on the breeding territory, joined in late winter by the male (Harrison, 1979). Reported territory size ranges from 1.5 to 37 acres, and it varies with habitat quality (Lawrence, 1967).

Hairy woodpeckers are most abundant in mature woods with large old trees suitable for cavity nesting. They are also common in medium-aged forests. They prefer woods with a dense canopy (Bushman and Therres, 1988). The hairy woodpecker will use tree cavities for roosting and winter cover, and they may excavate new cavities in fall to be used for roosting (Sousa, 1987). Overall, the hairy woodpecker appears to be minimally affected by forest fragmentation, although a few studies have reported a decline in numbers as forest patch size decreases. The presence of suitable cavity trees is a more important consideration (Bushman and Therres, 1988).

Hairy woodpeckers eat mainly insects (beetles, ants, and caterpillars), especially boring larvae, obtained from the bark or wood of trunks and branches of trees or from soft shrubs or old giant thistle stalks. The hairy woodpecker may concentrate feeding in areas of insect outbreaks. Seeds may be an important food in winter.

Environmental Baseline

The hairy woodpecker occupies habitat including aspen, Douglas-fir, lodgepole, ponderosa, and spruce-fir forests. Breeding birds have been confirmed in Jefferson, Clear Creek, Summit, Eagle, and Garfield counties, as well as others (Kingery 1998). Forest-wide amounts of snags are generally high, and the mountain pine beetle epidemic is serving to increase lodgepole pine snags dramatically (USDA, 1997).

The global abundance for hairy woodpeckers is estimated to be between 10,000 and 1 million individuals. The global short-term trend is stable (unchanged or within ±10 percent fluctuation in population, range, area occupied, and/or number or condition of occurrences). Hairy woodpeckers have been reported to be declining (in the 1980s) in several parts of their range (Ehrlich et al. 1992), although these declines probably were only local. The global and statewide ranks are both secure (G5, S5).

Most baseline population estimates of density fall in the range of 1 to 3 individuals per 100 acres. The best population data available for the ARNF come from old-growth spruce-fir in the Indian Peaks Wilderness Area, where (1988) 2.8 individuals were found per 100 acres. No population trend is apparent for the ARNF from the BBS (ARNF and PNG, 2002). However, the number of individuals recorded on the Evergreen/Idaho Springs CBC appears to be fairly stable, at least by CBC standards, remaining in the range of 0.22 to 0.66 individuals per observer party-hour, suggesting a comparatively stable population. The only statistically significant trends for larger areas are for the continent-level BBS, which shows an increasing trend (ARNF and PNG, 2002). For 1999 and 2000, the RMBO "Monitoring Colorado's Birds" (MCB) program results for hairy woodpecker, in a variety of habitats, yielded a density estimate of 0.8 birds per 100 acres (ARNF and PNG, 2002). **Table BR - 63** presents transect count data for the hairy woodpecker in the ARNF.

Table BR - 63. Hairy Woodpecker (Monitoring Colorado Birds Data, RMBO 2005) ARNF (number/transect/year)

Transect	1998	1999	2000	2001	2002	2003	2004	2005	Avg/Yr
AS28	2	NR	1	NR	NR	NR	1	2	1.0
AT02	NR	NR	NR	NR	1	0	0	NR	0.3
AT03	NR	0	NR	0	0	0	NR	0	0.0
AT04	NR	0	NR	NR	0	0	0	0	0.0
AT05	NR	0	0	0	0	0	0	0	0.0
AT06	NR	0	0	0	0	0	0	0	0.0
GR01	NR	0	0	0	0	0	0	0	0.0
GR02	NR	0	0	0	0	0	0	0	0.0
GR03	NR	0	NR	0	0	0	0	0	0.0
GR05-02	NR	NR	NR	NR	0	NR	NR	0	0.0
GR15	NR	NR	0	NR	0	0	0	0	0.0
HR05	NR	NR	0	0	NR	0	0	0	0.0
HR09	NR	0	0	0	0	NR	1	0	0.2
HR10	NR	NR	2	3	0	NR	0	NR	1.3
HR18	NR	0	NR	NR	0	0	0	0	0.0
HR25	NR	0	0	0	0	0	0	0	0.0
MC03	NR	1	0	0	1	0	1	0	0.4
MC27	NR	0	0	0	0	0	1	0	0.1
PP13	6	2	2	0	0	NR	NR	0	0.8
PP15	0	0	NR	0	0	NR	0	1	0.2
PP16	4	0	1	0	4	NR	2	13	3.3
PP21	3	1	0	4	1	NR	5	2	2.2
PP29	0	1	1	NR	0	NR	NR	NR	0.7
SF16	0	NR	0	0	NR	NR	0	NR	0.0
SF17	0	0	NR	0	0	NR	0	1	0.2
SF30	NR	2	0	NR	NR	NR	2	0	1.3
Total birds	**15**	**7**	**7**	**7**	**7**	**0**	**13**	**19**	**6.8**
# of transects w/ hits	**4**	**5**	**5**	**2**	**3**	**0**	**7**	**5**	**3.9**

Transect	1998	1999	2000	2001	2002	2003	2004	2005	Avg/Yr

NA = Transect not in Arapaho/Roosevelt during this year NR = Transect not conducted in this year

Population numbers dipped from 1999 through 2003 for the ARNF, but numbers rebounded to their 1998 levels in 2004 and 2005. Breeding surveys show increasing trends at a continental level (RMBO, 2005).

Estimated Effects and Rationale

Action Alternatives

The potential for action alternatives to affect hairy woodpeckers is based on the extent to which MIS habitats are likely to be affected.

Direct Effects

Key Habitat Change

No key habitat has been identified for the hairy woodpecker. The presence of old trees with cavities is probably the most important factor for this species (Bushman and Therres, 1988).

Management Indicator Habitat Change

Table BR - 64 and **Table BR - 65** provide the estimated direct impacts on potential hairy woodpecker habitat on the ARNF. Direct impacts on the hairy woodpecker are based on mapped vegetation in Douglas-fir, lodgepole pine, ponderosa pine, spruce-fir, and piñon-juniper forests.

Impacts from the Preferred Alternative would range from 3.1 acres (Minimum Program [55 or 65mph]) to 6.5 acres (Maximum Program [55 or 65mph]).

The greatest impacts would be associated with the Combination Six-Lane Highway with Rail and Intermountain Connection (8.7 acres), followed by the Combination Six-Lane Highway with Advanced Guideway System (6.5 acres) and the Maximum Program 55 or 65mph (6.5 acres). The least impacts would be associated with the Advanced Guideway System (0.9 acres) and the Bus in Guideway (1.4 acres) alternatives. Road effect zone-related disturbance would also affect this species due to increased transportation activities associated with all action alternatives.

Impacts from alternatives are expected to be relatively small. The total coniferous habitat acreage in the ARNF is estimated at 943,000. The alternatives may disturb up to 0.001 percent of that area near the ARNF.

Table BR - 64. Direct Impacts on MIS Hairy Woodpecker Habitat (acres): Preferred Alternative

	Minimum Program		Maximum Program	
	Specific Highway Improvements with AGS		Combination 6-Lane Highway with AGS	
	55 mph	65 mph	55 mph	65 mph
ARNF	3.1	3.1	6.5	6.5

Data provide the minimal to maximum impacts for the Preferred Alternative.

Table BR - 65. Direct Impacts on MIS Hairy Woodpecker Habitat (acres): Action Alternatives Evaluated in the Draft PEIS

	Minimal Action	Rail with IMC	AGS	Dual-Mode Bus in Guideway	Diesel Bus in Guideway	Six-Lane Highway 55 mph	Six-Lane Highway 65 mph	Reversible/ HOV/HOT Lanes	Combination Six-Lane Highway with Rail and IMC	Combination Six-Lane Highway with AGS	Combination Six-Lane Highway with Dual-Mode Bus in Guideway	Combination Six-Lane Highway Diesel Bus in Guideway
ARNF	2.1	5.3	0.9	1.4	1.4	2.9	3.0	4.6	8.7	6.5	6.3	6.3

Population Change

The loss of from 0.9 to 8.7 acres of MIS habitat from the action alternatives is estimated not to cause a downward trend in the hairy woodpecker population on the ARNF, as these losses are a very small portion of the total that occurs near the Corridor and on the ARNF. The resultant effect on individual hairy woodpeckers from loss of foraging and nesting habitat would be increased difficulty in foraging and nesting, possibly causing them to enlarge their foraging area and seek out new nesting areas. Increased difficulty in foraging and nesting would add stress to individuals but would not likely cause a viability risk to the species overall.

Indirect and Cumulative Effects

In Clear Creek County, induced traffic from alternatives would not be expected to induce growth based on past growth trends. Susceptibility to changes in population due to induced or suppressed travel demand would be limited to Eagle and Summit counties, outside ARNF lands. Clear Creek County is not expected to experience growth-inducing effects from project alternatives (see Chapter 3, Section 3.9 of the Draft PEIS).

However, the existing mountain pine beetle epidemic that is killing thousands of acres of trees may be a source of food for the hairy woodpecker. Available suitable habitat for hairy woodpeckers is extensive within the ARNF. Other cumulative effects include snowmobile and ATV use within the ARNF. The Combination and Highway alternatives are associated with possible increased dispersed recreation activities that would include snowmobile and ATV use.

No Action Alternative

Indirect impacts on woodpecker habitat areas that currently occur within the road effect zone would remain. No additional impacts are expected to result from the No Action Alternative. If I-70 congestion continues to increase, forest visitation may even decrease somewhat.

Effects Summary

Based on the analyses conducted above, minimal effect is expected on individual hairy woodpeckers, and no change in the forest-wide population trend is expected with any alternative. Accordingly, no viability risk is expected. None of the alternatives being considered for this project would threaten the viability of hairy woodpecker within the project area of influence, on the ARNF, or in the state. Because the No Action Alternative would not cause any changes to the existing condition of habitat, this alternative would have no risk of reduced viability on hairy woodpeckers.

Pygmy Nuthatch (*Sitta pygmaea*), MIS

Pygmy nuthatch is a very small, pine-loving nuthatch, in the family Sittidae, genus *Sitta*. They normally measure 4.25 inches long, with a wingspan of 7.75 inches, and they weigh 0.37 ounces. They usually occur in small flocks. (Sibley, 2000).

The main issues for this species involve maintenance of cavity nesting substrates (old-growth), maintenance of ponderosa pine cover on the forests, and the potential for more intense fires in this forest type (USDA, 2005a).

Distribution

The pygmy nuthatch is a resident of southern interior British Columbia, northern Idaho, western Montana, central Wyoming, and southwestern South Dakota, south to northern Baja, California, southern Nevada, central and southeastern Arizona, central New Mexico, extreme western Texas, and extreme western Oklahoma, south in the mountains to central Mexico (AOU, 1983). It may be found at elevations up to approximately 9,800 feet.

Pygmy nuthatch distribution in Colorado matches almost exactly the distribution of ponderosa pine forest (Kingery, 1998). Their home range size is approximately 3 acres per breeding pair. Records in the

Colorado Breeding Bird Atlas indicate confirmation of breeding birds in Jefferson, Clear Creek, and Summit counties but no records for Eagle or Garfield counties (Kingery, 1998).

Natural History

Pygmy nuthatches are monogamous, with one brood per year and six to eight eggs typically produced. The nest is normally an excavated cavity in a ponderosa pine tree. The diet consists of insects and spiders gleaned from the bark of trees and conifer seeds (Ehrlich et al., 1988). They tend to forage in the crowns of trees. In a poor pine-cone year, pygmy nuthatches may switch from pine to spruce and fir seeds (USDA, 1997).

Environmental Baseline

Pygmy nuthatch was selected as an ARNF MIS for potential old-growth forests. The primary habitat for pygmy nuthatch is ponderosa pine forest. Ponderosa pine has primary distribution within the Corridor between U.S. 40 and Idaho Springs, and over much of the Corridor through Jefferson County. Pygmy nuthatch have also been documented at times within spruce-fir, Douglas-fir, and lodgepole pine stands.

Their home range averages 19.77 acres. In prime habitat, their density ranges from 119 to 189 adults per square mile (Dolbeer and Clark, 1975).

In Colorado, the Natural Heritage Status Rank for the species is S4, apparently stable (NatureServe, 2005h). Pygmy nuthatch densities vary greatly across the species' range; breeding season densities from the ARNF range from 6.0 to 49.0 pairs per 100 acres. Based on Breeding Bird Atlas methodology, Kingery (1998) estimates the statewide population at between 51,461 and 339,142 breeding pairs. Kingery (1998) reports that because pygmy nuthatches have such a strong affinity for ponderosa pine, their populations will rise and fall with the availability of those trees. Breeding records for Colorado document evidence of breeding for this species in Clear Creek and Summit counties (ARNF) (Kingery 1998).

Table BR - 66 presents transect count data for pygmy nuthatch in the ARNF. Transect surveys indicate a highly variable trend. The pygmy nuthatch appeared stable from 1998 through 2001, then experienced a dramatic increase in 2002 and 2004, and then a return to lower and more stable levels in 2005. Note that transect surveys in typical habitat (ponderosa pine) were not conducted in 2003. No trend was discernable at larger geographic scales (RMBO, 2005).

Table BR - 66. Pygmy Nuthatch (Monitoring Colorado Birds Data, RMBO 2005) ARNF (number/transect/year)

Transect	1998	1999	2000	2001	2002	2003	2004	2005	Avg/Yr
AS28	0	NR	0	NR	NR	NR	0	0	0.0
AT02	NR	NR	NR	NR	0	0	0	NR	0.0
AT03	NR	0	NR	0	0	0	NR	0	0.0
AT04	NR	0	NR	NR	0	0	0	0	0.0
AT05	NR	0	0	0	0	0	0	0	0.0
AT06	NR	0	0	0	0	0	0	0	0.0
GR01	NR	0	0	0	0	0	0	0	0.0
GR02	NR	0	0	0	0	0	0	0	0.0
GR03	NR	0	NR	0	0	0	0	0	0.0
GR05-02	NR	NR	NR	NR	0	NR	NR	0	0.0
GR15	NR	NR	0	NR	0	0	0	0	0.0
HR05	NR	NR	0	0	NR	0	0	0	0.0
HR09	NR	0	0	0	1	NR	0	0	0.2
HR10	NR	NR	0	0	0	NR	0	NR	0.0

Transect	1998	1999	2000	2001	2002	2003	2004	2005	Avg/Yr
HR18	NR	0	NR	NR	0	0	0	0	0.0
HR25	NR	0	0	0	0	0	0	0	0.0
MC03	NR	0	0	0	0	0	4	0	0.6
MC27	NR	0	0	0	0	0	4	0	0.6
PP13	0	0	0	0	0	NR	NR	1	0.2
PP15	0	0	NR	3	10	NR	0	1	2.8
PP16	0	0	0	0	0	NR	5	3	1.3
PP21	1	2	0	0	4	NR	14	0	3.3
PP29	3	0	0	NR	0	NR	NR	NR	0.0
SF16	0	NR	0	0	NR	NR	0	NR	0.0
SF17	0	0	NR	0	0	NR	0	0	0.0
SF30	NR	0	2	NR	NR	NR	0	0	0.7
Total birds	**4**	**2**	**2**	**3**	**15**	**0**	**27**	**5**	**8.2**
# of transects w/ hits	**2**	**1**	**1**	**1**	**3**	**0**	**4**	**3**	**1.9**

NA = Transect not in Arapaho/Roosevelt during this year   NR = Transect not conducted in this year

Estimated Effects and Rationale

Action Alternatives

Direct Effects

The potential for action alternatives to affect pygmy nuthatch is based on whether MIS habitats are likely to be affected. The amount of area and habitat affected is related to the size of the alternative footprint and the construction disturbance zone, and its extent through the Corridor. Cross-referencing the applicable vegetation types that have been mapped along the Corridor identified the MIS habitats. The amount of applicable vegetation types that would be disturbed by construction of the alternative (footprint) and by disturbances within the construction disturbance zone was then tabulated to determine potential impacts on pygmy nuthatch habitat.

Key Habitat Change

No key habitat is quantified for this species on the ARNF.

Management Indicator Habitat Change

Table BR - 67 and **Table BR - 68** present the estimated direct impacts on potential MIS habitat for the pygmy nuthatch on the ARNF. Impacts from the Preferred Alternative would range from 3.1 acres (Minimum Program 55 or 65mph) to 6.5 acres (Maximum Program 55 or 65mph).

The Advanced Guideway System alternative would have the potential to directly affect 0.9 acres of pygmy nuthatch habitat, versus 8.6 acres of direct effect for the Combination Six-Lane Highway with Rail and Intermountain Connection. The direct effects of the remaining alternatives would lie between these two extreme values. The direct effect for the Combination Six-Lane Highway with Rail and Intermountain Connection (8.6 acres) would represent a loss of approximately 0.03 percent of the MIS habitat estimated for this species (a total of 25,973 acres of old-growth ponderosa pine forest is present on the ARNF [USDA, 1997]).

The loss of pygmy nuthatch habitat from the alternatives, although small, could cause a slight reduction in populations or displace some individuals near I-70. Forest-wide, the small loss of habitat in relation to the total is unlikely to change pygmy nuthatch populations.

Table BR - 67. Direct Impacts on MIS Pygmy Nuthatch Habitat (acres): Preferred Alternative

	Minimum Program		Maximum Program	
	Specific Highway Improvements with AGS		Combination 6-Lane Highway with AGS	
	55 mph	65 mph	55 mph	65 mph
ARNF	3.1	3.1	6.5	6.5

Data provide the minimal to maximum impacts for the Preferred Alternative.

Table BR - 68. Direct Impacts on MIS Pygmy Nuthatch Habitat (acres): Action Alternatives Evaluated in the Draft PEIS

	Minimal Action	Rail with IMC	AGS	Dual-Mode Bus in Guideway	Diesel Bus in Guideway	Six-Lane Highway 55 mph	Six-Lane Highway 65 mph	Reversible/ HOV/HOT Lanes	Combination Six-Lane Highway with Rail and IMC	Combination Six-Lane Highway with AGS	Combination Six-Lane Highway with Dual-Mode Bus in Guideway	Combination Six-Lane Highway Diesel Bus in Guideway
ARNF	2.1	5.2	0.9	1.4	1.4	2.9	3.0	4.6	8.6	6.5	6.3	6.3

Population Change

Because of the small loss of MIS habitat in relation to the total, a change in pygmy nuthatch population is considered unlikely to occur.

Indirect and Cumulative Effects

In Clear Creek County, induced traffic from alternatives would not be expected to induce growth, based on past growth trends. Susceptibility to changes in population due to induced or suppressed travel demand would be limited to Eagle and Summit counties, outside ARNF lands. Clear Creek County is not expected to experience growth-inducing effects from project alternatives (see Chapter 3, Section 3.9 of the Draft PEIS).

Other actions, such as fire/fuel management and ski area development on ARNF lands, may cause cumulative impacts on pygmy nuthatch habitat by reducing or fragmenting existing habitat. Other cumulative effects include snowmobile and ATV use within the ARNF, which could affect pygmy nuthatch habitat. The Combination and Highway alternatives are associated with possible increased dispersed recreation activities that would include snowmobile and ATV use.

Effects of No Action

No new nesting or foraging habitat would be directly affected by the No Action Alternative. Population trends would not be expected to change.

Effects Summary

After evaluating the alternatives, none of the action alternatives would create negative trends that would affect the achievement of Forest Plan MIS objectives or create viability concerns for the pygmy nuthatch. This species will continue to be monitored across the ARNF using the protocols developed as a part of the Revised Plan.

For the ARNF, the maximum direct effect would be realized from the Combination Six-Lane Highway with Rail and Intermountain Connection alternative. The habitat potentially lost for pygmy nuthatch would represent only 0.03 percent of the total MIS habitat available for this species on the ARNF. None of the alternatives being considered for this project would threaten the viability of the species in the project area of influence, on the ARNF, or in Colorado.

Mountain Bluebird (*Sialia currucoides*), MIS

The mountain bluebird is a passerine bird in the family Turdidae, genus *Sialia*. They normally measure 7.25 inches in length, 14 inches in wingspan, and weigh 1 ounce (Sibley, 2000).

The mountain bluebird is designated an MIS species for openings within and adjacent to forest stands on the ARNF. Approximately 17 percent of forested lands on the ARNF are estimated to contain openings (ARNF and PNG, 2005), which means up to 160,300 acres of openings may be available to species such as the mountain bluebird.

Distribution

Mountain bluebird breeding distribution includes central Alaska, the southern Yukon to southwestern Manitoba, south into the mountains to California, Nevada, northern Arizona, southern New Mexico, western Oklahoma, Colorado, western Nebraska, South Dakota, and North Dakota (NatureServe, 2006). The species is both a local and long-distance migrant. Mountain bluebirds nest in nearly all forest types in the Rocky Mountain region, usually from 7,000 to 11,000 feet (USDA, 2005a).

In Colorado, mountain bluebirds breed throughout the western two-thirds of the state. Confirmed breeding has been documented for Jefferson, Clear Creek, Summit, Eagle, and Garfield counties (Kingery 1998).

Natural History

In the south, mountain bluebirds are usually found at elevations above 4,900 feet. In winter and during migration, they also inhabit desert, brushy areas and agricultural lands. Nests are built in natural tree cavities or abandoned woodpecker holes. Mountain bluebirds may also use bird boxes, old swallow nests, rock crevices, or old mammal burrows (NatureServe, 2006). Clutch size is usually 5 to 6 eggs. Sometimes this species will have two broods per year. Incubation requires about 13 to 14 days (Harrison, 1978).

Mountain bluebirds are insectivorous. They feed on beetles, ants, bees, wasps, caterpillars, grasshoppers, and other insects. They may also consume some berries and grapes seasonally. They hover and drop to the ground while foraging or they may dart out from a low perch to catch prey (NatureServe, 2006). Nearly 92 percent of their diet is animal material (USDA, 1997).

Environmental Baseline

Mountain bluebird habitat may include alpine meadows, tundra, Douglas-fir forest, grass/forb meadows, mountain shrubland, ponderosa pine forest, and sagebrush shrubland.

Mountain bluebird populations have been observed to be increasing on state, national, and continental levels. To conserve habitat in Colorado, means for preserving snags and live trees with cavities is needed (Kingery 1998). The global and state ranks for the species are secure (G5, S5).

Population data are uncommon for this species and winter numbers are too variable to exhibit a trend (USDA, 2003). No trend data are available on the ARNF, but breeding trends at the continental level are slightly increasing (USDA, 2003). The RMBO MCB program monitored bluebirds in 1999, 2000, and 2001. In 1999, they observed bluebird densities of 8.0, 9.2, and 122.8 birds per 100 acres in aspen, mixed conifer, and ponderosa pine, respectively. In 2000, bluebird densities observed were 2.4, 1.6, and 1.2 in the same respective habitats (USDA, 2005a).

Range-wide, the general picture from BBS, as reported in the species conservation assessment, is that the abundance of mountain bluebirds has remained relatively stable in the western U.S. (Wiggins 2006). Available data suggest that these bluebirds have declined in abundance in Region 2 of the USDA Forest Service since 1980, but at the state level, the decline is statistically significant only in South Dakota. Local declines are apparent in South Dakota, Nebraska, eastern Colorado, and eastern Wyoming. Populations appear to be relatively stable in central and western Wyoming and western Colorado.

However, caution must be used when interpreting BBS data. Data from CBC show high annual fluctuations in abundance in Colorado, New Mexico, and Kansas, but they give no indication of a long-term decrease in abundance (Wiggins, 2006).

Transect counts in and near ARNF since 1998 show that population trends have been relatively stable but variable forest-wide, with greater densities in alpine tundra, high-elevation riparian, and ponderosa pine habitats (USDA, 2005a). Other habitats used by the bluebird include grass/forb meadows, mountain shrubland, sagebrush shrubland, ponderosa pine and Douglas-fir. Forest-wide, 15 percent of forested lands are in natural openings and 2 percent are in natural or created openings of grasses, forbs, shrubs, or seedlings (USDA, 1997). This would amount to approximately 160,000 acres of openings. **Table BR - 69** presents transect count data for the mountain bluebird on the ARNF.

Table BR - 69. Mountain Bluebird (Monitoring Colorado Birds Data, RMBO 2005) ARNF (number/transect/year)

Transect	1998	1999	2000	2001	2002	2003	2004	2005	Avg/Yr
AS28	0	NR	0	NR	NR	NR	0	0	0.0
AT02	NR	NR	NR	NR	1	1	2	NR	1.3
AT03	NR	4	NR	3	0	0	NR	0	1.8
AT04	NR	3	NR	NR	1	2	2	0	1.6
AT05	NR	2	0	0	0	0	1	0	0.4
AT06	NR	0	0	1	0	0	0	0	0.1
GR01	NR	0	0	0	0	0	NR	0	0.0
GR02	NR	0	0	0	0	0	0	0	0.0
GR03	NR	0	NR	0	0	0	0	0	0.0
GR05-02	NR	NR	NR	NR	0	NR	NR	0	0.0
GR15	NR	NR	0	NR	0	0	0	0	0.0
HR05	NR	NR	0	0	NR	0	0	0	0.0
HR09	NR	0	0	0	0	NR	0	0	0.0
HR10	NR	NR	0	0	0	NR	0	NR	0.0
HR18	NR	0	NR	NR	0	0	0	0	0.0
HR25	NR	0	0	4	2	1	0	0	1.0
MC03	NR	0	0	0	0	0	0	0	0.0
MC27	NR	0	0	0	0	0	0	0	0.0
PP13	0	0	0	0	0	NR	NR	0	0.0
PP15	0	0	NR	0	6	NR	1	1	1.6
PP16	0	0	0	0	1	NR	1	6	1.3
PP21	3	0	0	0	0	NR	0	2	0.3
PP29	0	0	0	NR	NR	NR	NR	NR	0.0
SF16	0	NR	0	0	NR	NR	0	NR	0.0
SF17	0	0	NR	0	0	NR	0	0	0.0
SF30	NR	0	0	NR	NR	NR	0	0	0.0
Total birds	**3**	**9**	**0**	**8**	**11**	**4**	**7**	**9**	**6.5**
# of transects w/ hits	**1**	**3**	**0**	**3**	**5**	**3**	**5**	**3**	**3.1**

NA = Transect not in Arapaho/Roosevelt during this year NR = Transect not conducted in this year

Transect survey data for the ARNF indicate that mountain bluebird population trends are somewhat variable but stable. Breeding trends at the continental level slightly increased from 1966 to 2000, but winter trends are too variable to be discernable (RMBO, 2002).

Estimated Effects and Rationale

Action Alternatives

The main risk factor for the mountain bluebird is the loss of old and downed trees used for perching and nesting, and the loss of forest openings used for foraging. Early seral habitats created by forest management activities may provide favorable habitat conditions for this species. Harvest activities may increase open areas and edge. Later seral stages would likely provide older trees with cavities. This species would most likely be affected by habitat loss, either directly or due to induced growth, and an increase in road effect zone-related disturbance

Direct Effects

Key Habitat Change

No key habitat was identified for the mountain bluebird on the ARNF. Forest openings could be considered key habitat, but vegetation mapping for the project did not identify forest openings. Because the ARNF has indicated that, forest-wide, approximately 15 percent of forested areas are in openings, it may be a reasonable assumption that 15 percent of any loss of MIS habitat in forest ecosystems identified earlier, may be a loss of openings.

Management Indicator Habitat Change

No management indicator habitat changes were identified for the mountain bluebird on the ARNF.

Forest-wide Standards and Guidelines require maintaining openings and managing to create new openings (USDA, 1997). Similar actions are occurring outside the ARNF, which may also have an impact on reproduction or habitat. None of the project alternatives is expected to measurably affect the habitat or populations of this species because the amount of disturbance is so small relative to adjacent habitat. All action alternatives would have minor direct effects from actual removal of habitat ranging from 2.4 to 20.2 acres.

Population Change

Because a large amount of habitat is available in and near the Corridor and effects from the Corridor would be relatively small in scope, impacts on the local population in the APE are expected to be negligible. The resultant effect on individual mountain bluebirds from loss of foraging and nesting habitat would be increased difficulty in foraging and nesting, possibly causing them to enlarge their foraging area and seek out new nesting areas. Increased difficulty in foraging and nesting would add stress to individuals but would not likely cause a viability risk to the species overall.

Indirect and Cumulative Effects

Possible indirect effects from the alternatives could result in increased forest visitation and possible increases in induced growth. The Transit alternatives may increase visitation to developed recreation areas and induce additional growth near the transit centers. Combination alternatives could contribute to a moderate amount of growth in Clear Creek County. The indirect effects would increase human presence and may remove some foraging habitat for the mountain bluebird.

In Clear Creek County, induced traffic from alternatives would not be expected to induce growth, based on past growth trends. Susceptibility to changes in human population due to induced growth would be limited to Eagle and Summit counties, outside ARNF lands **(see Chapter 3, Section 3.9 of the Draft PEIS).**

Cumulative effects are not likely to affect the mountain bluebird nesting habitat of older trees with cavities but may affect the broad use of meadow foraging habitat in the Corridor.

Effects of No Action

Because the No Action Alternative would not have any new impacts on habitat, the current level of impacts on the species would remain.

Effects Summary

Because a large amount of habitat is available in and near the Corridor and effects from the Corridor would be relatively small in scope, little change in habitat is expected forest-wide. Even though possible impacts may affect some individual mountain bluebirds, none of the action alternatives are expected to change forest-wide population trends. Accordingly, none of the alternatives being considered for this project would threaten the viability of mountain bluebirds. While there may be site-specific differences, there will be no measurable differences among alternatives on the ARNF populations.

Warbling Vireo (*Vireo gilvus*), MIS

Warbling vireo is a small passerine bird in the family Vireonidae, and the genus *Vireo*. These birds typically measure 5.5 inches long, with a wingspan of 8.5 inches, and weigh 0.42 ounces (Sibley, 2000).

Distribution

Distribution for the warbling vireo includes most of the U.S. and southern Canada. Breeding bird distribution in Colorado is concentrated in the western mountains (Kingery, 1998). There is documentation of breeding birds in Jefferson, Clear Creek, Summit, Eagle, and Garfield counties, among others in Colorado (Kingery, 1998). Although the warbling vireo is an MIS for aspen, data presented in RMBO (2002) for the ARNF showed higher densities in mixed conifer, ponderosa pine, and especially willow communities (RMBO, 2002).

Natural History

Warbling vireos in Colorado occupy two main habitat types: riparian stream bottoms and aspen forests. Breeding habitat in Colorado is primarily aspen woodlands. Warbling vireos build their nests in aspen trees or shrubs within 12 feet of the ground. The nests are compact basket-like deep cups, typically suspended from the forked tip of a branch or twig. They produce four eggs per brood on average (Ehrlich et al., 1988). Warbling vireos glean most of their food from the mid to upper canopy of deciduous trees, and their diet consists of caterpillars, beetles, grasshoppers, and ants (USDA, 1997), and occasionally spiders and berries (Ehrlich et al., 1988). In Colorado, warbling vireos are common on the plains during migration and in the mountains during summer.

Environmental Baseline

Warbling vireo is designated an MIS for aspen communities (USDA, 1997). Warbling vireos forage and breed almost exclusively in deciduous habitats. Significant stands of aspen within the Corridor are located in eastern Eagle County, Vail, and Dillon. Stands of aspen are also scattered within the portions of the Corridor on the ARNF.

Considered secure in Colorado (NatureServe, 2005), the warbling vireo is a fairly common summer resident in the foothills and lower mountains. In the western valleys and Eastern Plains, it is considered uncommon to fairly common. As a spring and fall migrant, it is thought to be uncommon in the western valleys, foothills, and Eastern Plains (Andrews and Righter, 1992). Breeding records exist for this species in Clear Creek County (Kingery, 1998), which contains a portion of the Corridor adjacent to ARNF.

The estimated statewide population in 1998 was 345,820 to 1,572,584 breeding pairs. Densities vary widely in Colorado (3.0 to 78.9 territories per 100 acres) and across the species' range (4.8 to 96.0 pairs per 100 acres) (RMBO, 2002). A clear population trend is not apparent for BBS data for ARNF. A slight increasing trend is apparent at the continental scale for all time periods examined (RMBO, 2002).

Table BR - 70 presents transect counts for warbling vireo in and near the ARNF since 1998. Population trends are variable, with decreases from 2001 through 2004 and a return to levels similar to 1998-1999 in 2005, noting that several transects were not read in 2003. A slight increasing trend is apparent at the continental scale in each of three different time periods from 1966 to 2000 (RMBO, 2002). The highest bird densities occurred in aspen, ponderosa pine habitats, and high-elevation riparian areas.

Table BR - 70. Warbling Vireo (Monitoring Colorado Birds Data, RMBO 2005) ARNF (number/transect/year)

Transect	1998	1999	2000	2001	2002	2003	2004	2005	Avg/Yr
AS28	21	NR	6	NR	NR	NR	1	8	3.5
AT02	NR	NR	NR	NR	0	0	0	NR	0.0
AT03	NR	0	NR	0	0	0	NR	0	0.0
AT04	NR	1	NR	NR	0	0	0	0	0.2
AT05	NR	0	0	0	0	0	0	0	0.0
AT06	NR	0	0	0	0	0	0	0	0.0
GR01	NR	0	0	0	0	0	0	0	0.0
GR02	NR	0	0	0	0	0	0	0	0.0
GR03	NR	0	NR	0	0	0	0	0	0.0
GR05-02	NR	NR	NR	NR	0	NR	NR	0	0.0
GR15	NR	NR	0	NR	0	0	0	0	0.0
HR05	NR	NR	2	0	NR	0	0	0	0.4
HR09	NR	0	7	7	5	NR	1	5	4.2
HR10	NR	NR	7	14	0	NR	1	NR	5.5
HR18	NR	0	NR	NR	0	0	0	0	0.0
HR25	NR	7	19	6	3	0	0	0	5.0
MC03	NR	4	1	7	0	2	3	8	3.6
MC27	NR	4	0	2	0	0	4	13	3.3
PP13	15	4	7	14	4	NR	NR	0	5.8
PP15	2	0	NR	0	0	NR	0	0	0.0
PP16	0	4	6	16	3	NR	5	4	6.3
PP21	0	0	0	3	6	NR	2	3	2.3
PP29	7	12	5	NR	5	NR	NR	NR	7.3
SF16	0	NR	0	0	NR	NR	0	NR	0.0
SF17	0	4	NR	1	0	NR	0	0	1.0
SF30	NR	0	0	NR	NR	NR	0	0	0.0
Total birds	**45**	**40**	**60**	**70**	**26**	**2**	**17**	**41**	**35.8**
# of transects w/ hits	**4**	**8**	**9**	**9**	**6**	**1**	**7**	**6**	**6.6**

NA = Transect not in Arapaho/Roosevelt during this year *NR = Transect not conducted in this year*

Estimated Effects and Rationale

Action Alternatives

Direct Effects

The potential for action alternatives to affect warbling vireo is based on whether MIS habitats are likely to be affected. The amount of area and habitat affected is related to the size of the alternative footprint and the construction disturbance zone, and its extent through the Corridor. Cross-referencing the applicable vegetation types that have been mapped along the Corridor identified the MIS habitats. The amount of applicable vegetation types that would be disturbed by construction of the alternative (footprint) and within the construction disturbance zone were then tabulated to determine potential impacts on warbling vireo habitat.

Key Habitat Change

No key habitat, only management indicator habitat (aspen), has been quantified for this species on the ARNF.

Management Indicator Habitat Change

None of the action alternatives would directly affect any acreage of warbling vireo's primary habitat of aspen woodland located on the ARNF, and none of this habitat occurred within the sensitivity zone.

Population Change

Lack of habitat changes indicates that none of the alternatives would affect the species. This species will continue to be monitored across the ARNF using the protocols developed as a part of the Revised Forest Plan. Aspen habitats on the ARNF landscape are expected to expand in the short and long term as mature lodgepole pine trees die as a result of a mountain pine beetle epidemic (Sumerlin et al., 2005).

Indirect and Cumulative Effects

In Clear Creek County, induced traffic from alternatives would not be expected to induce growth, based on past growth trends. Susceptibility to changes in population due to induced or suppressed travel demand would be limited to Eagle and Summit counties, outside ARNF lands. Clear Creek County is not expected to experience growth-inducing effects from project alternatives (see **Chapter 3, Section 3.9 of the Draft PEIS**).

Actions such as fire/fuel management and ski area development on ARNF lands may cause cumulative impacts on warbling vireo habitat by reducing or fragmenting existing habitat. Other cumulative effects include snowmobile and ATV use within the ARNF, which could affect warbling vireo habitat. The Combination and Highway alternatives are associated with possible increased dispersed recreation activities that would include snowmobile and ATV use. Also, planned development and induced population growth on private land could lead to increased recreation in warbling vireo MIS habitats.

Effects of No Action

No additional nesting or foraging habitat for warbling vireo would be directly affected by the No Action Alternative. Population trends would not be affected.

Effects Summary

The resultant effect on individual warbling vireos from loss of aspen habitat would be increased difficulty in feeding and nesting, possibly causing them to enlarge their feeding area and seek other nesting areas, possibly less suitable. Increased difficulty in foraging and less suitable nesting areas would add stress to individuals and may result in reduced success in reproduction but is not likely to cause any noticeable change to the species overall. Human intrusion may displace some nesting pairs but is unlikely to affect warbling vireo populations locally or the population trend forest-wide. There is no viability risk for warbling vireo (the potential for the population to substantially decrease is unlikely), and none of the project alternatives would threaten the viability of this species in the planning area or in the state.

Wilson's Warbler (*Wilsonia pusilla*), MIS

Wilson's warbler is a small passerine bird, in the family Parulidae, genus *Wilsonia.* The birds normally measure 4.75 inches long, with a wingspan of 7 inches and a weight of 0.27 ounces (Sibley, 2000).

Distribution

Wilson's warbler breeds from northern Alaska, northern Yukon, northern Ontario, southeastern Labrador, and Newfoundland south to southern California, central Nevada, northern Utah, northern New Mexico, central Ontario, northern New England, and Nova Scotia. They winter from southern California and southern Texas to Panama. The species conservation assessment (Johnson and Anderson 2003) states that within Region 2, suitable habitat occurs locally and is not extensive. The mountains of north-central Colorado support the greatest abundance of Wilson's warbler. Both Wyoming and Colorado have broadly dispersed populations due to distribution of high-elevation riparian habitats in those states (Johnson and Anderson, 2003). They are considered widespread in Colorado at high elevations during the breeding season. Wilson's warblers may be found in willow or alder thickets along the edge of streams, lakes, and beaver ponds (Kingery, 1998).

Natural History

Wilson's warblers are polygynous (one male mates with two or more females), producing a single brood per year with four to six eggs (Ehrlich et al., 1988). They usually build nests at the base of small trees or shrubs, often well concealed in a grass hummock. They eat insects gleaned from the ground and twigs or caught by flycatching, and they also eat spiders and fruit pulp (USDA, 1997).

Environmental Baseline

Wilson's warbler is designated a MIS species for montane riparian and wetland ecosystems (USDA 1997). Riparian areas within the Corridor are located along Clear Creek and Georgetown Lake, as well as scattered riparian areas.

Reported population densities vary widely in Colorado (1.0 to 432 breeding territories per 100 acres) and across the species' range (8.8 to 212 males per 100 acres), probably due to differences in survey technique, scale, and habitat suitability (RMBO, 2002). BBS data indicate a slight downward trend at the continental scale for the period 1980 to 2000 (RMBO, 2005). Breeding records for this warbler exist for Clear Creek County (Kingery, 1998), which contains a portion of the Corridor adjacent to ARNF. Kingery (1998) estimated the statewide population at 60,483 to 379,676 breeding pairs (mid-range estimate of 206,257 pairs), based on Breeding Bird Atlas methodology.

Table BR - 71 presents the results of transect monitoring for Wilson's warbler on the ARNF. Population trends are variable, apparently increasing from 1998 to 2001, decreasing in 2002, and increasing to average levels again in 2003 through 2005. At the continental scale, there is a slight downward breeding trend for the period 1980 to 2000 (RMBO 2002).

Table BR - 71. Wilson's Warbler (Monitoring Colorado Birds Data (RMBO 2005) ARNF (number/transect/year)

Transect	1998	1999	2000	2001	2002	2003	2004	2005	Avg/Yr
AS28	1	NR	0	NR	NR	NR	0	0	0.0
AT02	NR	NR	NR	NR	0	0	0	NR	0.0
AT03	NR	0	NR	0	0	0	NR	0	0.0
AT04	NR	0	NR	NR	0	1	0	1	0.4
AT05	NR	0	0	3	0	6	1	0	1.4
AT06	NR	0	0	0	0	0	0	0	0.0
GR01	NR	0	0	0	0	0	0	0	0.0
GR02	NR	0	0	0	0	0	0	0	0.0
GR03	NR	0	NR	0	0	0	0	0	0.0
GR05-02	NR	NR	NR	NR	0	NR	NR	0	0.0

Transect	1998	1999	2000	2001	2002	2003	2004	2005	Avg/Yr
GR15	NR	NR	0	NR	0	0	0	0	0.0
HR05	NR	NR	4	13	NR	0	4	0	4.2
HR09	NR	6	7	16	3	NR	0	5	6.2
HR10	NR	NR	4	1	3	NR	6	NR	3.5
HR18	NR	0	NR	NR	0	0	0	8	1.6
HR25	NR	0	0	6	1	7	2	5	3.0
MC03	NR	0	0	0	0	1	0	0	0.1
MC27	NR	0	0	0	0	0	0	0	0.0
PP13	0	1	0	0	0	NR	NR	0	0.2
PP15	0	0	NR	0	0	NR	0	0	0.0
PP16	0	0	0	0	0	NR	0	0	0.0
PP21	0	0	0	0	0	NR	0	0	0.0
PP29	0	0	0	NR	0	NR	NR	NR	0.0
SF16	0	NR	0	0	NR	NR	0	NR	0.0
SF17	0	0	NR	0	0	NR	0	0	0.0
SF30	NR	0	0	NR	NR	NR	0	0	0.0
Total birds	**1**	**7**	**15**	**39**	**7**	**15**	**13**	**19**	**16.0**
# of transects w/ hits	**1**	**2**	**3**	**4**	**3**	**4**	**4**	**4**	**3.4**

NA = Transect not in Arapaho/Roosevelt during this year *NR = Transect not conducted in this year*

Estimated Effects and Rationale

Action Alternatives

Direct Effects

The potential for action alternatives to affect Wilson's warbler is based on whether MIS habitats are likely to be affected. The amount of area and habitat affected is related to the size of the alternative footprint and construction disturbance zone, and its extent through the I-70 Corridor. Cross-referencing the applicable vegetation types that have been mapped along the Corridor identified the MIS habitats. The amount of applicable vegetation types that would be disturbed by the alternative footprint and by disturbances within the construction disturbance zone were then tabulated to determine potential impacts on Wilson's warbler habitat (see **Table BR - 72** and **Table BR - 73**). The ARNF has 1,937 miles of perennial streams flowing over National Forest System Lands (USDA, 1997).

Key Habitat Change

No key habitat, only management indicator habitat (that is, montane riparian and wetlands), has been quantified for Wilson's warbler.

Management Indicator Habitat Change

Table BR - 72 and **Table BR - 73** present the estimated direct impacts on potential MIS habitat for Wilson's warbler on the ARNF. Impacts from the Preferred Alternative would range from 0.4 acres (Minimum Program 55 or 65mph) to 4.6 acres (Maximum Program 55 or 65mph).

The Advanced Guideway System alternative would have the minimum direct effects on Wilson's warbler habitat (0.2 acres) versus the maximum direct effects of the Combination Six-Lane Highway with Rail and Intermountain Connection (5.2 acres). The direct effects of the remaining alternatives lie between these two extreme values. The direct effect for the Combination Six-Lane Highway with Rail and

Intermountain Connection alternative would represent a loss of approximately 0.01 percent of the total aspen habitat of 43,600 acres (including all structural stages) in the ARNF (USDA, 1997).

Table BR - 72. Direct Impacts on MIS Wilson's Warbler Habitat (acres): Preferred Alternative

	Minimum Program		Maximum Program	
	Specific Highway Improvements with AGS		Combination 6-Lane Highway with AGS	
	55 mph	65 mph	55 mph	65 mph
ARNF	0.4	0.4	4.6	4.6

Data provide the minimal to maximum impacts for the Preferred Alternative.

Table BR - 73. Direct Impacts on MIS Wilson's Warbler Habitat (acres): Action Alternatives Evaluated in the Draft PEIS

	Minimal Action	Rail with IMC	AGS	Dual-Mode Bus in Guideway	Diesel Bus in Guideway	Six-Lane Highway 55 mph	Six-Lane Highway 65 mph	Reversible/ HOV/HOT Lanes	Combination Six-Lane Highway with Rail and IMC	Combination Six-Lane Highway with AGS	Combination Six-Lane Highway with Dual-Mode	Combination Six-Lane Highway Diesel Bus in Guideway
ARNF	0.3	0.6	0.2	0.3	0.3	2.4	2.4	3.1	5.2	4.6	4.4	4.4

Population Change

The maximum direct effect would result from the Combination Six-Lane Highway with Rail and Intermountain Connection alternative. The habitat potentially lost for Wilson's warbler represents only 0.01 percent of the total MIS habitat available for this species on the ARNF. None of the alternatives being considered for the project are expected to noticeably change habitat or influence the Wilson's warbler within the Corridor area.

Indirect and Cumulative Effects

In Clear Creek County, induced traffic from alternatives would not be expected to induce growth, based on past growth trends. Susceptibility to changes in population due to induced or suppressed travel demand would be limited to Eagle and Summit counties, outside ARNF lands. Clear Creek County is not expected to experience growth-inducing effects from action alternatives (see **Chapter 3, Section 3.9 of the Draft PEIS**).

Other actions, such as fire/fuel management and recreation area development on ARNF lands, along with planned land use changes on lands adjacent to the ARNF may cause cumulative impacts on Wilson's warbler habitat by reducing or fragmenting existing habitat. Also, planned development and induced population growth on private land could lead to increased recreation in Wilson's warbler MIS habitats. Other cumulative effects include snowmobile and ATV use within the ARNF, which could affect Wilson's warbler's habitat. The Combination and Highway alternatives are associated with possible increased dispersed recreation activities that would include snowmobile and ATV use.

Effects of No Action

No additional nesting or foraging habitat would be directly affected by the No Action Alternative beyond what is already occurring. Population trends would not be affected.

Effects Summary

Because of the small percentage of management indicator habitat affected by the action alternatives, no change in the population of this species is expected in forest-wide trends. The resultant effect on individual Wilson's warblers from loss of foraging and breeding habitat would be increased difficulty in nesting and rearing young. In response, individual pairs may find new breeding habitat that may not be as suitable, possibly causing them to fail in their attempts at reproduction. Increased difficulty in reproducing would add stress to the local population and may cause a negligible decline in the number of local individuals. However, there is no viability risk for Wilson's warbler (the potential for the population to substantially decrease is unlikely), and none of the project alternatives would threaten the viability this species in the planning area or in the state.

Boreal Toad (*Bufo boreas boreas*), MIS

Boreal toad is designated as a MIS for the ARNF, as well as a Region 2 Forest Service Sensitive Species. This species is a MIS for montane riparian, wetland, and aquatic habitats (USDA, 1997).

Effects Summary

Amphibians under **Section BR.4.1.1 Sensitive Species** of this report should be referenced for habitat, environmental baseline (including population information, see **Table BR - 41** and **Table BR - 43** for trend data), proposed project effects, and viability determination as a sensitive species. Boreal toad population trends on the ARNF are variable. Some sites showed peak populations in the late 1990s and some as recent as 2002. Some sites appear to have stable, but small, populations. However, the ARNF population appears to have a downward trend.

The amount of acreage of boreal toad habitat directly affected by the project (less than 13.5 acres) would represent approximately 0.02 percent of the 87,000 acres of riparian vegetation on the ARNF. Additionally, the ARNF is implementing Forest Standards and Guidelines for the protection of the species and its habitat, which apply to Tier 2 project implementation. Therefore, none of the action alternatives are expected to change the ARNF population. Accordingly, none of the action alternatives being considered for this project would threaten the viability of the boreal toad.

The No Action Alternative would not cause any additional changes to the existing condition of habitat, create any additional impacts, or change ARNF population trends. The No Action Alternative would not create a viability risk for the boreal toad population.

Brook Trout (*Salvelinus fontinalis*) and Brown Trout (*Salmo trutta*), MIS

Brook trout is actually a char in the family Salmonidae, genus *Salvelinus.* It is considered an exotic, introduced fish in Colorado. Brown trout also is in the family Salmonidae, genus *Salmo*. These trout species are designated MIS for montane aquatic habitats.

Distribution

Brook trout is native to most of eastern Canada from Newfoundland to the western side of Hudson Bay, south in the Atlantic, Great Lakes, and Mississippi River basins to Minnesota and (in the Appalachians) northern Georgia. The species is introduced in western North America and temperate regions in many other parts of the world (NatureServe, 2006).

Brown trout is native to Europe and western Asia. It was introduced and established throughout much of the U.S. and southern Canada and is locally common (NatureServe, 2006).

Natural History

According to information compiled by Sumerlin, Popovich, and Renner (2005), the primary threats to brook and brown trout in their home range include loss of habitat due to logging, fires, river impoundment, road and railroad construction, land clearance for agriculture and human habitation, and encroachment of introduced rainbow trout and brown trout (Larson and Moore, 1985). In general, a brook trout population responds most negatively to factors that decrease survival of large juveniles and small adults and that decrease growth rates of small juveniles (Larscheid and Hubert, 1992).

Brook trout are often believed to be a primary agent in the disappearance of native salmonid species, including bull trout (*S. confluentus*) and cutthroat trout (*O. mykiss* spp.) (Buktenica, 1997; and Peterson, Fausch, and White, 2004). Therefore, many state and federal agencies have been working cooperatively to remove brook trout from streams where they conflict with native species and to limit the expansion of their range into areas where they may detrimentally affect the native aquatic biota (Drake and Naiman, 2000; and CDOW, 2001a).

Brook trout occupy clear, cool, well-oxygenated creeks, and small to medium rivers and lakes. They may move from streams into lakes or seas to avoid high temperatures in summer. Their preferred temperature range is between 57 and 61 degrees F (Sublette, Hatch, and Sublette, 1990). Brook trout usually spawn over gravel beds in shallow headwaters. Brook trout will feed opportunistically on various invertebrate and vertebrate animals, including terrestrial and aquatic insects and planktonic crustaceans (in lakes) (NatureServe, 2005g).

Brook trout spawn during late summer or fall. Eggs hatch in 47 to 165 days, depending on the temperature. Brook trout mature early, with males generally spawning after their second year and females generally after their third year (Moyle, 1976). Brook trout can migrate over extensive stream and river networks. They have been observed to ascend channels with gradients greater than 22 percent and falls more than 3.9 feet high (Adams, 1994).

Brown trout were introduced into Colorado streams in the early 1880s and have supplanted many of the native species, as well as introduced trout species in Forest drainage systems. This species is able to out-compete other trout species, and it can survive in warmer water and lower oxygen levels (Pijoan, 1985). Brown trout prey on other species of trout and compete with them for food and space (Sublette et al., 1990). Brown trout spawn from fall into winter.

Environmental Baseline

Brook trout populations on the ARNF generally have a stable trend. Of six populations monitored (see **Table BR - 74**), because data points are few in number with several years intervening, it is difficult to determine population trends in the streams. Within the project area, brook trout are the dominant aquatic species and are present in Clear Creek (downward trend) and Vasquez Creek (upward).

Table BR - 74. Brook Trout Abundance and Trend Data on the ARNF

Stream Name	Years Surveyed						
Vasquez Creek	**1990**	**1992**	**2001**	**2004**			
fish/mile	0	8	414	258			
St. Louis Creek	**1978**	**1986**	**1987**	**1988**	**2000**	**2003**	**2005**
fish/mile	317	612	201	1647	1973	3408	531
Kinney Creek	**1992**	**1997**	**2000**	**2003**			
fish/mile	239	387	143	432			
Little Muddy Creek	**1979**	**1992**	**2000**	**2006**	**2009**		
fish/mile	0	352	1083	1175			
Deadman Creek	**1981**	**2000**	**2004**	**2008**			
fish/mile	211	1503	105	1557			
WFK Clear Creek	**1973**	**1994**	**1995**	**1999**	**2000**	**2001**	**2009**
fish/mile	0	198	271	860	798	883	

Brown trout populations have fluctuated considerably in the streams during the period that monitoring has been conducted (see **Table BR - 75**). Biological monitoring conducted at 10 locations on the Eagle River annually from 1990 through 2003 documents that brown trout population estimates “peaked” in varying years from 2001 through 2003, depending on the station. For example, below Redcliff, brown trout “peaked” in 2001; above Belden, the peak was in 2003. The numbers at various stations seem to be evenly divided among 2001, 2002, and 2003 (Hebein, 2006). There are electrofishing data for the Blue

River below Dillon Dam from 1985 through 1994. Sampling in that reach was not conducted between 1995 and 2000. In fall 2001, the number of brown trout per mile just below the dam stood at 2,880, which was more than any previous sampling period (Hebein, 2006).

Table BR - 75. Brown Trout (*Salmo trutta*) Population Estimates on the ARNF

Stream Name	Years Surveyed						
Big Thompson	**1974**	**1987**	**1989**	**2000**			
fish/mile	195	333	555	1149			
Nunn Creek	**1981**	**2000**	**2003**	**2004**	**2006**	**2008**	
fish/mile	106	1475	97	90	2250	2270	
Cache la Poudre	**1994**	**2000**	**2001**	**2002**			
fish/mile	817	1790	1199	258			

Estimated Effects and Rationale

Action Alternatives

The potential for action alternatives to affect trout is based on whether MIS habitats, both stream and open water, are likely to be affected.

Direct Effects

Key Habitat Change

Key habitat was not quantified for brook and brown trout. All analyses were conducted on MIS habitat (streams, lakes, and ponds).

Management Indicator Habitat Change

Table BR - 76 and **Table BR - 77** provide estimated direct impacts on open waters on the ARNF. The footprints of all the action alternatives would encroach on stream habitats, as would the construction and sensitivity zones. Overall, impacts from the alternative footprints would be relatively small. Impacts from the Preferred Alternative would range from 0.2 acres (Minimum Program 55 or 65mph) to 1.0 acre (Maximum Program 55 or 65mph).

Six alternatives would affect 0.2 acres of open water (lakes and ponds): Minimal Action, Advanced Guideway System, Dual-Mode Bus in Guideway, Diesel Bus in Guideway, Minimum Program Preferred Alternative (55 mph), and Minimum Program Preferred Alternative (65 mph). The Rail with Intermountain Connection alternative would disturb 0.3 acres, while the two Six-Lane Highway alternatives would disturb 0.4 acres of open water. At 1.2 acres, the Combination Six-Lane Highway with Rail and Intermountain Connection alternative would disturb the greatest amount of open water. The Reversible HOV/HOT Lanes, the Maximum Program Preferred Alternative (55 or 65mph), and all other Combination alternatives would disturb between 0.7 and 1.1 acres of open water habitat. The maximum impacts from the action alternatives would represent less than 0.001 percent of the open water resources of the ARNF (13,400 acres).

Table BR - 76. Direct Impacts on Open Waters (acres of open water): Preferred Alternative

	Minimum Program		Maximum Program	
	Specific Highway Improvements with AGS		Combination 6-Lane Highway with AGS	
	55 mph	65 mph	55 mph	65 mph
ARNF	0.2	0.2	1.0	1.0

Data provide the minimal to maximum impacts for the Preferred Alternative.

Table BR - 77. Direct Impacts on Open Waters (acres of open water): Action Alternatives Evaluated in the Draft PEIS

	Minimal Action	Rail with IMC	AGS	Dual-Mode Bus in Guideway	Diesel Bus in Guideway	Six-Lane Highway 55 mph	Six-Lane Highway 65 mph	Reversible/ HOV/HOT Lanes	Combination Six-Lane Highway with Rail and IMC	Combination Six-Lane Highway with AGS	Combination Six-Lane Highway with Dual-Mode	Combination Six-Lane Highway Diesel Bus in Guideway
ARNF	0.2	0.3	0.2	0.2	0.2	0.4	0.4	0.7	1.2	1.0	1.1	1.1

Table BR - 78 and **Table BR - 79** provide estimated direct impacts on streams on the ARNF, in linear feet of stream. Stream habitat for trout species also would be disturbed by construction activities for the action alternatives. The least amount of stream disturbance would result from the Minimal Action, Transit, and Minimum Program 55 or 65mph alternatives (feet). The Highway alternatives would disturb from 1,949.4 to 2672.9 linear feet, the Combination alternatives would disturb from 3317.1 to 3638.3 linear feet, and the Maximum Program 55 or 65mph alternatives would disturb 3317.1 linear feet. These affected stream reaches represent approximately 0.4 percent of perennial streams.

Table BR - 78. Direct Impacts on Open Waters (linear feet of stream): Preferred Alternative

	Minimum Program		Maximum Program	
	Specific Highway Improvements with AGS		6-Lane Highway with AGS	
	55 mph	65 mph	55 mph	65 mph
ARNF	840.5	840.5	3317.1	3317.1

Data provide the minimal to maximum impacts for the Preferred Alternative.

Table BR - 79. Direct Impacts on Streams (linear feet of stream): Action Alternatives Evaluated in the Draft PEIS

	Minimal Action	Rail with IMC	AGS	Dual-Mode Bus in Guideway	Diesel Bus in Guideway	Six-Lane Highway 55 mph	Six-Lane Highway 65 mph	Reversible/ HOV/HOT Lanes	Combination Six-Lane Highway with Rail and IMC	Combination Six-Lane Highway with AGS	Combination Six-Lane Highway with Dual-Mode	Combination Six-Lane Highway Diesel Bus in Guideway
ARNF	840.5	840.5	840.5	840.5	840.5	1949.3	1940.5	2672.9	3638.3	3317.1	3444.8	3444.8

Population Change

The relatively small amount of stream disturbance from construction is unlikely to reduce trout populations. Indirect effects that decrease habitat quality may affect some population segments. Reduction of these effects will be developed as part of the Preferred Alternative, which would help maintain and possibly increase population numbers. The resultant effect on individual trout from loss of aquatic habitat would be increased difficulty in rearing young and foraging. In response, trout may have difficulty finding new suitable breeding habitat, possibly causing them to fail in their attempts at reproduction. Increased difficulty in foraging and reproducing would add stress to the local population and may cause a decline in the local population, but may or may not cause a viability risk to the species overall.

Indirect and Cumulative Effects

In Clear Creek County, induced traffic from alternatives would not be expected to induce growth, based on past growth trends. Susceptibility to changes in population due to induced or suppressed travel demand would be limited to Eagle and Summit counties, outside ARNF lands. Clear Creek County is not expected to experience growth-inducing effects from project alternatives **(see Chapter 3, Section 3.9 of the Draft PEIS).**

Continued human population growth, associated developments, and planned land use changes on lands adjacent to the ARNF, especially in Clear Creek County, have the potential to affect aquatic habitats from increased runoff rates and the amount of sedimentation and contamination that would occur in area streams. Increased runoff rates also cause stream channelization, which, along with decreases in water quality, would degrade fishery habitat values.

CDOT is currently evaluating measures to reduce the amount of winter maintenance material entering stream systems, even though with the addition of traffic lanes for the Highway and Combination alternatives, more material would be applied. Construction of alternatives, although directly affecting aquatic habitats, also would provide an opportunity in these areas to improve aquatic habitat and mitigate impacts that occurred during the original construction of I-70. Such mitigation is part of the design of the action alternatives.

Effects of No Action

Under the No Action Alternative, no construction-related effects would occur and no additional loss of stream habitat would occur as a result of project activities. However, growth and land use conversion would continue to affect streams and riparian habitats. Conversely, fewer opportunities would be realized to capture greater amounts of road runoff and to improve stream habitat along the highway.

Effects Summary

Most of the impacts on stream habitat and on trout would occur during construction activities. Increases of contamination and sedimentation, however, would also be likely to occur with the addition of lanes, transportation modes, and volumes. Conversely, construction also would provide an opportunity to reduce the current impact levels that occur from roadway runoff of contaminants and from winter maintenance materials, as well as to improve reaches of stream habitat that were negatively affected by the original I-70 construction.

Based on the above evaluations, none of the action alternatives would create any viability risk (the potential for populations to substantially decrease) for trout. None of the alternatives being considered for this project would threaten the viability of trout within the Corridor area of influence, on the ARNF, or in Colorado.

Effects on brook and brown trout and their habitat associated with the No Action Alternative may include similar levels or even gradual increases of road maintenance materials runoff and sediment loading of aquatic habitats and wetlands. This assumes no additional construction of drainage or water quality mitigation measures in the Corridor.

Colorado River Cutthroat Trout (*Oncorhynchus clarki pleuriticus*), MIS

Colorado River cutthroat trout is a MIS for the ARNF, as well as a Region 2 Forest Service Sensitive Species. This species is designated a MIS for montane riparian habitats and wetlands (USDA, 1997). See Fish under **Section BR.4.1.1 Sensitive Species** of this report for more information about the distribution, natural history, environmental baseline, and proposed project effects. That section also presents a Determination of Effects and Rationale as a sensitive species. Colorado River cutthroat trout are known on the ARNF from the upper reaches of the Colorado River in Grand County, and from Little Muddy and Kelly creeks on the Sulphur District in Grand County.

Information from the USFS (2000) indicated that conservation populations do not occur in the Corridor near the ARNF. However, individuals have been recorded at locations near the Corridor in the Blue and Eagle river drainages. Locations in the Blue River drainage include Polk and Meadow creeks and Dillon

Reservoir. Records in the Eagle drainage include Berry and Black Gore creeks, and Miller, Booth, and Pitkin creeks in the upper and middle Gore Creek drainage, as well as Gore Creek itself.

Effects Summary

Open water habitat for trout would be disturbed by all of the action alternatives. Impact tables for this disturbance were presented in Section 0 for brook trout and brown trout species on the ARNF. Open water disturbance on the ARNF would range from 0.2 to 1.1 acres. All action alternatives would disturb less than 1 acre of open water except for Combination Six-Lane Highway with Rail and Intermountain Connection and the two Combination alternatives with Dual-Mode and Diesel Bus in Guideway, disturbing 1.2, 1.1, and 1.6 acres, respectively. The maximum open water disturbance figure represents approximately 0.01 percent of the 14,000 acres of open water on the ARNF.

Stream habitat for trout would be disturbed by all of the action alternatives. Impact tables for this disturbance were presented under the discussion for brook trout and brown trout species on the ARNF. Stream disturbance on the ARNF would range from 840.5 to 3638.3 linear feet. Minimal Action and the Transit alternatives (except for Rail with Intermountain Connection) would disturb from 840.5 linear feet. The Highway alternatives would disturb from 1940.5 to 2672.9 linear feet. The greatest stream habitat disturbance would result from the Combination alternatives (3317.1 to 3638.3 linear feet). The maximum stream disturbance figure represents approximately 0.4 percent of the 1,937 miles of perennial streams on the ARNF.

None of the action alternatives would create disturbance in the drainages that contain Colorado River cutthroat trout on the ARNF. Due to the high level of concern for Colorado River cutthroat trout viability, additional Forest Standards and Guidelines were developed to greatly restrict management-related disturbance near stream reaches known to contain this trout. The Standards and Guidelines were designed to achieve the goals of perpetuating water-related values and sustaining riparian areas. Differences among action alternatives would not be measurable forest-wide, and even the variations at the project level would not have measurable differences for the trout habitat.

Based on the above evaluations, none of the action alternatives would create any viability risk (the potential for populations to substantially decrease) for the Colorado River cutthroat trout. None of the alternatives being considered for this project would threaten the viability of Colorado River cutthroat trout within the planning area, on the ARNF, or in Colorado.

The No Action Alternative would result in a continuation of the adverse impacts on water quality from sedimentation and materials used for winter highway maintenance.

Greenback Cutthroat Trout (*Oncorhynchus clarki stomias*), MIS

Greenback cutthroat trout is designated as a MIS for the ARNF, as well as being a federally listed threatened species. This species is a MIS for montane aquatic environments (USDA 1997). **Section BR.3.1.3** of this report should be referenced for distribution, natural history, environmental baseline, including population information, proposed project effects, and viability determination as a management indicator species.

The greenback cutthroat trout currently occurs in 61 sites that total 410 acres of lakes and 100 miles of stream habitat in the upper tributaries of the South Platte and Arkansas River drainages (USFWS, 1998). Nine “historic” populations remain that have been identified through recovery efforts conducted since 1973. Pure greenbacks have been introduced in 52 additional streams and lakes within the species historic range. At present, 20 populations are believed to stable self-sustaining populations. The “historic” populations are located in the higher elevations of the species’ historic range, probably because of less habitat disturbance and less accessibility to humans than occurred in the lower elevations (USFWS, 1998).

Greenback cutthroat trout in the Clear Creek population may be directly affected by construction or road effect zone impacts such as increased runoff volume, runoff of highway maintenance solutions, and sedimentation. However, the viable Dry Gulch greenback cutthroat trout populations occur upstream of I-70 by approximately 400 feet or more, which minimizes the potential for direct impacts. The maintenance of stream barriers between Clear Creek and Dry Gulch is imperative in maintaining the pure strain of greenback cutthroat in Dry Gulch. The Clear Creek population is unlikely to be reproducing, may already be affected by heavy metal contamination, and may exist due to trout migrating from Dry Gulch (B. Rosenlund pers. comm. with L. Hettinger, 2004).

Direct impacts on habitat for this species in Clear Creek include 0.49 acres in the I-70 footprint zone and 0.14 acres in the construction disturbance zone. However, any water depletions may affect this Platte River basin species.

Effects Summary

Direct impacts on habitat for the greenback cutthroat trout will result from construction of all action alternatives, where construction would include impacts in sensitive portions of the occupied habitat in Clear Creek. Temporary indirect effects are also possible if water depletions are required for construction and if contaminants or sedimentation affects greenback cutthroat trout habitat in upper Clear Creek. However, additional sediment control features are designated as part of the Preferred Alternative, as are BMPs that are mandated by CDOT. The additional sediment control and the best management practices are expected to the maintain water quality of upper Clear Creek. After considering the above, it was determined that the action alternatives may affect individual greenback cutthroat trout and perhaps the local population in upper Clear Creek, but not the viable population in Dry Gulch. However, there is no viability risk for this trout (the potential for the population to substantially decrease is unlikely), and none of the project alternatives would threaten the viability of this species in the planning area or in the state.

The No Action Alternative would result in a continuation of the adverse impacts on water quality from sedimentation and materials used for winter highway maintenance.

BR.4.3 Summary of Determinations/Estimation of Effects (Before Implementing Mitigation)

Table BR - 80 summarizes determinations/estimated effects. Most species that live in aquatic environments or depend directly on water for habitat were determined to be “affected” until water requirements are known for specific projects. Also, some temporary effects from construction runoff may affect water habitats. Mitigation measures that are an integral part of the description of the alternative that include sediment traps on new sections of roadways would reduce contaminant runoff from new lane addition areas. **Table BR - 80** is a summary of all species that have been analyzed in this document after having been carried forward from **Table BR - 2**, **Table BR – 3**, and **Table BR - 4**.

Table BR - 80. Summary of Estimated Effects

Common Name	Scientific Name	Status[a]	Impact Determination[b] No Action	Minimal Action	Transit Alternatives	Highway Alternatives	Combination Alternatives (includes Preferred Alternative)
Federally Listed Species							
Canada lynx	*Lynx canadensis*	FT	LAA, NCEL	LAA, PCEL	LAA, PCEL	LAA, PCEL	LAA, PCEL
Least tern	*Sterna antillarum*	FE	NE	LAA	LAA	LAA	LAA
Piping plover	*Charadrius melodus*	FT	NE	LAA	LAA	LAA	LAA
Whooping crane	*Grus americana*	FE	NE	LAA	LAA	LAA	LAA
Bonytail chub	*Gila elegans*	FE	NE	LAA	LAA	LAA	LAA
Colorado pikeminnow	*Ptychocheilus lucius*	FE	NE	LAA	LAA	LAA	LAA
Humpback chub	*Gila cypha*	FE	NE	LAA	LAA	LAA	LAA
Razorback sucker	*Xyrauchen texanus*	FE	NE	LAA	LAA	LAA	LAA
Pallid sturgeon	*Scaphirhynchus albus*	FE	NE	LAA	LAA	LAA	LAA
Greenback cutthroat trout	*Oncorhynchus clarki stomias*	FT, FS-MIS	NE	LAA	LAA	LAA	LAA
Western prairie fringed orchid	*Platanthera praeclara*	FT	NE	LAA	LAA	LAA	LAA
Ute ladies'-tresses orchid	*Spiranthes diluvialis*	FT	NE	LAA	LAA	LAA	LAA
USFS-Sensitive Species							
Pygmy shrew	*Sorex hoyi montanus*	FS-S	MAII, NCEL	MAII, NCEL	MAII, NCEL	MAII, NCEL	MAII, NCEL
River otter	*Lontra canadensis*	FS-S	MAII NCEL	MAII, NCEL	MAII, NCEL	MAII, NCEL	MAII, NCEL
American marten	*Martes americana*	FS-S	MAII, NCEL	MAII, PCEL	MAII, PCEL	MAII, PCEL	MAII, PCEL
North American wolverine	*Gulo gulo luscus*	FS-S	MAII, NCEL	MAII, PCEL	MAII, PCEL	MAII, PCEL	MAII, PCEL
Bighorn sheep	*Ovis canadensis*	FS-S, FS-MIS	MAII NCEL	MAII, PCEL	MAII PCEL	MAII PCEL	MAII PCEL
Bald eagle	*Haliaeetus leucocephalus*	FS-S	NI	MAII	MAII	MAII	MAII
Northern goshawk	*Accipiter gentilis*	FS-S	NI	MAII	MAII	MAII	MAII
American peregrine falcon	*Falco peregrinus anatum*	FS-S	NI	MAII	MAII	MAII	MAII
White-tailed ptarmigan	*Lagopus leucurus*	FS-S	NI	MAII	MAII	MAII	MAII
Boreal owl	*Aegolius funereus*	FS-S	NI	MAII	MAII	MAII	MAII
Flammulated owl	*Otus flammeolus*	FS-S	MAII	MAII	MAII	MAII	MAII
Black swift	*Cypseloides niger*	FS-S	NI	MAII	MAII	MAII	MAII
Brewer's sparrow	*Spizella breweri*	FS-S	NI	MAII	MAII	MAII	MAII
American three-toed woodpecker	*Picoides tridactylus dorsalis*	FS-S	NI	MAII	MAII	MAII	MAII
Olive-sided flycatcher	*Contopus cooperi*	FS-S	NI	MAII	MAII	MAII	MAII

Common Name	Scientific Name	Status[a]	Impact Determination[b] No Action	Minimal Action	Transit Alternatives	Highway Alternatives	Combination Alternatives (includes Preferred Alternative)
Boreal toad	*Bufo boreas boreas*	FS-S, FS-MIS	MAII, NCEL	MAII, NCEL	MAII, NCEL	MAII, NCEL	MAII, NCEL
Northern leopard frog	*Rana pipiens*	FS-S	MAII, NCEL	MAII, NCEL	MAII, NCEL	MAII, NCEL	MAII, NCEL
Colorado River cutthroat trout	*Oncorhynchus clarki pleuriticus*	FS-S, FS-MIS	NI	MAII	MAII	MAII	MAII
Bluehead sucker	*Catostomus discobolus discobolus*	FS-S	NI	MAII	MAII	MAII	MAII
Flannelmouth sucker	*Catostomus latipinnis*	FS-S	MAII	MAII	MAII	MAII	MAII
Harrington's Beardtongue	*Penstemon harringtonii*	FS-S	MAII	MAII	MAII	MAII	MAII
Front Range or Rocky Mountain cinquefoil	*Potentilla rupincola*	FS-S	MAII	MAII	MAII	MAII	MAII
Narrow-leaved moonwort	*Botrychium lineare*	FS-S	MAII	MAII	MAII	MAII	MAII
Paradox moonwort	*Botrychium paradoxum*	FS-S	MAII	MAII	MAII	MAII	MAII
Upswept moonwort	*Botrychium ascendens*	FS-S	MAII	MAII	MAII	MAII	MAII
Altai cotton-grass	*Eriophorum altaicum var. neogaeum*	FS-S	NI	NI	NI	NI	NI
Autumn willow	*Salix serissima*	FS-S	NI	NI	NI	NI	NI
Baltic sphagnum	*Sphagnum balticum*	FS-S	NI	NI	NI	NI	NI
Budding monkeyflower	*Mimulus gemmiparus*	FS-S	NI	NI	NI	NI	NI
Dwarf raspberry [*Rubus arcticus* var. *acaulis*]	*Cylactis*	FS-S	MAII	MAII	MAII	MAII	MAII
Hoary willow	*Salix candida*	FS-S	NI	NI	NI	NI	NI
Kotzebue's grass-of-Parnassus	*Parnassia kotzebuei*	FS-S	NI	NI	NI	NI	NI
Lesser bladderpod	*Utricularia minor*	FS-S	NI	NI	NI	NI	NI
Lesser panicled sedge	*Carex diandra*	FS-S	MAII	MAII	MAII	MAII	MAII
Livid sedge	*Carex livida*	FS-S	NI	NI	NI	NI	NI
Yellow lady's-slipper	*Cypripedium parviflorum (=C. calceolus ssp. Parviflorum)*	FS-S	NI	NI	NI	NI	NI
Park milkvetch	*Astragalus leptaleus*	FS-S	MAII	MAII	MAII	MAII	MAII
Porter's feathergrass	*Ptilagrostis porteri*	FS-S	NI	NI	NI	NI	NI
Roundleaf sundew	*Drosera rotundifolia*	FS-S	NI	NI	NI	NI	NI
Simple kobresia	*Kobresia simpliciuscula*	FS-S	MAII	MAII	MAII	MAII	MAII
Colorado tansy-aster	*Machaeranthera coloradoensis*	FS-S	NI	NI	NI	NI	NI
Slender cotton-grass	*Eriophorum gracile*	FS-S	NI	NI	NI	NI	NI
Hall's fescue	*Festuca hallii*	FS-S	NI	NI	NI	NI	NI
Sphagnum	*Sphagnum angustifolium*	FS-S	NI	NI	NI	NI	NI
Selkirk's violet	*Viola selkirkii*	FS-S	MAII	MAII	MAII	MAII	MAII

Common Name	Scientific Name	Status[a]	Impact Determination[b]: No Action	Minimal Action	Transit Alternatives	Highway Alternatives	Combination Alternatives (includes Preferred Alternative)
USFS MIS							
WRNF							
Elk	*Cervus elaphus*	FS-MIS	PEU, HEU, NCEL	PEU, HEU, PCEL	PEU, HEU, PCEL	PEU, HEU, PCEL	PEU, HEU, PCEL
Virginia's warbler	*Vermivora virginiae*	FS-MIS	NI	PEU, HEU	PEU, HEU	PEU, HEU	PEU, HEU
All trout	All species	FS-MIS	NI	PEU, HEU	PEU, HEU	PEU, HEU	PEU, HEU
Aquatic macroinvertebrates	All species	FS-MIS	NI	PEU, HEU	PEU, HEU	PEU, HEU	PEU, HEU
ARNF							
Elk	*Cervus elaphus*	FS-MIS	PEU, HEU, NCEL	PEU, HEU, PCEL	PEU, HEU, PCEL	PEU, HEU, PCEL	PEU, HEU, PCEL
Mule deer	*Odocoileus hemionus*	FS-MIS	PEU, HEU, NCEL	PEU, HEU, PCEL	PEU, HEU, PCEL	PEU, HEU, PCEL	PEU, HEU, PCEL
Bighorn sheep	*Ovis canadensis*	FS-S, FS-MIS	PEU, HEU, NCEL	PEU, HEU, PCEL	PEU, HEU, PCEL	PEU, HEU, PCEL	PEU, HEU, PCEL
Hairy woodpecker	*Picoides villosus*	FS-MIS	NI	PEU, HEU	PEU, HEU	PEU, HEU	PEU, HEU
Pygmy nuthatch	*Sitta pygmaea*	FS-MIS	NI	PEU, HEU	PEU, HEU	PEU, HEU	PEU, HEU
Mountain bluebird	*Sialia currucoides*	FS-MIS	NI	PEU, HEU	PEU, HEU	PEU, HEU	PEU, HEU
Warbling vireo	*Vireo gilvus*	FS-MIS	NI	PEU, HEU	PEU, HEU	PEU, HEU	PEU, HEU
Wilson's warbler	*Wilsonia pusilla*	FS-MIS	NI	PEU, HEU	PEU, HEU	PEU, HEU	PEU, HEU
Trout species (brook, brown)	(*Salvelinus fontinalis* and *Salmo trutta*)	FS-MIS	NI	PEU, HEU	PEU, HEU	PEU, HEU	PEU, HEU
Boreal toad	*Bufo boreas boreas*	FS-MIS	NCEL	PEU HEU	PEU HEU	PEU HEU	PEU HEU
Colorado River cutthroat trout	*Oncorhynchus clarki pleuriticus*	FS-MIS	NI	PEU HEU	PEU HEU	PEU HEU	PEU HEU
Greenback cutthroat trout	*Oncorhynchus clarki stomias*	FT, FS-MIS	HEL	PEU HEL	PEU HEL	PEU HEL	PEU HEL

Status
FE = Federally listed as endangered
FT = Federally listed as threatened
FS-S = Listed as Forest Service sensitive

USFS Determinations
NI = No Impact
MAII = May adversely impact individuals but not likely to result in a loss of viability in the Planning area nor cause a trend to federal

Common Name	Scientific Name	Status[a]	Impact Determination[b]: No Action	Minimal Action	Transit Alternatives	Highway Alternatives	Combination Alternatives (includes Preferred Alternative)

FC = Federal candidate for listing
FS-MIS = Management Indicator Species

listing.
LRLV = Likely to result in loss of species viability

[b] Impact Determinations

Federal Determinations
NE = No Effect
LAA = Likely to Adversely Affect
NLAA = May Affect, Not Likely to Adversely Affect
Other PEIS Determinations
PCEL = Positive Wildlife Crossing Effects Likely
NCEL = Negative Wildlife Crossing Effects Likely

MIS Determinations
PEU = Population Effects Unlikely
HEU – Habitat Effects Unlikely
PEL = Population Effects Likely
HEL = Habitat Effects Likely

** Action alternatives would have relatively greater impacts on occupied habitats than the No Action Alternative. Impacts associated with action alternatives would increase proportionally to the amount of occupied area that could be disturbed from each action alternative or with increasing recreational visitor use.*

BR.4.4 Responsibility for a Revised Biological Evaluation

This Biological Report was prepared based on the best currently available scientific information. If the action is modified in a manner that causes effects not considered, or if new information becomes available that reveals that the action may affect endangered, threatened, proposed, or sensitive species in a manner or to an extent not previously considered, a new or revised Biological Report would be required.

BR.4.5 Monitoring

Population trend monitoring for MIS is appropriate at a broad scale and not conducted on a project-level basis. Monitoring to evaluate the effectiveness of treatment design for some species is recommended and should be addressed further in Tier 2 processes. Results may be used as the basis to modify project design in the future.

BR.4.6 Wildlife Linkage Interference Zone Mapping

The following figures provide individual maps of each of the 15 wildlife linkage interference zones identified by the ALIVE Committee throughout the Corridor.

BR.4.7 References and/or Literature Cited

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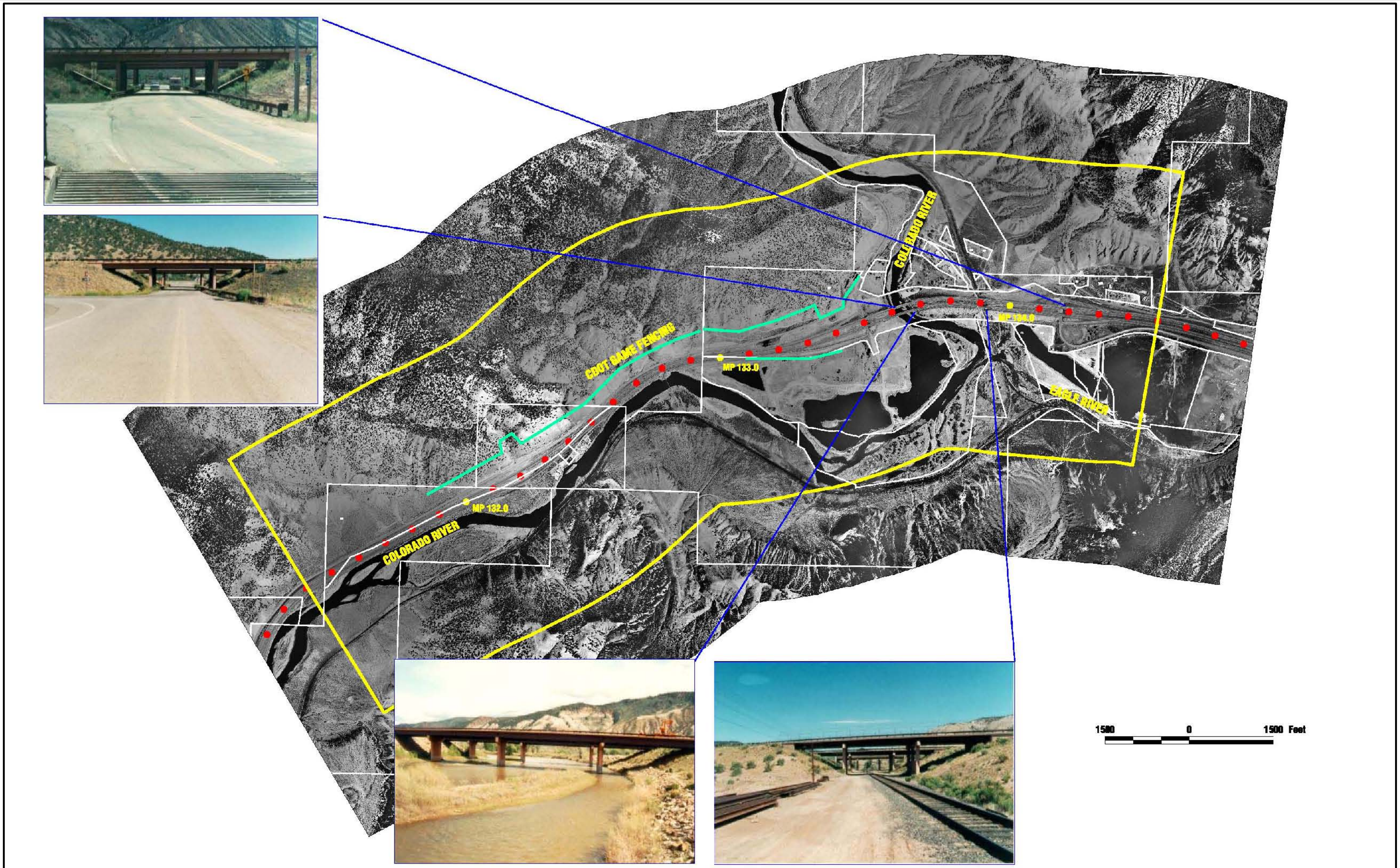

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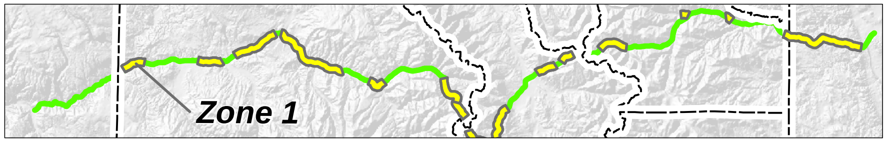
- I-70 Shoulder Barriers
- I-70 Median Barriers
- Bridges, Culverts & Drainages



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Wildlife Linkage Interference Zone 1: Dotsero Area

Map 1 of 14

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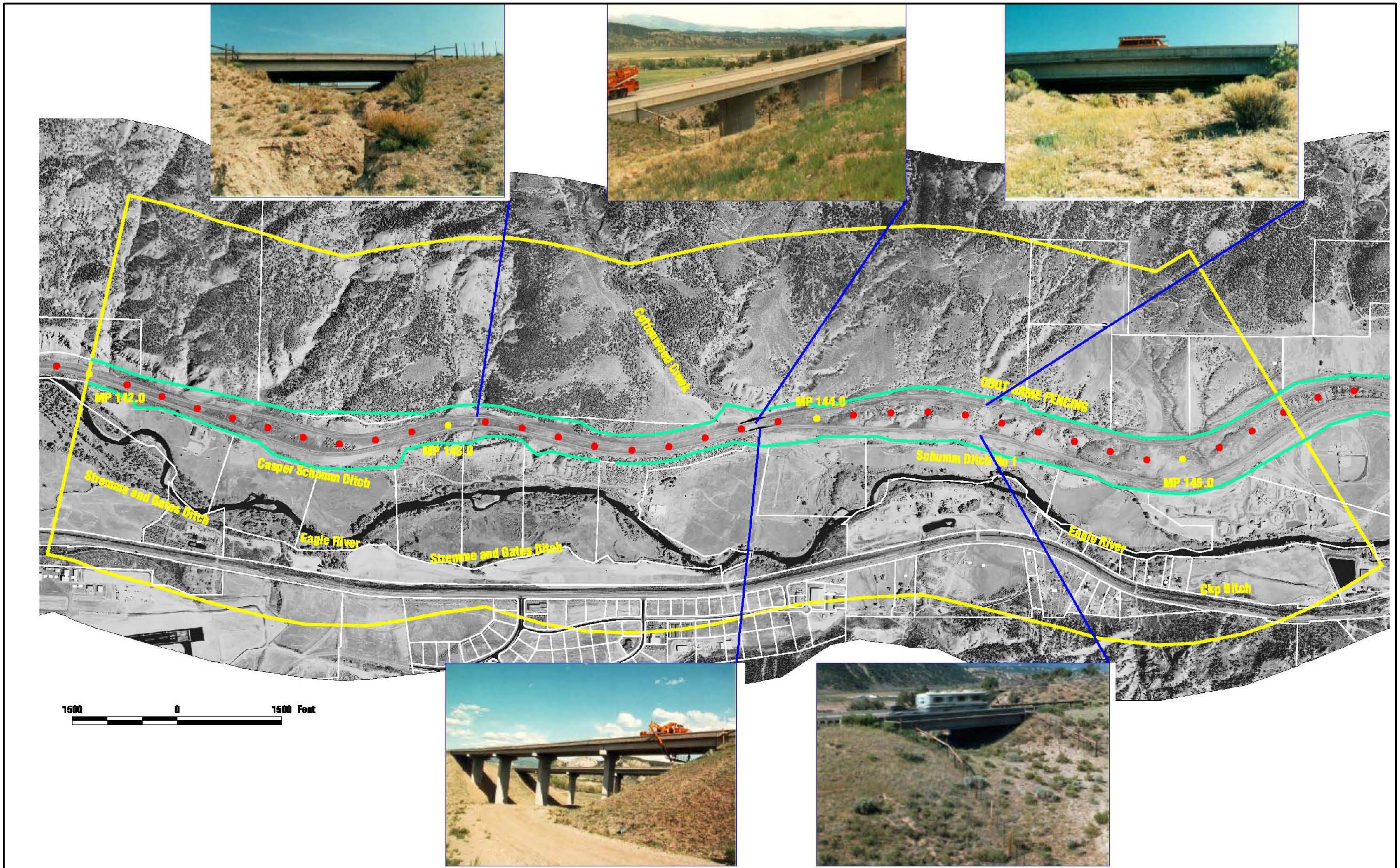

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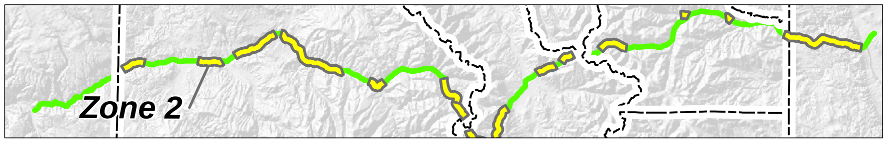

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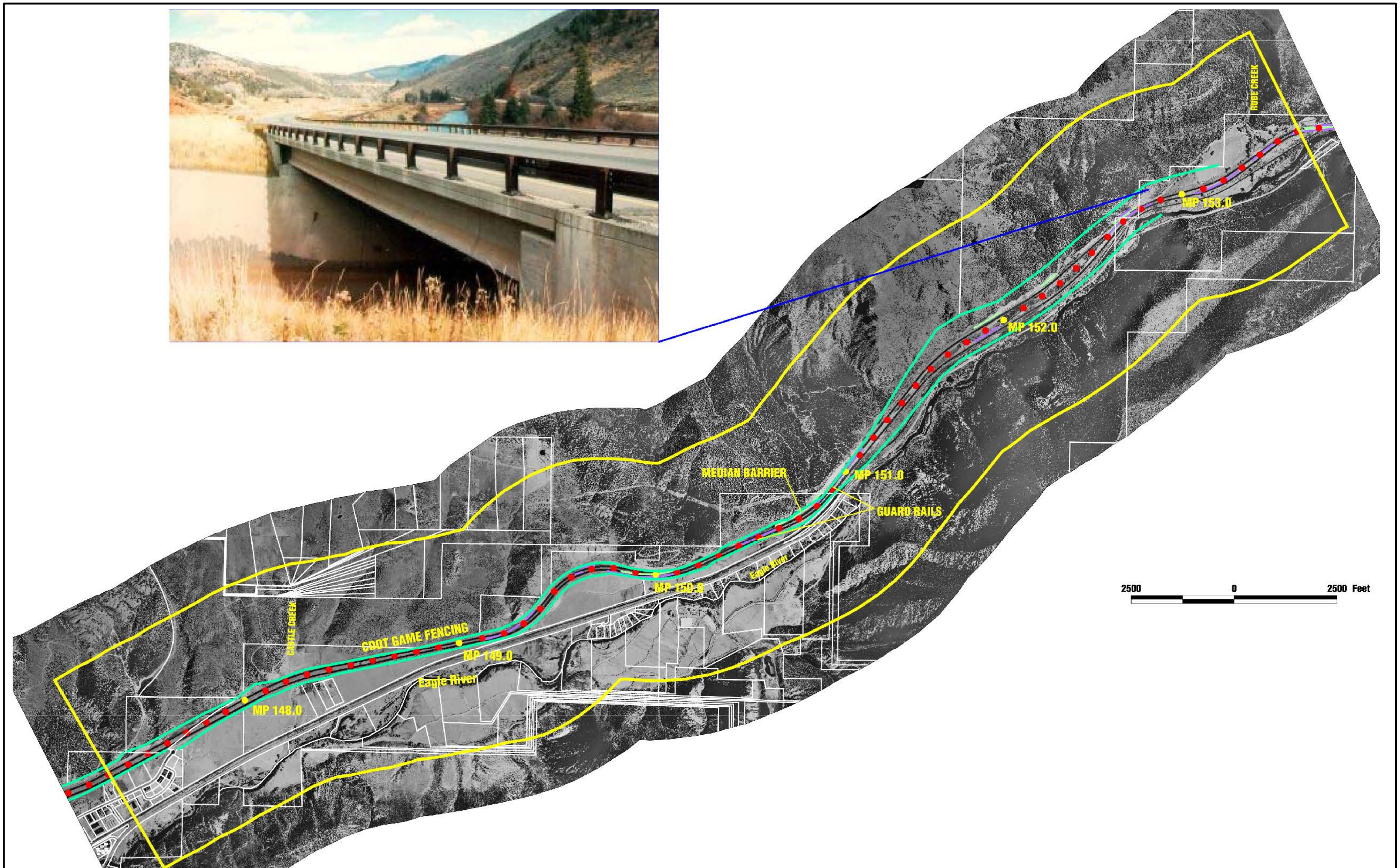
Wildlife Linkage Interference Zone 2: Eagle County Airport Area



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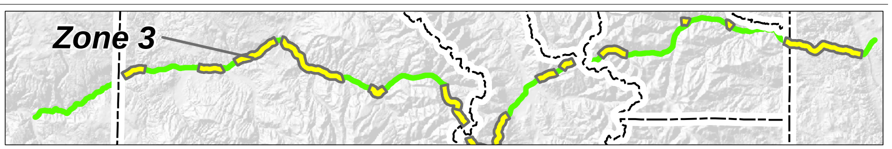

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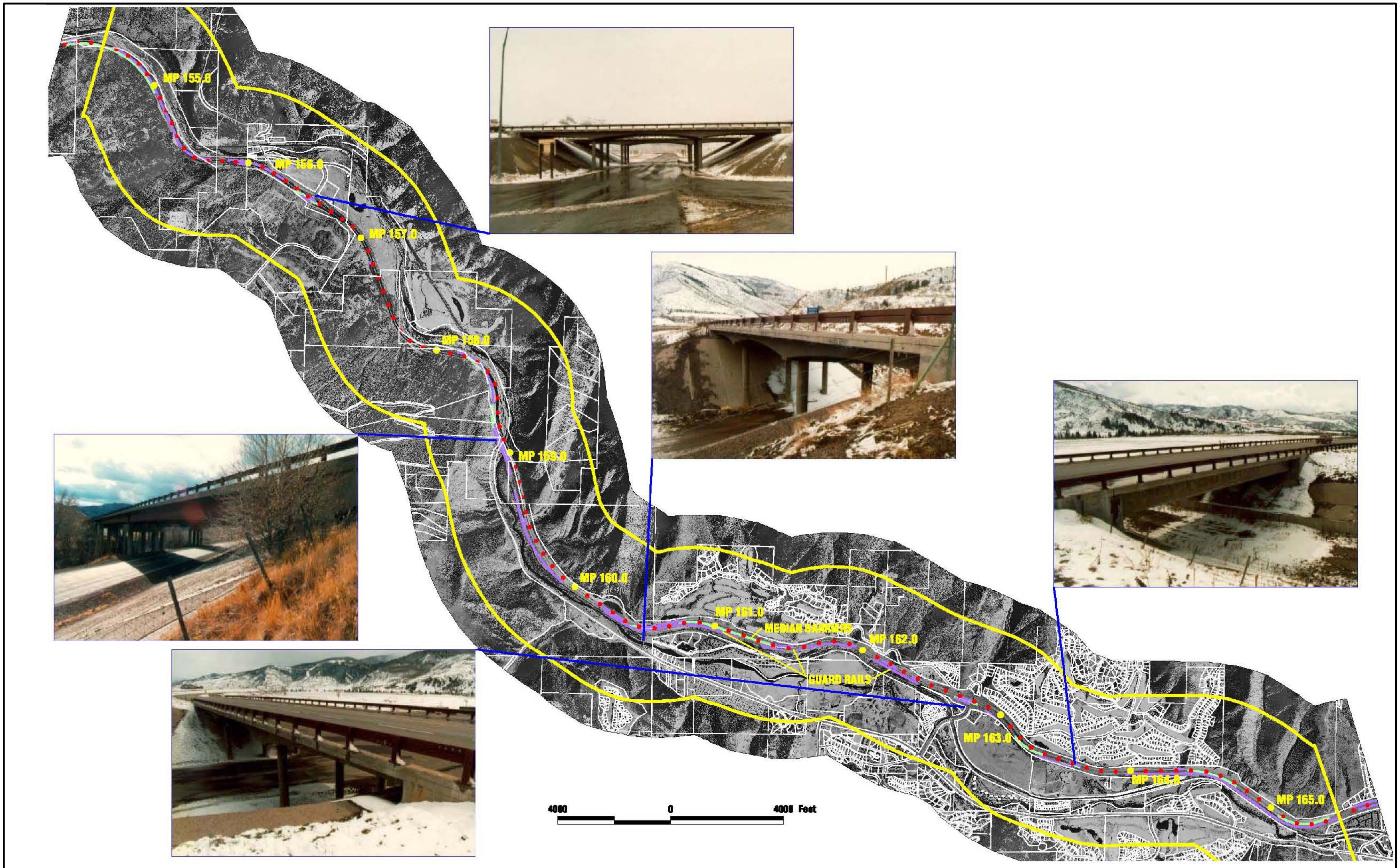
Wildlife Linkage Interference Zone 3: Eagle to Wolcott

Map 3 of 14



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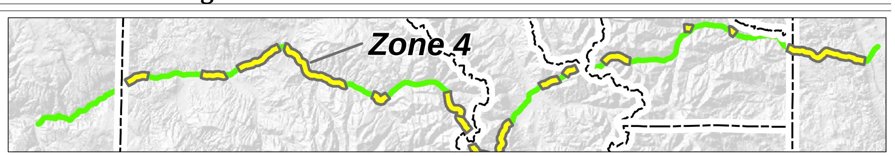

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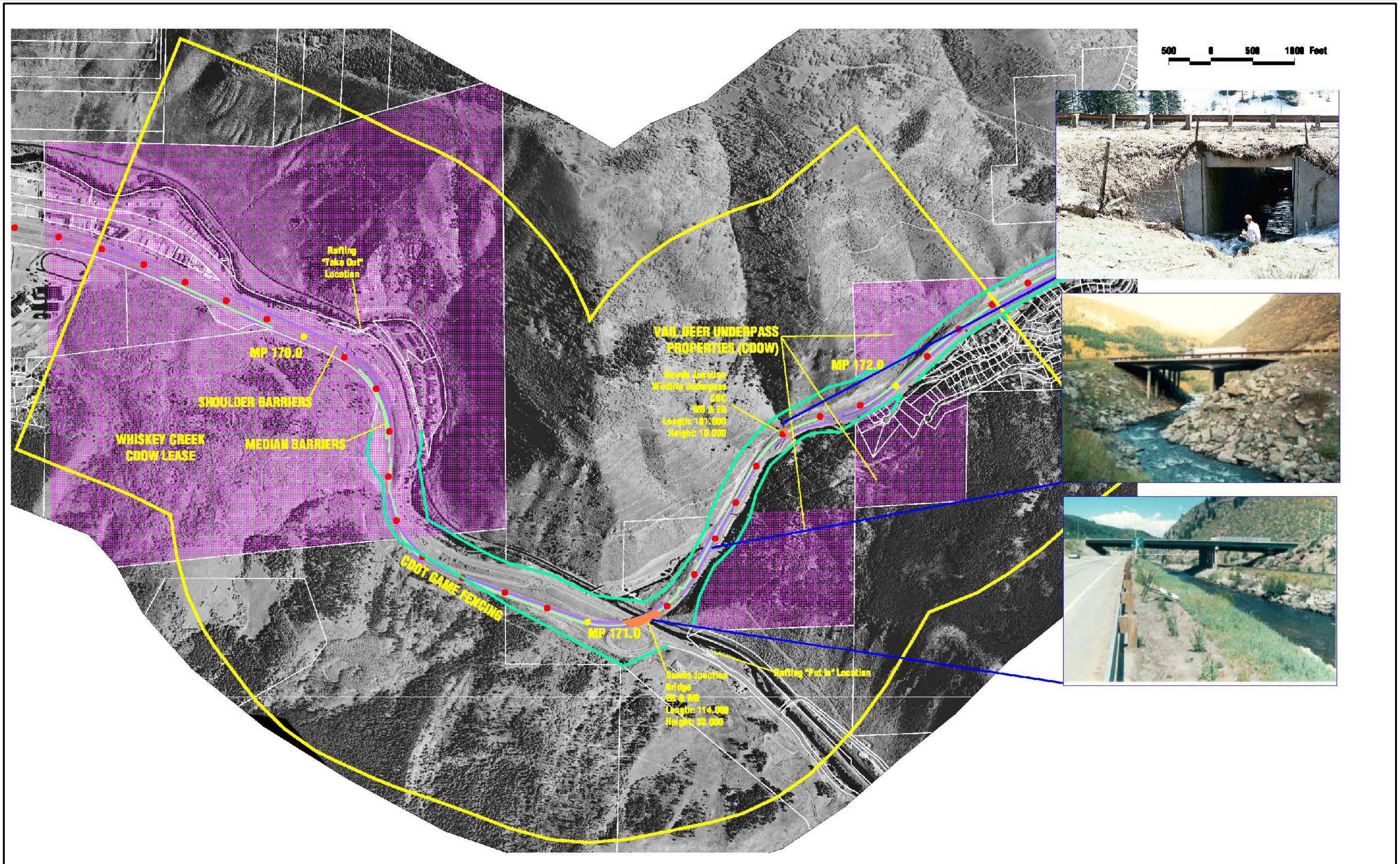
Wildlife Linkage Interference Zone 4: Wolcott to Avon

Map 4 of 14



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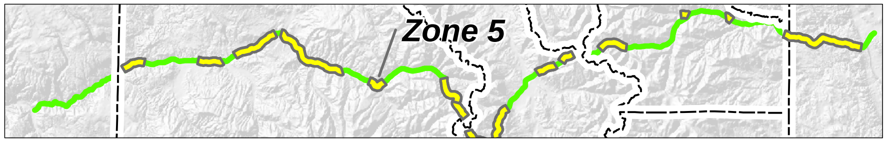

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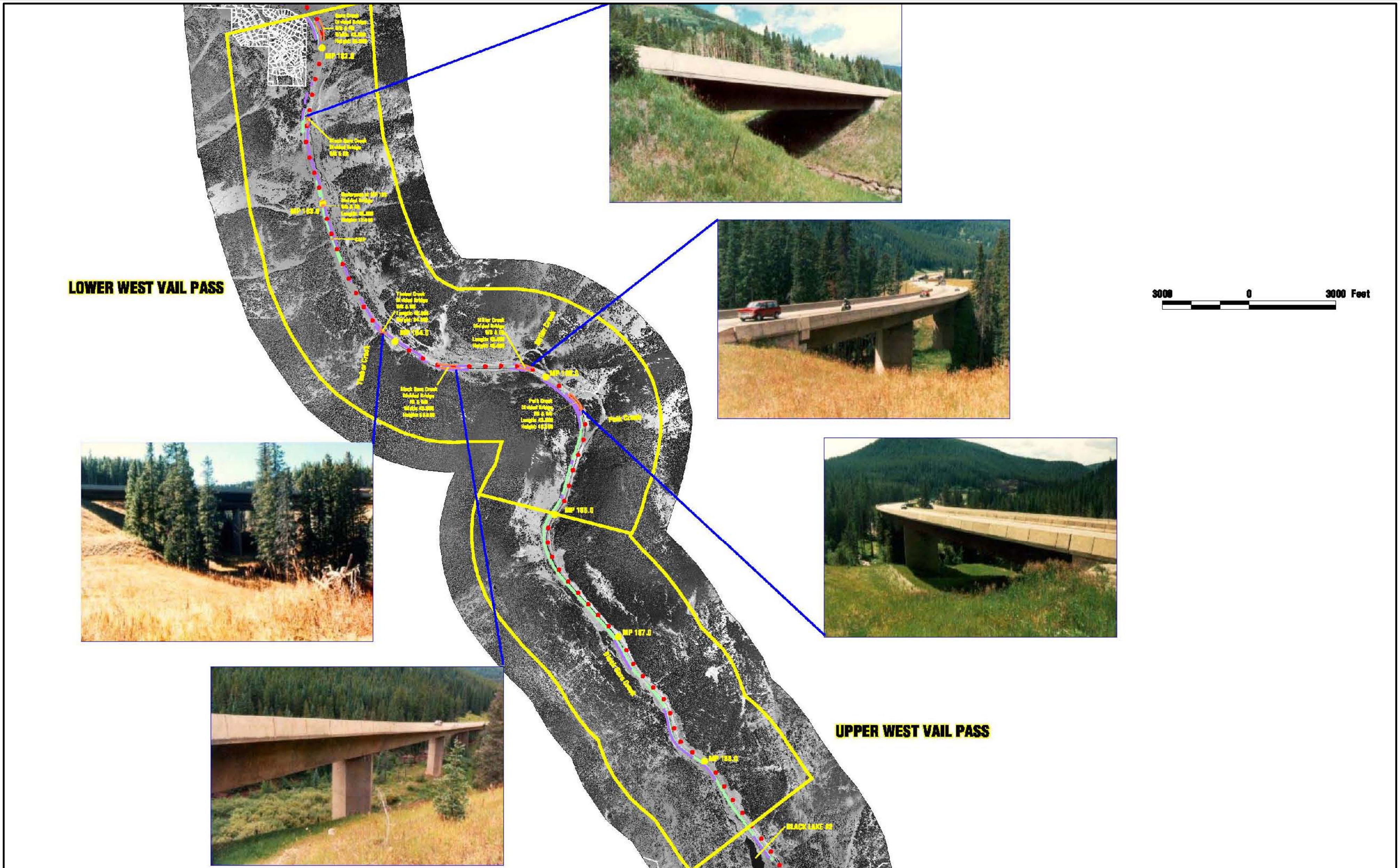
Wildlife Linkage Interference Zone 5: Dowd Canyon Area

Map 5 of 14



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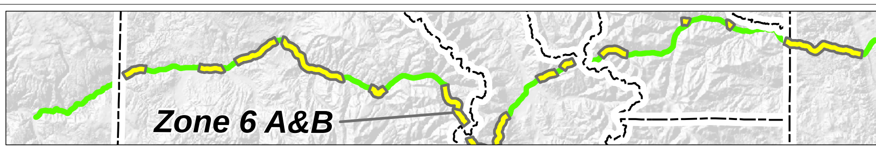

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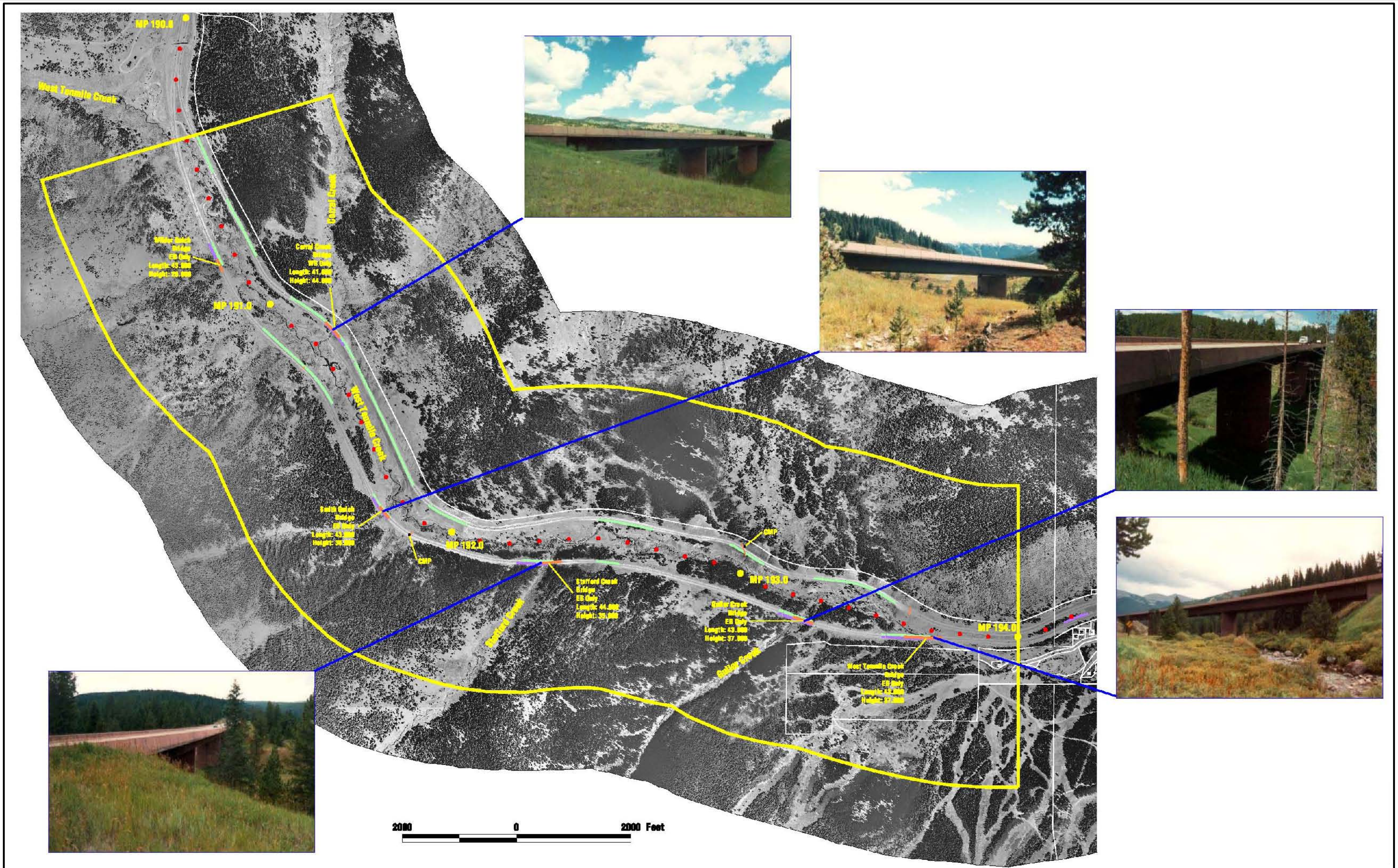
Wildlife Linkage Interference Zone 6A & 6B: Upper & Lower West Vail Pass

Map 6 of 14



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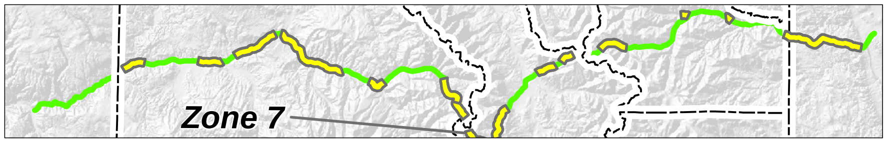

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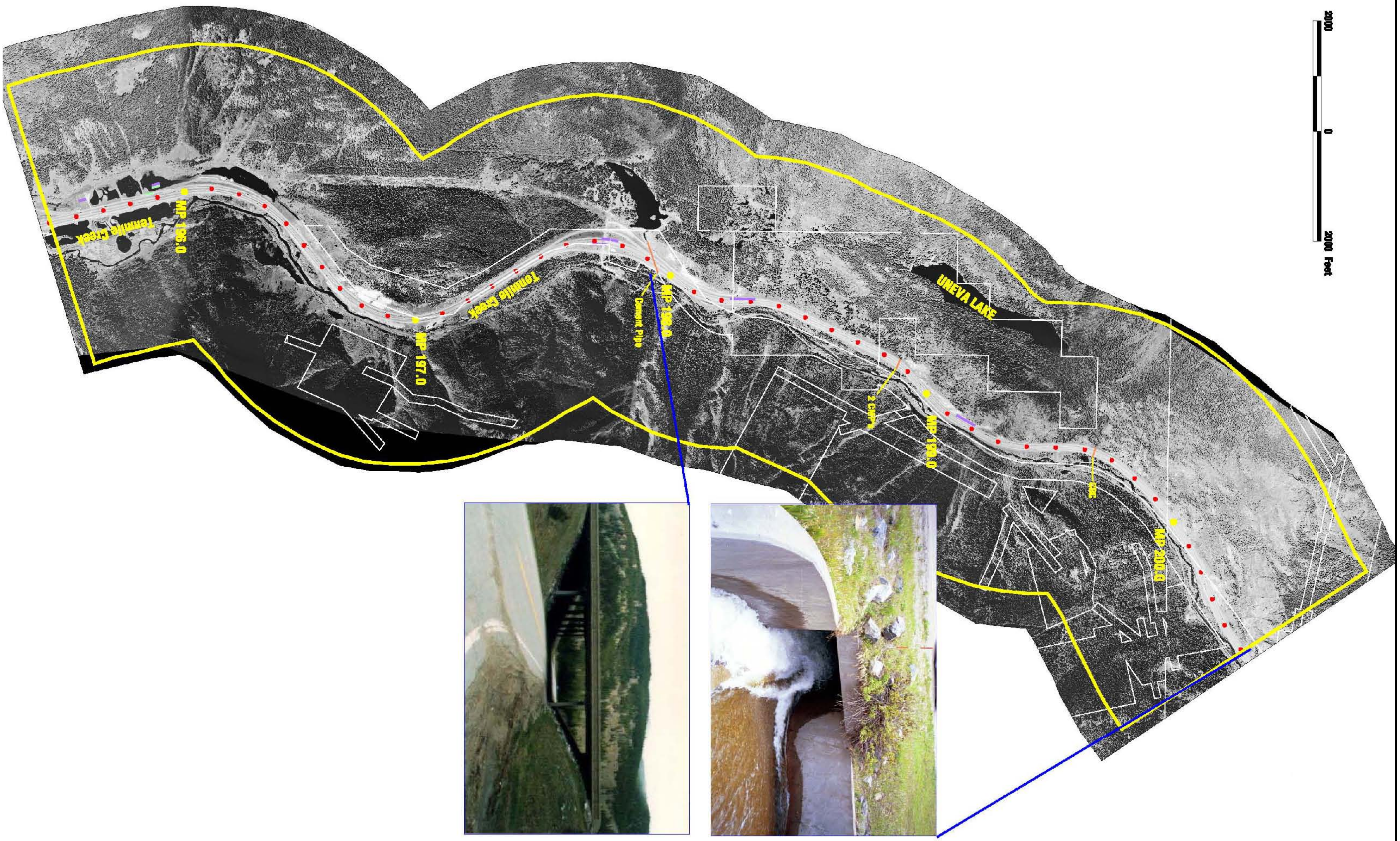
Wildlife Linkage Interference Zone 7: East Vail Pass

Map 7 of 14



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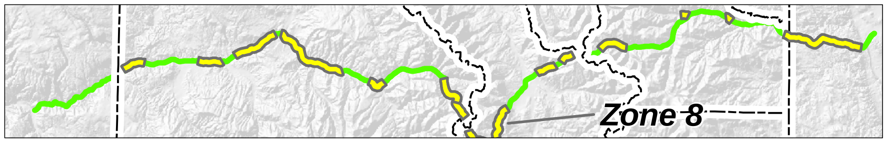

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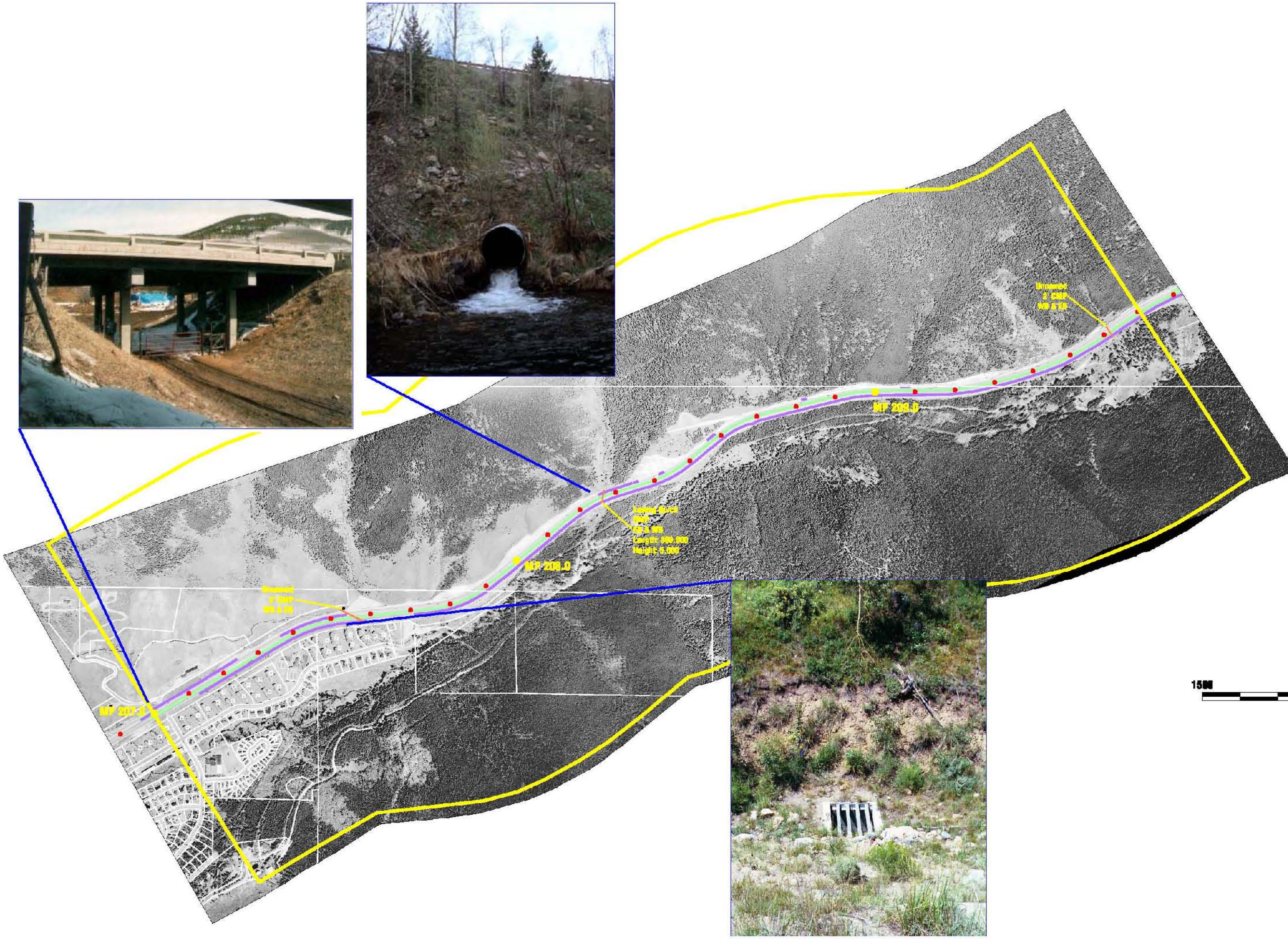
Wildlife Linkage Interference Zone 8: Officers Gulch / Owl Canyon

Map 8 of 14



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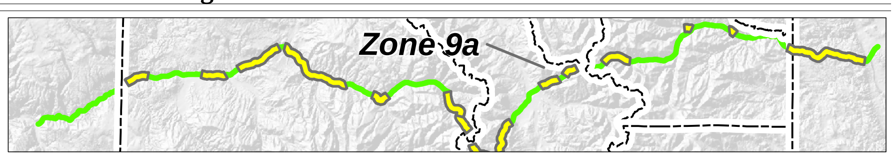

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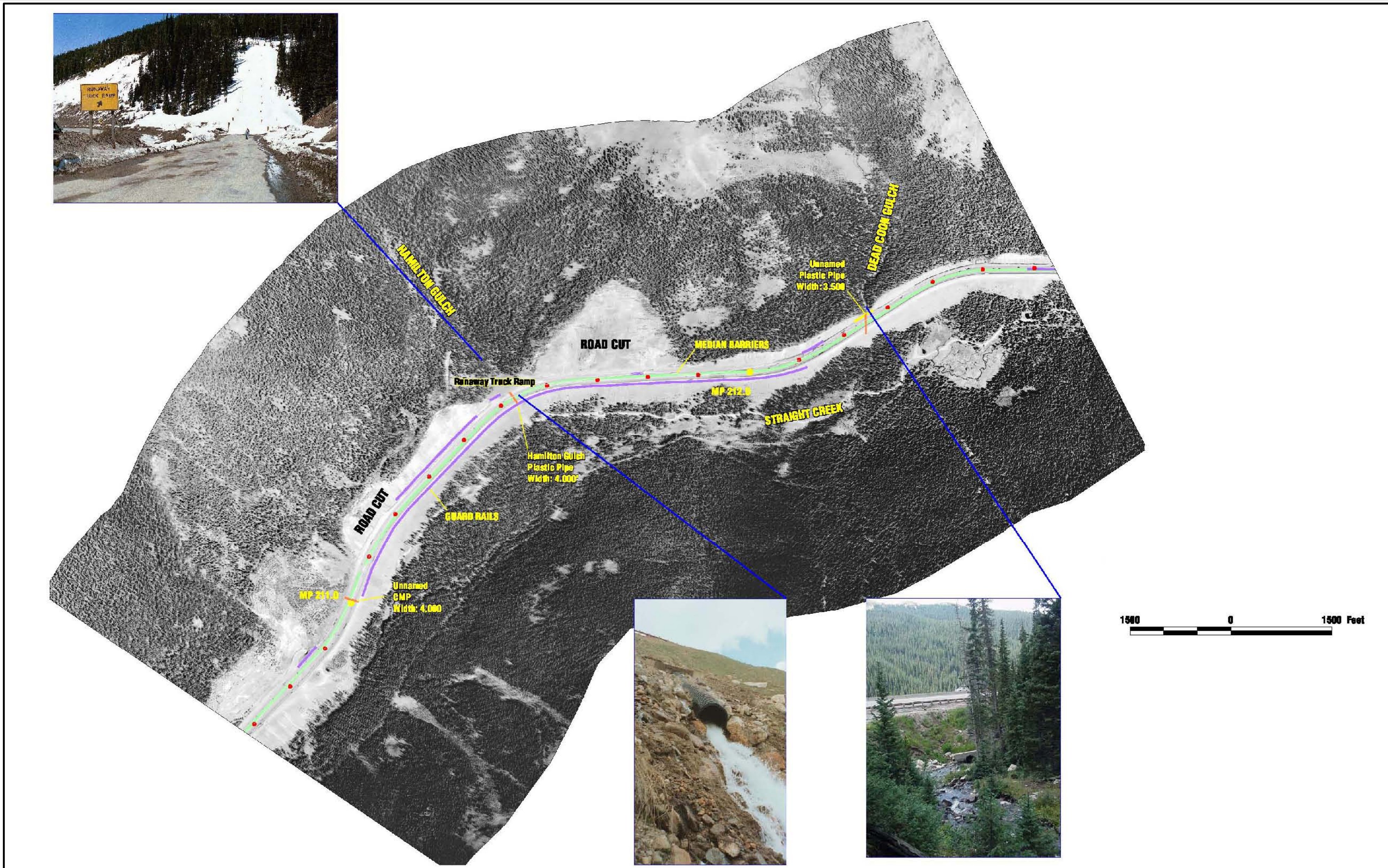
Wildlife Linkage Interference Zone 9a: Laskey Gulch

Map 9 of 14



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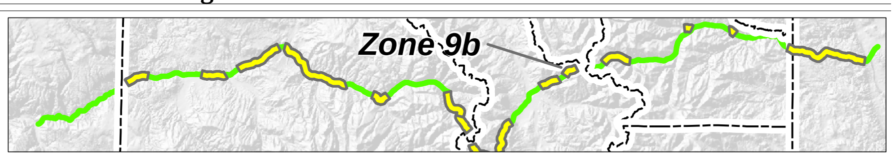

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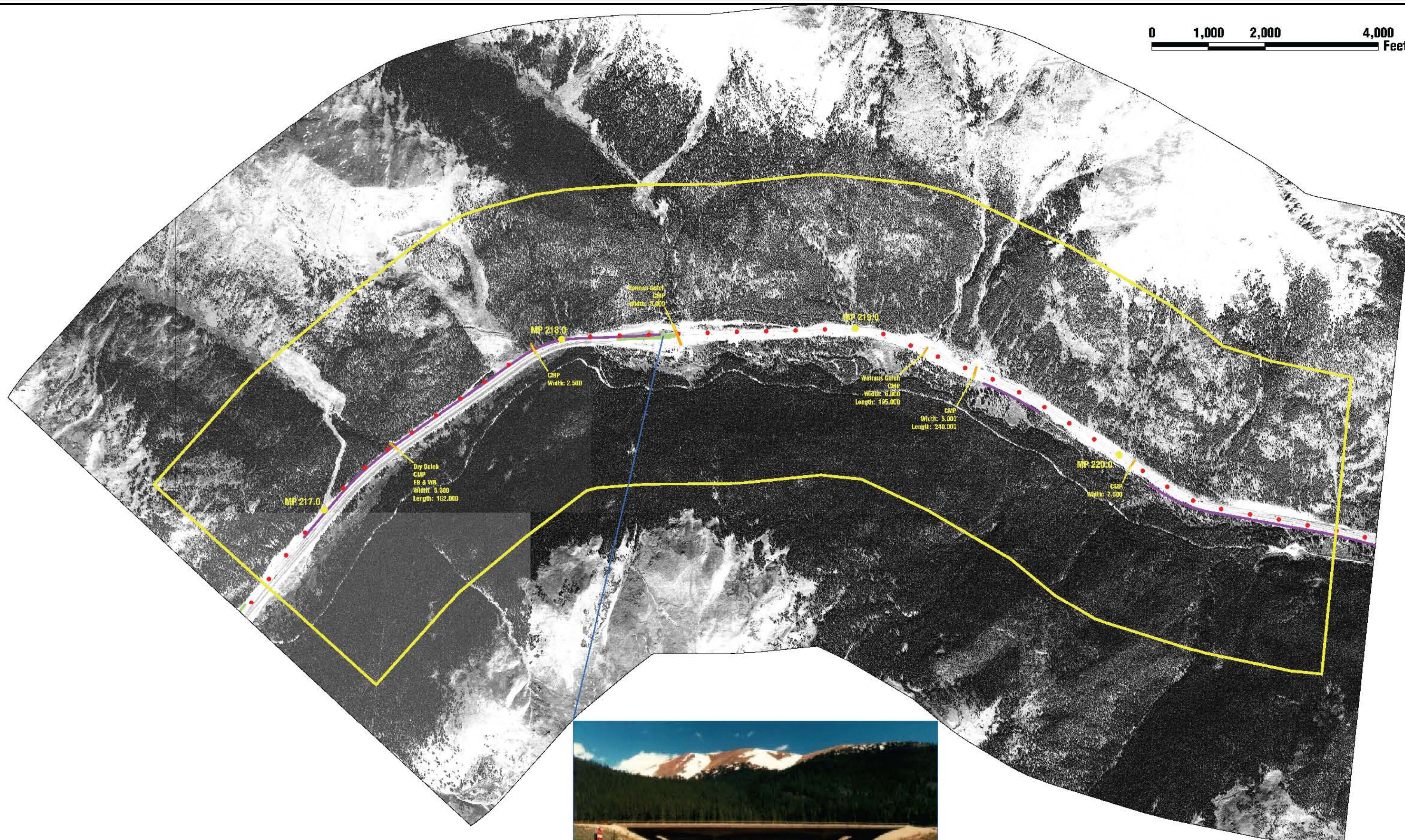
Wildlife Linkage Interference Zone 9b: Hamilton Gulch / Dead Coon Gulch

Map 10 of 14



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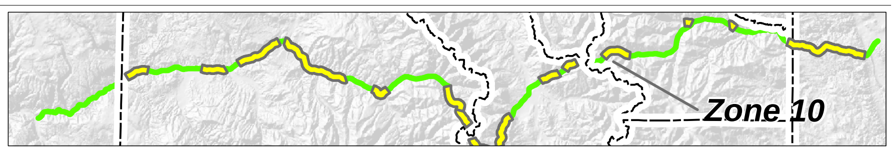

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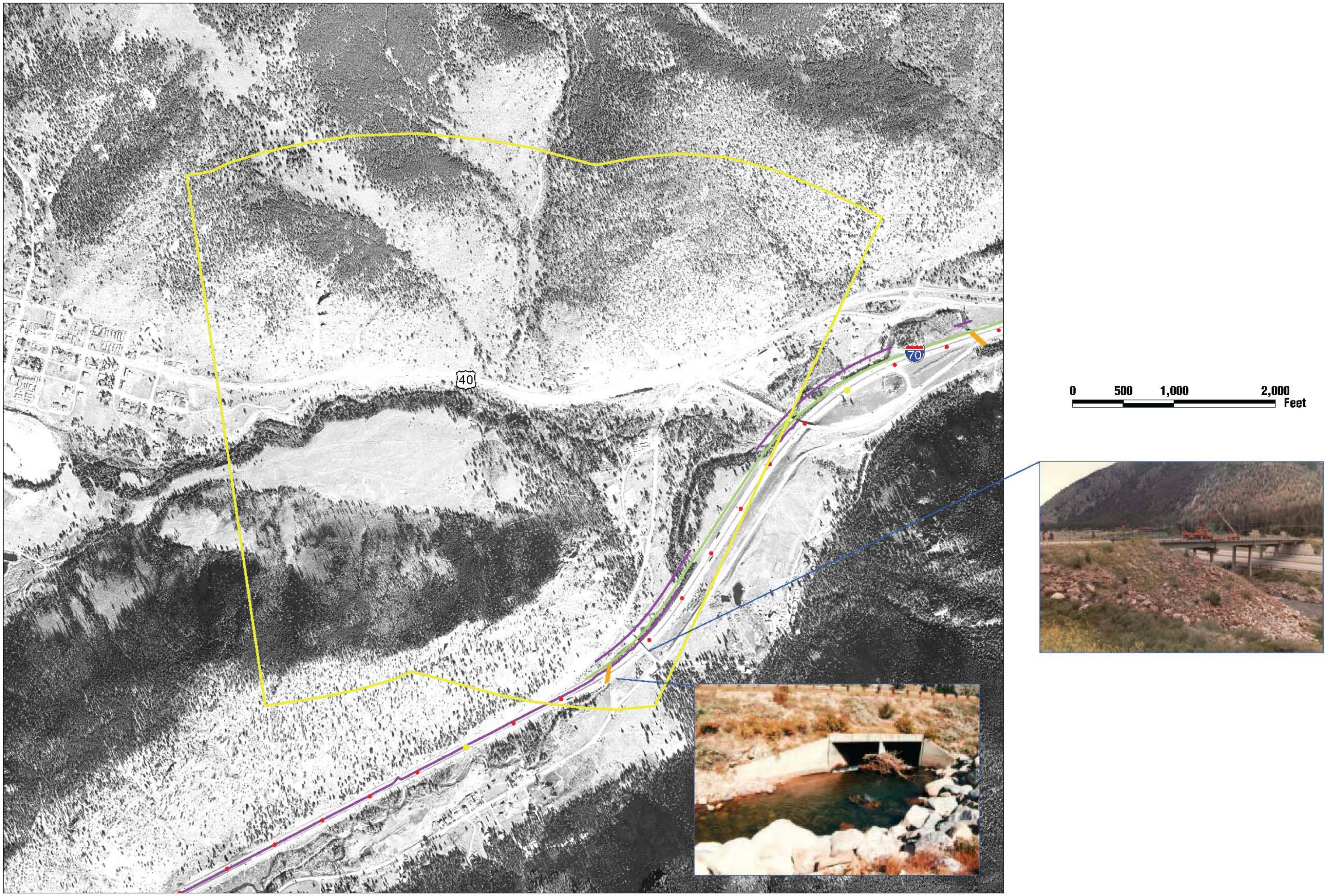
Wildlife Linkage Interference Zone 10: Herman Gulch / Bakerville



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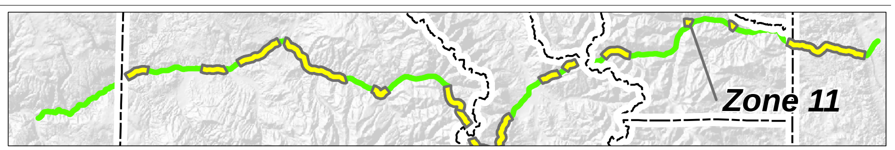

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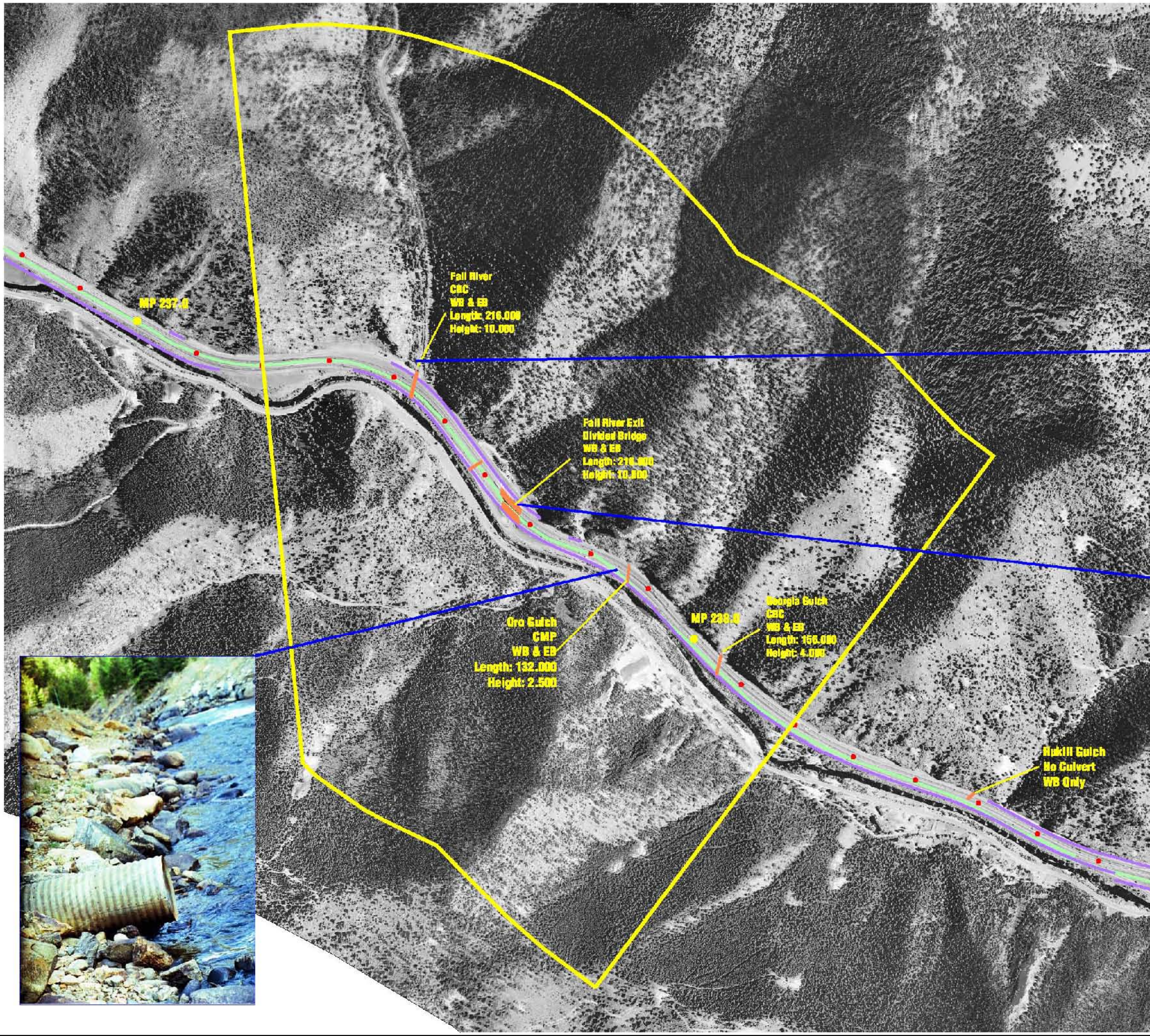
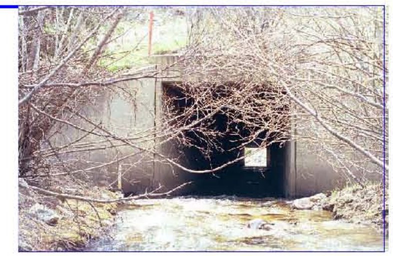
Wildlife Linkage Interference Zone 11: East of Empire on US 40

Map 12 of 14





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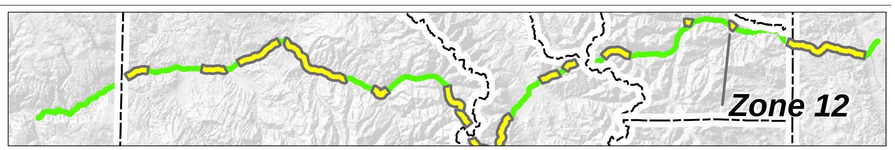

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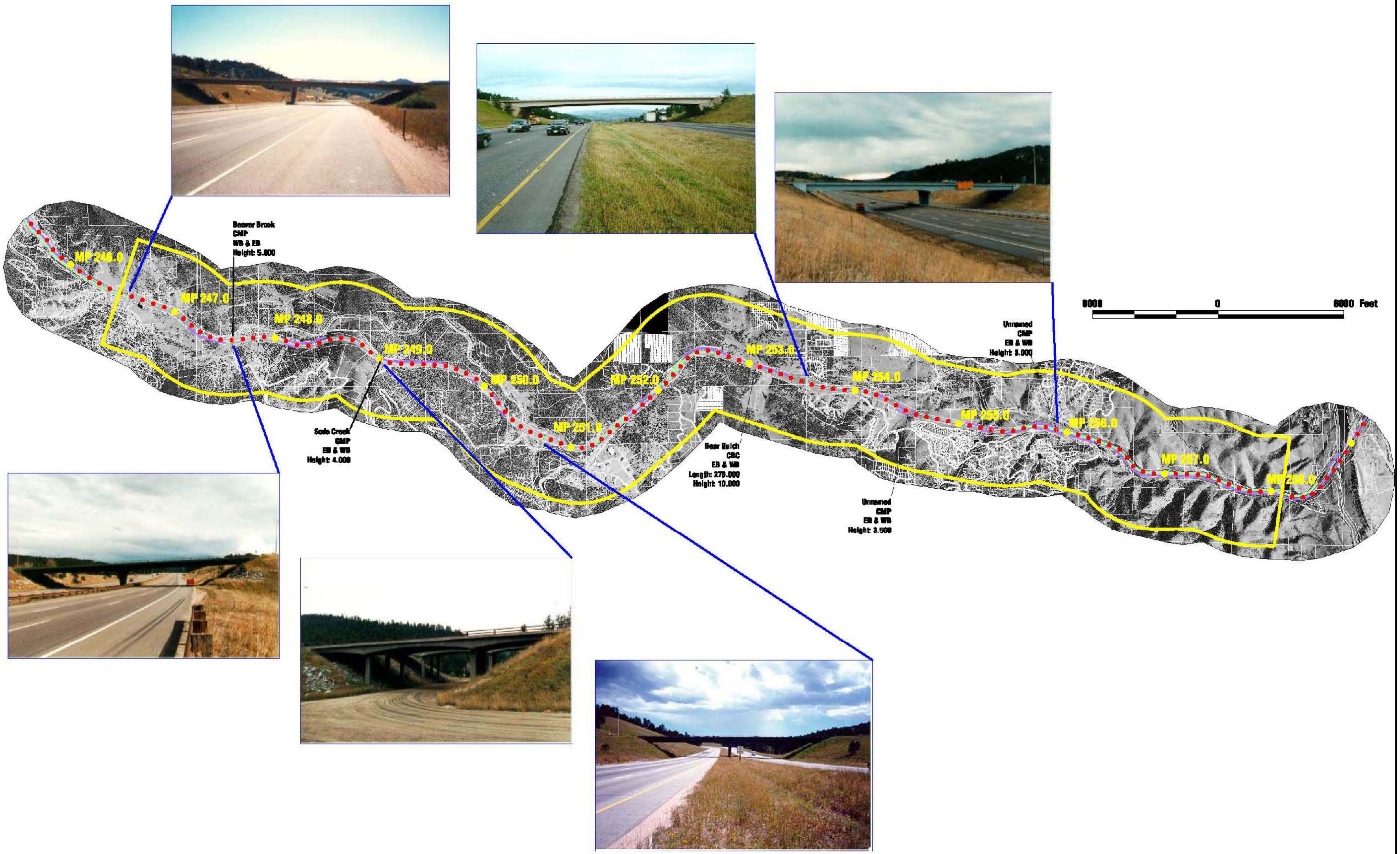
Wildlife Linkage Interference Zone 12: Fall River

Map 13 of 14



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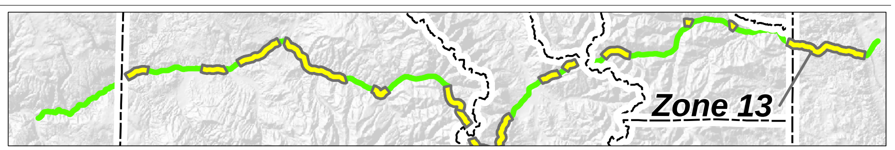

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U.S. Department of Transportation Federal Highway Administration

Wildlife Linkage Interference Zone 13: Mount Vernon Canyon

Map 14 of 14

Appendix B.

Factors Impacting the Health of Roadside Vegetation

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Report No. CDOT-DTD-R-2005-12
Final Report

DTD Applied Research and Innovation Branch

Where Ideas Become Reality

FACTORS IMPACTING THE HEALTH OF ROADSIDE VEGETATION

Nichole A Trahan and Curt M. Peterson
University of Northern Colorado

April 2007

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH BRANCH

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
CDOT-DTD-2005-12		

4. Title and Subtitle FACTORS IMPACTING THE HEALTH OF ROADSIDE VEGETATION	5. Report Date April 2007
	6. Performing Organization Code
7. Author(s) Nicole A. Trahan and Curt M. Peterson	8. Performing Organization Report No.
9. Performing Organization Name and Address Department of Biological Sciences 501 20th Street University of Northern Colorado Greeley CO, 80639	10. Work Unit No. (TRAIS)
	11. Contract or Grant No.
12. Sponsoring Agency Name and Address Colorado Department of Transportation - Research 4201 E. Arkansas Ave. Denver, CO 80222	13. Type of Report and Period Covered Final
	14. Sponsoring Agency Code 41.70

15. Supplementary Notes
Prepared in cooperation with the US Department of Transportation, Federal Highway Administration

16. Abstract
This study provides an ecological impact assessment of factors affecting the health of roadside vegetation in the state of Colorado including potential biotic and abiotic plant stressors and deicer applications. Across eight field sites, an evaluation was completed for foliar injury, physiology by leaf-level gas exchange, salt exposure, long-term drought stress, nutrient availability, pollutant exposure, disease, and insect damage in roadside lodgepole (*Pinus contorta*) and ponderosa (*Pinus ponderosa*) pines. These measures were compared with conifers away from the roadside environment in the same location in the winter/spring and summer/ fall of 2004. Additionally, a controlled assessment of the impacts of sand/salt and magnesium chloride deicers on foliar injury and leaf-level gas exchange in saplings of *P. ponderosa* and *P. contorta* was performed. Seed germination and viability in response to various commercial deicers was also evaluated in native Colorado plant species. Generally, roadside conifers exhibited significant foliar injury and needle loss compared to their off road counterparts, while roadside plant tissues and soils exhibited elevated levels of sodium, magnesium, and chloride. Injury to the tree crown correlated most strongly with levels of chlorides in older needle foliage ($R^2 = 0.696$, $p < 0.0001$). A significant depression of leaf-level photosynthesis rates was observed in roadside trees during the winter deicing season but not during the subsequent growing season. Roadside and off-road trees did not evince any difference in long-term drought stress as demonstrated by pre-dawn leaf tissue water potentials. Colorado roadside soils were relatively nutrient poor, although a concomitant deficiency of nutrients in plant tissues was not observed. Measures of pollutant exposure including nitrous oxides, sulfur dioxides and heavy metals were significantly elevated in roadside tree tissues and soils compared to their off-road counterparts. Overall, nutrient availability and pollutant exposure levels correlated much less strongly with conifer foliar injury than salt exposure. Although evidence of disease and insect, animal, and abiotic damage occurred in Colorado conifers, these phenomena were not serious enough to affect either tree health or physiology. Magnesium chloride deicer, especially when applied to sapling foliage, was far more damaging to conifer saplings than exposure to sand/salt, and led to foliar injury, overall depression in leaf-level photosynthesis rates, and sapling mortality. Exposure to commercial deicers reduced or inhibited native seed germination percentages but not seed viability. Recommendations for future research include: reductions in the use and amount of deicing salt on Colorado highways; the impacts of non-chloride based deicers on roadside vegetation; application feasibility and ameliorative effects of soil additives; removal of needle surface depositions in roadside trees; reducing vegetation deicer exposure by minimizing the deicer splash zone and aerial drift of deiciing particulates; and salinity tolerances of other species potentially impacted by deicer applications.

17. Keywords	18. Distribution Statement
deicing salt, sodium chloride, magnesium chloride, foliar injury, leaf-level gas exchange, plant nutrition, seed germination, seed viability, air pollution, drought stress, conifer pathology, heavy metals, *Pinus ponderosa*, *Pinus contorta*	No restrictions. This document is available to the public through the National Technical Information Service, Springfield, VA 22161

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None	None	262	

FACTORS IMPACTING THE
HEALTH OF ROADSIDE VEGETATION

By

Nicole A. Trahan and Dr. Curt M. Peterson

Report No. CDOT-DTD-R-2005-12

Prepared by
Department of Biological Sciences
University of Northern Colorado
Greeley, CO 80639

Sponsored by the
Colorado Department of Transportation
In Cooperation with the
U.S. Department of Transportation
Federal Highway Administration

April 2007

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(303) 757-9506

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the comments, support, and contributions of the Study Review Panel. The members of the review panel include Ms. Cathy Curtis, DTD Environmental; Mr. Ken Wissel, CDOT R-1; Mr. Bill Slade, CDOT, R-4 Maintenance; Mr. Jeff Moll, U.S Forest Service; Ms. Jennifer Finch, CDOT – DTD; Mr. Tom Boyce, CDOT – DTD; Ms. Stacey Stegman, CDOT – Public Relations; Mr. Ed Fink, CDOT – Staff Maintenance; and Mr. Richard Griffin, CDOT – Research Branch Manager. A special thanks goes out to Mr. Phillip Anderle CDOT R-1, for going the extra mile with his support and assistance.

A project this size becomes by nature a truly collaborative effort. The authors would also like to acknowledge the invaluable support, comments, expertise and assistance of Dr. Warren Buss, Dr. Margaret Heimbrook, Dr. Robert Reinsvold, Mr. Ken Cochran, Dr. Susan Hutchinson, Dr. Jamis Perrett, Dr. Matt Semack, Mr. Chad Eschleman, Mr. Nick Callaway, Ms. Diana Podein, and Ms. Cindy Mondragon of the University of Northern Colorado. Thanks are also due to the professionalism and assistance of Dr. Bill Jacobi, and Ms. Rhonda Kosch of Colorado State University; Mr. Randy Moench of the CSU State Forest Service Nursery; Ms. Annette Miller of the National Center for Genetic Resources Preservation; Mr. John Skok and Mr. Nick Cornelius of the Colorado School of Mines; and to Mr. Seth Willis and Mr. David Bossie of Weld Laboratories, Inc. for excellent and timely work.

Finally, the authors are indebted to the laboratory research crew that persevered through extremely demanding field conditions in order to make this research possible. A heartfelt thanks to Mr. John Gallagher, Ms. Jessica Honea, Ms. Jessica Kiser, Ms. Cynthia Pritekel, Mr. Justin Darnell, Ms. Margaret Bell, Mr. Karl Wyant, and Mr. SaDune Quarles.

EXECUTIVE SUMMARY

Roadside vegetation is exposed to a variety of biotic and abiotic stresses that can impact plant health. Drought, pollution, disease, insects, lack of nutrients, and roadbed management practices may potentially act alone or synergistically to adversely affect plants in proximity to the roadside. To date, little published research documents the impacts of certain deicers on vegetation in relationship to other potential stresses. This study provides an ecological impact assessment of factors affecting the health of roadside vegetation in the state of Colorado including potential biotic and abiotic plant stressors and deicer applications. Five main objectives were investigated:

1. **Determination of the extent and mode of Colorado roadside vegetation exposure to deicers and the relationship to tree health**
2. **Evaluation of photosynthesis and leaf level gas exchange in Colorado roadside conifers prior to and over a deicing season**
3. **Laboratory investigation and comparison of the effects of various sand/salt mixtures and liquid deicers on plant health, photosynthesis, and seed germination**
4. **Assessment of leaf water status in conifer trees within designated plots accounting for the presence of drought stress prior to and throughout the deicing season**
5. **Direct and indirect assessment of other factors potentially deleterious to roadside vegetation including: pollution, nutrient availability, disease, and insect impacts in areas where deicer stress may be a concern.**

The extent and mode of Colorado roadside vegetation exposure to deicers and the relationship to tree health

Conifers at study sites along Colorado roadways exhibited substantial foliage damage not seen in their counterparts away from the roadside environment. The patterns and characteristics of foliar injury in these trees conform to previously reported deicing salt damage patterns, including exposure to magnesium chloride. Damage to photosynthetic tissue characteristically occurred as necrosis and chlorosis in the needle tips, with tissue death advancing to the needle base. Damaged older foliage tended towards premature abscission, resulting in less needle retention and thinner overall crown vegetation.

Deicing salt contamination can also be linked as the causal factor in foliage damage in Colorado pines through the presence of significantly elevated salt levels in roadside soils and tree tissues. Soil pH, total soluble soil salts, and soil sodium levels were higher in roadside soils compared to soils at a distance from the roadside. Needle sodium, magnesium, and chloride as well as twig sodium and chloride contents were significantly elevated in tree foliage along the roadside. Foliage damage in roadside conifers also was correlated significantly and very robustly with the presence of salt ions in plant tissues. As the sodium ($R^2 = 0.611$, $p < 0.0001$) and chloride ($R^2 = 0.696$, $p < 0.0001$) content in needle tissues increased, so did observed levels of foliar injury in Colorado roadside pines. Across all sites, chloride content in needle tissue correlated with foliage damage more strongly than any other factor examined in the study. Additionally, levels of sodium and chloride in the tissues of Colorado roadside ponderosa and lodgepole pines exceed levels known to damage foliage even in late fall, indicating that salts remain in the needle tissue causing year-round and long-term stress to the exposed trees.

A direct and damaging deicer splash zone exists due to snow plowing and passing vehicular traffic along Colorado highways. In addition, aerial drift of deicing particles contributed to salt accumulation in tissues that exceeded reported background levels for pines trees even over 100m (328 feet) from the roadway. Conifer needle surface deposits consisting of magnesium, sodium, and chloride salts as well as fine rock particulates are likely a product of roadside deicing practices and were noted in study trees as far away as 115m (377 feet) in some locations.

Photosynthesis and leaf level gas exchange in Colorado roadside conifers prior to and over a deicing season

During the late winter and early spring, leaf-level photosynthesis rates in roadside trees were significantly reduced compared to their counterparts away from the roadside environment. This finding concurs with other studies establishing that salinity reduces the rate of photosynthesis. In contrast to the deicing season, no significant differences in photosynthesis rates or other gas exchange parameters between roadside and off-road conifers were observed in the summer and late fall. The leaching of salt ions from roadside soils and plant tissues may account for this difference, as well as imply that a certain level of physiological recovery is possible for roadside trees during the growing season.

Total canopy photosynthesis is reduced in Colorado roadside trees due to the greater levels of chlorotic and necrotic foliage as well as the reduced amount of tree needle retention. The presence of non-viable foliage and the premature abscission of needles decreases the available photosynthetic area, and therefore the overall photosynthetic capacity of the tree. A decline in photosynthetic capacity in turn leads to decreased growth rates and a loss of plant vigor.

Measures of soil salinity and sodicity exhibited significant but weak negative correlations with fall photosynthesis rates in Colorado conifers indicating that soil salinity may inhibit tree physiology through osmotic stress. While negative correlations of photosynthetic rates and the presence of salt ions in plant tissues have been reported in controlled experiments, these correlations were not found in this field study. Additionally, stomatal diffusion of water vapor and carbon dioxide may have been impaired in roadside trees during the deicing season due to the presence of a heavy coating of resuspended road particulates on the needles of study site trees.

Comparison of the effects of various sand/salt mixtures and liquid deicers on plant health, photosynthesis, and seed germination

Deicer exposure caused significant foliar injury in saplings of ponderosa and lodgepole pine during controlled greenhouse experiments, with exposure to higher concentrations of the magnesium chloride ($MgCl_2$) based deicer FreezGard leading to complete sapling mortality. Patterns of tissue necrosis in deicer-exposed saplings were similar between deicers types and corresponded with observed foliar injury at study field sites along Colorado highways.

Overall, exposure to the $MgCl_2$ deicer was far more deleterious to sapling health and physiology than exposure to sand/salt. As magnesium has not demonstrated appreciable phytotoxicity or significant correlations with foliage damage in the field, the likely cause of sapling injury in this case stems from chloride exposure. In this case, chloride toxicity may be exacerbated due to the heavier concentration of chloride anions per application of FreezGard compared with an application of sand/salt.

Strikingly, direct foliar contact with the $MgCl_2$ deicer was far more injurious to saplings than exposure to $MgCl_2$ through the soil matrix. Aerosolized $MgCl_2$ deicer appears to act equivalently to NaCl spray as a non-selective herbicide, with conifers demonstrating particular sensitivity. Ponderosa pine saplings demonstrated immediate (1 hour) physiological sensitivity to foliar applications of $MgCl_2$ deicer (FreezGard). Net carbon assimilation (photosynthesis), A, and water use efficiency, WUE, in *P. ponderosa* saplings decreased precipitously upon application of any concentration of aerosolized $MgCl_2$. A clear concomitant reduction in stomatal conductance, g_s, was not observed however, implying a potential reduction in the capacity of leaf mesophyll cells to fix carbon. Additionally, *P. contorta* saplings exposed to full strength $MgCl_2$ deicer through the soil demonstrated a possible physiological inhibition in response to osmotic stress. Depressed levels of net carbon assimilation, stomatal conductance, transpiration, and corresponding higher water use efficiency were observed in these saplings.

As exposure to deicer concentrations increased, germination percentages decreased in western wheat grass (*Pascopyrum. smithii*), green needle grass (*Stipa viridula*) and Idaho fescue (*Festuca idahoensis*). Of the three species evaluated, *P. smithii* demonstrated the highest overall deicer germination tolerance, followed by *S. viridula* and *F. idahoensis*. The least amount of germination was seen in Ice Ban, Caliber M-1000, Caliber M-2000, and CDOT $MgCl_2$ (FreezGard). Seeds exposed to Sand/Salt had significantly higher germination than any other salts tested, as would be expected considering the lower level of salinity of the deicer.

Surprisingly, non-viable seeds did not correlate with increasing deicer concentration but instead were only significantly higher at the intermediate or 10% deicer concentration level. This suggests that germination suppression by deicers is not a function of toxicity, but is due instead to osmotic inhibition. However, in this case, confounding fungal contamination may explain these results.

Only seeds previously exposed to $MgCl_2$ deicer (FreezGard) and Caliber M-1000 underwent full germination recovery after a period of deicer exposure. Seeds previously exposed to NC-3000 and Ice Slicer displayed the least amount of germination recovery. These data suggest that the suppression of seed germination by $MgCl_2$ deicer (FreezGard) and Caliber M-1000 is a function of osmotic inhibition, whereas germination suppression by other tested deicers may be more related to an associated toxicity. Of the species tested, *P. smithii* exhibited the greatest percentage of germination recovery $\bar{x} = 78.2\%$, followed by *S. viridula* $\bar{x} = 69.2\%$ and *F. idahoensis* $\bar{x} = 52.5\%$.

Impacts of $MgCl_2$ deicer (FreezGard) on germination percentages in a range of Colorado native plants including *Gaillardia aristata*, *Hilaria jamesii*, *Elymus trachycaulus*, *Bromus* *marginatus, Bouteloua gracilis, Picea engelmannii, Rudbeckia hirta, Pinus ponderosa,* and *Chrysothamnus nauseosus* produced similar results**.** Germination decreased as exposure to deicer concentration increased. Seeds of *P. engelmannii, E. trachycaulus, R hirta*, *F. idahoensis,* and *G. aristata* were prominently more sensitive to the deicer than other seeds tested. Again, non-viable seeds occurred most often at intermediate salt concentration exposures due to fungal contamination, suggesting that deicer stress may act synergistically with environmental pathogens to impact seed viability.

Drought stress and leaf water status in conifer trees

Drought stress in the roadside environment could not be linked to foliage injury in Colorado roadside conifers. No significant differences were observed in water stress between trees adjacent to roadside or distant from the roadside in either the winter or throughout the growing season. Although roadside trees may experience higher levels of insolation due to vegetative cover loss, these results indicate that water stress is not directly contributing to tissue death in roadside vegetation. While significant differences were seen in water stress by site location, water stress failed to significantly correlate with distance from the roadside or any measure of foliar injury. Leaf tissue pre-dawn water potentials also did not correlate with measures of salt exposure.

Impacts of pollution, nutrient availability, disease, and insect, animal, and other abiotic damages on roadside conifer health and physiology

The surface profile of Colorado roadside soils was of relatively poor quality compared to soils further away from the roadside environment. Roadside study site soils exhibited significantly lower levels of major plant nutrients including total nitrogen, potassium, calcium, and phosphorus. Additionally, soil organic matter and total organic carbon content was significantly reduced adjacent to the roadbed than in soils further away. Leaching of soil magnesium, potassium, and calcium cations due to the presence of elevated sodium levels was also observed.

Decreases in soil organic matter, total nitrogen, and potassium levels correlated significantly but very weakly with increased overall crown necrosis levels. In addition, soil organic matter and total organic carbon content formed weak positive correlations with fall leaf-level photosynthesis rates, indicating that nutrient availability in this case may potentially affect net carbon assimilation. In contrast, as soil potassium, calcium, and phosphorous levels and conifer needle and twig calcium increased, a corresponding decrease in photosynthesis rates was observed. This depression may be related to overall soil salinity as leaf-level photosynthesis rates were also reduced in relation to the overall levels of total soluble salts in roadside soils.

Although significant degradation of the nutrient status was observed in roadside soils, concomitant differences in nutrient status between the tissues of roadside and off-road study trees was not observed. Only total organic carbon in conifer needle tissue was significantly lower in roadside trees compared to their off-road counterparts. This suggests that roadside soils although relatively nutrient depleted, still offer a sufficiency of most mineral nutrients for vegetation growth and physiology.

Reduced organic carbon content in needle tissue correlated moderately with increased foliar injury, and may be related to reduced total canopy photosynthesis in roadside trees. Overall, these data suggest that in most cases, salinity in Colorado roadside soils does not appreciably affect nutritional balance in the shoot and leaf tissues of lodgepole and ponderosa pines.

Trees and soils along Colorado roadsides exhibited increased levels of pollutants and trace metals than their counterparts away from the roadside environment. Specifically, significantly elevated levels of sulfur in needle and twig tissue, nitrogen and copper in needle tissue, and lead in twig tissue and soils were observed. Needle total sulfur concentrations have been linked to stomatal uptake of sulfur dioxides, and needle nitrogen concentrations to dry or wet deposition of atmospheric nitrous oxides.

Needle and twig tissue sulfur content and needle tissue nitrogen and lead content correlated weakly but significantly with observed levels of foliar necrosis. Although a contribution to foliar injury is likely, changes in these factors explained only a small amount of the variation in crown necrosis compared to the accumulation of salt ions in plant tissues. Additionally, unlike reported patterns of salt injury, sulfur dioxide injury is concentrated in new needle growth due to increased levels of foliar absorption.

Needle and twig sulfur contents, needle and soil cadmium contents, soil copper levels and needle zinc contents all formed weak negative correlations with conifer photosynthesis rates. These data suggest that pollutant exposure may contribute to some degree to physiological depression in roadside conifers.

Although symptoms of ozone foliar injury in ponderosa pines are highly similar to symptoms of salt foliar injury, ozone is a widely distributed pollutant capable of forest impact on a regional scale. That foliar injury is significantly concentrated in the roadside environment points instead to a localized causative agent.

Finally, study site trees exhibited only minor damage attributable to disease, insect, animal and abiotic damage, unlikely to impact tree health and physiology. Previous examinations of sodium-damaged ponderosa pines in Denver also exposed no fungi, insects or nematodes that could be implicated as causal agents of foliar injury.

Implementation Statement

Recommendations for future research include:

- investigations into methods designed to reduce the use and amount of deicing salt on Colorado highways
- research into the impacts of non-chloride based deicers on roadside vegetation
- examinations of the application feasibility and ameliorative effects of soil

additives such as gypsum

- studies of methods to remove needle surface depositions in roadside trees
- research on reducing vegetation deicer exposure through changes in application methods and the use of protective barriers designed to minimize the deicer splash zone and aerial drift of deicing particulates
- investigations into salinity tolerances of other species potentially impacted by deicer applications

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INTRODUCTION

Although the use of deicing chemicals remains important for road maintenance and traffic safety, it has been well established that road deicers have potential deleterious impacts on living organisms. It is also evident from the literature that roadside vegetation in particular may be acutely affected. While many studies have looked at effects of chloride-based deicers on roadside vegetation, less is known about whether comparable effects are caused through exposure to newer magnesium chloride ($MgCl_2$) based liquid deicers. For example, although observations of harmful effects of high concentrations of magnesium chloride on roadside foliage exist (Conner, 1993), to our knowledge, no studies have examined liquid deicer effects on photosynthesis and gas exchange, important physiological processes that influence plant health and vigor.

In addition, little published research documents the impacts of certain deicers on vegetation in relationship to other potential roadside stresses. Roadside environments may impose many potential biotic and abiotic pressures on a plant community. Vegetation may be exposed to pollutants such as heavy metals, ozone, and sulfur dioxide. The roadside soil structure may be compacted and nutrient availability low, while increased levels of insolation along the roadway may lead to added drought stress. These factors in turn may act synergistically to render vegetation more vulnerable to infection by fungal or insect pathogens.

The goal of this research therefore, is to provide an ecological impact assessment of deicing chemicals on roadside vegetation in the context of other abiotic and biotic plant stresses. Firstly, this study documents both the presence and mode of deicer exposure for Colorado roadside vegetation. Along Colorado highways, physiology and health were evaluated in two native conifer species, ponderosa pine (*Pinus ponderosa*) and lodgepole pine (*Pinus contorta*) prior to and during a deicing season. At the field study sites, these same conifers also were assessed for the presence and potential impact of nutrient availability, pollution, and pests or disease. Finally, this study compared the effects of various liquid deicers and solid sand/salt mixtures on seed germination and conifer sapling health and physiology in controlled laboratory conditions.

This research addressed five main objectives:

1. Determination of the extent and mode of Colorado roadside vegetation exposure to deicers and the relationship to tree health
2. Evaluation of health and leaf level gas exchange in Colorado roadside conifers compared to off-road conifers prior to and over a deicing season
3. Laboratory investigation and comparison of the effects of various sand/salt mixtures and liquid deicers on plant health, leaf level gas exchange, and seed germination
4. Assessment of leaf water status in conifer trees within designated plots accounting for the presence of drought stress prior to and throughout the deicing season
5. Direct and indirect assessment of other factors potentially deleterious to roadside vegetation including: pollution, nutrient availability, disease, and insect impacts in areas where deicer stress may be a concern.

Background

In the state of Colorado, an array of road deicers is used to melt snow and ice and suppress dust during dry periods. During a snow event, the Colorado Department of Transportation (CDOT) applies liquid magnesium chloride ($MgCl_2$) deicer solution at 80gal/lane mile and sand/salt at 500lbs/lane mile. For preventative deicing or anti-icing, $MgCl_2$ is applied at 40gal/lane mile (Phillip Anderle Greeley CDOT, 2004 personal communication). Other deicers utilized statewide include Ice Slicer and Caliber M-1000. Salt is the active ingredient in most of these deicers, most commonly $MgCl_2$ or sodium chloride (NaCl). Commercial deicers may also contain inert binders and/or anti-corrosives, which are proprietary and depend on the manufacturer.

The primary environmental impacts of deicers can be categorized by their main components into chloride-based deicers, acetate-based deicers, and sand (Fischel, 2001). Of primary concern to this study are the chloride based deicers NaCl and $MgCl_2$, and therefore they encompass the focus of the following literature review. The most prominent chloride salt used as a deicer in North America is sodium chloride, consisting of approximately 40% sodium and 60% chloride by weight (Environment Canada, 1999). As such, most documented environmental impact involves sodium chloride based deicers.

Impacts of Deicing Salts on Roadside Vegetation: Deleterious deicing salt impacts on roadside vegetation have been well established by numerous studies (Westing, 1969; Hall et al., 1972; Dochinger & Townsend, 1979; Bryson & Barker, 2002;) including a negative impact on the foliage health of ponderosa pine in Denver, Colorado (Spotts et al., 1972). From 1957- 1962, Spotts et al. observed what they characterized as a "tipburn disease" of ponderosa pine in Denver, CO. They were not only able to induce identical symptoms on pines with sodium chloride salts in solution, but were also able to document that foliar chloride (Cl^-) content was more closely related to foliar injury than any other factor tested. Additionally, soil surrounding injured pines displayed significantly higher soluble salt and chloride levels than soil surrounding healthy pines. Damaged ponderosa pines along California roadways also displayed elevated sodium chloride levels in tissues and adjacent soils, although damage from bark beetle infestation was also present (Gidley, 1990).

Although both Mg^{2+} and Cl^- are essential plant nutrients, excess Cl^- can be harmful to vegetation. Magnesium allows activation of numerous enzymes including those involved in carbon fixation, is a component of chlorophyll, and is involved in protein synthesis (Uno et al., 2001). Cl^- is a micronutrient, and is involved in photosynthesis and cell division. Chloride is easily translocated, and rarely, if ever, deficient in nature (Hinz et al., 2001). Chloride is considered the most toxic element of deicing salt, although mechanisms of chloride accumulation in plant tissues remains poorly understood (Jones et al., 1992). Sodium is a micronutrient in C4 plants, readily enters and is transported within plants, and may be persistent and toxic within plant tissues (Jones et al., 1992). Sodium may be more likely to accumulate in the woody tissues of stems (Dobson, 1991).

Pines in general are particularly noted for their sensitivity to roadside deicing salts (Hofstra & Hall, 1970; Lumis et al., 1973; Barrick et al., 1979; Townsend, 1982; Kelsey & Hootman, 1992; Bryson & Barker, 2002). Symptoms of salt damage in pines are expressed primarily in older needle growth and include chlorosis and necrosis of needle tissue beginning from the needle apex, with premature needle abscission, twig dieback, growth suppression, and mortality occurring in more severe cases (Staley et al., 1968; Hall et al., 1972; Lumis et al., 1973; Townsend, 1982; Hautala & et al., 1992; Kozlowski, 1997; Viskari & Karenlampi, 2000; Bryson & Barker, 2002). Foliar concentrations of chloride have been established to be directly correlated with levels of tissue necrosis in roadside trees (Holmes & Baker, 1966; Hofstra & Hall, 1970; Hall et al., 1972; Sucoff et al., 1976; Townsend, 1982; Bogemans et al., 1989; Pedersen et al., 2000). Additionally, symptom severity has also been associated with sodium content of foliage (Smith, 1970; Spotts et al., 1972; Sucoff et al., 1976; Kelsey & Hootman, 1992; Bryson & Barker, 2002), or both sodium and chloride ions (Hofstra & Lumis, 1975; Lumis et al., 1976; Northover, 1987; Viskari & Karenlampi, 2000;).

Effects of Deicing Salts on the Soil Matrix: Roadside vegetation may be either directly affected by deicing chemicals through root or foliar uptake of salts, or indirectly affected through deicer driven changes to the soil matrix. Deicing salts are plowed along with snow onto the shoulder of the road. As the snow melts, dissolved salts move overland until they percolate into the soil matrix or enter surface water systems. Through the action of vehicular traffic, deicing salts may also be splashed on to soils adjacent to the roadways or deposited further away through the drift of aerially suspended particulates (Jones et al., 1992). Soil infiltration is dependent upon slope, drainage, exposure (amount and distance from road), frost, and soil permeability (Langile, 1976; Harrison & Wilson, 1985; Jones et al., 1992). Langile (1976) found that one season of deicing on a newly opened highway significantly increased the presence of sodium (Na^+)

and chloride (Cl^-) ions in adjacent soils and plant tissues up to 61m away from the roadbed.

As deicing salts accumulate in roadside soils, they indirectly impact roadside vegetation through effects on soil structure, soil nutrient status, and through a reduction in soil osmotic potential. Effects on soil structure are ion dependent; for example, chloride is the principle anion contributing to soil salinity. The effects of chlorides on the soil include swelling, deterioration of structure, decreased permeability and increased erosion potential (Environment Canada, 1999). However chloride ions are highly soluble, and as they do not readily volatilize, precipitate, or form complexes, they are freely transported and leached out of the soil matrix relatively rapidly (Environment Canada, 1999; White & Broadley, 2001; Norrstrom & Bergstedt, 2000; Westing, 1969). Chloride ions may also complex with heavy metals, increasing their water solubility and likely translocation into plant tissues (Environment Canada, 1999). Smolders and McLaughlin (1996) reported that chloride enhanced the mobilization through the soil and plant uptake of the toxic heavy metal cadmium (Cd).

An abundance of sodium ions also leads to harmful effects on soil structure. As sodium ions leach through the ground adsorbing onto negatively charged soil particles, they may replace other cations (usually calcium and magnesium) present in the organic fractions and clay in the soil (Jones et al., 1992). When a soil is saturated with sodium and depleted of calcium and magnesium, the soil becomes alkali and the pH may increase to as high as 10. Deicing salt treatments containing sodium have been documented to increase the pH of the soil matrix and decrease the electrical conductivity of the soil due to Na^+ saturation (Holmes, 1961; Bryson & Barker, 2002). At high pH values, the soil solution contains bicarbonate and carbonate ions that tend to precipitate calcium (Ca^{2+}) and Mg^{2+} as carbonates, further destabilizing the soil structure (Bedunah & Trilca, 1977). Additionally, Na^+ in roadside soils can disperse soil colloids, promoting accumulated heavy metals to mobilize into ground water (Norrstrom & Bergstedt, 2000).

Magnesium compounds are also highly soluble and readily transportable (Environment Canada, 1999), but in contrast, have a beneficial effect on soil structure, reducing erosion and sediment loads in aquatic systems (Lewis, 1999). Magnesium is an important plant nutrient and component of chlorophyll, although amounts to meet metabolic requirements are low. Magnesium is thought not to be toxic even at high concentrations (Lewis, 1997), but some contrary evidence exists for vegetation (Tobe et al., 2002). The primary detriment to excess magnesium ions (Mg^{2+}) in roadside soils seems to be their potential to contribute to heavy metal mobility (Fischle, 2001). Magnesium ions (Mg^{2+}) are better able to compete for cation exchange sites than Na^+ for trace metals (Pb^{2+}, Cd^{2+}, Cu^{2+}, Zn^{2+}, Ni^{2+}, Cr^{3+}). Thus Mg^{2+} may displace and mobilize heavy metals to a greater extent than Na^+ (Amrhein & Strong, 1990).

When high levels of sodium and chloride ions cause deterioration of the soil structure, permeability decreases and hydraulic conductivity is reduced. This in turn lowers the soil osmotic potential, which can inhibit water and nutrient uptake by plants due to osmotic imbalances, resulting in reduced shoot and root growth and drought like symptoms. These changes also lead to increasing surface runoff, erosion, and poor aeration, further creating deleterious conditions for roadside vegetation (Jones et al., 1992; Westing, 1969; Environment Canada, 1999).

Additionally, when sodium from deicing salts becomes prevalent enough to significantly participate in ion exchange processes within the soil matrix, the ion promotes extended leaching of calcium, potassium, and magnesium base cations, and thereby affects the nutrient status of roadside soils (Norrstrom & Bergstedt, 2000). High levels of sodium also displace potassium and other important plant nutrients by commandeering ionic carrier proteins during plant uptake (Jenning, 1976; Westing, 1969). Most of the significant impact on soil ion exchange pools has been found to occur within 6m of the roadbed, with salinity in roadside soils usually limited to within 9-12m of the roadbed (Westing, 1969).

To summarize, elevated sodium and chloride levels in the soil matrix or plant tissue can inhibit water and nutrient uptake by plants due to osmotic imbalances, resulting in reduced shoot and root growth and drought like symptoms; cause nutritional imbalances by disrupting and replacing the uptake of other nutrients; and lead to long term growth inhibition and direct toxicity to the plant cells (Environment Canada, 1999).

Aerial Drift of Deicing Salts: Deicing salts may infiltrate the roadside environment and impact vegetation not only through surface runoff and soil penetration, but also through the airborne drift of salt particles (Bedunah & Trilca, 1977; Hofstra & Hall, 1970; Smith, 1970; Davidson, 1970; Lumis et al., 1973; Northover, 1987). These particulates are primarily a product of vehicle splash, plowing, and wind, and significant amounts of deicer are potentially transported in this manner. For example, Blomqvist & Johansson (1999) demonstrated that between 20 and 63% of the NaCl based deicing salts applied to highways in Sweden were carried through the air and deposited on the ground 2-40m from the roadside. Ninety percent of this deposition occurred within 20m of the roadside. Nicholson and Branson (1990) demonstrated that large fractions of particulates deposited on the road, including Na^+ and Cl^-, could be removed and resuspended by the first passage of a vehicle, which in wet conditions could result in large-scale distribution of deicer particulates. As vehicle speed increases, wind currents and updrafts from high-speed traffic allow suspend particulates to be carried by wind, leading to a potentially greater vegetation impact along freeways (Kelsey & Hootman, 1992). Lumis et al. (1973) reported specific salt injury symptoms in deciduous and conifer trees growing within 8 to 40 meters (26 to 131 feet) of a roadway exposed to aerial drift of deicing salt, while Smith (1970) documented damaging levels of sodium in white pine tissues greater than 28m downwind of a highway. Kelsey and Hootman (1992) described an aerial plume of deicing salt from an adjacent toll way as 15m (49 feet) high and 67m (220 feet) wide. Sodium deposition within 122m (400 feet) of the toll way and sodium related plant damage within 378m (1,240 feet) of the toll way also was reported.

Conifers may be especially vulnerable to aerial drift of salts due to the high surface to volume ratio of their foliage and their physiological activity during the deicing season.

Salt deposition on roadside conifer foliage has been shown to cause both specific ion toxicities in tissues and osmotic stress resulting in water loss and cell plasmolysis. This ultimately causes necrosis (tissue death) and premature needle abscission (Bedunah & Trilca, 1977; Barrick & Davidson, 1980; Bryson & Barker, 2002; Townsend, 1982; Hall et al., 1972).

It appears that salt enters the tree through the non-lignified foliage (needles) rather than through the woody tissue (Dobson, 1991). When a species absorbs salt readily through foliage, its tolerance to salinity may be markedly reduced (Bernstein, 1975). Deicing salt exposure due to spray within 10-20m of the road was demonstrated to cause a greater severity of foliar damage than soil uptake alone (Hofstra & Hall, 1971; Viskari & Karenlampi, 2000; Bryson & Barker, 2002). Many studies have indicated that needle necrosis, twig dieback, and bud kill are associated with areas of heavy deicing salt usage, with trees and foliage down wind and facing the roadside more heavily affected than trees further away (Hofstra & Hall, 1970; Lumis et al., 1973; Sucoff et al., 1976; Pederson et al., 2000).

Precipitation, Temperature, and Deicer Stress: The necrosis associated with deicing salts also is impacted by precipitation levels (Spotts et al., 1972). Salt levels in roadside soils can be ameliorated by high levels of precipitation and correspondingly exacerbated by a decrease in precipitation (Jones et al, 1992; Environment Canada, 2000). Although spring and summer precipitation leaches salts from roadside soils (Jones et al., 1992), significantly elevated levels of NaCl in roadside soil water was found in one study to be maintained year-round (Pedersen et al., 2000). While leaching of salts occurred in the spring, the salts were concentrated via evapotranspiration in the summer, and therefore present in the environment throughout the growing season. Several studies suggest that once salt has entered the needle tissue it remains throughout the year creating a long-term stress in exposed plants (Hall et al., 1972; Viskari & Karenlampi, 2000).

Damage from deicing salts has been documented to occur from late winter to early spring (Smith, 1970; Sucoff et al., 1976), but also to appear in the spring and summer (Hall et al., 1972; Lumis et al., 1976; Bryson & Barker, 2002). This later damage was attributed to the increased intake of water leading to the increased translocation and transpiration of Na^+ ions. Foliar tissue levels of sodium and chloride have been found to decline in summer months (Lumis et al., 1976), although tissue necrosis was found to increase over the growing season, suggesting that warmer temperatures are influential in the uptake of salts by roadside vegetation (Hall et al., 1972; Viskari & Karenlampi, 2000). Hall et al. (1972) were able to suppress foliar injury in eastern white pine (*Pinus strobus*) saplings exposed to deicing salt spray at 1.5ºC. When saplings were transplanted to a 15ºC greenhouse however, symptoms of foliar damage emerged within two days.

Winter weather conditions also noticeably affect the accumulation of salt and injury in needle tissue. These conditions not only dictate the amount of deicer exposure (via application to roadways), but also the ion penetration into plant foliage. In dry conditions salt remains crystallized on the surface of needle tissues, whereas high atmospheric humidity (> 75%) and moisture in low temperatures causes salt dissolution and changes in the needle cuticle which promote uptake of salt ions (Simini & Leone, 1982; Northover, 1987; Viskari & Karenlampi, 2000). Low temperatures and temperature fluctuations may also increase foliage damage as salt accumulation may reduce the frost hardiness of vegetation (Hofstra & Hall, 1971; Sucoff et al., 1976; Lumis et al., 1976; Hautala et al., 1992; Viskari & Karenlampi, 2000). Chloride uptake by leaves has shown to increase with decreasing temperatures and photoperiods and higher relative humidities, potentially due to chemical and structural changes increasing the permeability of the plant cuticle (Simini & Leone, 1982).

Salt Impact on Needle Anatomy: Salt exposure in pine needles has several direct effects on needle anatomy, leading to tissue necrosis. In both ponderosa (*Pinus ponderosa*) and lodgepole (*Pinus contorta*) pines, needle anatomy undergoes a general response to stress, including salt and water stress, consisting of a hypertrophy of the epithelial tissue occluding the resin canals, and the granulation and transfusion of mesophyll parenchyma cells (Stewart et al., 1973). Salt injury in ponderosa pine leads to an early collapse and clearing of the outer mesophyll cells in the needle, as well as minor abnormalities in phloem tissue. Changes in external surface structure in NaCl sprayed pines revealed that exposed needles exhibited coalesced epicuticular wax and had rows of flaccid subsidiary cells (Krause, 1982).

Impact of Deicers on Plant Physiology: Salinity limits the vegetative and reproductive growth of plants by inducing physiological dysfunctions and causing widespread direct and indirect harmful effects (Kozlowski, 1997). Injury may be caused by salt induced changes in metabolic processes such as photosynthesis, respiration, protein and nucleic acid synthesis, and through the alteration or suppression of enzyme activity and hormone balance. Direct exposure to salinity inhibits the in vitro activity of many enzymes (Greenway & Munns, 1980), and Kozlowski (1997) cites studies documenting decreases in protein synthesis, and the early senescence of plant tissues due to the increasing production of the plant hormones abscisic acid and ethylene.

Salinity can also injure cell membranes and increase solute leakage (Hautala et al, 1992). Indirectly, salinity may affect roadside vegetation by decreasing the available soil moisture. A high level of salinity in roadside soils increases the osmotic gradient between the soil solution and the cells of plant roots (Westing, 1969; Jones et al., 1992). Plant growth limitations imposed by short-term salinity have been shown to be a product of the water status of the plant's roots (Munns & Termaat, 1986).

Salt stressed trees often exhibit symptoms similar to drought stress for these reasons. Decreased water content in leaf tissues and more negative water potentials have been documented in vegetation in saline and sodic soils (Leonardi & Fluckiger, 1985; Simini & Leone, 1986). Other physiological responses similar to drought stress include increased organic solute synthesis and decreased stomatal conductance (Petersen & Eckstein, 1988). Stomatal closure both decreases water loss through transpiration, and decreases the movement of Cl^- through the plant and its accumulation at sites of evaporation.

Salinity may also indirectly affect roadside vegetation through altered nutrient availability (see below) and impaired root aeration. Roots may be damaged by the soil compaction caused by sodium ions (Dobson, 1991), and plasmolysed by soil salinity, reducing a plants overall root volume. Sugar maples exposed to deicing salts experienced a significant loss of root volume and reduction of surface root systems correlating with sodium and chloride ion content of root tissues (Guttay, 1976).

Although many plants, especially halophytes, can compensate for low soil osmotic potentials through the cellular accumulation of metabolites or inorganic solutes in the cytoplasm, the physiological cost may include a decreased growth rate (Bernstein, 1975). Additionally, some trees have been shown to be able to preferentially take up water from areas in the soil with reduced salinity (West, 1978).

Directly, excesses of both Na^+ and Cl^- create specific ion toxicities leading to growth depression, leaf tissue necrosis, shoot dieback, and in severe cases, mortality (Westing, 1966). Trees and other woody plants are generally more salt sensitive than herbaceous plants, especially grasses. Overall specific ion toxicities and osmotic stress may act synergistically to reduce cell turgor, inhibit cell membrane function, inhibit enzyme activity and photosynthesis, induce ion deficiencies, and limit the production of metabolites for plant growth (Hasagewa et al., 1986).

Salt Injury, Stomatal Closure, and Photosynthesis: Salt exposure causes deleterious effects on stomatal conductance and net carbon assimilation in plants. Both stomatal closure and impairment may occur in the presence of salinity, decreasing the efficiency of photosynthesis and transpiration in plants. Bernstein (1975) cites evidence that salt alterations of the plant hormone kinetin balance may decrease stomatal apertures. Also, ion imbalances induced by an excess of chloride may contribute to stomatal closure. Large quantities of Cl^- were found to accumulate in the vacuoles of stomatal guard cells in the salt damaged tissues of ash leaves (Leonardi & Fluckiger, 1986). This accumulation increased the presence of Ca^{2+} and Mg^{2+} cations in guard cells and epidermal cells, impairing normal electrolyte transfer and injuring the stomatal mechanism. If stomates become injured, leaf necrosis could occur due to increased leaf temperature from poor transpiration. That characteristic salt scorch often appears after the onset of warmer dry weather supports the idea that accumulations of saline ions may impair a plants ability to regulate water loss through inhibiting normal stomatal closure (Bernstein, 1975).

Poor osmotic adjustment of plants to saline soils also leads to turgor loss and stomatal closure, which is then followed by reduced gas exchange and photosynthesis (Shannon, 1997). Deicer exposure has been shown to lower the xylem water potentials of Ponderosa pine, mimicking drought stress, and likely lowering photosynthetic rates through stomatal and non-stomatal effects (Bedunah & Trilca, 1977). Water potentials also were reduced in seedlings of green ash exposed to soil salinity (Pezeshki & Chambers, 1986) and in black spruce exposed to NaCl in solution (Redfield & Zwiazek, 2002).

It has been clearly established that salinity reduces the rate of photosynthesis in plants (Bedunah & Trilca, 1977; Pezeshki & Chambers, 1985; Yeo et al., 1985; West et al., 1986; Banuls & Primo-Millo, 1992; Meinzer et al., 1994). For example, root-zone exposure to NaCl solutions has been demonstrated to decrease photosynthesis and reduce pre-dawn xylem potentials in the tropical fruit tree Sapodilla (Mickelbart & Marler, 1996). This reduction in net carbon assimilation and subsequent growth may be a more important indicator for determining overall impact and injury than visible damage or the specific ion content of the foliage (Bedunah & Trilca, 1977).

Salinity inhibition of net carbon assimilation can be described as a product of the response of the plant’s stomates to salt exposure, and the diffusion independent effects on the photosynthetic system’s capacity and efficiency. Closing of the stomata, often as a physiological response to conserve water through reduced transpiration, also limits the diffusion of carbon dioxide (CO_2) into plant tissues and therefore the overall rate of photosynthesis (Wong et al., 1979). Stomatal affects have been clearly implicated in photosynthetic inhibition (Longstreth & Nobel, 1979; Pezeshki & Chambers, 1985;

Seemann & Critchley, 1985; West et al., 1986; Brugnoli & Lauteri, 1991; Meinzer et al., 1994), although the levels of actual impact may be overestimated (Farquhar & Sharkey, 1982).

Photosynthetic reduction can also be a product of non-stomatal factors precipitated by osmotic effects or specific ion toxicities, although these effects are not as clearly understood (Golombek & Ludders, 1993; Yeo et al., 1985; Bethke & Drew, 1991; Kozlowski, 1997). In some plants and photosynthetic protists, salinity lowers the efficiency of photosynthetic enzymes and the electron transport chain, reduces leaf chlorophyll content, and injures the light-harvesting complex as a possible consequence of the failure to keep salt ions out of the cytoplasm (Kaiser & Heber, 1981; Seeman & Critchley, 1985; Gonzalez-Moreno et al., 1997).

Still other studies find a combination of both stomatal and non-stomatal effects on photosynthesis, with variation by species and salinity exposure level (Longstreth & Nobel, 1979; Everard et al., 1994). For example, Brugnoli & Bjorkman (1992) in examining growth and net carbon assimilation in cotton under continuous salinity stress found that stomatal closure accounted for nearly all of the photosynthetic inhibition observed at lower salinities. As salinity exposure increased however, non-stomatal effects increased in impact. In this case, these effects were not associated with detrimental effects on the photosynthetic apparatus, but instead to the decreased allocation of enzymes involved in carbon fixation.

Foliar exposure to salts may have less of an impact on photosynthesis and stomatal conductance than the uptake of salts by the plant's roots. In one study, foliar application of NaCl spray to the leaves of well watered citrus seedlings was shown to be less detrimental than root zone salinity, as similar rates of photosynthesis and stomatal conductance was observed between salt sprayed and water sprayed leaves (Romero-Aranda & Syvertsen, 1996). Other studies have also reported minimal physiological effects in response to low level foliar exposure to aerosolized salts (Hofmann et al., 1987, cited in McCune, 1991).

Plant physiological response to salinity may be rapid and immediate, involving water stress (Pezeshki & Chambers, 1986; Golombek & Ludders, 1993) or delayed as ions accumulate in plant tissues (Yeo et al., 1985, Bethke & Drew, 1991). Low environmental humidity and small water deficits as may be found in saline environments decreases photosynthesis rates through stomatal closure, while severe dehydration has been tied to photoinhibition through increased concentrations of solutes in dehydrated cells causing protein and enzyme interactions as well as membrane damage (Kaiser, 1987).

Ultimately salt exposure may lead to decreased growth, vigor and plant mortality. Decreased growth may result from a loss of photosynthetic capacity (Longstreth & Nobel, 1979; Bongi & Loretto, 1989), leaf necrosis, and premature abscission (Dobson, 1991). In response to long-term salinity, growth seems to be limited by leaf tissue tolerance, where necrosis of tissues may decrease photosynthetic area to the point of affecting growth (Munns & Termaat, 1986).

Deicer Impact on Seed Germination: Plant recruitment may suffer in roadside environments due to higher levels of salinity (Biesboer & Jacobson, 1994), and salinity in roadside snowmelt has been observed to suppress seed germination (Isabelle et al., 1987). Additionally, seeds collected from roadside populations were shown to possess less fitness than their counterparts isolated from roads (Beaton & Dudley, 2004).

This prevention of seed germination may be detrimental to maintaining roadside plant communities. For many plant species, salt stress is more inhibitory during germination than at any other time during their life cycle (Houle et. al, 2001; Dodd & Donovan, 1992). It has been well documented that seed germination percentages and rates of seedling emergence decrease with an increase in environmental salinity and are inhibited all together by higher salt concentrations (Almansouri et al., 2001; Bani-Aameur & Sipple-Michmerhuizen, 2001; Houle et al., 2001; Essa, 2002; Mauromicale & Licandro, 2002; Ramoliya & Pandey, 2003; Taleisnik et al., 1998; Tobe et al., 2000). Soil salinity in the form of Na^{+}, Mg^{2+}, K^{+}, and Ca^{2+} chlorides and sulfates has been found not only to decrease germination, but also to reduce and retard plant growth, lower the overall dry mass leaf production, and lower the nitrogen, potassium and phosphorus content of plant tissues (Ramoliya et al., 2004; Ramoliya & Pandey, 2002; Mer et al., 2000).

Most published studies attribute germination suppression by salt to osmotic inhibition, which prevents the imbibition of water by dormant seeds (Al-Karaki, 2001; Bliss et al., 1986; Baji et al., 2002; Macke & Ungar, 1970; Dodd & Donovan, 1999; Rubio- Casal et al., 2002). However, toxicity and other physiological effects also have been observed (Almansouri et al., 2001; Al-Ansari, 2003). For example, Tobe et al., 2002, found that both Mg^{2+} and Na^{+} ions have toxic effects on the radicles of *Kalidium caspicum*, while Myers & Morgan (1989) noted both toxic ion and osmotic factors in germination suppression in the salt tolerant grass *Diplachne fusca*.

Physiological mechanisms by which salinity reduces germination percentages and retards plant growth have not been readily identified in many cases and most likely vary by plant species. Several studies have suggested that salt stress may reduce germination by influencing mobilization of stored reserves (Lin & Kao, 1995; Prakash & Prathapasenan, 1988), by facilitating the intake of toxic ions (Bernstein & Hayward, 1958; Smith & Comb, 1991), by reducing protein hydration (Kramer, 1983), by changing activities of enzymes involved in germination (Dubey & Rani, 1990), or by affecting the structural organization or synthesis of proteins in the embryo (Almansouri et al., 2001; Ramagopal, 1990).

It is important to emphasize that salinity tolerance varies widely by plant species, population, and cultivar (Ries & Hofmann, 1983; Ashraf et al., 1989; Rubio-Casal et al., 2003, Talesnik et. al., 1998; Lovato et al., 1999). And that germination suppression varies by salt type (Tobe et. al., 2002; Mer et. al, 2000; Ries & Hofmann, 1983; Ryan et al., 1975). For instance, Hyder and Yasmin, 1972, found that in using salts of equal osmotic concentration, $MgCl_2$ depressed germination the most in the grass *Alkali sacaton*, followed in decreasing order by KCl, $CaCl_2$, and NaCl.

While it has been thoroughly demonstrated that salinity adversely affects germination, little direct assessment of deicing chemicals has been undertaken. In 2000, Roosevelt and Fitch demonstrated that concentrations of the deicer Ice Ban suppressed germination in turf grass seeds more than concomitant concentrations of sodium and magnesium chloride. Glycol based aircraft deicers have been shown to cause germination suppression and toxic effects in ryegrass (*Lolium perenne*) and lettuce (*Lactuca sativa*) (Pillard & DuFresne, 1999). Bang and Johnstone (1998) noted germination suppression in lettuce (*Lactuca sativa*) and bean (*Phaseolus vulgaris*) exposed to 2g/kg sodium acetate/formate deicer (Ice Shear™) in soil. Additionally, NaCl was found to suppress germination to a greater extent than calcium magnesium acetate in cress (*Lepidium sativum*), barley (*Ordeum vulgare*), red fescue grass (*Festuca rubra*), and Kentucky bluegrass (*Poa pratensis*) (Robidoux & Delisle, 2001).

Pollutant Impacts on Roadside Vegetation: Vehicle emissions have led to higher levels of trace metals in roadside vegetation and soils. Tetra-ethyl lead gasoline (Pb), diesel oil (Cd), anti-knocking additives to gasoline (Mn), tire attrition (Ba, Zn, Cd), steel parts attrition (Ni, Cr, V, W, Mo, Fe, Mn, Al, Zn), wire corrosion, brake shoe attrition (Cu, Mn), radiator fluid (Cu), and catalytic converter emissions (Pt, Pd, Ru) all contribute trace metals to roadside soils (Amrhein & Strong, 1990; Monaci et al., 2000; Beaton & Dudley, 2004). Metal emissions are usually in particulate form and are either 1) deposited on the road surface and subsequently remobilized as dust or removed in drainage water; or 2) dispersed by the atmosphere, but deposited close to the highway causing elevated levels in roadside soil and vegetation; or 3) the metal is dispersed by the atmosphere and deposited far from the roadside (Harrison et al, 1985).

Roadside vegetation can be successfully used as a bioindicator of trace metal exposure, as plants will incorporate these metals into their tissues through soil and foliar exposure (Mukherjee & Bhowal, 1995; Monaci et al., 2000). Conifers are considered good accumulators of trace metals due to their large surface areas per unit tissue weight, their waxy and resinous needle coating and the long life span of their needles (Alfani et al., 2000; Lombardo et al., 2001).

Low concentrations of trace metal pollutants in vegetation depress physiology and cause asymptomatic injuries, including reduced growth and early senescence. Heavy metal content positively correlates with lowered vitality, cell membrane damage, and decreased photosynthetic efficiency in lichens (Garty et al, 2002). Higher concentrations of metals produce noticeable changes in morphology and tissue necrosis (Lombardo et al., 2001). Characteristic symptoms caused by many heavy metals may be similar to one another. For example Zn, Ni, Cr, Pb or Cd may produce similar leaf chlorosis and necrosis symptoms in exposed plants (Foy et al., 1978). Pine needles also will exhibit similar foliar injuries in response to a range of pollutants. Necrosis due to collapse of needle mesophyll cells in pines can be characterized by ozone, boron, sulfur dioxide, or salt toxicity (Stewart et al., 1973). Additionally, ozone and sulfur dioxide damage may also erode epicuticular wax in conifers (Bytnerowicz & Turunen, 1994, cited in Schreuder et al., 2001).

Air pollution from vehicle emissions in the form of hydrocarbons and nitrous oxides (NO_x) which produce ozone (O_3), and sulfur dioxide (SO_2), which contributes to acid rain, also impacts the health of roadside vegetation. Ozone produces reactive oxygen species in the leaf apoplast, disrupting biochemical and physiological processes in the plant, potentially leading to foliar lesions and reduced growth (Langebartels et al., 2002). Shamay et al., 2001 cites studies demonstrating that long term exposure to low levels of ozone can lead to decreased photosynthesis, increased ion leakage, accelerated senescence, and altered carbohydrate allocation. Exposure to higher levels may lead to necrotic lesions and acute injury soon after exposure. Ponderosa pine exhibit these responses when exposed to ozone. Ponderosa pine needles fumigated with 0.5ppm ozone (a high level) for 9-12 days developed chlorotic mottling, terminal dieback, and increased early senescence (Miller et al., 1963). Stem diameter growth in ponderosa seedlings exposed to twice ambient ozone was significantly reduced compared to controls (Momen et al, 2002), and reduced foliar biomass in ponderosa pine forests of Arizona’s Rincon mountains also correlated with ozone exposure (Diem, 2002). Additionally, mature ponderosa pines with greater ozone exposure in the field exhibited reduced net carbon assimilation rates (Grulke, 2002). In contrast, Momen et al. (2000) found elevated levels of ozone did not significantly depress photosynthesis in ponderosa pine, although simulated exposure to acid rain (pH 3) decreased photosynthesis in current year foliage. Finally, ozone may further depress growth in plants already stressed by salinity (Welfare et al., 2002).

Chronic airborne nitrogen and sulfur deposition can result in increased levels of these elements in plant tissues, as nitrogen and sulfur are readily uptaken through plant stomates (Alfani et al., 2000; Manninen & Huttunen, 2000). Exposure to SO_2 was found to correlate with chlorosis and necrosis of stomatal areas and needle tips in Scots pine and Norway spruce, with damage prevalent in the new needle tissues (Manninen & Huttunen, 2000). Sulfur dioxide exposure reduced photosynthetic efficiency in many species in a European forest community, but not in Scots pine (*Pinus sylvestris*) however (Odasz-Albrigtsen, et al., 2000).

Free radicles produced by nitrous oxides in polluted dew were found to reduce photosynthesis in Japanese red pine (*Pinus densiflora*) (Kume et al., 2001). This decrease was attributed to permanent damage of the leaf cuticle and/or chloroplast membranes. Elevated levels of sulfur (200 to 400% above standard) and nitrogen along with correlated erosion of epicuticular wax were found in the needle tissues of European Scots pine exposed to sulfur dioxide and nitrous oxide air pollution (Grodzinska-Jurczak & Szarek-Lukaszewska, 1999).

Deicer Impact on Nutrient Availability: Plants accumulate Na^+ at the expense of Ca^{2+} and K^+ in saline conditions. Sodic soils reduce Ca^{2+}, Mg^{2+}, and K^+ in shoot tissues and may have a toxic effect when Na^+ interferes with membrane function and integrity by replacing membrane bound Ca^{2+}, or interferes with the function of K^+ as a cofactor in cellular reactions (Khan et al., 2000; Essa, 2002).

Calcium acts as a transducer of hormonal and environmental signals controlling the phosphorylation process and therefore ultimately a large number of cellular biochemical reactions (Rengel, 1992). Replacement of Ca^{2+} by Na^+ weakens cell membrane integrity and alters Ca^{2+} homeostasis and biochemical reactions in the cell (Rengel, 1992). Potassium is a major essential plant nutrient which helps maintain plant cellular water relations through osmotic pressure in stomatal guard cells, and is important for plant metabolism including protein synthesis and enzyme activation (Uno et al., 2001). Ability to maintain the cytoplasmic levels of potassium critical to metabolism is an important factor to survival in saline environments (Chow et al., 1990), and K^+ may be critical to maintaining the integrity of the photosynthetic system under high salinity (Brugnoli & Bjorkman, 1992). The reduction in K^+ ion concentration can ultimately inhibit growth by reducing the osmotic capacity for cell turgor maintenance, or through deleterious effects on metabolic function (Greenway & Munns, 1980). Although the increased concentration of Na^+ ions may help offset loss of turgor, Na^+ is unable to substitute for the specific functions of Ca^{2+}, K^+ and Mg^{2+}, such as enzyme activation and protein synthesis (Chow et al., 1990; Essa, 2002).

NaCl in soil solution has been shown to profoundly affect the mineral content of maritime pine (*Pinus pinaster*) tissue (Saur et al., 1995). In response to salinization, growth rates were significantly reduced, and N and K concentrations increased in root tissues while and P, Ca, and Mg concentrations decreased. However, NaCl injury from exposure to road deicers did not correlate with deficiencies in essential elements (N, K, and P) in roadside sugar maples (Hall et al., 1973). McCune (1991) cites studies where saline spray significantly reduced foliar levels of Ca, Mg, and B in cotton foliage, and other instances where salinity reduced K^+, Mg^{2+}, and Ca^{2+} in plant tissues. In the tropical fruit tree Sapodilla exposed to root zone NaCl, increased concentrations of Na^+ and Cl^-, as well as an increased Na:K ratio in leaf tissues were reported, although no consistent influence on foliar N, S, Mg, Fe, B, Cu, and Zn were found. When the Na: K ratio exceeds 1, Na^+ may be substituted for K^+ in maintaining cell turgor (Mickelbart & Marler, 1996).

Deicing Salts and Plant Pathogens: It has also been well established that physiological stress factors including deicing salts may contribute to plant susceptibility to environmental pathogens (Westing, 1969; Dobson, 1991; Kelsey & Hootman, 1992). For example, bleeding canker (*Phytophthora cactorum*) in sugar maples and citrus root rot (*Phytophthora parasitica*) correlated positively with the presence of soil salinity (Lacasse & Rich, 1964; Blaker & MacDonald, 1986). Lodgepole pines (*Pinus contorta*) damaged by deicer applications also were heavily impacted by bark beetle infestation (Gidley, 1990). Pine needle cast fungus (*Lophodermium seditiosum*) and aphid activity (*Cinara pinea*) have also been associated deicing salt damage to roadside trees (Viskari & Karenlampi, 2000).

Environmental Impacts Specific to Magnesium Chloride: Unlike information on NaCl based deicers, studies on the impacts of $MgCl_2$ based deicers have been limited. Soil applied $MgCl_2$ was found to cause foliar injury in one-year-old ponderosa pine ramets, but to a lesser degree than NaCl (Spotts et al., 1972). Lewis (1999) in a report to the Colorado Department of Transportation concluded that $MgCl_2$ deicer use in Colorado is unlikely to cause or contribute to environmental damage at greater than 20 yards (18.3m) from the roadway. Although no evidence exists that current deicing practices lead to runoff with concentrations known to be harmful to aquatic life, Lewis concludes that the chloride components may damage roadside vegetation. In an aquatic toxicity test of the algal genus *Selenastrum*, significant suppression of physiology and cell division were observed at 0.1% dilution of $MgCl_2$ deicer, indicating a high sensitivity to the deicer within potential environmental exposure ranges adjacent to the roadside. A field site comparison of algal communities receiving and removed from deicer exposure failed to demonstrate any significant differences in physiology however (Lewis, 1999).

In 1993, 293 lodgepole pine and spruce trees within six feet of county road 491 in Rocky Mountain National Park were found to be dead or dying. The roads had been treated with $MgCl_2$ as a dust palliative, and elevated levels of magnesium and chloride were found to be present in affected pine tissues (Connor, 1993). The damage was attributed to the salt although it was unclear if the uptake had been through root or foliar pathways. Currently, Rocky Mountain National Park no longer uses $MgCl_2$ for dust stabilization.

Lastly, it is important to note that liquid deicers such as $MgCl_2$ improve air quality by reducing particulates in the atmosphere. Sand particulates may deleteriously impact roadside vegetation through occluding stomata and reducing photosynthesis rates and preventing absorption of nutrients and water from the soil (Hinz et al., 2000).

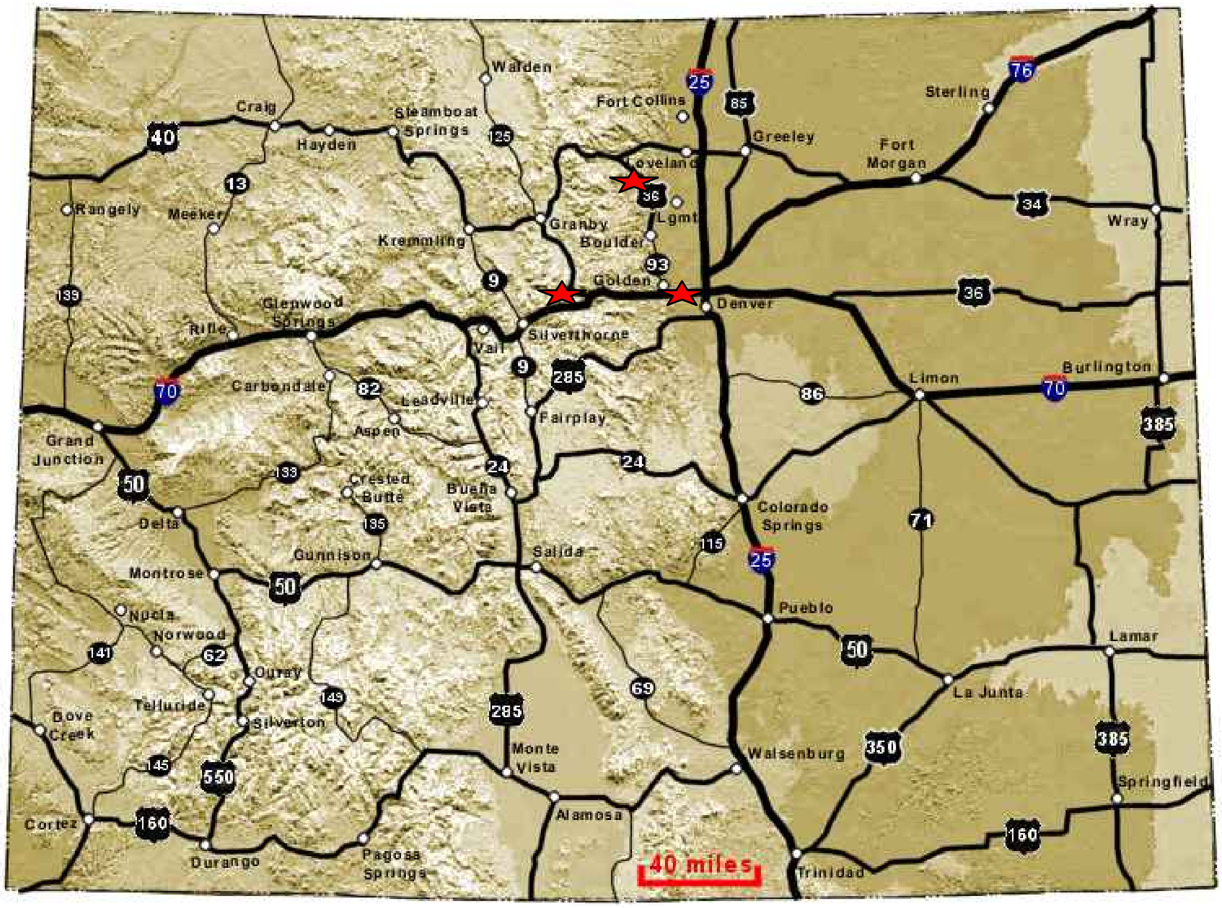
Field Study Sites

Eight study sites along Colorado highways were selected in cooperation with CDOT personnel, representing areas where roadside conifer health and survivorship was of concern. Four study sites surveyed lodgepole pine (*Pinus contorta*) at high altitude sites along the I-70 corridor, and four sites surveyed ponderosa pine (*Pinus ponderosa*) at lower elevations along highway 36 and in metro Denver (Figure 1.). In each location, at least two sites were present, one comprising less damaged or 'healthier' roadside vegetation, and one site possessing more damaged roadside vegetation. Sites were also chosen where adjacent and accessible off roadside trees of equivalent trunk diameter and stand structure existed in order to make health and physiological comparisons. The distance of selected trees away from the roadside varied by site from between approximately 30m to 100m (Table 1.). However, sites were selected without researcher knowledge of the type of potential deicer exposure, allowing for a blind comparison between locations.

Table 1. Mean distance from the road in meters of compared roadside and off-roadside conifers at eight field sites

Site	Mean distance of study trees from roadside (m) Roadside	Control
111D (I-70)	9.9	50.0
112H (I-70)	11.7	63.6
113H (I-70)	11.9	94.0
114D (I-70)	7.8	48.8
121H (Hwy 34)	7.0	87.1
122D (Hwy 34)	5.1	47.0
131H (Metro Denver)	9.5	46.7
132D (Metro Denver)	8.1	52.3

Table 2. and 3. summarize the characteristics of each field site and include location, GPS coordinates, elevation, slope, aspect, site slope relationship to the roadbed, slope position, topographic configuration, habitat type, stand structure, land use, disturbances, dominant tree species, and relative roadside vegetation health classification. Detailed explanations of slope position, topographic configuration, and stand structure may be found in Appendix A.



Map source: Old Colorado Almanac. Used with permission.

Figure 1. State map giving approximate general locations of the study field sites.

Table 2. Site characteristics for high altitude lodgepole pine (*P. contorta*) sites along the I-70 corridor.

Site ID	111D	112H	113H	114D
Location	Summit County, Westbound I-70 mile marker 211	Clear Creek County, Westbound I-70, mile marker 224	Clear Creek County, Eastbound I-70, mile marker 219	Clear Creek County, Westbound I-70, mile marker 223
GPS Coordinates	N39º39’47” W105º58’53”	N39º41’47” W105º45’20”	N39º42’06” W105º50’55”	N39º41’42” W105º46’30”
Elevation (meters, feet)	3,140m 10,300’	3,042m 9,980’	3,109m 10,200’	2,921m 9,583’
Slope	32º	R* = 20º, C* = 8º	R* = 23º, C* = 6º	R* = 14º, C* = 10º
Aspect	140ºS	159ºS	169ºS	165ºS
Up/downslope of road	Upslope	Upslope	Downslope	Upslope
Slope Position	C* = shoulder R* = backslope	Toeslope	C* = toeslope R* = backslope	Backslope
Topographic Configuration	Convex	Concave	Concave	Convex; Broken; Undulating
Habitat Type	Forested/Wooded	Forested/Wooded	Forested/Wooded; Riparian zone	Forested/Wooded; Rock/cliff
Stand Structure	Open canopy, multi-storied	Open canopy, multi-storied	Mosaic	Open canopy, multi-storied
Land Use	Forest/Open land	Forest/Open land	Forest/Open land	Forest/Open land; Other
Disturbances	Road maintenance; Other	Road maintenance	Land Clearing; Road maintenance; Other	Mining; Road maintenance; Other
Dominant Tree Species	Lodgepole pine *Pinus contorta*	Lodgepole pine *Pinus contorta*	Lodgepole pine *Pinus contorta*	Lodgepole pine *Pinus contorta*
Roadside Vegetation Classifiation	Damaged	Healthier	Healthier	Damaged

*R = roadside trees; C = control trees

Table 3. Site characteristics for low altitude ponderosa pine (*P. ponderosa*) sites along Hwy 36 and in metro Denver.

Site ID	121H	122D	131H	132D
Location	Boulder County, Southbound HWY 36, mile marker 8	Boulder County, Southbound/ Northbound HWY 36, mile marker 11	Jefferson County, Intersection of I-70 and Wadsworth Blvd.	Denver County, Intersection of I-25 and I-70
GPS Coordinates	N40º18'54" W105º24'03"	N40º18'19" W105º29'18"	N39º47'12" W105º04'49"	N39º46'50" W104º59'28"
Elevation (meters, feet)	2,253m 7,392'	2,188m 7,178'	1,617m 5,304'	1,582m 5,190'
Slope	R* = 28º, C* = 10º	R* = 36º, C* =18º	R* = 20º, C* = 5º	R* = 2º, C* = 5º
Aspect	R* = 175ºW, C* = 92ºE	270ºW	330ºN	170ºN
Up/downslope of road	Downslope	C* = upslope R* = downslope	Downslope	C* = downslope R* = upslope
Slope Position	C* = toeslope R* = backslope	C* = shoulder R* = backslope	C* = toeslope R* = shoulder	Variable
Topographic Configuration	Concave; Undulating	Concave	Concave	Linear or planar; Undulating
Habitat Type	Forested/Wooded	Forested/Wooded	Artificial planting; Wetland	Artificial planting
Stand Structure	Open canopy, multi-storied	Open canopy, multi-storied	Mosaic	Mosaic
Land Use	Forest/Open land; Recreation	Forest/Open land; Residential	Intersection; Other	Intersection
Disturbances	Road maintenance; Other	Tree cutting; Road maintenance	Artificial regeneration; mowing/ landscaping; Road maintenance; Other	Artificial regeneration; Tree cutting; mowing/ landscaping; Road maintenance; Other
Dominant Tree Species	Ponderosa pine *Pinus ponderosa*	Ponderosa pine *Pinus ponderosa*	Ponderosa pine *Pinus ponderosa*	Ponderosa pine *Pinus ponderosa*
Roadside Vegetation Classifiation	Healthier	Damaged	Healthier	Damaged

*R = roadside trees; C = control trees

OBJECTIVE ONE: ESTABLISHING THE EXTENT AND MODE OF ROADSIDE VEGETATION DEICER EXPOSURE

Introduction

Evidence of deicer exposure was assessed across the eight field study sites in order to determine if salt exposure could be correlated with necrosis and foliage loss in Colorado roadside conifers. At each field site, five conifers along the roadside, and five conifers of equivalent trunk diameter away from the roadside, were assessed for foliage health through a visual evaluation of necrotic foliage in the crown, both in the winter (2003-04) and subsequent fall. In fall 2004, study trees were also evaluated for the number of years of needle growth retained on the branches, and plant tissues and soils were collected and analyzed for evidence of deicer exposure. Pine needle tissue, twig tissue, and soil samples 1m from the base of the tree were analyzed for sodium, chloride, and magnesium content. In addition, soil samples were analyzed for pH and electrical conductivity as a measure of salinity. Evidence of exposure was then correlated with foliage health at each site.

Sampling for chemical analysis occurred in early fall 2004, a time when levels of salts in soils and plant tissues should be greatly reduced due to seasonal precipitation and leaching, in order to determine if salinity is a long term and year round problem. Additionally, it became evident through field observation that trees adjacent to the roadside demonstrated a deposited coating on their foliage. The nature and presence of this coating was investigated using scanning electron microscopy (SEM).

Methods

Assessment of Conifer Health: At each field site, average percent necrotic foliage in the tree's crown was visually estimated in order to provide an overall appraisal of tree health. In the lower canopy, average percent necrosis in the needle tissue of the current year's growth, as well as needle tissue of all previous years' growth was also visually estimated. The pattern of tissue death displayed and the number of years of needle growth retained by the tree (foliage density) was recorded.

Sampling: Needle tissue, twig tissue and soil samples were collected at each field study site from mid-September and early October 2004, prior to the beginning of deicing applications. Samples were obtained from five pine trees adjacent to the roadside and five pine trees located off roadside at each individual site for a total of eighty trees. Three soil cores up to 12" deep were taken at random locations one meter from the trunk of each tree and homogenized. Needle and twig tissue representative of overall current year and previous years foliage was recovered with a tree trimming head and separated into primary photosynthetic tissue (needles) and secondary lignified tissue (twigs).

Chemical Analyses: All chemical analyses were carried out by Weld Laboratories, Inc., Greeley, CO, USA. Soil pH and total salt content via electrical conductivity (mmhos/cm) were found via a 1:2 water extraction according to methods 9045 and 9050 in the EPA publication SW-846, 3rd edition, *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods*. Soil sodium and magnesium content were quantified using exchangeable atomic absorption methods and chloride by titration according to *Methods of Soil Analysis*, A.L. Page, et. al., 1982. Needle and twig tissue were oven dried, ground in a Wiley mill, and analyzed for percent dry weight magnesium content using atomic absorption and sodium content using atomic emission method 3.2.05, and chloride content by method 3.4.04 in the *Official Methods of Analysis of AOAC International*; Dr. William Horwitz, editor; 17th Ed., 2000.

Scanning Electron Microscopy: Three needles per tree from mature fascicles representative of average foliage health were examined using scanning electron microscopy. Three 5-8mm pieces per needle were excised and mounted on aluminum stubs and gold coated in an EMS 550 sputter coater. Needle segments were examined with a Jeol JSM-5200 scanning microscope at 10-25kv and 35x-3500x magnification for presence of surface coating and stomatal occlusion. Elemental composition of needle coating was investigated using an SEM with an attached energy dispersive spectrometry (EDS) system at the Colorado School of Mines.

Statistical analysis of all data utilized SAS version 8.1, SAS Institute Inc., Cary, NC, USA. Differences in measures of foliage health between roadside and control (off-roadside) conifers were assessed in the winter and subsequent fall using a site by exposure (roadside vs. control or off-roadside) repeated measures factorial MANOVA by Wilks' Lambda. Variation in salt presence in plant tissues and soils were evaluated between control and roadside conifers across sites via a site by exposure factorial ANOVAs for each analyte. Finally, Pearson correlation coefficients were calculated to find relationships between salt presence, foliage health variables, and distance of conifers from the roadside. In all MANOVA cases, significant relationships ($p < 0.05$) were evaluated through Bonferroni post hoc comparisons with significance levels (α) of 0.05.

Results

Roadside Conifer Foliage Health: Damage to conifers varied by site and exposure for lodgepole and ponderosa pines. Site 132D in the Denver metro area and site 111D along the I-70 corridor exhibited the greatest overall foliage damage. During the deicing season (winter) as well as pre-deicing season (summer and fall), conifers adjacent to the roadside exhibited much greater foliage damage than off roadside conifers. An exception existed in the metro Denver site of 131H however, where foliage damage was slight overall in both roadside and control trees. Overall, conifer crown necrosis exhibited a significant negative correlation with tree distance from the roadbed, $R^2 = 0.246$, $p < 0.0001$). Across all sites, conifers exhibited more damage in older foliage than in current year needle growth, and increasing amounts of tissue necrosis were observed in tree foliage during the growing season in the subsequent fall and summer than during the winter at most sites. Tables 4. and 5. summarize the overall mean percent foliage necrosis (tissue death) and standard error in roadside and control (off-roadside) conifers across sites and seasons.

Table 4. Mean percent foliage necrosis and standard error in roadside and off-road conifers at eight field sites, winter 2004.

Site	Mean Percent Foliage Necrosis ± SE	Exposure Roadside	Exposure Off-road
111D (I-70)	Crown	34.0 ± 8.5	1.4 ± 1.0
	Current year needles	8.0 ± 2.0	1.2 ± 1.0
	Previous years needles	31.0 ± 7.5	1.8 ± 0.8
112H (I-70)	Crown	16.4 ± 5.7	1.2 ± 1.0
	Current year needles	3.4 ± 1.0	0.0 ± 0
	Previous years needles	21.0 ± 5.1	1.8 ± 0.8
113H (I-70)	Crown	23.0 ± 3.4	2.0 ± 0.6
	Current year needles	5.2 ± 2.7	1.4 ± 0.9
	Previous years needles	35.0 ± 5.9	2.8 ± 1.8
114D (I-70)	Crown	29.2 ± 5.0	1.2 ± 0.5
	Current year needles	10.0 ± 3.5	0.2 ± 0.2
	Previous years needles	48.0 ± 14.6	1.8 ± 0.8
121H (Hwy 36)	Crown	13.4 ± 6.4	3.0 ± 0.7
	Current year needles	11.0 ± 2.9	0.2 ± 0.2
	Previous years needles	24.0 ± 7.5	5.6 ± 1.2
122D (Hwy 36)	Crown	25.0 ± 8.3	2.0 ± 0.9
	Current year needles	16.0 ± 2.9	0.0 ± 0
	Previous years needles	26.6 ± 6.9	2.6 ± 1.0
131H (metro Denver)	Crown	0.0 ± 0	1.0 ± 0.6
	Current year needles	0.0 ± 0	0.0 ± 0
	Previous years needles	0.0 ± 0	1.2 ± 1.0
132D (metro Denver)	Crown	27.2 ± 7.9	8.6 ± 4.2
	Current year needles	21.0 ± 9.0	0.2 ± 0.2
	Previous years needles	34.2 ± 10.1	16.2 ± 8.5

Table 5. Mean percent foliage necrosis and standard error in roadside and off-road conifers at eight field sites, summer and fall 2004.

Site	Percent Tissue Necrosis ± SE	Exposure Roadside	Exposure Control
111D (I-70)	Crown	33.0 ± 8.5	3.6 ± 1.8
	Current year needles	6.4 ± 2.7	0.0 ± 0
	Previous years needles	34.0 ± 5.1	6.2 ± 1.7
112H (I-70)	Crown	8.2 ± 2.9	0.8 ± 0.4
	Current year needles	1.2 ± 1.0	0.2 ± 0.2
	Previous years needles	11.0 ± 3.7	1.8 ± 0.8
113H (I-70)	Crown	26.0 ± 7.6	1.0 ± 0.3
	Current year needles	5.2 ± 2.1	0.4 ± 0.2
	Previous years needles	35.0 ± 8.7	1.0 ± 0.0
114D (I-70)	Crown	14.0 ± 4.0	1.2 ± 0.2
	Current year needles	1.2 ± 1.0	0.8 ± 0.2
	Previous years needles	23.0 ± 7.7	1.0 ± 0.0
121H (Hwy 34)	Crown	21.4 ±11.3	0.8 ± 0.4
	Current year needles	3.2 ± 1.1	0.0 ± 0
	Previous years needles	31.0 ± 10.3	1.8 ± 0.8
122D (Hwy 34)	Crown	34.0 ± 10.3	1.4 ± 0.9
	Current year needles	12.4 ± 5.6	0.6 ± 0.2
	Previous years needles	56.0 ± 13.6	4.4 ± 1.7
131H (Metro Denver)	Crown	2.2 ± 0.7	2.2 ± 0.7
	Current year needles	0.6 ± 0.2	0.4 ± 0.2
	Previous years needles	4.2 ± 0.8	5.4 ± 2.0
132D (Metro Denver)	Crown	42.8 ± 15.4	13.0 ± 5.1
	Current year needles	31.8 ± 17.5	1.4 ± 0.9
	Previous years needles	65.0 ± 16.0	24.2 ± 10.1

In general, damaged needles characteristically displayed necrosis and chlorosis in their tips first, with tissue death advancing to the needle base. In addition, occasional banding in ponderosa pine needles was noted. Observed damage was in all cases concentrated in older needle growth, and was frequently more severe on the side of the tree facing the roadway. Figure 2. displays characteristic foliage damage in roadside ponderosa and lodgepole pines, and provide a comparison with off-road undamaged conifer foliage.


a
b
c
d
e

Figure 2. Comparisons of foliage health in studied conifers adjacent and distant from the roadside. ***a***: *P. ponderosa* needles away from roadside, site 121H. ***b***: *P. ponderosa* needles adjacent to the roadside exhibiting necrosis from the tips, site 122D. ***c:*** *P. ponderosa* needles adjacent to the roadside exhibiting necrosis primarily in previous years (older) needle tissues, site 132D. ***d:*** *P. ponderosa* off-road, site 132D. Note density of foliage. ***e:*** *P. ponderosa* adjacent to roadside, site 132D. Note scarcity of foliage. ***f:*** *P. ponderosa* needles adjacent to the roadside exhibiting tip necrosis and banding, site 121H. ***g:*** *P. contorta* needles from off-road tree, site 111D. ***h:*** *P. contorta* needles adjacent to roadside exhibiting necrosis in older growth, site 111D. ***i:*** *P. contorta* away from roadside, site 111D. Note foliage density. ***j:*** *P. contorta* adjacent to roadside, site 114D. Note foliage scarcity on trees facing the roadside.

Trees adjacent to the roadside also retained significantly less years of foliage growth ($\bar{x}$ = 3.0) than off-road trees ($\bar{x}$ = 5.0) according to Bonferroni post hoc t-tests (see also Figure 2.). Table 6. compares years of needle growth retained by conifers in relation to roadside exposure during the growing season, 2004.

Table 6. Mean number of years needle growth retained and standard error in roadside and off-road conifers at eight field sites, summer and fall 2004.

Site	Mean retained years of needle growth ± SE Roadside	Control
111D (I-70)	4.4 ± 0.4	7.6 ± 0.4
112H (I-70)	3.4 ± 0.2	6.2 ± 0.6
113H (I-70)	2.2 ± 0.2	5.6 ± 0.5
114D (I-70)	2.2 ± 0.2	5.0 ± 0.3
121H (Hwy 34)	3.8 ± 0.4	4.4 ± 0.5
122D (Hwy 34)	2.8 ± 0.6	3.8 ± 0.4
131H (Metro Denver)	3.6 ± 0.2	4.0 ± 0.3
132D (Metro Denver)	1.8 ± 0.4	3.6 ± 0.2

Mean foliage necrosis levels were analyzed through a site by exposure repeated measures factorial MANOVA for winter and subsequent fall and summer tree health evaluations. The MANOVA was used to compare overall crown death and needle tissue death by foliage age in roadside and off-roadside trees across study sites. Overall necrosis levels in Colorado conifers varied significantly by site ($F = 5.00$, $p < 0.0001$), by exposure ($F = 68.79$, $p < 0.0001$) and the interaction of site location and tree exposure ($F = 2.40$, $p < 0.05$). According to Bonferroni post hoc comparisons, sites 132D and 111D demonstrated the most overall damage, significantly different from sites that exhibited the least, 112H and 131H. Figure 3. summarizes overall levels of mean crown necrosis by study site.

Additionally, although observed overall necrosis levels in the studied conifers did not differ significantly overall between winter and subsequent summer and fall foliage evaluations, necrosis levels differed significantly by site over time ($F = 4.98$, $p < 0.001$). A notable increase in necrotic foliage during the growing season was observed in sites

132D, 122D, and 121H, while a decrease in overall necrotic foliage during the growing season was observed in sites 114D and 112H (Figure 3.).

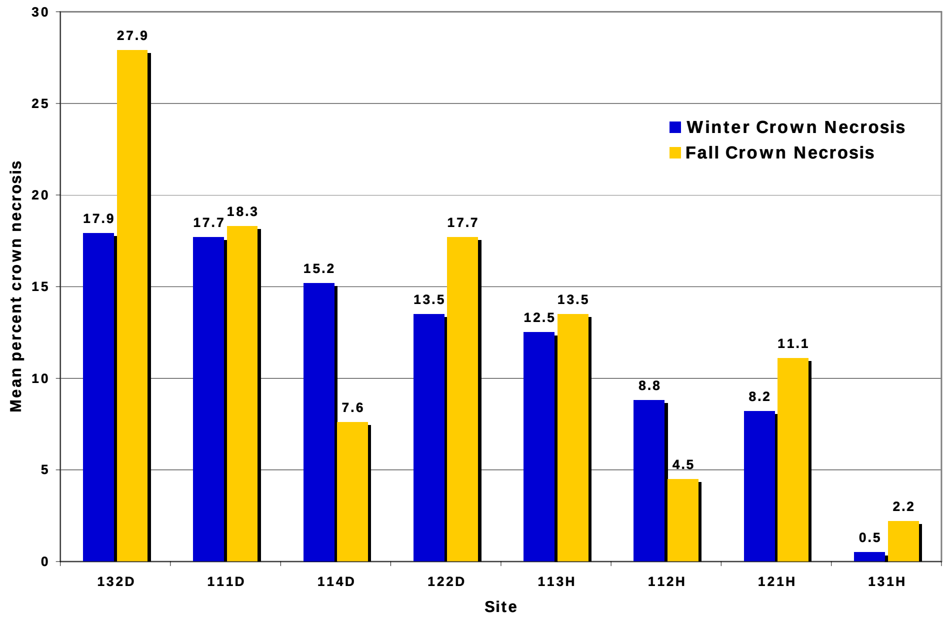


Figure 3. Mean percent necrotic foliage in tree crown in winter 2004 and subsequent fall by field study site

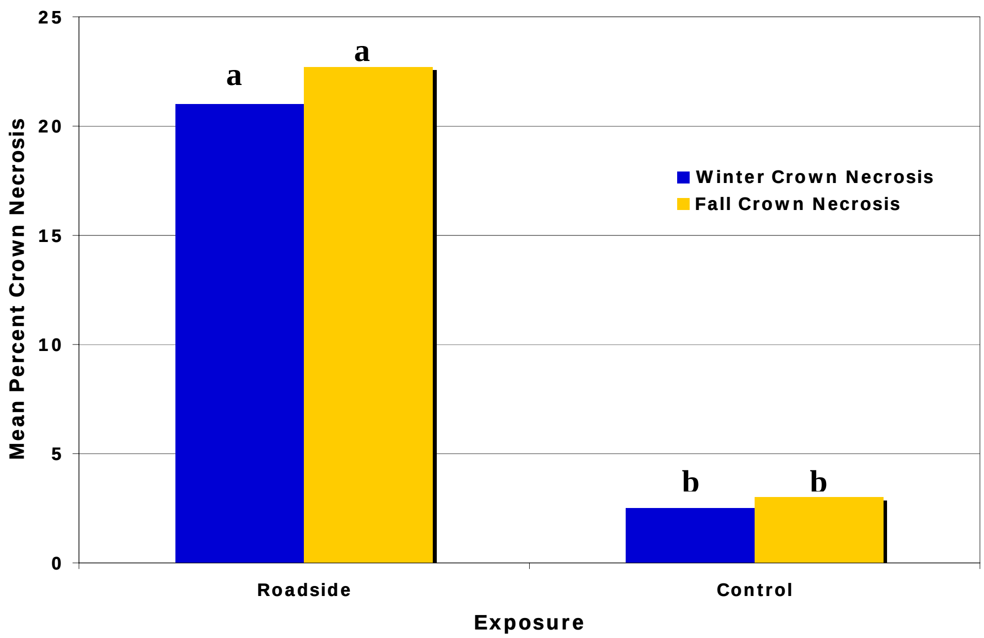


Figure 4. Mean percent crown necrosis in roadside versus control trees across study sites

Across all sites and seasons, trees adjacent to the roadside demonstrated significantly more foliage damage than trees removed from the roadside environment (Figure 4). During the winter, mean percent overall crown necrosis across study sites for roadside conifers was 21.0%, while off-road trees exhibited only 2.6%. In the subsequent fall, mean percent crown necrosis was 22.7%, while control trees exhibited 3.0%. No significant differences were observed between the health observations in the winter and subsequent summer and fall by tree exposure.

Older foliage was more susceptible to damage than new needle growth. Levels of overall crown necrosis, previous years needle necrosis and current year needle necrosis significantly differed from one another ($F = 49.32$, $p < 0.0001$), differed by exposure ($F = 21.90$, $p < 0.0001$), and differed over time ($F = 4.39$, $p < 0.05$). Figure 5. indicates that damage in conifers adjacent to the roadside is concentrated primarily in older needle growth, and that this damage increases in the subsequent growing season but decreases in new growth put out by the trees.

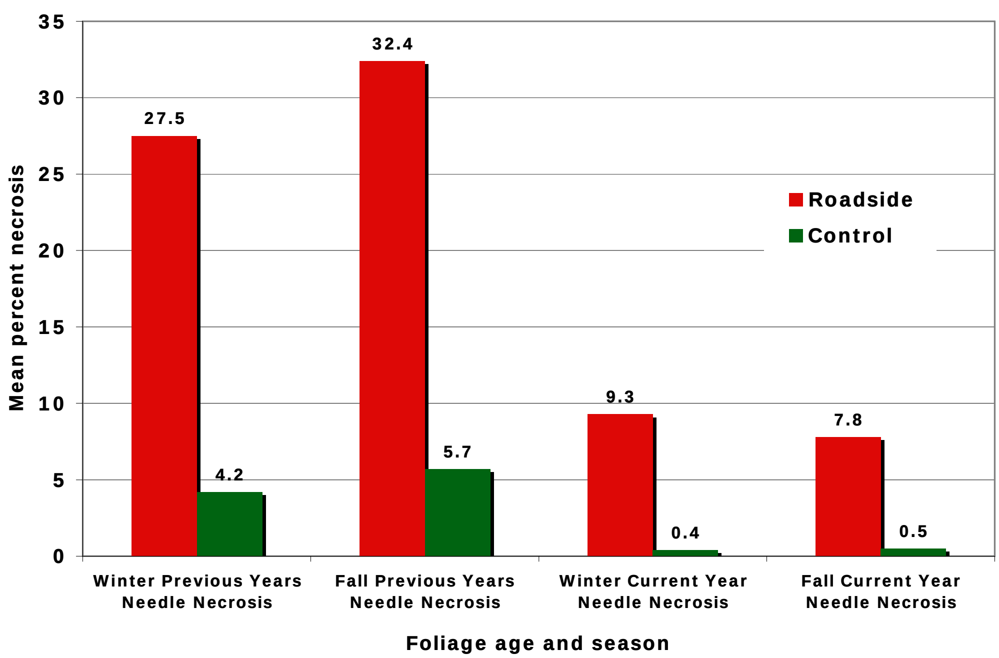


Figure 5. Mean percent necrosis in previous years' needle growth and current year needle growth by tree exposure and season.

Conifer Exposure to Deicing Chemicals: Overall, soil pH, total soil salts (mmhos/cm), and soil sodium levels (ppm) were significantly elevated in roadside soils compared to soils at a distance from the roadside. However, soils from off-road sites had significantly higher magnesium content than roadside soils. Denver metro area sites exhibited some of the highest soil pH, total soil salts, soil sodium, magnesium, and chloride contents of all sites tested. Sites 114D and 112H along I-70 tended to be lowest in soil pH, total soil salts, soil sodium, magnesium, and chloride content of tested study sites.

Needle sodium, magnesium, and chloride contents were significantly elevated in tree foliage along the roadside compared to off-road trees. Needle sodium content was highest in metro Denver and Hwy 36 area sites, and lower in the I-70 corridor sites. In contrast, needle magnesium content patterns were reversed, with higher levels observed in the I-70 sites, and lower levels in the metro Denver and Hwy 36 sites. Needle chloride content was variable by location with the highest overall levels noted at sites 132D (Denver) and 122D (Hwy 36), and the lowest levels at site 131H (Denver) and 114D (I-70).

Twig sodium and chloride contents were significantly higher in trees along the roadside than in trees away from the roadside. The highest levels of twig sodium contents were observed in the Denver metro area, while the lowest were observed in sites 112H and 121H along I-70 and Hwy 34 respectively. The highest levels of twig magnesium were recorded in sites 112H and 113H along I-70, while the lowest levels were found in 132D (Denver) and 111D (I-70). Twig chloride levels did not vary significantly by site.

Tables 7., 10., 14., and 17., summarize soil pH, total dissolved salts, soil sodium, magnesium, and chloride, needle sodium, magnesium, and chloride, and twig sodium magnesium and chloride contents by site location and tree exposure. Statistical analyses follow all data.

Soil pH and total soil salts:

Table 7. Mean and standard error of soil pH and soluble soil salts (mmhos/cm) 1m from roadside and off-road conifers at eight field sites.

Site	Mean soil pH and electrical conductivity (EC) ± SE	Exposure	
		Roadside	Off-road
111D (I-70)	pH	6.04 ± 0.07	5.78 ± 0.11
	EC (mmhos/cm)	0.452 ± 0.048	0.320 ± 0.039
112H (I-70)	pH	5.2 ± 0.07	4.96 ± 0.22
	EC (mmhos/cm)	0.356 ± 0.038	0.212 ± 0.017
113H (I-70)	pH	6.78 ± 0.17	5.42 ± 0.16
	EC (mmhos/cm)	0.280 ± 0.033	0.864 ± 0.138
114D (I-70)	pH	5.26 ± 0.14	5.20 ± 0.08
	EC (mmhos/cm)	0.296 ± 0.022	0.268 ± 0.033
121H (Hwy 36)	pH	5.52 ± 0.26	4.96 ± 0.15
	EC (mmhos/cm)	0.560 ± 0.115	0.360 ± 0.023
122D (Hwy 36)	pH	6.50 ± 0.18	4.60 ± 0.18
	EC (mmhos/cm)	0.340 ± 0.034	0.276 ± 0.043
131H (Denver)	pH	7.08 ± 0.07	7.32 ± 0.05
	EC (mmhos/cm)	1.004 ± 0.158	0.732 ± 0.058
132D (Denver)	pH	7.76 ± 0.10	7.40 ± 0.05
	EC (mmhos/cm)	0.896 ± 0.093	0.660 ± 0.067

Soil pH levels were analyzed through a site by exposure factorial ANOVA. Overall soil pH levels varied significantly by site location ($F = 86.71$, $p < 0.0001$), by tree exposure ($F = 62.23$, $p < 0.0001$), and the interaction of site and exposure ($F = 12.50$, $p < 0.0001$). Sites in the Denver metro area exhibited the highest soil pH levels according to Bonferroni post hoc comparisons, while site 112H along the I-70 corridor exhibited the lowest (Table 8.). Soils along roadsides exhibited significantly higher soil pH ($\bar{x} = 6.27$) than soils away from the roadside ($\bar{x} = 5.71$) also by Bonferroni comparisons. Analyses of the soil pH site by exposure interaction indicate that soil pH is significantly elevated at site 113H, 122D, and 132D compared to soil pH away from the roadside. However, soil roadside pH is significantly lower compared to control soil pH at site 131H (see Table 7.).

Table 8. Bonferroni post hoc comparison of soil pH by site location, n = 10. Means with the same letter are not statistically different.

Bonferroni grouping		Mean soil pH	Site
	A	7.58	132D
	A	7.20	131H
	B	6.10	113H
C	B	5.91	111D
C	D	5.55	122D
E	D	5.24	121H
E	D	5.23	114D
E		5.08	112H

Total soil salt levels as measured by electrical conductivity were analyzed through a site by exposure factorial ANOVA. Overall soil salt levels varied significantly by site location ($F = 19.44$, $p < 0.0001$) and the interaction of site location and tree exposure ($F = 7.01$, $p < 0.0001$). By Bonferroni comparisons, Denver metro sites 131H and 132D exhibited the highest levels of soil salts, while sites 112D, 112H, and 114D along I-70 exhibited the lowest (Table 9.). Analyses of site by exposure interactions indicated that roadside soil salt levels were significantly elevated compared with control soils in site 112H. Uniquely, control soil salt levels were significantly elevated over roadside soils in site 113H (see Table 7.).

Table 9. Bonferroni post hoc comparison of total soluble salts via electrical conductivity (EC) levels by site location, n = 10. Means with the same letter are not statistically different.

Bonferroni grouping		Mean EC (mmhos/cm)	Site
	A	0.868	131H
B	A	0.778	132D
B	C	0.572	113H
D	C	0.460	121H
D	C	0.386	111D
D		0.308	122D
D		0.284	112H
D		0.282	114D

Needle, twig, and soil sodium content:

Table 10. Mean and standard error of sodium content in needle tissue and twig tissue by percent dry weight, and adjacent soils in ppm, in roadside and off-roadside conifers at eight field sites.

Site	Mean Na content ± SE	Exposure: Roadside	Exposure: Off-road
111D (I-70)	Needle (%)	0.094 ± 0.032	0.02 ± 0.003
	Twig (%)	0.032 ± 0.004	0.014 ± 0.002
	Soil (ppm)	200 ± 23.1	97 ± 7.5
112H (I-70)	Needle (%)	0.014 ± 0.002	0.016 ± 0.002
	Twig (%)	0.016 ± 0.002	0.018 ± 0.004
	Soil (ppm)	125 ± 3.9	101 ± 9.4
113H (I-70)	Needle (%)	0.056 ± 0.013	0.024 ± 0.002
	Twig (%)	0.018 ± 0.004	0.022 ± 0.005
	Soil (ppm)	125 ± 20.8	231 ± 28.9
114D (I-70)	Needle (%)	0.020 ± 0.006	0.028 ± 0.006
	Twig (%)	0.034 ± 0.014	0.014 ± 0.002
	Soil (ppm)	120 ± 3.2	95 ± 6.1
121H (Hwy 36)	Needle (%)	0.192 ± 0.082	0.012 ± 0.002
	Twig (%)	0.014 ± 0.002	0.010 ± 0.000
	Soil (ppm)	215 ± 53.0	88 ± 3.4
122D (Hwy 36)	Needle (%)	0.300 ± 0.106	0.026 ± 0.002
	Twig (%)	0.030 ± 0.015	0.028 ± 0.013
	Soil (ppm)	206 ± 35.5	93 ± 4.6
131H (metro Denver)	Needle (%)	0.064 ± 0.011	0.178 ± 0.138
	Twig (%)	0.056 ± 0.036	0.046 ± 0.024
	Soil (ppm)	149 ± 19.2	95 ± 5.5
132D (metro Denver)	Needle (%)	0.482 ± 0.154	0.154 ± 0.053
	Twig (%)	0.184 ± 0.068	0.052 ± 0.012
	Soil (ppm)	338 ± 52.2	117 ± 12.3

Needle sodium content as percent dry weight was analyzed through a site by exposure factorial ANOVA. Overall needle sodium levels varied significantly by site location ($F = 4.96$, $p < 0.001$), by tree exposure ($F = 9.02$, $p < 0.01$), and the interaction of site and exposure ($F = 2.86$, $p < 0.05$). Trees in the Denver metro area and trees along Hwy 36 demonstrated the greatest overall sodium content in their needle tissues, while trees along the I-70 corridor displayed the least (Table 11.). Across study sites, trees along the roadside exhibited higher concentrations of sodium in their foliage ($\bar{x}$ = 0.153%) than trees distant from the roadside ($\bar{x}$ = 0.057%) according to Bonferroni post hoc tests. Analysis of the site by exposure interaction for needle sodium content reveals significantly elevated levels of sodium in roadside tree foliage as compared to control foliage in site 113H (I-70) and 122D (Hwy 36) (see Table 10.).

Table 11. Bonferroni post hoc comparison of needle sodium content by site location, n = 10. Means with the same letter are not statistically different.

Bonferroni grouping		Mean needle Na content (%)	Site
	A	0.318	132D
B	A	0.163	122D
B	A	0.121	131H
B		0.102	121H
B		0.057	111D
B		0.040	113H
B		0.024	114D
B		0.015	112H

Twig sodium content as percent dry weight was analyzed through a site by exposure factorial ANOVA. Overall twig sodium levels varied significantly by site location ($F = 5.31$, $p < 0.0001$), by tree exposure ($F = 4.43$, $p < 0.05$), and the interaction of site and exposure ($F = 2.22$, $p < 0.05$). Twig sodium content was significantly elevated in sites 132D and 131D in metro Denver in comparison with other study sites (Table 12.). According to Bonferonni post hoc tests, across all study sites trees adjacent to the roadsides had significantly higher twig sodium content ($\bar{x}$ = 0.048%) than trees distant from the road ($\bar{x}$ = 0.026%). Twig sodium content was also significantly elevated in roadside conifer foliage compared to control foliage in site 111D along the I-70 corridor (see Table 10.).

Table 12. Bonferroni post hoc comparison of twig sodium content by site location, n = 10. Means with the same letter are not statistically different.

Bonferroni grouping		Mean twig Na content (%)	Site
	A	0.118	132D
B	A	0.051	131H
B		0.029	122D
B		0.024	114D
B		0.023	111D
B		0.020	113H
B		0.017	112H
B		0.012	121H

Soil sodium levels in ppm were analyzed through a site by exposure factorial ANOVA. Overall soil sodium levels varied significantly by site location ($F = 5.24$, $p < 0.0001$), by tree exposure ($F = 33.55$, $p < 0.0001$), and the interaction of site and exposure ($F = 7.84$, $p < 0.0001$). Soil sodium levels were highest at site 132D in metro Denver, site 113H along I-70, and sites 121H and 122D along Hwy 36 (Table13.). By Bonferonni post hoc comparisons, soil in proximity to the roadsides had significantly higher overall levels of sodium ($\bar{x}$ = 184.8ppm) than soil at a distance from the road ($\bar{x}$ = 114.6ppm). Also, soil sodium was significantly elevated in roadside soils compared to control soils in sites 132D, 131H, 122D, 121H, 111D and 114D. Uniquely, levels of soil sodium were significantly elevated away from the road compared to near the roadbed in site 113H along I-70 (see Table 10.).

Table 13. Bonferroni post hoc comparison of soil sodium content by site location, n = 10. Means with the same letter are not statistically different.

Bonferroni grouping		Mean soil Na content (ppm)	Site
	A	227.5	132D
B	A	178.0	113H
B	A	151.5	121H
B	A	149.5	122D
B		148.5	111D
B		122.0	131H
B		113.0	112H
B		107.5	114D

Needle, twig, and soil magnesium content:

Table 14. Mean and standard error of magnesium content in needle tissue and twig tissue by percent dry weight, and adjacent soils in ppm, in roadside and off-roadside conifers at eight field sites.

Site	Mean Mg content ± SE	Exposure	
		Roadside	Off-road
111D (I-70)	Needle (%)	0.554 ± 0.007	0.422 ± 0.014
	Twig (%)	0.308 ± 0.011	0.306 ± 0.007
	Soil (ppm)	343.2 ± 44.41	433.8 ± 46.12
112H (I-70)	Needle (%)	0.552 ± 0.024	0.506 ± 0.029
	Twig (%)	0.414 ± 0.047	0.360 ± 0.015
	Soil (ppm)	265.4 ± 30.92	178.4 ± 14.05
113H (I-70)	Needle (%)	0.610 ± 0.022	0.512 ± 0.024
	Twig (%)	0.370 ± 0.021	0.372 ± 0.012
	Soil (ppm)	285.6 ± 25.23	980.0 ± 46.82
114D (I-70)	Needle (%)	0.568 ± 0.028	0.574 ± 0.019
	Twig (%)	0.374 ± 0.028	0.342 ± 0.013
	Soil (ppm)	336.6 ± 18.73	314.2 ± 52.34
121H (Hwy 36)	Needle (%)	0.452 ± 0.018	0.422 ± 0.014
	Twig (%)	0.346 ± 0.012	0.334 ± 0.020
	Soil (ppm)	403.8 ± 55.55	461.8 ± 36.44
122D (Hwy 36)	Needle (%)	0.540 ± 0.020	0.472 ± 0.014
	Twig (%)	0.338 ± 0.012	0.356 ± 0.018
	Soil (ppm)	192.6 ± 26.79	211.8 ± 9.79
131H (metro Denver)	Needle (%)	0.420 ± 0.020	0.420 ± 0.023
	Twig (%)	0.350 ± 0.029	0.322 ± 0.064
	Soil (ppm)	576.0 ± 36.10	604.6 ± 42.38
132D (metro Denver)	Needle (%)	0.402 ± 0.054	0.380 ± 0.010
	Twig (%)	0.180 ±0.015	0.236± 0.020
	Soil (ppm)	692.4 ± 135.06	606.8 ± 53.32

Needle magnesium content as percent dry weight was analyzed through a site by exposure factorial ANOVA. Overall needle magnesium levels varied significantly by site location ($F = 16.01$, $p < 0.0001$) and by tree exposure ($F = 17.26$, $p < 0.0001$). Needle magnesium content was highest in sites 114D and 113H along the I-70 corridor, and lowest in sites 131H and 132D in metro Denver (Table 15.). Across sites, needle tissue in conifers adjacent to the roadside had significantly higher levels of magnesium ($\bar{x}$ = 0.512%) than in the needle tissue of conifers distant from the roadside ($\bar{x}$ = 0.464%) according to Bonferroni post hoc comparisons.

Table 15. Bonferroni post hoc comparison of needle magnesium content by site location, n = 10. Means with the same letter are not statistically different.

Bonferroni grouping			Mean needle Mg content (%)	Site
	A		0.571	114D
B	A		0.561	113H
B	A		0.529	112H
B	A	C	0.506	122D
B	D	C	0.488	111D
E	D	C	0.437	121H
E	D		0.420	131H
E			0.391	132D

Twig magnesium content as percent dry weight was analyzed through a site by exposure factorial ANOVA. Overall twig magnesium levels varied significantly by site location (F = 9.30, p < 0.0001). Mean twig magnesium content was significantly lower ($\bar{x}$ = 0.208%) at site 132D in metro Denver than at all other sites by Bonferroni post hoc comparisons (see Table 14.).

Soil magnesium levels in ppm were analyzed through a site by exposure factorial ANOVA. Overall soil magnesium levels varied significantly by site location (F = 25.11, p < 0.0001), by tree exposure (F = 11.93, p < 0.01), and the interaction of site and exposure (F = 12.67, p < 0.0001). Sites with the heaviest soil magnesium content were 132D in metro Denver and site 113H along I-70. Sites with the lowest soil magnesium content were 112H along I-70 and 122D along Hwy 36 (Table 16.). Overall in contrast to other ions, soils away from the roadside environment displayed higher levels of magnesium ($\bar{x}$ = 473.9ppm) than soils adjacent to the roadside ($\bar{x}$ = 387.0ppm) according to Bonferonni post hoc tests. Additionally, analyses of site by exposure interactions indicated soil magnesium levels were significantly higher in off-road soils at site 113H than soils along the roadside. However roadside soils in site 112H were significantly higher in magnesium content than distant soils (see Table 14.).

Table 16. Bonferroni post hoc comparison of soil magnesium content by site location, n = 10. Means with the same letter are not statistically different.

Bonferroni grouping		Mean soil Mg content (ppm)	Site
	A	649.6	132D
	A	632.8	113H
B	A	590.3	131H
B	C	432.8	121H
	C	388.5	111D
D	C	325.4	114D
D		221.9	112H
D		202.2	122D

Needle, twig, and soil chloride content:

Table 17. Mean and standard error of chloride content in needle tissue and twig tissue by percent dry weight, and adjacent soils in ppm, in roadside and off-roadside conifers at eight field sites.

Site	Mean Cl content ± SE	Exposure Roadside	 Off-road
111D (I-70)	Needle (%)	1.420 ± 0.247	0.246 ± 0.041
	Twig (%)	0.090 ± 0.260	0.216 ± 0.147
	Soil (ppm)	1224 ± 241.6	760 ± 100.5
112H (I-70)	Needle (%)	0.928 ± 0.088	0.164 ± 0.029
	Twig (%)	0.096 ± 0.018	0.036 ± 0.006
	Soil (ppm)	1322 ± 137.2	1172 ± 129.7
113H (I-70)	Needle (%)	1.308 ± 0.375	0.572 ± 0.131
	Twig (%)	0.160 ± 0.021	0.046 ± 0.006
	Soil (ppm)	814 ± 66.2	1806 ± 537.2
114D (I-70)	Needle (%)	0.794 ± 0.229	0.190 ± 0.023
	Twig (%)	0.086 ± 0.011	0.038 ± 0.002
	Soil (ppm)	1268 ± 188.6	1020 ± 24.5
121H (Hwy 36)	Needle (%)	1.23 ± 0.329	0.214 ± 0.033
	Twig (%)	0.888 ± 0.513	0.056 ± 0.010
	Soil (ppm)	1072 ± 182.3	1256 ± 308.7
122D (Hwy 36)	Needle (%)	2.65 ± 0.375	0.212 ± 0.019
	Twig (%)	0.230 ± 0.023	0.032 ± 0.005
	Soil (ppm)	1084 ± 150.3	966 ± 35.2
131H (metro Denver)	Needle (%)	0.760 ± 0.157	0.276 ± 0.047
	Twig (%)	0.188 ± 0.035	0.128 ± 0.026
	Soil (ppm)	1806 ± 439.9	1452 ± 330.3
132D (metro Denver)	Needle (%)	2.190 ± 0.609	0.638 ± 0.094
	Twig (%)	0.300 ± 0.095	0.112 ± 0.010
	Soil (ppm)	2820 ± 1016.2	4010 ± 1018.5

Needle chloride content as percent dry weight was analyzed through a site by exposure factorial ANOVA. Overall needle sodium levels varied significantly by site location ($F = 4.93$, $p < 0.001$), by tree exposure ($F = 82.00$, $p < 0.0001$), and the interaction of site and exposure ($F = 3.52$, $p < 0.01$). Trees in site 122D along HWY 36, and site 132D in metro Denver had highest overall levels of needle chlorides, while trees in sites 131H and 114D had the lowest (Table 18.). For all sites, trees adjacent to the roadside contained significantly elevated levels of needle chlorides ($\bar{x}$ = 1.411%) compared to off-road trees ($\bar{x}$ = 0.314%) by Bonferroni post hoc comparisons. Analyses of site by exposure interactions reveal needle chloride levels in roadside trees were significantly elevated above chloride levels in control trees at all sites except 113H along the I-70 corridor (Table 17.). It should be noted however, that roadside foliage chloride content at site 113H was more than twice the chloride content of control foliage.

Table 18. Bonferroni post hoc comparison of needle chloride content by site location, n = 10. Means with the same letter are not statistically different.

Bonferroni grouping		Mean needle Cl content (%)	Site
	A	1.433	122D
	A	1.414	132D
B	A	0.940	113H
B	A	0.833	111D
B	A	0.722	121H
B		0.546	112H
B		0.518	131H
B		0.492	114D

Twig chloride content as percent dry weight was analyzed through a site by exposure factorial ANOVA. Overall twig chloride levels varied significantly by tree exposure ($F = 6.35$, $p < 0.05$), and the interaction of site and exposure ($F = 2.19$, $p < 0.05$). Across all study sites roadside trees experienced significantly elevated levels of chlorides in their woody tissue ($\bar{x}$ = 0.255%) compared to off-road trees ($\bar{x}$ = 0.083%) by Bonferroni post hoc comparisons. Additionally, significantly higher levels of chloride in woody tissues were found in roadside trees compared to control trees in sites 112H, 113H, and 114D along the I-70 corridor, as well as site 122D along Hwy 36 (see Table 17.).

Soil chloride content in ppm was analyzed through a site by exposure factorial ANOVA. Overall soil chloride levels varied significantly by site location ($F = 6.96$, $p < 0.0001$). Site 132D in the Denver metro area had significantly higher soil chloride levels ($\bar{x} =$ 3415ppm) than all other sites tested according to Bonferroni comparisons (see Table 17.).

Conifer Foliage Exposure to Aerosolized Salts: After field work revealed the presence of a deposited coating on the foliage of roadside conifers (Figure 6.), needle samples from each study site were collected in the winter of 2004 and analyzed through scanning electron microscopy (SEM) for the presence and characteristics of surface deposits. From these analyses, it becomes apparent that trees in proximity to the roadside are more likely than trees further away to exhibit coating on needle surfaces. Presence of needle coating was significantly ($p < 0.0001$) negatively correlated with distance from the roadside, $R^2 = 0.215$.

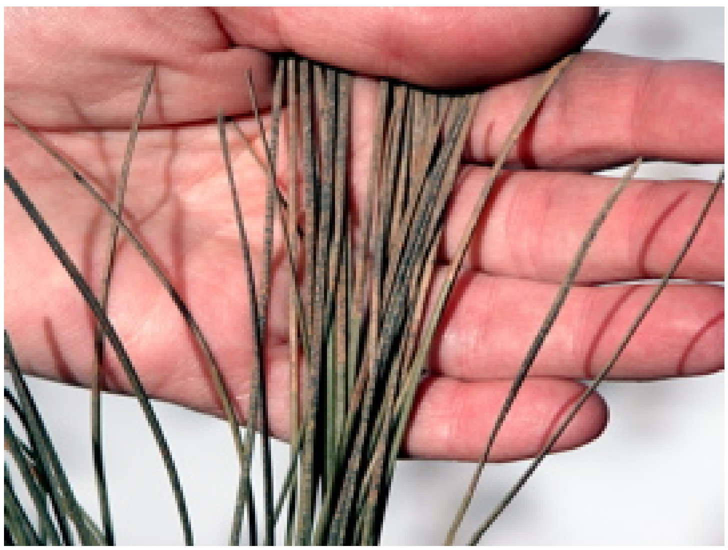


Figure 6. *P. ponderosa* needles from site 132D (Denver) displaying a dark mottling of surface deposits on needle tissue.

Needle samples from conifers along the roadside in the I-70 corridor consistently demonstrated surface deposits, while those conifers further off-road exhibited deposits less frequently (Table 19.). Roadside needle samples from sites along Hwy 36 and in the metro Denver area were likely to (but did not always) display surface deposits. Off-road trees in these areas, especially those trees closer to the roadside such as in the Denver metro sites, often displayed surface coatings as well (Table 19.).

Table 19. Percent of needle samples exhibiting surface deposits by site and exposure, n = 5.

Site	Percent of trees with foliar coating Roadside	Control
111D (I-70)	100	0
112H (I-70)	100	20
113H (I-70)	100	40
114D (I-70)	100	60
121H (Hwy 36)	100	40
122D (Hwy 36)	80	40
131H (Denver)	60	80
132D (Denver)	80	100

Surface deposit characteristics:

Where present, amorphous, granular, and crystalline deposits heavily coated the visible needle surface, occluding the plants' stomata. Figure 7. depicts surface coating characteristics of ponderosa (*P. ponderosa*) and lodgepole (*P. contorta*) pine needles detected from field samples. Observations of these coated needles using elemental analysis coupled to SEM demonstrated that the surface deposits contained a number of different elements including the salts magnesium (Mg), sodium (Na), and chloride (Cl) (Figure 8.). Granitic silt-like deposits probably consisting of quartz (SiO_2) and feldspar (aluminum and potassium silicates) found in igneous rock were also present in great abundance in this coating (Figure 8.).

Needles artificially treated in the laboratory with sand/salt deicer and liquid magnesium chloride deicer display similar elemental analyses patterns and coating characteristics (Figure 9.). For example, aluminum (Al), silicon (Si), potassium (K), and chloride (Cl) patterns were similar between the sand/salt deicer employed by CDOT (Figure 9. a) and needle surface deposits on roadside conifers (Figure 8.). Characteristic cubic crystals of sodium chloride (NaCl) found on needles artificially treated with sand/salt deicer (Figure 9. b) closely resemble crystals observed in the surface deposits on roadside conifers (Figure 7. g). Needles artificially treated with magnesium chloride ($MgCl_2$) deicer display an amorphous coating on the needle surface (Figure 9. c). Given these similarities, it is highly likely that the salts and fine rock particulates on the roadside conifer needles are a product of roadside deicing practices, and that the foliage of roadside trees is exposed to the aerial drift of deicing particles.

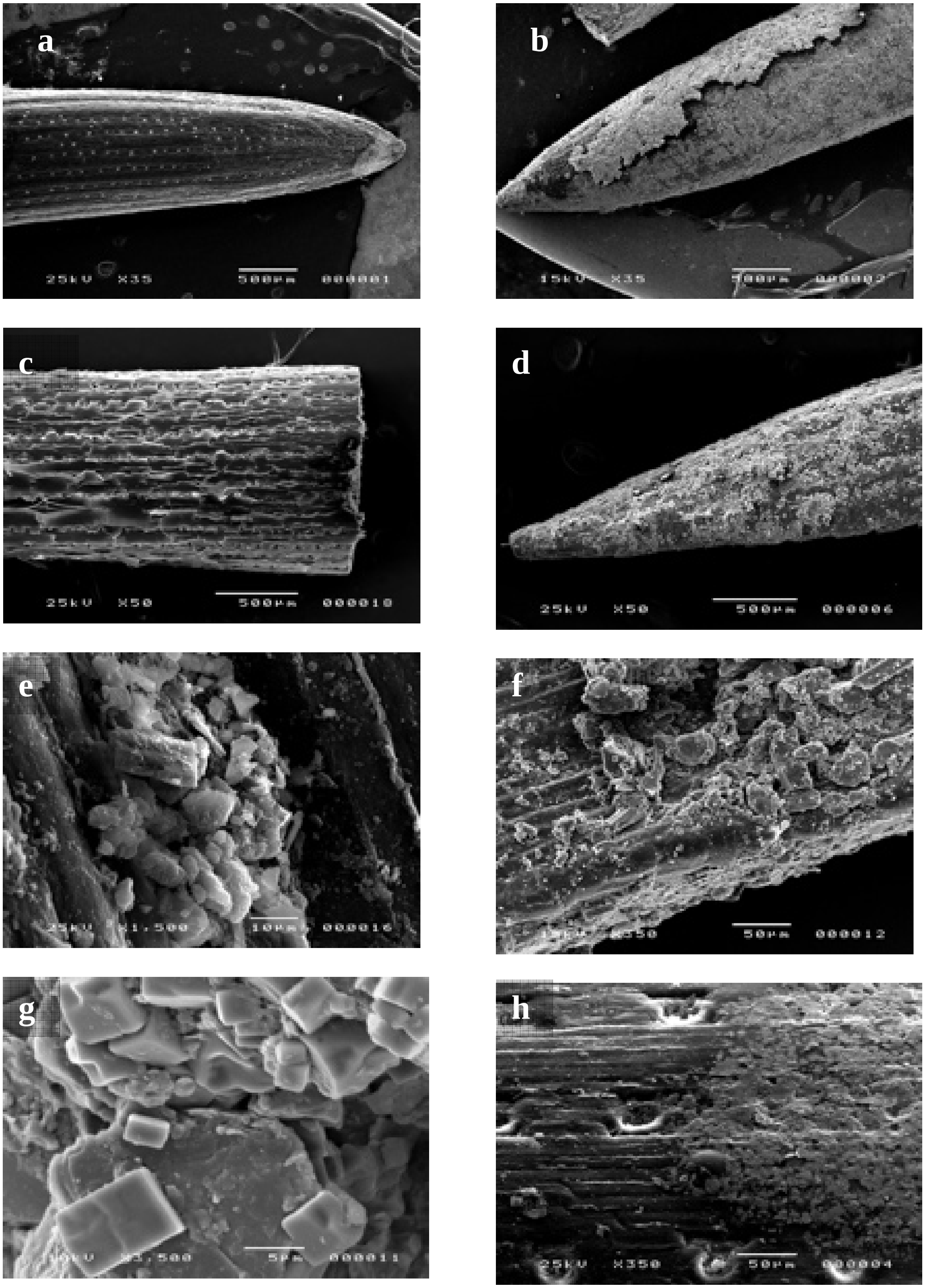

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Figure 7. (Opposite page). SEM images of conifer needle surfaces and surface deposit characteristics. ***a:*** Uncoated *P. contorta* needle tip with visible stomates, site 114D (I-70). ***b:*** Heavily coated *P. contorta* needle tip, site 113H (I-70). ***c:*** Uncoated *P. ponderosa* needle segment with visible stomates and plate-like epicuticular wax, site 122D (Hwy 36). ***d:*** Heavily coated *P. ponderosa* needle tip, site 131H (metro Denver). ***e:*** Magnified amorphous and granular surface deposits on *P. ponderosa* needle , site 131H (metro Denver). ***f:*** Magnified amorphous, granular, and crystalline surface deposits on *P. contorta* needle, site 111D (I-70). ***g:*** Highly magnified crystalline surface deposits on *P. contorta* needle, site 111D (I-70). ***h:*** Surface deposits occluding stomates of *P. ponderosa* needle, site 132D (metro Denver).

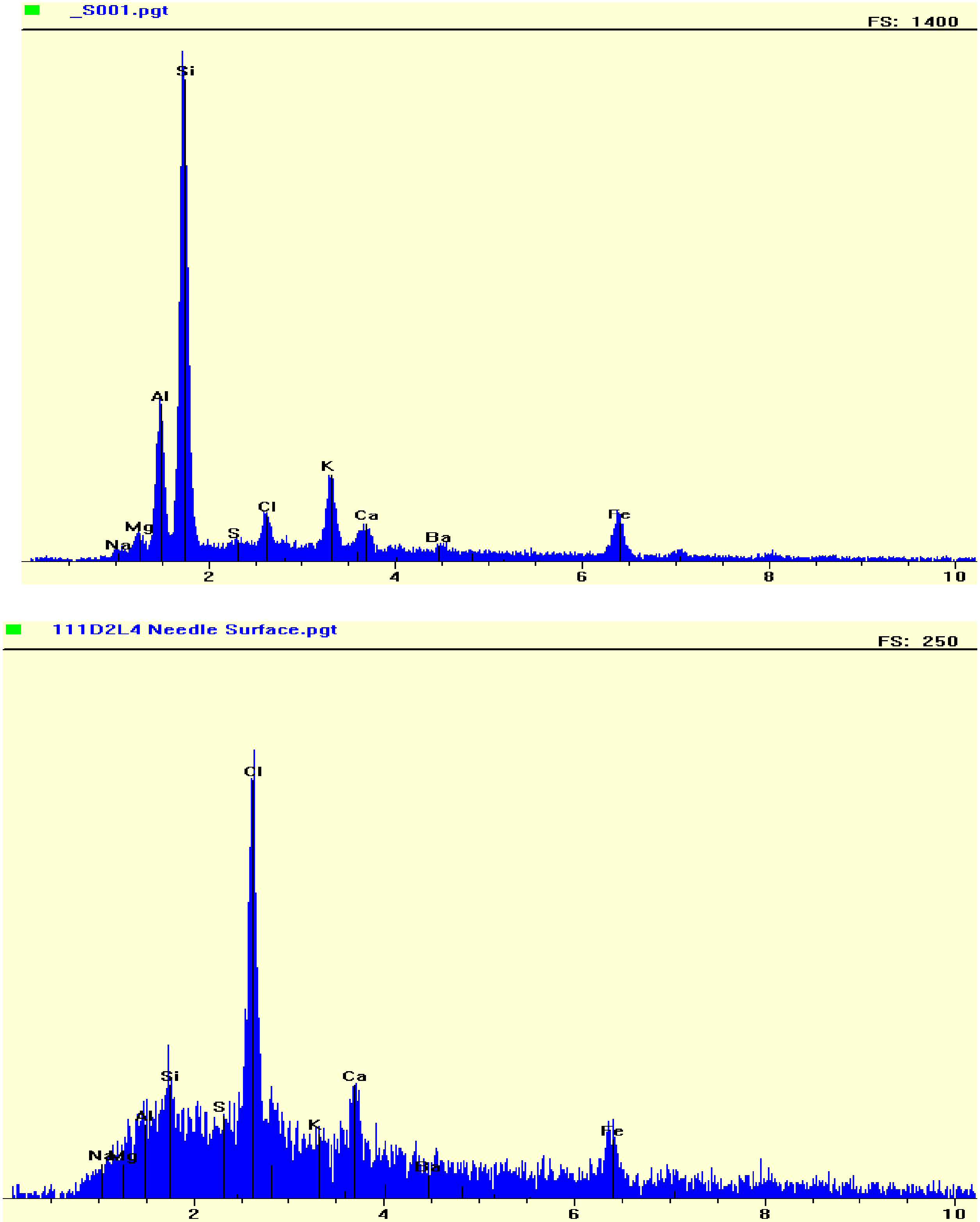


Figure 8. Two elemental analyses of surface deposits on *P.contorta* needles, site 111D (I-70), documenting the presence of Na, Mg, and Cl, as well as minerals associated with quartz and feldspars (see also Figure 7. f).

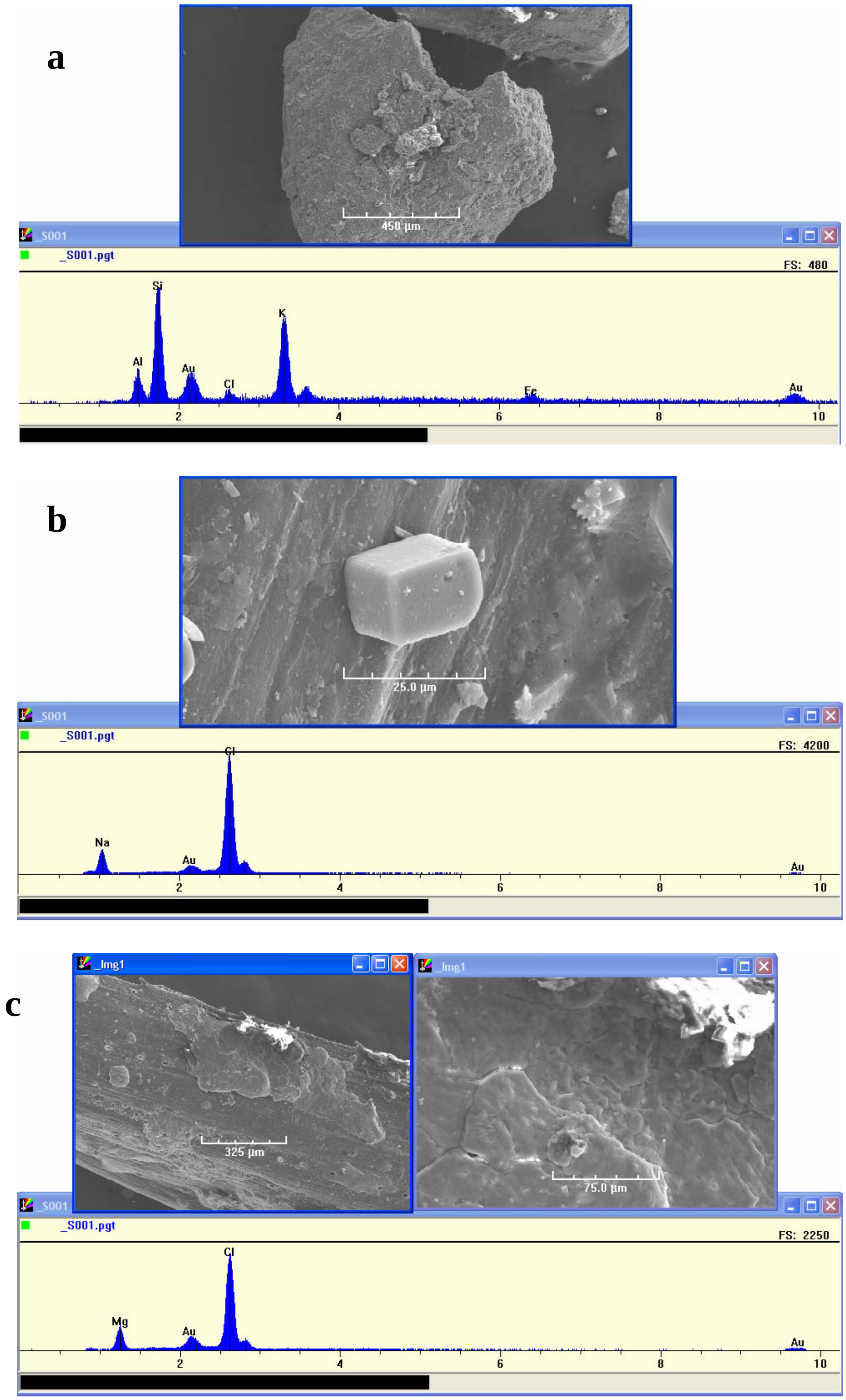


Figure 9. SEM images and elemental analyses of deicing chemicals and artificially treated pine needles. ***a:*** Sand/salt deicer, 70x. ***b:*** NaCl crystal on sand/salt deicer treated needle surface, 1100x. ***c:*** Amorphous coating of $MgCl_2$ deicer on treated needle surface, 95x, 400x. The presence of Au is an artifact of the SEM coating process.

Correlation of Foliage Health and Deicer Exposure: Foliage death in Colorado conifers correlated significantly with indices of salt exposure. Overall, the sodium and chloride content in needle tissue and the sodium content in twig tissue provided robust correlations with necrosis in tree foliage. Although the presence of other salt related factors such as needle surface deposits, soil pH, and twig magnesium also formed significant correlations with tree health, these relationships were much weaker. Tables 20. through 23. summarize the significant correlations found between salt presence in needle tissue, twig tissue, and soils, distance from the roadbed, presence of needle surface deposits and measures of tree health.

Sodium exposure and tree health:

Sodium content as percent dry weight of needle tissue provided significant and robust correlations with overall foliage necrosis in the tree's crown $R^2 = 0.510$, $p < 0.0001$ (Table 20.). As percent needle Na increased, percent observed crown necrosis also increased with more severe foliage damage observed at concentrations above 0.2% (Figure 10.). Twig and soil Na content also correlated significantly but weakly with overall crown necrosis (Table 20.). Interestingly, damage to new foliage growth correlated most strongly with needle sodium content $R^2 = 0.611$, $p < 0.0001$ (Figure 11). Presence of sodium in woody tissues (twigs) also correlated robustly with tissue death in current year needles $R^2 = 0.556$, $p < 0.001$, while the occurrence of soil Na content (ppm) correlated much less strongly (Table 20.).

Damage to older foliage growth correlated strongly with needle sodium content as well $R^2 = 0.539$, $p < 0.001$, and significantly but more weakly with Na presence in adjacent soils and twig tissue. Years of needle growth retained by the tree showed weak negative correlations with Na content in needle, twig tissue, and adjacent soils. Needle and soil Na also negatively correlated with distance from the roadbed, and twig Na positively with the presence of needle surface deposits (Table 20.).

Table 20. Significant correlations between tree health measures and sodium content of needle and twig tissues and soils. * indicates a negative correlation.

Significantly correlated variables		R^2	p value
Crown necrosis (%)	Needle Na content (%)	0.510	< 0.0001
	Twig Na content (%)	0.226	< 0.0001
	Soil Na content (%)	0.195	< 0.0001
Current year needle necrosis (%)	Needle Na content (%)	0.611	< 0.0001
	Twig Na content (%)	0.556	< 0.0001
	Soil Na content (%)	0.201	< 0.0001
Previous years needle necrosis (%)	Needle Na content (%)	0.539	< 0.0001
	Twig Na content (%)	0.234	< 0.0001
	Soil Na content (%)	0.285	< 0.0001
Years of foliage growth retained*	Needle Na content* (%)	0.176	< 0.0001
	Twig Na content* (%)	0.136	< 0.001
	Soil Na content* (%)	0.071	< 0.05
Distance from the roadbed* (m)	Needle Na content* (%)	0.073	< 0.05
	Soil Na content* (%)	0.075	< 0.05
Presence of needle surface deposits	Twig Na content (%)	0.059	< 0.05

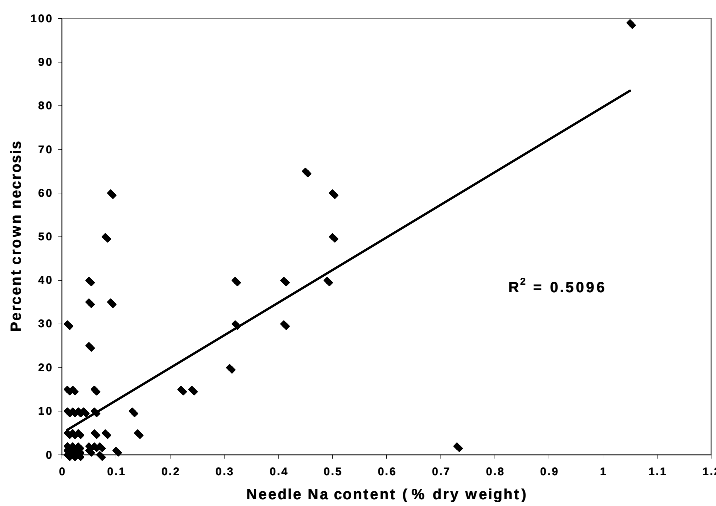


Figure 10. Needle sodium content and overall crown necrosis.

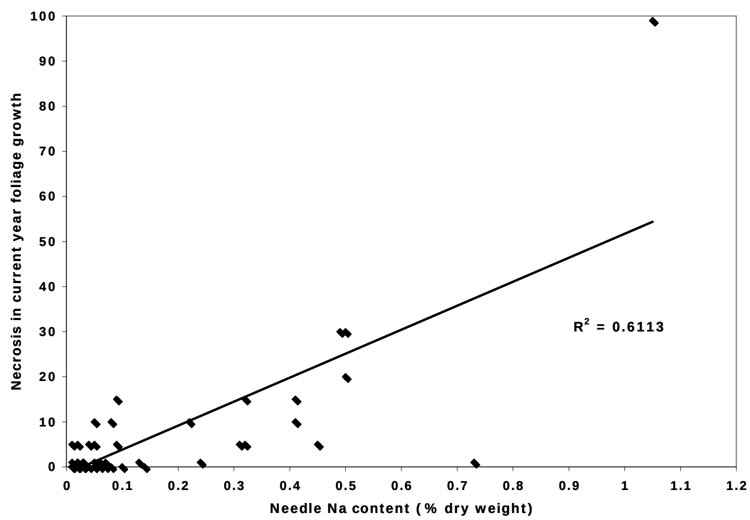


Figure 11. Needle sodium content and necrosis in new growth

Magnesium exposure and tree health:

In most instances, the presence of magnesium in plant tissues and soils did not correlate significantly with damage to roadside trees. However, levels of twig magnesium formed a negative correlation with overall crown necrosis $R^2 = 0.052$, $p < 0.05$. Although not robust, this correlation was the only one in which salt levels decreased as observed levels of foliage necrosis increased.

Chloride exposure and tree health:

Overall crown necrosis correlated robustly with the occurrence of chloride in the needle tissue $R^2 = 0.602$, $p < 0.0001$ (Table 21.). As needle chloride content increased over 1.0% of total dry weight, more severe levels of necrosis were noted in sampled trees (Figure 12.). The strength of this relationship increased further when needle chloride content was compared to tissue death in older tree foliage $R^2 = 0.696$, $p < 0.0001$ (Figure 13.). Needle chloride content also correlated moderately with necrosis in recent or current year growth, $R^2 = 0.387$, $p < 0.0001$, while twig chloride content correlated weakly with both overall crown necrosis and necrosis in previous years needles (Table

21.). The occurrence of soil chlorides however, did not significantly correlate with foliage damage in roadside trees.

Years of needle growth retained by the tree correlated negatively with levels of needle chlorides $R^2 = 0.269$, $p < 0.0001$. Needle chloride also exhibited a negative moderate correlation with distance from the roadbed, while twig chloride content correlated much less strongly (Table 21.). Finally, needle chlorides showed a weak but significant correlation with the presence of needle surface deposits.

Table 21. Significant correlations between tree health measures and chloride content of needle and twig tissues. * indicates a negative correlation.

Significantly correlated variables		R^2	p value
Crown necrosis (%)	Needle Cl content (%)	0.602	< 0.0001
	Twig Cl content (%)	0.141	< 0.001
Current year needle necrosis (%)	Needle Cl content (%)	0.387	< 0.0001
Previous years needle necrosis (%)	Needle Cl content (%)	0.696	< 0.0001
	Twig Cl content (%)	0.144	< 0.001
Years of foliage growth retained*	Needle Cl content* (%)	0.269	< 0.0001
Distance from the roadbed* (m)	Needle Cl content* (%)	0.307	< 0.0001
	Twig Cl content* (%)	0.069	< 0.05
Presence of needle surface deposits	Needle Cl content (%)	0.109	< 0.01

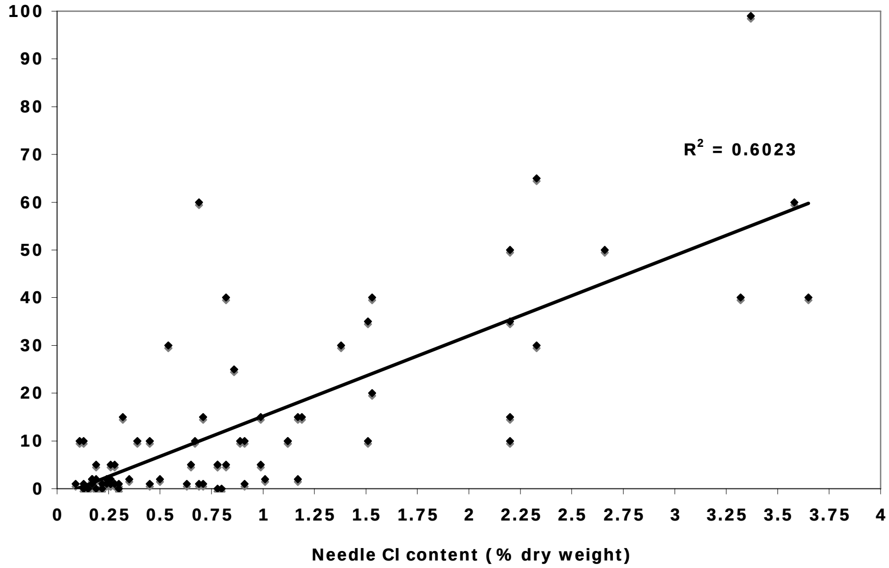


Figure 12. Needle tissue chloride content and overall crown necrosis.

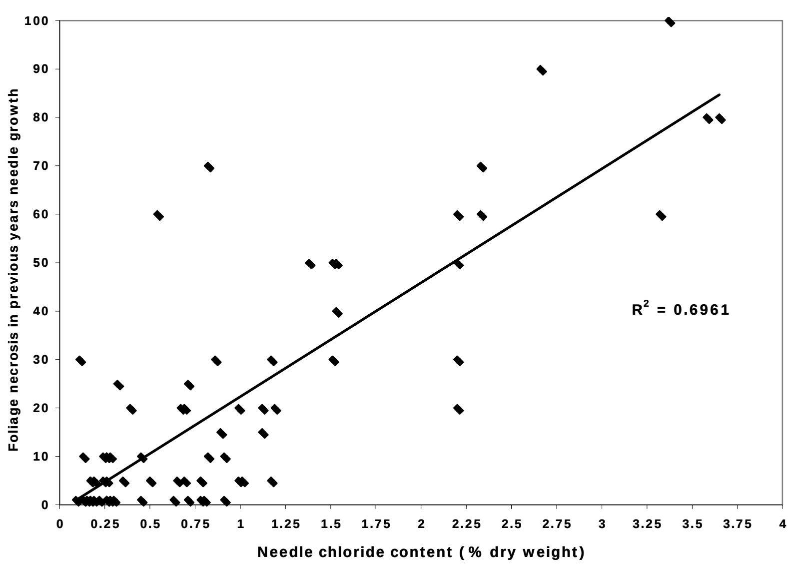


Figure 13. Needle chloride content and necrosis in older foliage

Soil pH, needle surface deposits, and tree health:

Significant but weak correlations formed between tree foliage health and soil pH, as well as between foliage health and the occurrence of needle surface deposits (Table 22.). In contrast, soluble soil salts (mmhos/cm) did not correlate with tree health or distance from the roadside. Overall crown necrosis as well as necrosis in older and new foliage correlated with an increase in soil pH, while years of foliage growth retained and distance from the roadbed correlated with a decrease in pH. Presence of needle surface deposits correlated with an increase in overall crown necrosis and in older foliage necrosis, and negatively with years of needle growth retained by the tree and distance from the roadbed (Table 22).

Table 22. Significant correlations between tree health measures, needle surface deposits, and soil pH. * indicates a negative correlation.

Significantly correlated variables		R^2	p value
Crown necrosis (%)	Soil pH	0.166	< 0.001
	Surface deposits	0.102	< 0.01
Current year needle necrosis (%)	Soil pH	0.129	< 0.01
Previous years needle necrosis (%)	Soil pH	0.214	< 0.0001
	Surface deposits	0.119	< 0.01
Years of foliage growth retained*	Soil pH*	0.143	< 0.001
	Surface deposits*	0.256	< 0.0001
Distance from the roadbed* (m)	Soil pH*	0.120	< 0.01
	Surface deposits*	0.215	< 0.0001

Conclusions

Conifers along Colorado roadways can exhibit substantial foliage damage not seen in their off-road counterparts. At the sites studied, lodgepole and ponderosa trees adjacent to the roadside exhibited significantly greater levels of crown needle tissue death ($\bar{x}$ = 21%) and foliage loss than trees away from the roadside ($\bar{x}$ = 2.6%). This pattern of damage reflected exposure to salt contamination through deicing practices and site topography. Foliar injury was concentrated along roadways or where surface runoff collected. Also, foliar injury was generally noted to be more severe on the side of the tree facing the roadway (Figure 2.*j*.). These factors conform to previously reported deicing salt injury patterns, including exposure to $MgCl_2$ (Lumis et al., 1973; Connor, 1993; Environment Canada, 2000).

Damage to photosynthetic tissue characteristically occurred as necrosis and chlorosis in the needle tips, with tissue death advancing to the needle base. Across all sites, conifers exhibited significantly more damage in older foliage than in current year (new) needle growth (Figure 5.). This damaged older foliage frequently resulted in premature abscission, resulting in less needle retention and thinner overall crown vegetation. These patterns are commiserate with damage occurring in ponderosa pine saplings treated with NaCl solutions (Bedunah & Trilca, 1977), mature ponderosa pines in Denver exposed to deicing salts (Staley et al., 1968), and conifers exposed to aerial drift and soil contamination of deicing salts or salinity (Hall et al., 1972; Sucoff et al., 1976; McCune et al., 1977; Townsend, 1983; Dobson, 1991; Kelsey & Hootman, 1992; Kozlowski, 1997; Viskari & Karenlampi, 2000; Bryson & Barker, 2002). Necrosis in older plant tissue has been characterized as a response to long-term salinity (Munns & Termaat, 1986). In this case, prolonged transpiration may bring in and concentrate salt ions in older tissue growth leading to the observed necrosis and premature abscission.

In general over the growing season, foliage damage increased in older needles, and was present to a lesser extent in emerging new growth (Figure 5.). Consistent with other observations (Hall et al., 1972; Lumis et al., 1976; Bryson & Barker, 2002), overall necrosis levels increased throughout the growing season at most sites (Figure 3.). The greatest foliage deterioration occurred at sites 132D (Denver), 121H and 122D (Hwy 36). These sites exhibited the highest levels of Na in plant tissues (Table 10.), indicating a possible link with persistent sodium toxicity. Overall necrosis levels were found to decrease over the growing season at sites 114D and 112H (I-70). This may indicate some degree of recovery as precipitation leaches salt ions from the environment. These conclusions should be treated as tentative however, as premature abscission of damaged needles over the summer months can mask the degree of crown damage.

Deicing salt contamination also can be linked as the causal factor in foliage damage in Colorado pines through the presence of elevated deicing salt ions in roadside soils. Significantly higher levels of soil pH, total soluble soil salts by electrical conductivity (mmhos/cm), and soil sodium levels (ppm) were found in roadside soils compared to soils at a distance from the roadside (Table 7. and 10.).

Although soil pH and total dissolved salts (mmhos/cm) were significantly elevated in roadside soils compared to soils away from the roadside, these values were not elevated to an extent thought to be detrimental to vegetation. Tested soils were not classifiable as either saline or sodic. Saline soils can be defined as soils with an electrical conductivity exceeding 4.0mmhos/cm and a pH < 8.5, while sodic soils display an EC < 4.0mmhos/cm and a pH > 8.5 (Waskom et al., 2004). It should be noted however, that EC is dependent on soil moisture content and temperature, and therefore values may fluctuate seasonally (Bedunah & Trilca, 1977; Jones et al., 1992). More extensive sampling may be warranted to determine levels of total soluble soil salts that are almost certainly to be present in greater amounts in the soil surface profile during the deicing season.

Scots pine (*Pinus sylvestris*) has been demonstrated to exhibit decreased emergence, growth and survival at soil salinity electrical conductivity levels of approximately 6mmhos/cm (Werkhoven et al., 1966), a greater EC than noted at any of the study plots. Overall, foliar injury did not significantly correlate with total dissolved soil salts, indicating that damage may be due to accumulated specific ion toxicities in plant tissues rather than soil osmotic stress (Dirr, 1974), as well as direct foliar exposure to salt ions by aerial drift.

Elevated soil pH however, did significantly correlate with foliar injury in Colorado conifers (Table 22.). Alkaline soils exhibit a pH > 7.8, and are related to nutrient deficiencies in crop species manifesting as chlorotic and stunted plants (Waskom et al., 2004). Roadside soil in site 132D (Denver) exhibited a mean pH of 7.78, approaching this threshold, which is likely the product of the high levels of Na^+ ions present ($\bar{x}$ = 338ppm). Additionally, at a soil pH > 7 observed at both Denver metro sites (Table 7.), increased dispersion of soil colloids and heavy metal mobility becomes likely (Norrstrom & Bergstedt, 2001). These factors influence the soil cation exchange capacity and may have contributed to the extensive damage observed in conifers at site 132D.

Soil sodium levels were both significantly elevated in roadside soils (Table 10.) and correlated to conifer foliage damage (Table 20.). A review of scientific literature by Cain et al. (2001) for Environment Canada (2000) establishes threshold ranges in ppm of soil sodium levels for an effective concentration that leads to significant damage in 25% of a population of woody plant species (EC_{25}). The EC_{25} threshold is reached in woody plants exposed to soil sodium levels between 67.5-300ppm. Two-year old ponderosa pine saplings were the most sensitive of species reported, establishing the EC_{25} sodium threshold at 67.5ppm and mortality at 140ppm based on the soil application of a NaCl solution (Bedunah & Trilca, 1977). All study sites demonstrated soil sodium levels in excess of 67.5ppm even at distances greater than 100m from the roadway (Table 10.). At all sites with ponderosa pine, soil sodium levels in the surface profile of soils adjacent to the roadside exceeded 140ppm.

These results are equivalent to reported values for soil sodium content reported along Maine highways (Hutchinson, 1970), but greatly exceed reported levels of sodium along California mountain highways exhibiting damaged vegetation including ponderosa pines (Gidley, 1990). Although most elevated soil Na levels in this study were localized within 15m (49 feet) of the roadway similar to results reported in other studies (Jones et al., 1992), an exception to this pattern occurred at site 113H along the I-70 corridor (Table 10.). In this case, levels of soil sodium near off-roadside trees ($\bar{x}$ = 231ppm) were nearly twice the soil sodium levels near roadside trees ($\bar{x}$ = 125ppm), and significantly increased levels of total dissolved salts were present as well (Table 7.).

This discrepancy is explainable however, in terms of site topography and the aerial drift of deicing particles. At site 113H, roadside trees were located on a steep 23º slope down from the roadbed (Table 2.), which likely increased horizontal leaching of Na^+ ions through the soil matrix. Soils near off-road trees were located in a riparian habitat zone and rich in clay composition. Soils of low topographic position within 150m of the roadway have been found to accumulate significant levels of Na due to the aerial drift of deicing particles, especially within drainage ways and wetland depressions (Iverson, 1984 in Kelsey & Hootman, 1992).

In general, roadside soils along the I-70 corridor displayed elevated levels of magnesium compared to off-roadside soils (Table 14.). Again, site 113H proved the exception, where off-roadside soil Mg levels were significantly elevated compared to roadside soils. Levels of magnesium in roadside soils were not significantly greater than off-road soils at sites along Hwy 36 (121H and 122D) or in site 131H in metro Denver. Denver metro sites in general however, had significantly higher levels of soil magnesium than most other study sites (Table 16.). Soil magnesium content did not correlate significantly with tree necrosis, suggesting that elevated soil magnesium does not adversely impact foliage health.

Although present in excess of quantities thought to be detrimental to conifers, soil chloride levels also did not correlate significantly with foliage death in study site trees. The EC_{25} threshold in woody plants exposed to soil chloride levels is between 215-1500ppm (Cain et al., 2001, for Environment Canada 2000). Again, the lower threshold of foliar injury at 215ppm was established by the work of Bedunah and Trilca (1977) with ponderosa pines. Mortality in the pine saplings occurred at 350ppm soil applied chloride. Additionally, exposure to sodium chloride as low as 100ppm in soil has been found to inhibit seed germination and root growth in grasses and wildflowers (Environment Canada, 2000).

Soil chloride levels at Colorado study sites greatly exceeded the EC_{25} thresholds, from a high in off-roadside soils at Denver site 132D of ($\bar{x}$ = 4,010ppm) to a low of ($\bar{x}$ =750ppm) at I-70 site 111D in off-roadside soils (Table 17.). These soil chloride levels surpass reported values along Maine highways by at least 2 to 1 (Hutchinson, 1970), and greatly surpass reported values along California mountain highways exhibiting damaged ponderosa and lodgepole pines, the exception being soil samples taken directly from road medians (Gidley, 1990).

In this case, it is likely that soil chlorides affect foliar injury given the documented relationship between soil Cl levels and pine necrosis, and the excessive levels observed in study plot soils. In this case, foliage damage may not have correlated with soil chlorides due to the mobility of the Cl^- ion in the soil matrix as a result of spring and summer precipitation. Levels of soil chlorides also failed to form a significant correlation with distance from the roadbed, along the lines of earlier findings where topsoil concentrations of chloride lacked of correlation to salt use on the roadway (Hofstra & Hall, 1971; Viskari & Karenlampi, 2000). In some cases, chloride levels in off-roadside soil samples exceeded that of those taken from those in proximity to the roadside, although these differences were not statistically significant (Table 17.). This was noted in sites located down slope from the roadbed: 113H (I-70), 121H (Hwy 36), and 132D (Denver) (Table 2. and 3.).

Denver metro area sites exhibited some of the highest soil pH, total soil salts, soil sodium, magnesium, and chloride contents of all sites tested. Sites 114D and 112H along I-70 tended to be lowest in soil pH, total soil salts, soil sodium, magnesium, and chloride content of tested study sites. These relationships were not necessarily good predictors of tree foliage health however (see Figure 3.). Instead, the accumulation of salt ions within the tissues of Colorado ponderosa and lodgepole pines provided much more significant and robust correlations with foliar injury.

Needle sodium, magnesium, and chloride and twig sodium and chloride contents were significantly elevated in tree foliage along the roadside compared to trees distant from the roadside. These findings concur with other studies of salt exposure in roadside vegetation (Hofstra & Hall, 1971; Lumis et al., 1973; Viskari & Karenlampi 2000). Foliage damage in roadside conifers also was correlated significantly with the presence of salt ions in plant tissues. Both sodium and chloride content in needle tissue and the sodium content in twig tissue provided robust correlations with necrosis in tree foliage. These findings are consistent with reported salt ion accumulation and foliage damage from deicer applications in ponderosa and lodgepole pines along California highways (Gidley, 1990).

Sodium is reported to be toxic above 0.2-0.5% dry weight in leaves (Westing, 1969; Smith, 1970; Hofstra & Hall, 1971; Hofstra and Lumis, 1975; Bernstein, 1975). Sodium only approached these concentrations in the needle foliage of roadside trees at sites along Hwy 36 and in the Denver metro area. Needles collected from roadside trees at site 121H had a mean dry weight percentage of sodium 0.19%, while needles from roadside trees at site 122D displayed a mean Na percentage of 0.30%. Na content in needle foliage from roadside ($\bar{x}$ = 0.48%) and off-roadside ($\bar{x}$ = 0.15%) trees at site 132D in Denver also approached or exceeded this threshold. Although Na is considered by some authorities to be less toxic than Cl, Na is reported to be more persistent in woody tissue and toxic at lower exposure levels than Cl (Smith, 1970). This idea is supported by this study in several respects. Although sodium accumulations in roadside plant tissues occurred at lower dry weight percentages than chloride accumulations, needle sodium and twig contents form moderately strong correlations with foliar injury in Colorado conifers (Table 20.). Unlike tissue Cl content, which correlates more strongly with damage to older foliage, a moderately strong significant correlation formed between twig sodium content and new foliage growth (R^2 = 0.556). If Na accumulations persist in woody tissues over time, new growth may then reflect exposure to that toxicity.

Magnesium in soils and plant tissues displayed a notably different relationship to vegetation damage than Na and Cl. Overall, the increased magnesium in plant tissues and soils did not significantly correlate with increased damage to roadside trees. Instead, levels of twig magnesium formed a weak negative correlation with overall crown necrosis $R^2 = 0.052$, $p < 0.05$. These finding support the conclusions of other researchers that magnesium is unlikely to be biologically toxic even at high concentrations (Lewis, 1999).

Injury symptoms tend to occur as leaf chloride content exceeds 1.0% dry weight in deciduous trees and 0.5% dry weight in conifers (Holmes & Baker, 1966; Westing, 1969; Bernstein, 1975; Dobson, 1991; Blomqvist, 2001). Salt damage symptoms in field observations of lodgepole pine (*Pinus contorta*) occurred around 0.67% dry weight chloride in needle tissue (Edwards et al., 1981 in Dobson, 1991). At all sites dominated by lodgepole pine along I-70, mean needle chloride content exceeded 0.67% dry weight in all roadside trees, but not in off-road trees (Table17.).

Controlled application of salt to ponderosa pines (*Pinus ponderosa*) resulted in visible damage to foliage at needle chloride concentrations between 1.36 and 3.3% dry weight (Spotts et al., 1972; Scharpf & Srago, 1974; Bedunah & Trilca, 1979; in Dobson, 1991). However, complete foliage death in deicer-exposed white pines (*Pinus strobus*) has been documented to be associated with needle chloride levels of about 1.0% dry weight (Hofstra & Hall, 1970). In roadside trees at sites dominated by ponderosa pine along Hwy 36 and in metro Denver, sites 122D and 132D exhibited average needle chloride contents in excess of 2.0% dry weight (Table 17.). Mean roadside needle chloride contents were 1.23%, and 0.76% at site 121H and 131H respectively. The results of this study indicate that ponderosa pines may be more sensitive to foliar accumulations of Cl^- ions than previously reported. At the study plots, as needle chloride content increased over 1.0% of total dry weight, more severe levels of necrosis were noted in sampled trees (Figure 12.).

Across all sites, Cl content in needle tissue correlated with foliage damage more strongly than any other factor tested. These results support previous findings that that foliar chloride content is better correlated than sodium with foliage salt damage (Spotts et al., 1972; Dobson, 1991). Overall crown necrosis correlated robustly with the occurrence of chloride in the needle tissue $R^2 = 0.602$, $p < 0.0001$ (Table 21.). The strength of this relationship increased further when needle chloride content was compared to tissue death in older tree foliage $R^2 = 0.696$, $p < 0.0001$ (Figure 13.). This finding is consistent with the increased severity of damage seen in older foliage (Figure 5.). Both sodium and chloride accumulation were found to increase in older needles of Scots pine (*Pinus sylvestris*) (Viskari & Karenlampi, 2000).

This relationship is clearly represented in the Denver metro sites 131H and 132D. At site 131H, foliar damage to ponderosa pines was less than 6%, the lowest reported. Needle chloride content in roadside trees also was lower than in any other site tested, averaging 0.76% dry weight. This site lies surrounded by a cloverleaf style on-ramp to I-70 rather than directly adjacent the freeway, which may provide some protection from deicer exposure. Site 132D demonstrated the highest overall levels of roadside foliage necrosis ($\bar{x} =$ 34.2% in older fall foliage) and the second highest mean needle chloride content ($\bar{x} =$ 2.19%).

Twig Cl content was lower in exposed trees than needle chloride content, and correlated significantly but much more weakly with foliage damage across sites (Table 21). As found in previous studies, Cl accumulated in higher concentration in the plant leaves and stems, although Na accumulated in both needles and woody tissues in this study in contrast to being concentrated in woody tissue (Dirr, 1974; Townsend, 1980).

It is important to note that sampling of soils and tree tissues in the late summer and early fall minimized the amount of salts present, as precipitation leaches salts from the soil surface profile. Maximum soil salt concentrations occur throughout the winter and gradually decrease during the spring summer and fall (Jones et al., 1992; Viskari & Karenlampi, 2000), while salt levels in plant tissues have been found to decline as well (Hall et al., 1972). That levels of Na^+ and Cl^- in the tissues of Colorado roadside ponderosa and lodgepole pines exceed levels known to damage foliage even in late fall indicates that salts remain in the needle tissue causing long-term stress to the exposed trees.

Along Colorado roadways, evidence occurs that aerial drift of deicing particles damages roadside vegetation and may have more severe consequences for plant health than soil uptake of salts. Firstly, overall foliar injury did not significantly correlate with total dissolved soil salts but did correlate strongly with foliar accumulation of sodium and chloride. This may provide some indication that damage may be due to direct foliar exposure to salt ions by aerial drift. Secondly, overall crown necrosis correlated weakly with tree distance from the roadside (R^2 = 0.246) compared to the correlation of crown necrosis and salt exposure measured by ion accumulation in plant tissues (R^2 = 0.602). This supports the idea that wind patterns and site topography may play an equally important role in salt exposure.

Thirdly, immediately adjacent to the roadside, the areas of tree crown facing the road exhibited greater amounts of damage than areas sheltered from roadside exposure. This indicates that a direct splash zone of deicer exists from snow plowing and passing vehicular traffic along Colorado highways. Bryson and Barker (2002) noted the greatest severity of salt damage to vegetation within 15m (49 feet) of the roadway and attributed that damage to direct salt spray. They also noted that coniferous species were highly susceptible to the damage.

Fourthly, aerial drift of deicing particles has been documented to occur over extensive distances. Lumis et al. (1973) found vegetation within 40m (131 feet) of the roadbed affected by the aerial drift of suspended salt particulates. Hofstra & Hall (1971) found evidence of salt spray damage up to 120m (394 feet) away from the roadway. Elevated Na and Cl levels in foliage were found in foliage 61m (200 feet) away after one deicing season on a new stretch of highway, while soil sodium increased a distances up to 12m (39 feet), and soil chlorides up to 61m (200 feet) (Langille, 1976). Aerial drift has been documented to occur as far as 500m (1,640 feet) from the roadway (Jones et al., 1992).

It is likely that the trees in this study even removed over 100m (328 feet) from the roadway even did not completely escape influence from deicing applications. Background needle Na and Cl contents have been reported in Scots pine as 0.004% Na and 0.01-0.005% Cl (Viskari & Karenlampi, 2000) and 0.009%Na and 0.043% Cl in ponderosa pine (Bedunah & Trilca, 1977), both of which were exceeded by Na and Cl contents of off-roadside trees in this study. Another indication of aerial drift is the presence of needle surface deposits in off-road trees as far away as 115m (377 feet).

Many study plot trees near and removed from the roadside environment displayed needle surface deposits that are likely indicators of aerial exposure to suspended particulates including deicing chemicals. Winter particulate deposits on vegetation surfaces in association with roadways have been previously noted (Blomqvist, 2001). In this study, surface deposits contained a number of different elements including Mg, Na, and Cl salts as well as granite derived silt-like deposits probably consisting of quartz (SiO_2) and feldspar (aluminum and potassium silicates) found in igneous rock. Patterns of elements found and coating morphology matched patterns seen on needles artificially treated in the laboratory with sand/salt deicer and liquid magnesium chloride deicer. Therefore, it is considerably likely that the salts and fine rock particulates on the roadside conifer needles are a product of roadside deicing practices.

Although salt spray has been associated with coalescence of epicuticular wax in some *Pinus* species (Krause, 1981), and resistance to salinity has been in some cases associated with the ability of thick waxy needle cuticles to exclude toxic salt ions (Hofstra & Hall, 1971; Lumis et al., 1973; but see Barrick et al., 1979), evaluation of needle surface morphology and fine structure was not undertaken due to time limitations and the prevalent surface deposits in needle samples.

Future research to determine the extent and mode of the exposure of Colorado vegetation to deicing chemicals might include wet chemistry examinations of needle surface deposits and examination of needle epicuticular waxes to further elucidate salt spray exposure. More extensive chemical sampling of vegetation tissues (including deciduous trees) and soils would provide evidence of seasonal exposure patterns that might then be related to application practices. Atmospheric deposition samplers might also be established at field sites to monitor the presence and patterns of aerial drift of salt particulates.

OBJECTIVE TWO: EVALUATION OF PHOTOSYNTHESIS AND LEAF-LEVEL GAS EXCHANGE IN COLORADO ROADSIDE CONIFERS

Introduction

To further explore the nature of impacts to roadside vegetation, an assessment of tree physiology through leaf-level gas exchange was undertaken for an additional measure of tree health and vigor. At each of the eight field study sites, five conifers of either lodgepole (*Pinus contorta*) or ponderosa (*Pinus ponderosa*) pines along the roadside and five conifers of equivalent trunk diameter away from the roadside were assessed for net carbon assimilation or photosynthesis, stomatal conductance, transpiration, and water use efficiency. One round of assessment occurred during active deicing applications or soon after in March through May of 2004. A subsequent assessment of tree physiology for comparison occurred at the end of the growing season prior to the beginning of deicing applications in August through October of 2004. Conifer physiology was compared for significant differences in roadside and off-roadside trees across all study sites. Between site differences were not examined in depth due to the level of variation able to influence physiology inherent at each site. These factors include variables such as tree species, soil type, humidity, temperature and elevation. Finally, these data were examined for significant correlations with other indices of tree health and salt exposure.

Methods

Leaf-level gas exchange was measured on attached, fully developed and photosynthetically active needle tissue free of necrosis and chlorosis at each site using an infrared open gas exchange system via a Licor LI-6400 portable photosynthesis system (Li-Cor, Lincoln, NE). Conditions during gas exchange were standardized at a saturating irradiance of 1600 PAR using a LI-6400 02-B red-blue led light source. A 6400-01 CO_2 injector system maintained ambient CO_2 during measurement at 400ppm with in a 2 x 3 inch ($38.7 cm^2$) leaf chamber cuvette. Measurements were repeated twice in a series on each tree at each site, and were completed between 1000h and 1400h on the same day to minimize temperature and humidity differentials. Roadside and off-roadside tree physiology was evaluated in lodgepole and ponderosa pines after system equilibration through the gas exchange parameters of net carbon assimilation (photosynthesis) (**A**) in ($\mu mol\ CO_2\ m^{-2}\ s^{-1}$), stomatal conductance to water vapor ($\mathbf{g_s}$) in ($mol\ H_2O\ m^{-2}\ s^{-1}$), transpiration (**E**) in ($mmol\ H_2O\ m^{-2}\ s^{-1}$), and photosynthetic water use efficiency (**WUE**) in (%), based on the equations derived by von Caemmerer & Farquhar (1981).

Statistical analysis of all data utilized SAS version 8.1, SAS Institute Inc., Cary, NC, USA. Differences in gas exchange parameters between roadside and control (off-roadside) conifers were assessed in the winter and subsequent fall using a site location by tree exposure (roadside vs. off-roadside) repeated measures factorial MANOVA by Wilks' Lambda. Pearson correlation coefficients were calculated to find relationships between gas exchange parameters, foliage health variables, distance of conifers from the roadside, and indices of salt exposure for fall physiology measures. In all MANOVA cases, significant relationships ($p < 0.05$) were evaluated through Bonferroni post hoc comparisons with significance levels (α) of 0.05.

Results

Overall, plant physiological measures varied by site location and tree exposure (Table 23. and 24.). A site by exposure repeated measures factorial MANOVA was used to compare photosynthesis, stomatal conductance, transpiration and water use efficiency in roadside and off-roadside trees across study sites for winter and subsequent summer and fall measurements. For all physiology measures over the two seasons, only in the interaction of site and exposure did gas exchange measures vary significantly ($F = 3.08$, $p < 0.01$). According to visual analyses of site by exposure interactions for photosynthesis, net carbon assimilation in roadside trees was elevated at sites 111D (I-70), 121H (Hwy 36), and 131H (Denver) relative to other sites. Photosynthesis in roadside trees was lower in sites 113H (I-70) and 122D (Hwy 36) relative to other sites (Tables 23. and 24).

Table 23. Winter 2004 mean and standard error of gas exchange parameters in conifers adjacent to and away from the roadside across study sites. (See below for symbol definitions and units)

Site ID	Exposure	A ± SE	g_s ± SE	E ± SE	WUE ± SE
111D (I-70)	Roadside	8.96 ± 0.60	0.07 ± 0.01	0.76 ± 0.14	1.62 ± 0.32
(P. contorta)	Off road	7.89 ± 0.70	0.08 ± 0.01	1.23 ± 0.16	0.75 ± 0.12
112H (I-70)	Roadside	8.90 ± 1.09	0.13 ± 0.01	1.93 ± 0.23	0.56 ± 0.1 1
(P. contorta)	Off road	10.05 ± 0.35	0.14 ± 0.01	2.71 ± 0.24	0.39 ± 0.03
113H (I-70)	Roadside	5.91 ± 0.47	0.09 ± 0.01	2.15 ± 0.11	0.28 ± 0.02
(P. contorta)	Off road	6.69 ± 0.92	0.08 ± 0.01	2.28 ± 0.33	0.29 ± 0.01
114D (I-70)	Roadside	8.14 ± 0.60	0.02 ± 0.01	0.29 ± 0.17	1.64 ± 1.82
(P. contorta)	Off road	8.46 ± 0.48	0.07 ± 0.01	1.27 ± 0.16	0.78 ± 0.11
121H (Hwy 36)	Roadside	7.11 ± 0.83	0.03 ± 0.02	0.26 ± 0.13	8.59 ± 11.16
(*P. ponderosa*)	Off road	8.09 ± 0.63	0.07 ± 0.02	0.74 ± 0.20	1.24 ± 0.58
122D (Hwy 36)	Roadside	6.30 ± 0.74	0.002 ± 0.03	-0.03 ± 0.16	0.26 ± 1.89
(*P. ponderosa*)	Off road	10.38 ± 0.48	0.02 ± 0.02	0.83 ± 0.16	-0.82 ± 1.05
131H (Denver)	Roadside	8.47 ± 0.39	0.07 ± 0.02	1.13 ± 0.22	0.45 ± 0.20
(*P. ponderosa*)	Off road	7.99 ± 0.64	0.02 ± 0.04	0.68 ± 0.44	-0.12 ± 0.30
132D (Denver)	Roadside	7.64 ± 0.86	0.002 ± 0.04	0.11 ± 0.29	-1.18 ± 0.87
(*P. ponderosa*)	Off road	7.71 ± 0.52	0.08 ± 0.03	0.70 ± 0.25	4.63 ± 2.73

Symbol definitions: A = net carbon assimilation rate (photosynthesis), (μmol CO_2 m^{-2} s^{-1}); g_s = stomatal conductance to water vapor, (mol H_2O m^{-2} s^{-1}); E = transpiration rate, (mmol H_2O m^{-2} s^{-1}); WUE = percent water use efficiency, (A x 10^{-6} / E *100)

As expected, gas exchange parameters differed significantly between winter and subsequent summer and fall evaluations ($F = 15.96$, $p < 0.0001$) due to seasonal differences, including ambient temperature and humidity. That the interaction of site location and tree exposure over time also varied significantly among gas exchange measures is also to be expected due to the variability inherent in each site and differing ambient conditions during analysis. As these differences (between sites) do not necessarily reflect the impact of roadside exposure, they will not be discussed at this time.

Table 24. Fall 2004 mean and standard error of gas exchange parameters in conifers adjacent to and away from the roadside across study sites. (See below for symbol definitions and units)

Site ID	Exposure	A ± SE	g_s ± SE	E ± SE	WUE ± SE
111D (I-70)	Roadside	9.17 ± 0.56	0.14 ± 0.01	3.10 ± 0.23	0.31 ± 0.02
(P. contorta)	Off road	7.43 ± 0.52	0.09 ± 0.01	1.95 ± 0.40	0.50 ± 0.07
112H (I-70)	Roadside	5.14 ± 0.48	0.06 ± 0.01	2.09 ± 0.20	0.25± 0.02
(P. contorta)	Off road	7.88 ± 0.46	0.08 ± 0.01	3.30 ± 0.27	0.25 ± 0.01
113H (I-70)	Roadside	8.72 ± 0.51	0.16 ± 0.02	2.11 ± 0.19	0.45 ± 0.05
(P. contorta)	Off road	9.41 ± 0.70	0.12 ± 0.01	1.87 ± 0.18	0.52 ± 0.03
114D (I-70)	Roadside	6.93 ± 0.53	0.11± 0.01	1.77 ± 0.15	0.40 ± 0.03
(P. contorta)	Off road	8.85 ± 0.20	0.10 ± 0.01	1.89 ± 0.10	0.48 ± 0.03
121H (Hwy 36)	Roadside	9.97 ± 1.16	0.11 ± 0.02	3.24 ± 0.38	0.32 ± 0.03
(*P. ponderosa*)	Off road	9.56 ± 0.45	0.11 ± 0.01	2.88 ± 0.38	0.38 ± 0.05
122D (Hwy 36)	Roadside	12.15 ± 0.52	0.12 ± 0.01	2.11 ± 0.14	0.61 ± 0.07
(*P. ponderosa*)	Off road	12.26 ± 0.76	0.13 ± 0.003	2.11 ± 0.08	0.60 ± 0.05
131H (Denver)	Roadside	4.31 ± 1.06	0.06 ± 0.01	3.05 ± 0.31	0.13 ± 0.03
(*P. ponderosa*)	Off road	3.17 ± 0.71	0.05 ± 0.01	3.69 ± 0.39	0.10 ± 0.02
132D (Denver)	Roadside	3.98 ± 1.31	0.03 ± 0.01	1.32 ± 0.37	0.27 ± 0.08
(*P. ponderosa*)	Off road	1.20 ± 0.69	0.03 ± 0.01	1.48 ± 0.34	-0.09 ± 0.13

Although no significant differences in overall physiological parameters as measured by gas exchange were noted by exposure, significant differences were seen in individual gas exchange parameters by exposure over the two seasons ($F = 9.60$, $p < 0.0001$). Significant differences occurred for photosynthesis and transpiration in winter roadside versus off-road conifers, although equivalent differences were not seen over the growing season (Table 25.). It should be noted however, that the winter gas exchange measures for transpiration (E), and therefore water use efficiency (WUE) contained a high level of instability (note standard errors for these parameters in Table 23.) and therefore the validity of these results may be questionable.

Winter rates of photosynthesis correlated significantly but very weakly with necrosis in older conifer foliage ($R^2 = 0.050$, $p < 0.05$), but not with necrosis in new foliage, overall crown necrosis, or distance from the roadside. Fall rates of photosynthesis did not correlate with foliage injury, but formed significant correlations with indices of salt exposure. A moderate negative correlation formed between soil pH levels and fall photosynthesis rates, while weak but significant correlations formed between fall photosynthesis rates and total soluble soil salts, twig Na and Mg content, needle Mg content, and soil and chloride content (Table 26.).

Table 25. Mean gas exchange parameters in roadside and off-road conifers by season. * denotes a significant difference by Bonferroni post hoc t-test (α = 0.05)

Mean gas exchange parameter	Exposure	Winter	Fall
A	Roadside	**7.6***	7.42
	Off-road	**8.45***	7.58
g_s	Roadside	0.055	0.095
	Off-road	0.074	0.090
E	Roadside	0.89*	2.32
	Off-road	1.28*	2.41
WUE	Roadside	-0.44	0.34
	Off-road	0.28	0.34

Symbol definitions: A = net carbon assimilation rate (photosynthesis), (μmol CO_2 m^{-2} s^{-1}); g_s = stomatal conductance to water vapor, (mol H_2O m^{-2} s^{-1}); E = transpiration rate, (mmol H_2O m^{-2} s^{-1}); WUE = percent water use efficiency, (A x 10^{-6} / E *100)

Table 26. Significantly correlated variables with fall photosynthesis rates (μmol CO_2 m^{-2} s^{-1}). * indicates a negative correlation.

Significantly correlated variable	R^2	p value
Total soluble soil salts (EC mmhos/cm)	0.172*	< 0.0001
Soil pH	0.317*	< 0.0001
Twig Na content (% dry weight)	0.112*	< 0.01
Needle Mg content (% dry weight)	0.132	< 0.001
Twig Mg content (% dry weight)	0.089	< 0.01
Soil Mg content (ppm)	0.098*	< 0.01
Soil Cl content (ppm)	0.201*	< 0.0001

Conclusions

During the late winter and early spring, leaf-level photosynthesis rates in roadside trees were significantly reduced compared to their counterparts distant from the roadside environment (Table 25.). This finding concurs with other studies establishing that salinity reduces the rate of photosynthesis in plants (Bedunah & Trilca, 1977; Pezeshki & Chambers, 1985; Yeo et al., 1985; West et al., 1986; Banuls & Primo-Millo, 1992; Meinzer et al., 1994). In contrast to the deicing season, no significant differences in photosynthesis rates or other gas exchange parameters between roadside and off-road conifers were observed in the summer and late fall. The leaching of salt ions from roadside soils and plant tissues may account for this difference, as well as imply that a certain level of physiological recovery is possible for roadside trees during the growing season.

Although leaf-level photosynthesis throughout the growing season did not appear to be significantly affected by roadside exposure, it is important to realize that total canopy photosynthesis is undoubtedly reduced in roadside trees. Colorado roadside conifers displayed significantly greater levels of chlorotic and necrotic foliage than their counterparts distant from the roadside environment. During early fall 2004, mean percent crown necrosis was 22.7% in roadside trees, compared to only 3.0% in off-road trees (Figure 4.). Roadside trees also demonstrated significantly decreased levels of foliage density. At study sites, trees adjacent to the roadside retained an average of three years of needle growth, while trees removed from the roadside retained five (Table 6.).

The presence of non-viable foliage and the premature abscission of foliage decrease the available photosynthetic area, and therefore the overall photosynthetic capacity of the tree. A decline in photosynthetic capacity in turn leads to decreased growth rates and a loss of plant vigor (Longstreth & Nobel, 1979). Munns & Termaat (1986) suggest that when older leaves die due to excessive salt accumulation, the photosynthetic area of the plant will eventually decline to the point where it can no longer produce enough carbohydrate to support continued growth.

Measures of soil salinity and sodicity exhibited significant but weak negative correlations with fall photosynthesis rates in Colorado conifers (Table 26.), indicating that soil salinity may inhibit tree physiology through osmotic stress. While negative correlations of photosynthetic rates and the presence of salt ions in plant tissues have been reported in controlled experiments (Seeman & Critchley, 1985; Yeo et al., 1985; Bethke & Drew, 1991; Banuls & Primo-Millo, 1992), these correlations were not found in this field study. Analyses of salt content in plant tissues and roadside soils during the increased exposure of the deicing season may provide further insight into the relationship of foliar salt content and physiology in Colorado roadside trees.

In contrast, levels of magnesium in tree needle and twig tissue were weakly positively correlated with photosynthesis rates (Table 26.) as well as tree foliage health. Declines in the magnesium content of plant tissues in response to NaCl have been previously noted (Townsend, 1980; Saur et al., 1995). As levels of sodium increase in soil solutions, increases in exchangeable Na^+ in the soil cation pool are balanced by decreases in exchangeable Mg^{2+} and Ca^{2+}. This may lead to calcium and magnesium deficiencies in plant tissues (Bernstein, 1975). Although the use of $MgCl_2$ based deicers may somewhat offset sodium induced plant magnesium deficiencies, the benefits are unlikely to outweigh the negative impacts of chlorides on tree health.

An appreciable but non-significant reduction in stomatal conductance also occurred in roadside trees during the deicing season (Table 25.), implying that a stomatal inhibition of photosynthesis in this case is possible. However, conifer intercellular carbon dioxide concentration (Ci) (not shown) increased in roadside trees compared to off-road trees during the winter implying a reduction in mesophyll cell capacity for carbon assimilation (Farquhar & Sharkey, 1982; Yeo et al., 1985). A reduction in mesophyll photosynthetic capacity can in turn imply that specific ion toxicities may be directly affecting the cellular photosynthesis system. In the future, to further partition the stomatal and non-stomatal inhibition of photosynthesis, photosynthetic phytochemistry might be examined through chlorophyll fluorescence measurements.

Both decreased stomatal conductance and transpiration have been noted with salt exposure (Petersen & Eckstein, 1988; McCune, 1991; Brugnoli and Bjorkman, 1992). Stomatal closure (decreased stomatal conductance) can occur in plants in response to increased osmotic stress in salt contaminated soils, or as a result of injury to the stomatal mechanism through specific ion toxicities in leaf tissue (Leonardi & Fluckiger, 1986). Closure of the stomates is an adaptive response in plants, reducing water deficits by minimizing transpirational water loss and improving water use efficiency (Huck et al., 1983; Dobson, 1991).

Levels of stomatal conductance were reduced during the winter and early spring for roadside conifers in conjunction with a significant reduction in transpiration rates (Table 25.). This same reduction was not observed in the subsequent fall, although significant correlations between stomatal conductance and transpiration and the presence of soil salinity was observed. Fall stomatal conductance in study trees was negatively but weakly significantly correlated with the presence of soil magnesium ($R^2 = 0.057$, $p < 0.05$), soil chlorides ($R^2 = 0.165$, $p < 0.001$), soil pH ($R^2 = 0.116$, $p < 0.01$), and total dissolved soil salts ($R^2 = 0.143$, $p < 0.001$). Fall transpiration in study trees also demonstrated significant weak correlations with soil chloride levels ($R^2 = 0.062$, $p < 0.05$).

This combination of evidence potentially indicates a physiological response to soil salinity in roadside trees. That stomatal conductance (gs), transpiration rates (E), and water use efficiency (WUE) did not significantly differ between roadside and off-road conifers in the fall suggests that the presence of soil salts are mitigated by spring and summer precipitation to levels below which tree physiological impacts are observed. This concurs with soil pH and total dissolved salts levels recorded across field study sites in the fall. Although these factors were significantly elevated in roadside soils, they were not elevated to an extent thought to be detrimental to vegetation (Table 7.). Again, further analyses of salt accumulations in the roadside environment during deicing season may be warranted.

Additionally, stomatal diffusion of water vapor and carbon dioxide may have been impaired in roadside trees due to the presence of needle surface deposits. In many cases a heavy coating of resuspended road particulates on the needles of study site trees occluded stomatal openings (Figure 7**.** *h*). These surface deposits may potentially reduce photosynthesis in Colorado roadside conifers by limiting gas exchange through stomatal pores and by reduced light able to penetrate the coated epidermis. Although no significant reduction in stomatal conductance was observed in roadside trees at the end of the growing season, spring and summer precipitation had also reduced the visible presence and prevalence of these deposits on the needles of roadside trees.

Salt stress can also increase instantaneous water use efficiency (WUE) by reducing stomatal conductance and transpiration to a greater extent than photosynthesis (McCree & Richardson, 1987; Glenn & Brown, 1998). This enhancement in WUE is generally regarded as a mechanism to avoid salt ions, which may enter plant tissues in proportion to transpiration rates (Brugnoli & Bjorkman, 1992). Although observed in some halophytes and non-halophytes, this effect was not observed during either the winter/spring or summer/fall measurement periods in this study. Even though winter transpiration rates were significantly reduced, inconsistencies in measurements prevented an accurate assessment of water use efficiency in this case. To determine these physiological relationships, winter gas exchange measurements might be repeated at a future date.

OBJECTIVE THREE: LABORATORY EVALUATION OF THE EFFECTS OF VARIOUS SAND/SALT MIXTURES AND LIQUID DEICERS ON PLANT HEALTH, LEAF-LEVEL GAS EXCHANGE, AND SEED GERMINATION

Plant Health and Leaf-Level Gas Exchange

Introduction

In order to definitively evaluate of the impacts of deicer exposure on vegetation health, a controlled greenhouse study was undertaken comparing the effects of the $MgCl_2$ based deicer (FreezGard) and a NaCl based sand/salt deicer on lodgepole (*Pinus contorta*) and ponderosa (*Pinus ponderosa*) saplings. Sapling necrosis in new and older foliage, height, number of new branches, and caliper diameter was assessed at the start and conclusion of a three-month study designed to simulate vegetation salt exposure over the peak of the deicing season. The impact of the mode of deicer exposure also was evaluated through the treatment of saplings with deicing chemicals via the soil matrix or via direct foliar contact in order to simulate roadside aerial drift.

Sapling physiological response to deicer exposure was also assessed through leaf-level gas exchange parameters. Relative effects of deicer treatment type and concentration level on net carbon assimilation (photosynthesis), transpiration, intercellular carbon dioxide concentration, water use efficiency, and stomatal conductance in *P. contorta* and *P. ponderosa* were evaluated directly after an initial exposure to a deicing treatment to determine if an immediate physiological response to deicer exposure existed. After three months of deicing treatments, gas exchange parameters were re-evaluated to determine the effects of extended deicer exposure.

Methods

One hundred and forty-four two-year old saplings of *P. contorta* and 144 two-year-old saplings of *P. ponderosa* were obtained through the CSU State Forest Service Nursery, Fort Collins, CO. Saplings were selected for approximate equivalent size, caliper diameter, and health, and then randomly divided into twelve treatment blocks of twelve trees. Saplings were planted in a 1:1 mixture of peat moss and vermiculite in rectangular tree pots with a surface area of 116.6cm (18") and depth of 35.6cm (14"). Saplings were fertilized once per month with all-purpose Miracle-Gro in an equivalent concentration to 60ppm nitrogen. To remove any confounding drought stress, saplings were watered to one half of field capacity twice weekly. Temperature extremes were also prevented through greenhouse automated heating and cooling systems.

Saplings were exposed to a concentration gradient of either liquid $MgCl_2$ deicer (FreezGard) atomized to a fine mist and applied directly to the foliage, $MgCl_2$ deicer applied directly to the sapling container soil matrix, or sand/salt deicer applied directly to container soil. FreezGard consists of a base of 29-31% $MgCl_2$ hexahydrate in water, while the sand salt mixture used by CDOT consists of 15% NaCl in a matrix of granitic gravel and sand particles. A concentration gradient of deicers was selected with the upper bound being full roadbed application strength (100%), and subsequently reduced to 50% and 10% of roadbed application strength. Distilled water was used as a control (0%). Desired dilution levels were obtained by a reduction in application mass of sand/salt and through the addition of distilled water for $MgCl_2$.

Saplings were treated with 9.6g of sand/salt deicer and 12.2ml of $MgCl_2$ deicer at the appropriate concentration level every 10 days for three-months. Treatments were set to mimic deicing season conditions throughout the peak of the winter based on CDOT snow shift data for this study's field site locations. As calculations for simulated treatment amounts may be of interest to CDOT personnel, a brief description is included below.

Sand Salt:

- Sand/Salt is applied at 500 lbs / lane mile
- 12 ft wide lane x 5280 ft = 63360 ft^2/lane mile = 9123840 in^2/lane mile
- 1 planter surface area = 4.25 in x 4.25 in = 18.0625 in^2
- 9123840 in^2 per lane mile / 18.0625 in^2 per planter = 505126.08 planters per lane mile
- 500 lbs. Sand/Salt / lane mile / 505126.08 Planters / lane mile = 0.0009898 lbs Sand/Salt per planter
- 1 application of sand/salt is approximately 0.001 lbs = 0.453592 grams

Give each tree 0.45 g of sand salt to simulate one application

$MgCl_2$ Liquid Deicer:

- $MgCl_2$ is applied at 80 gal / lane mile during active deicing
- 12 ft wide lane x 5280 ft = 63360 ft^2/lane mile = 9123840 in^2/lane mile
- 1 planter = 4.25 in x 4.25 in = 18.0625 in^2
- 9123840 in^2 per lane mile / 18.0625 in^2 per planter = 505126.08 Planters per lane mile
- 80 gal $MgCl_2$ / lane mile / 505126.08 Planters / lane mile = 0.0001583 gal $MgCl_2$ deicer per planter
- 1 application of $MgCl_2$ deicer is approximately 0.00015 gal = 0.567812 ml

Give each tree 0.57 ml of deicer to simulate one application

Applications:

For a standard bell curve model of plowing frequency, the center three months (height of plowing/deicing season) corresponds to 96 snow shifts when the entire season is given at 169 snow shifts.

- If one snow shift contains two deicer applications: (1:2)
- 96 snow shifts = 192 applications in 3 months = 64 applications/month = 21.333 applications every 10 days

Sapling Treatments

- Sand/Salt: 21.333 applications x (0.45 g / application) = 9.6 g every 10 days
- $MgCl_2$: 21.333 applications x (0.57 ml / application) = 12.2 ml every 10 days

Gas Exchange: Leaf-level gas exchange was measured on attached, fully developed and photosynthetically active needle tissue free of necrosis and chlorosis using an infrared open gas exchange system via a Licor LI-6400 portable photosynthesis system (Li-Cor, Lincoln, NE). Conditions during gas exchange were standardized at a saturating irradiance of 1600 PAR using a LI-6400 02-B red-blue led light source. A 6400-01 CO_2 injector system maintained ambient CO_2 during measurement at 400ppm within a LI 6400-05 conifer chamber. Measurements were performed between 1000h and 1400h, and fluctuations in relative humidity and temperature were minimized under controlled system and greenhouse conditions. Tree physiology was evaluated after system equilibration through the gas exchange parameters of net carbon assimilation (photosynthesis) (**A**) in (µmol CO_2 m^{-2} s^{-1}), stomatal conductance to water vapor (**g_s**) in (mol H_2O m^{-2} s^{-1}), intercellular carbon dioxide content (**Ci**) in (µmol CO_2 mol^{-1}), transpiration (**E**) in (mmol H_2O m^{-2} s^{-1}), and photosynthetic water use efficiency (**WUE**) in (%), based on the equations derived by von Caemmerer & Farquhar (1981).

Sapling Growth & Health: Additional growth and health parameters, including seedling height, caliper diameter, number of new branches, and necrosis patterns and severity also were assessed pre- and post-treatment. Necrosis was determined as the averaged overall percentage of dead needle tissue in the current year's growth of needles and in needle growth all previous years. All saplings were photographed post treatment for reference purposes. Since growth parameters (height, caliper diameter, etc.) failed to be significantly different over the three-month treatment period, they will be omitted from discussion.

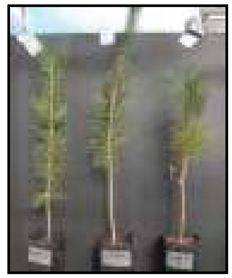
Statistical analysis of all data utilized SAS version 8.1, SAS Institute Inc., Cary, NC, USA. Differences in foliar injury were evaluated in saplings post all deicer treatments by a species by treatment type by concentration level factorial MANOVA by Wilks' Lambda. Differences in leaf-level gas exchange parameters in saplings were assessed after an initial deicer treatment and post all treatments using species by treatment type by concentration level factorial MANOVAs by Wilks' Lambda. In all MANOVA cases, significant relationships ($p < 0.05$) were evaluated through Bonferroni post hoc t-tests with significance levels (α) of 0.05. Significant interactions were re-evaluated using only photosynthesis as the variable of interest via a species by deicer treatment type by concentration level factorial ANOVA.

Results

Impacts of Deicing Chemical Type, Exposure Mode and Concentration Level on Necrosis Levels in Pinus contorta and Pinus ponderosa Saplings: Deicer exposure led to significant necrosis (tissue death) of conifer sapling foliage, and in some cases to complete sapling mortality. In general, exposed needles became necrotic and chlorotic from their tips first, with tissue death advancing to the needle base. Chlorotic mottling or spotting of affected needle tissue also was exhibited. Figure 14. on the following pages displays foliar injury patterns and severity characteristic of deicer treatment types and concentration levels in ponderosa and lodgepole pine saplings.

P. contorta, sand/salt deicer, 0%

P. contorta, sand/salt deicer, 0%



P. contorta, sand/salt deicer, 10%

P. contorta, sand/salt deicer, 10%

P. contorta, sand/salt deicer, 50%

P. contorta, sand/salt deicer, 50%

P. contorta, sand/salt deicer, 100%

P. contorta, sand/salt deicer, 100%

P. contorta, soil $MgCl_2$ deicer, 0%

P. contorta, soil $MgCl_2$ deicer, 0%

P. contorta, soil $MgCl_2$ deicer, 10%

P. contorta, soil $MgCl_2$ deicer, 10%

Figure 14. Overviews and close-ups of foliar necrosis in native conifer saplings post three months of deicer exposure to concentration levels of $MgCl_2$ applied to foliage and the soil matrix, and sand and NaCl applied to the soil.

P. ponderosa, soil $MgCl_2$ deicer, 50%

P. ponderosa, soil $MgCl_2$ deicer, 50%

P. ponderosa, soil $MgCl_2$ deicer, 100%

P. ponderosa, soil $MgCl_2$ deicer, 100%

P. ponderosa, foliar $MgCl_2$ deicer, 0%

P. ponderosa, foliar $MgCl_2$ deicer, 0%

P. ponderosa, foliar $MgCl_2$ deicer, 10%

P. ponderosa, foliar $MgCl_2$ deicer, 10%

P. ponderosa, foliar $MgCl_2$ deicer, 50%

P. ponderosa, foliar $MgCl_2$ deicer, 50%

P. ponderosa, foliar $MgCl_2$ deicer, 100%

P. ponderosa, foliar $MgCl_2$ deicer, 100%

Figure 14. Overviews and close-ups of foliar necrosis in native conifer saplings post three months of deicer exposure to concentration levels of $MgCl_2$ applied to foliage and the soil matrix, and sand and NaCl applied to the soil.

P. contorta,
soil $MgCl_2$
deicer, 50%

P. contorta,
soil $MgCl_2$
deicer, 50%

P. contorta,
soil $MgCl_2$
deicer, 100%

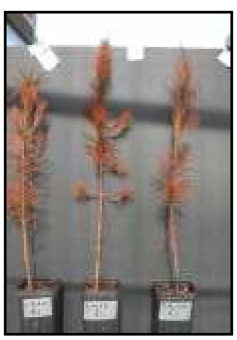
P. contorta,
soil $MgCl_2$
deicer, 100%

P. contorta,
foliar $MgCl_2$
deicer, 0%

P. contorta,
foliar $MgCl_2$
deicer, 0%

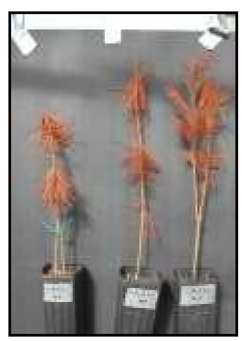
P. contorta,
foliar $MgCl_2$
deicer, 10%

P. contorta,
foliar $MgCl_2$
deicer, 10%



P. contorta,
foliar $MgCl_2$
deicer, 50%

P. contorta,
foliar $MgCl_2$
deicer, 50%



P. contorta,
foliar $MgCl_2$
deicer, 100%

P. contorta,
foliar $MgCl_2$
deicer, 100%

Figure 14. Overviews and close-ups of foliar necrosis in native conifer saplings post three months of deicer exposure to concentration levels of $MgCl_2$ applied to foliage and the soil matrix, and sand and NaCl applied to the soil.

Levels of necrotic foliage varied by deicer treatment type, salt concentration level, and species. $MgCl_2$ deicer applied directly to foliage proved to be the most detrimental to sapling tissue; treated plants demonstrated severe necrosis even when exposed to dilute concentrations of deicer. Saplings exposed to $MgCl_2$ deicer through the soil matrix exhibited significantly less tissue death than those experiencing direct deicer and foliage contact, and those exposed to sand/salt soil applications exhibited the least overall amount of necrosis. In general, as the concentration of deicer treatment increased, the percentage of sapling necrotic foliage also increased. Additionally, *P. ponderosa* saplings demonstrated greater tolerance of all deicer treatments than *P. contorta*. Table 27. summarizes mean foliar necrosis of sapling current year and previous years needle growth across deicer treatment types, concentrations, and species.

Necrosis data were analyzed for current year and previous years growth with a species by treatment type by concentration level factorial MANOVA. Overall necrosis levels varied significantly by species ($F = 6.01$, $p < 0.01$), deicer treatment type ($F = 145.75$, $p < 0.0001$), and concentration level ($F = 65.26$, $p < 0.0001$). Mean foliage necrosis across deicer treatment types and concentration levels was significantly higher in current year needle growth in *P. contorta* ($\bar{x} = 40.1$) than in *P. ponderosa* ($\bar{x} = 33.0$) according to Bonferroni post hoc comparisons ($\alpha = 0.05$). However, mean necrosis in previous years needle growth did not differ significantly by species (Figure 15.). Mean necrotic foliage percentage in treated saplings also varied significantly by each deicer treatment type for current year and previous years needle growth by Bonferroni post hoc t-tests. $MgCl_2$ applied in a fine mist to the foliage had the most severe and detrimental effects on needle tissue health, followed by $MgCl_2$ applied to the soil matrix. Saplings treated with sand/salt applications to the soil exhibited negligible foliage damage overall (Figure 16). In addition, foliar injury increased significantly as deicer concentration increased for both current year and previous years needle growth. Bonferroni post hoc comparisons ($\alpha = 0.05$) demonstrated significant differences between all concentration levels of deicers across species and application methods (Figure 17.).

Table 27. Mean percentage of necrotic tissue in current year and previous years foliage in saplings of *P. ponderosa* and *P. contorta* exposed to varying treatments of deicers

Species	Deicer Treatment	Concentration Level (%)	Mean Foliar Necrosis Percentage ± SE Current Year	Previous Years
Pinus ponderosa	Sand/Salt applied to soil	0	2.4 ± 0.7	6.9 ± 1.0
		10	3.7 ± 2.7	5.7 ± 1.0
		50	2.8 ± 1.0	7.5 ± 0.8
		100	1.3 ± 0.9	9.6 ± 1.1
	$MgCl_2$ applied to soil	0	2.9 ± 0.5	5.6 ± 1.3
		10	7.2 ± 5.7	6.3 ± 1.6
		50	23.6 ± 6.9	28.8 ± 7.4
		100	56.3 ± 12.7	78.3 ± 9.0
	$MgCl_2$ applied to foliage	0	3.8 ± 1.5	7.5 ± 0.8
		10	84.6 ± 5.3	90.4 ± 5.5
		50	100.0 ± 0.0	99.9 ± 0.1
		100	100.0 ± 0.0	99.6 ± 0.4
Pinus contorta	Sand/Salt applied to soil	0	0.0 ± 0.0	0.0 ± 0.0
		10	0.0 ± 0.0	0.3 ± 0.3
		50	4.3 ± 4.2	2.6 ± 2.1
		100	17.5 ± 8.0	7.3 ± 4.1
	$MgCl_2$ applied to soil	0	0.5 ± 0.3	0.3 ± 0.2
		10	28.2 ± 9.7	29.3 ± 9.5
		50	56.3 ± 12.7	57.1 ± 11.4
		100	80.0 ± 10.9	79.6 ± 10.8
	$MgCl_2$ applied to foliage	0	0.3 ± 0.3	0.8 ± 0.4
		10	94.1 ± 5.0	94.4 ± 3.7
		50	100.0 ± 0.0	100.0 ± 0.0
		100	100.0 ± 0.0	100.0 ± 0.0

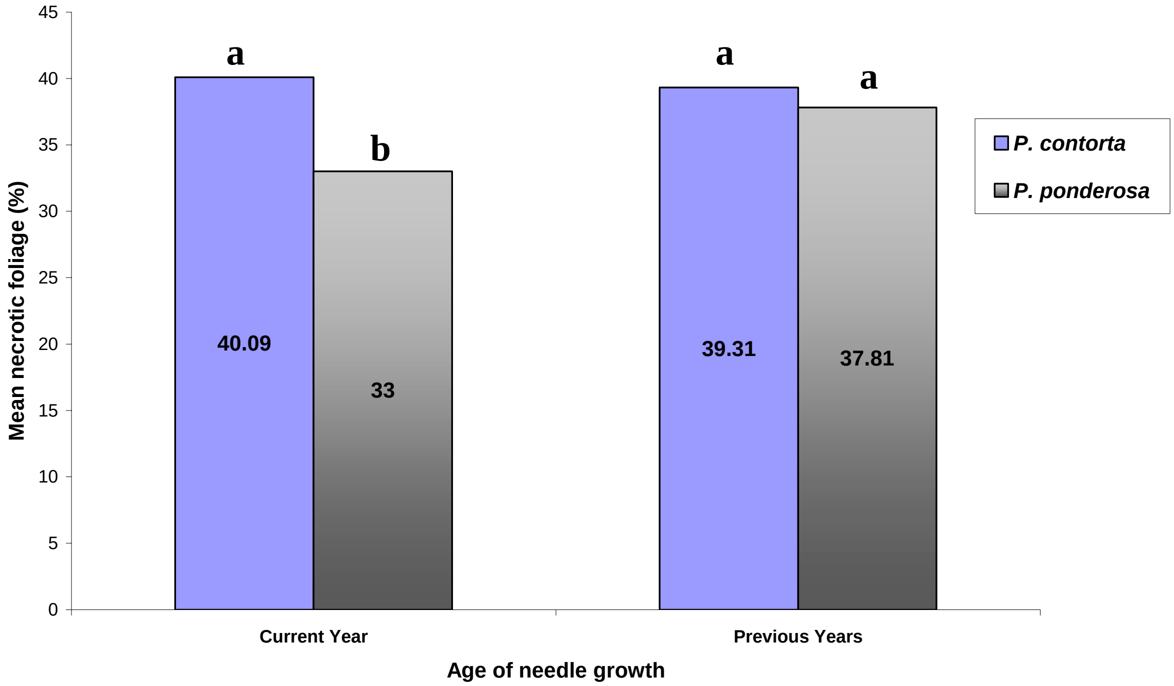


Figure 15. Mean percentage of necrotic foliage in *P. contorta* and *P. ponderosa* saplings across deicer treatment types and concentration levels

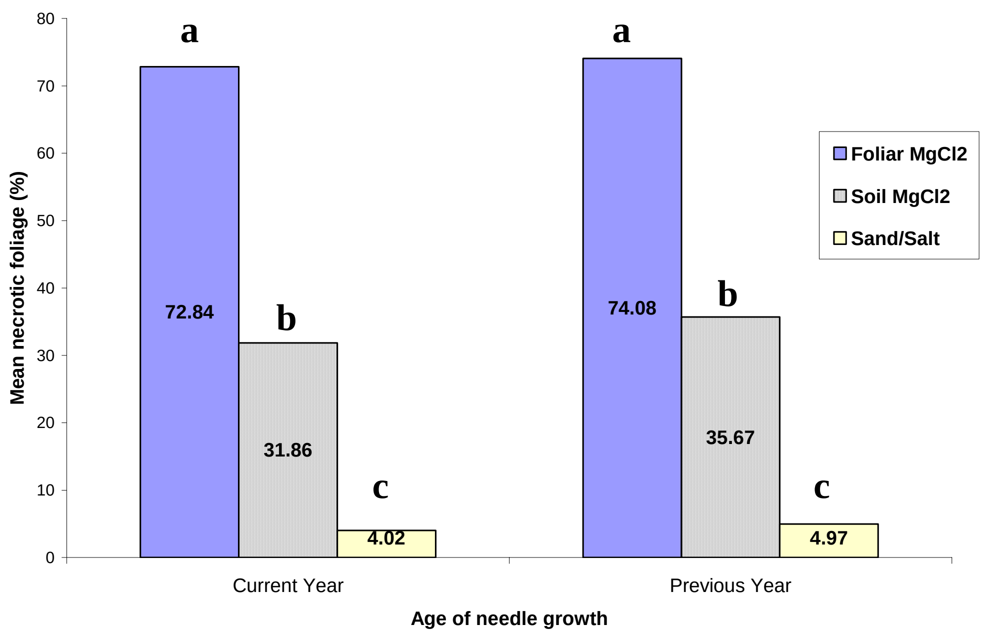


Figure 16. Mean necrotic foliage in current year and previous years needle growth by deicer treatment type

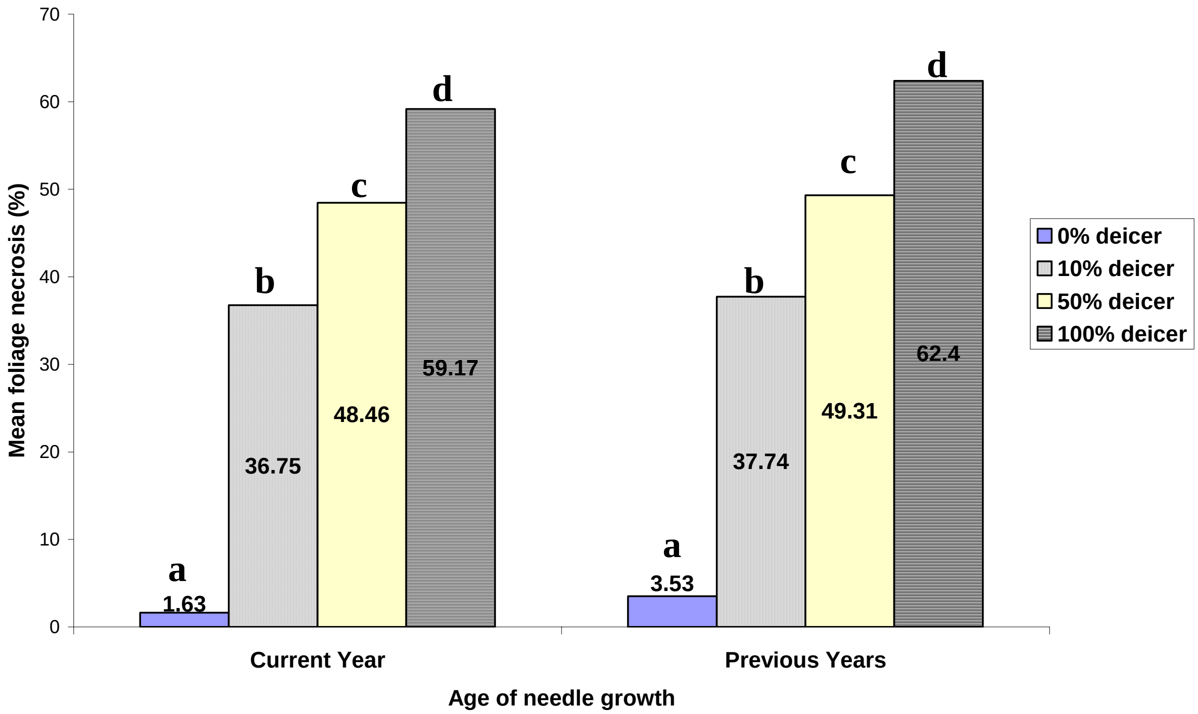


Figure 17. Mean foliage necrosis of current year and previous years needle growth across concentration levels of deicer

The interaction of species and deicer treatment type also proved significant ($F = 4.06$, $p < 0.01$). Graphical comparisons of mean foliage necrosis in *P. ponderosa* and *P. contorta* across deicer treatment types indicated that *P. ponderosa* possesses a greater tolerance to soil applications of $MgCl_2$ deicer than does *P. contorta*. Additionally, the interaction of species and deicer concentration level on foliage necrosis proved significant ($F = 2.34$, $p = 0.03$). Visual analyses of mean foliage necrosis in *P. ponderosa* and *P. contorta* across deicer concentration levels demonstrated the relatively increased deicer tolerance of ponderosa pine saplings exposed to 10 and 50 percent roadbed application strength deicing chemicals compared to lodgepole saplings. Finally, the interaction of deicer treatment type and deicer concentration level on foliage necrosis proved significant ($F = 25.26$, $p < 0.0001$). Graphical comparisons of mean deicer treatment types across concentration levels display marked overall differences in impacts on foliage health. The equivalent volume of $MgCl_2$ added to the soil matrix had significantly less effect on foliage health. Sapling previous years' needle growth demonstrated an increased sensitivity to full roadbed application strength (100%) $MgCl_2$ deicer added to the soil compared to sapling current year's needle growth. Sand/Salt deicer had notably less impact on foliage health; even at full roadbed application strength overall foliage necrosis failed to exceed 10%.

Impacts of Initial Contact of Deicing Chemical Type, Exposure Mode and Concentration Level on Leaf-Level Gas Exchange Parameters in Pinus contorta and Pinus ponderosa Saplings: Overall, ponderosa pine (*P. ponderosa*) saplings may have demonstrated immediate physiological sensitivity to foliar applications of $MgCl_2$ deicer (FreezGard) as compared to little or no effect from $MgCl_2$ deicer or sand/salt added to the soil matrix. Net carbon assimilation (photosynthesis), A, and water use efficiency, WUE, in *P. ponderosa* saplings decreased precipitously upon application of any concentration of aerosolized $MgCl_2$ deicer, although a concomitant reduction in stomatal conductance, g_s, was not observed. An increase in needle intercellular carbon dioxide concentration, Ci, and transpiration rates, E, in response to deicer application also was detected. Table 28. summarizes the mean initial response of leaf-level gas exchange characteristics across deicers, concentrations, and species.

In contrast, lodgepole pine saplings demonstrated no physiological gas exchange sensitivity to initial deicer foliage contact. *P. contorta* saplings exposed to foliar applications of $MgCl_2$ maintained comparative levels of gas exchange to saplings treated with distilled water (Table 28.). However, *P. contorta* saplings exposed to full strength $MgCl_2$ deicer through the soil demonstrated a possible physiological inhibition in response to osmotic stress. Depressed levels of net carbon assimilation, stomatal conductance, transpiration, and corresponding higher water use efficiency were observed in these saplings (Table 28.). Initial applications of sand/salt to the soil matrix did not demonstrably affect leaf-level gas exchange in *P. contorta* saplings.

Table 28. Mean and standard error of initial response leaf-level gas exchange parameters in *P. ponderosa* and *P. contorta* saplings exposed to varying treatments and concentration levels of commercial deicers

Species	Deicer Treatment	[] (%)	A ± SE	g_s ± SE	Ci ± SE	E ± SE	WUE ± SE
Pinus ponderosa	Sand/Salt applied to soil	0	9.00 ± 0.78	0.13 ± 0.02	252.3 ± 7.6	2.98 ± 0.30	0.31 ± 0.01
		10	9.93 ± 0.77	0.14 ± 0.02	224.9 ± 11.4	4.65 ± 0.61	0.24 ± 0.02
		50	9.66 ± 0.42	0.15 ± 0.01	254.8 ± 7.4	5.92 ± 0.49	0.17 ± 0.01
		100	8.66 ± 0.51	0.12 ± 0.01	231.4 ± 6.6	2.65 ± 0.21	0.34 ± 0.01
	$MgCl_2$ applied to soil	0	5.71 ± 0.62	0.07 ± 0.01	253.8 ± 4.8	1.17 ± 0.12	0.49 ± 0.02
		10	8.62 ± 0.53	0.13 ± 0.01	260.5 ± 5.7	3.87 ± 0.36	0.23 ± 0.01
		50	8.54 ± 0.33	0.14 ± 0.01	275.5 ± 3.0	3.97 ± 0.25	0.22 ± 0.01
		100	8.92 ± 0.78	0.15 ± 0.02	269.8 ± 5.8	4.30 ± 0.40	0.21 ± 0.01
	$MgCl_2$ applied to foliage	0	8.28 ± 0.93	0.21 ± 0.07	272.7 ± 15.3	3.43 ± 0.60	0.29 ± 0.03
		10	3.53 ± 0.64	0.18 ± 0.01	343.4 ± 6.0	5.41 ± 0.28	0.07 ± 0.01
		50	0.05 ± 0.11	0.25 ± 0.01	380.9 ± 1.2	5.86 ± 0.21	0.00 ± 0.00
		100	1.96 ± 0.84	0.18 ± 0.02	356.1 ± 9.8	5.41 ± 0.36	0.04 ± 0.02
Pinus contorta	Sand/Salt applied to soil	0	12.48 ± 0.89	1.31 ± 0.77	311.2 ± 9.2	6.95 ± 0.72	0.20 ± 0.02
		10	11.55 ± 1.02	0.28 ± 0.05	284.0 ± 4.9	4.55 ± 0.49	0.26 ± 0.01
		50	11.73 ± 1.24	0.38 ± 0.07	302.2 ± 6.0	5.32 ± 0.48	0.22 ± 0.01
		100	14.65 ± 0.85	0.42 ± 0.03	296.7 ± 3.1	6.63 ± 0.31	0.22 ± 0.01
	$MgCl_2$ applied to soil	0	12.37 ± 0.68	0.25 ± 0.02	276.6 ± 4.9	4.62 ± 0.34	0.28 ± 0.02
		10	13.45 ± 0.71	0.26 ± 0.03	268.3 ± 9.9	3.57 ± 0.33	0.41 ± 0.04
		50	14.17 ± 0.97	0.34 ± 0.04	288.8 ± 3.0	4.16 ± 0.28	0.34 ± 0.01
		100	7.02 ± 1.03	0.07 ± 0.01	214.7 ± 11.2	0.88 ± 0.13	0.81 ± 0.05
	$MgCl_2$ applied to foliage	0	5.17 ± 0.78	0.07 ± 0.01	244.3 ± 18.2	1.52 ± 0.29	0.38 ± 0.05
		10	3.70 ± 0.72	0.07 ± 0.02	275.6 ± 22.0	3.22 ± 0.56	0.10 ± 0.02
		50	4. 98 ± 0.81	0.27 ± 0.04	332.7 ± 7.3	7.42 ± 0.67	0.07 ± 0.01
		100	4.98 ± 0.71	0.09 ± 0.01	287.6 ± 8.2	2.35 ± 0.32	0.22 ± 0.02

Symbol definitions: [] = concentration level of deicer application in reference to standard roadbed application level; A = net carbon assimilation rate (photosynthesis), (μmol CO_2 m^{-2} s^{-1}); g_s = stomatal conductance to water vapor, (mol H_2O m^{-2} s^{-1}); Ci = intercellular CO_2 concentration, (μmol CO_2 mol^{-1}); E = transpiration rate, (mmol H_2O m^{-2} s^{-1}); WUE = percent water use efficiency, (A x 10^{-6} / E *100)

Although lower rates of net carbon assimilation, stomatal conductance, and transpiration were present in saplings of *P. ponderosa* exposed only to distilled water through the soil as compared to saplings exposed to soil $MgCl_2$, these data were not representative of a trend, and were likely due to individual physiologies and daily temperature differences in ambient conditions.

Initial responses of leaf-level gas exchange characteristics to deicer treatments were analyzed with a Species x Deicer Treatment Type x Concentration Level factorial MANOVA. Leaf-level gas exchange immediately after an initial exposure to deicer varied significantly by species ($F = 63.71$, $p < 0.0001$), deicer treatment type ($F = 100.01$, $p < 0.0001$) and deicer concentration level ($F = 24.16$, $p < 0.0001$). In addition, all interactions of species, treatment type and concentration levels displayed statistical significance.

As expected, *P. ponderosa* and *P. contorta* differed significantly in their gas exchange characteristics across deicer treatment types and concentration levels according to Bonferroni post hoc comparisons. Overall, saplings of *P. contorta* displayed significantly higher rates of net carbon assimilation (photosynthesis), stomatal conductance, and water use efficiency than saplings of *P. ponderosa* (Table 29.). The two species were comparatively similar in intercellular carbon dioxide concentration and demonstrated similar rates of transpiration. These differences should be interpreted as primarily due to individual species physiology at initial treatment, rather than a deicer treatment effect.

Table 29. Bonferroni post hoc determination (α = 0.05, n = 144) of mean gas exchange parameters by species. * denotes means that are statistically different.

Gas exchange parameter	Species	
	P. contorta	*P. Ponderosa*
A (μmol CO_2 m^{-2} s^{-1})	9.69*	6.90*
$\mathbf{g_s}$ (mol H_2O m^{-2} s^{-1})	0.32*	0.15*
Ci (μmol CO_2 mol^{-1})	281.9	281.3
E (mmol H_2O m^{-2} s^{-1})	4.26	4.14
WUE (%)	0.29*	0.22*

Mean gas exchange characteristics in the conifer saplings varied significantly in response to initial deicer treatment exposure, with a general greater inhibition of physiology observed in saplings treated with liquid $MgCl_2$ based deicers than solid sand/salt deicer for photosynthesis and stomatal conductance. Leaf-level net carbon assimilation (photosynthesis) in the saplings varied significantly by each deicer treatment type via Bonferroni post-hoc comparisons ($\alpha = 0.05$, $n = 96$). Saplings measured immediately after exposure to $MgCl_2$ deicer applied to the foliage in a fine mist exhibited lower gas exchange parameters. Saplings exposed to $MgCl_2$ deicer through the soil matrix also demonstrated lower overall levels of initial leaf-level photosynthesis than saplings treated with sand/salt applications to the soil (Figure 18.).

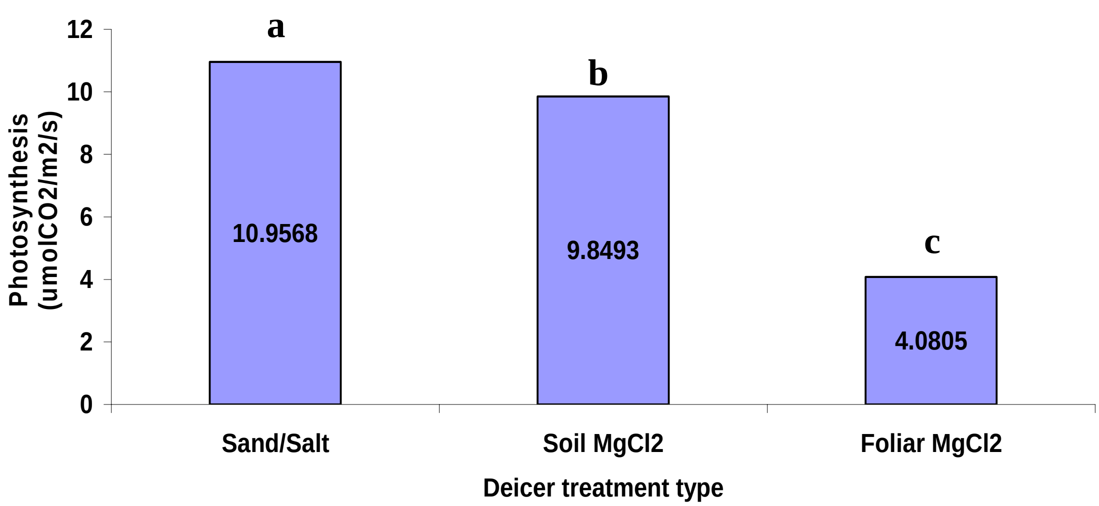


Figure 18. Mean leaf-level net carbon assimilation in relation to intitial deicer exposure type

This decrease in photosynthesis was correlated with a decrease in stomatal conductance (g_s), although treatment groups were not uniquely significantly different according to Bonferroni post hoc t-tests ($\alpha = 0.05$) (Table 30.). Saplings exposed to sand/salt deicer exhibited the highest levels of stomatal conductance, while saplings exposed to $MgCl_2$ deicer demonstrated a comparative stomatal inhibition. Saplings also varied significantly in intercellular CO_2 concentration (Ci), transpiration rates (E), and water use efficiency (WUE) in response to initial deicer exposure (Table 30.). These variations in gas exchange parameters may also be a product of ambient conditions and individual species physiology at initial treatment time, rather than a deicer treatment effect, and should be interpreted with caution.

Table 30. Bonferroni post hoc determination (α = 0.05, n = 96) of mean gas exchange parameters by deicer exposure. Means with the same letter are not statistically different.

Gas exchange parameter	Deicer Treatment Type		
	Sand/Salt	$MgCl_2$ Soil	$MgCl_2$ Foliar
A (μmol CO_2 m^{-2} s^{-1})	10.96 a	9.85 b	4.08 c
g_s (mol H_2O m^{-2} s^{-1})	0.36 a	0.18 a, b	0.17 b
Ci (μmol CO_2 mol^{-1})	269.7 a	263.48 a	311.7 b
E (mmol H_2O m^{-2} s^{-1})	4.96 a	3.32 b	4.33 c
WUE (%)	0.24 a	0.37 b	0.14 c

Immediate physiological gas exchange measures after initial deicer type exposure did not vary significantly overall across concentration levels for net carbon assimilation rates or stomatal conductance. Conifer saplings exposed to a 50% concentration of deicer treatment displayed significantly higher intercellular CO_2 concentrations and transpiration rates, along with a correspondingly significantly reduced water use efficiency (Table 31.). Again, these results should likely be interpreted in the context of individual sapling and species physiological variation rather than as a deicer effect.

Table 31. Bonferroni post hoc comparison (α = 0.05, n = 72) of mean gas exchange parameters by deicer concentration level. Means with the same letter are not statistically different.

Gas exchange parameter	Concentration Level (%)			
	0	10	50	100
A (μmol CO_2 m^{-2} s^{-1})	8.83 a	8.46 a	8.19 a	7.70 a
g_s (mol H_2O m^{-2} s^{-1})	0.34 a	0.25 a	0.18 a	0.18 a
Ci (μmol CO_2 mol^{-1})	268.5 a	276.1 a	305.8 b	276.0 a
E (mmol H_2O m^{-2} s^{-1})	3.45 a	4.21 b	5.44 c	3.70 a, b
WUE (%)	0.32 a	0.22 b	0.17 c	0.31 a

All interactions of species, deicer treatment type, and concentration level proved highly significant. These interactions will be discussed here in terms of net carbon assimilation (photosynthesis) as the primary physiological variable of interest. Data for interactions were re-evaluated using only photosynthesis as the variable of interest via a species by deicer treatment type by concentration level factorial ANOVA. This model significantly ($F = 25.83$, $p < 0.001$) explained leaf-level photosynthesis as a function of species, deicer treatment type, and concentration level. The model also was robust, explaining 69% of the observed variation ($R^2 = 0.692381$).

All main effects and interactions of the model retained statistical significance ($\alpha = 0.05$) when only examining data from net carbon assimilation with the exception of concentration level and the interaction of species and concentration level. First, the interaction of species and deicer treatment type proved significant ($F = 60.8$, $p < 0.01$). Graphical comparisons of mean initial leaf-level photosynthesis in *P. ponderosa* and *P. contorta* across deicer treatment types revealed increased species sensitivity to foliar applications of $MgCl_2$ deicer in *P. ponderosa* compared to *P. contorta.*

Secondly, the interaction of deicer treatment type and concentration level also was determined to be significant ($F = 9.17$, $p < 0.0001$). Graphical comparisons of mean initial leaf-level photosynthesis in deicer treatment types across concentration levels indicated an initial slight photosynthetic increase occurred in saplings exposed to 10 and 50 percent concentrations of soil applied $MgCl_2$ deicer. At full roadbed application strength of $MgCl_2$ deicer to the soil matrix, a depression in initial photosynthesis is notable. Saplings exposed to sand/salt maintained equivalent initial photosynthesis across concentration levels until exposed to 100% sand/salt, where upon a slight increase in photosynthetic rates occurred. Initial photosynthesis in saplings exposed to foliar applications of $MgCl_2$ deicer underwent a marked decrease at the 10% and 50% deicer concentration level compared to other treatments.

Finally, a significant three-way interaction occurred between species, deicer treatment type, and concentration level ($F = 11.87$, $p < 0.0001$). Additional graphical evaluation of the interaction revealed an initial depression in photosynthesis rates as a response to soil applications of 100% $MgCl_2$ deicer in *P. contorta*, while photosynthesis in *P. ponderosa* remained unaffected or increased across the deicer concentration gradient. Photosynthetic response in *P. contorta* saplings remained largely unaffected by a foliar application of $MgCl_2$ deicer, while initial photosynthesis in *P. ponderosa* was markedly depressed when exposed to aerosolized $MgCl_2$. Initial photosynthesis in both *P. contorta* and *P. ponderosa* remained unaffected by any concentration of sand/salt.

Impacts of Deicing Chemical Type, Exposure Mode and Concentration Level on Leaf-level Gas Exchange in Pinus contorta and Pinus ponderosa Saplings after Three Months of Simulated Exposure: Gas exchange in conifer saplings following a three-month treatment period simulating winter roadside exposure to deicers varied significantly by species, deicer treatment type, and concentration level. Overall, a decline in physiological gas exchange and foliage health characteristics was observed in saplings of *P. contorta* and *P. ponderosa* exposed to higher concentrations of foliar and soil applications of $MgCl_2$ deicer. Trees exposed to sand/salt in contrast, exhibited little to no impact in gas exchange parameters. Table 32. summarizes mean post treatment leaf-level physiological gas exchange characteristics of conifers across deicers, concentrations, and species.

Table 32. Mean (n = 12) and standard error of gas exchange parameters in *P. ponderosa* and *P. contorta* saplings after a three-month exposure to varying deicer treatments and concentration levels. (See below for symbol definitions and units)

Species	Deicer Treatment	[] (%)	A ± SE	g_s ± SE	Ci ± SE	E ± SE	WUE ± SE
Pinus ponderosa	Sand/Salt applied to soil	0	5.30 ± 0.64	0.05 ± 0.01	199.1 ± 5.9	1.80 ± 0.27	0.30 ± 0.01
		10	7.57 ± 0.65	0.08 ± 0.01	224.2 ± 7.2	2.55 ± 0.29	0.31 ± 0.02
		50	6.26 ± 0.83	0.06 ± 0.01	213.7 ± 9.0	2.28 ± 0.30	0.28 ± 0.02
		100	4.86 ± 0.78	0.05 ± 0.01	136.3 ± 62.1	0.82 ± 0.17	0.91 ± 0.21
	$MgCl_2$ applied to soil	0	4.61 ± 0.39	0.04 ± 0.00	202.8 ± 8.0	1.23 ± 0.10	0.38 ± 0.02
		10	7.19 ± 0.85	0.09 ± 0.01	240.8 ± 8.3	3.74 ± 0.32	0.19 ± 0.01
		50	1.74 ± 0.50	0.02 ± 0.01	181.4 ± 32.8	0.65 ± 0.18	0.19 ± 0.04
		100	0.44 ± 0.24	0.00 ± 0.00	41.0 ± 22.0	0.09 ± 0.05	0.13 ± 0.07
	$MgCl_2$ applied to foliage	0	5.22 ± 1.18	0.05 ± 0.01	176.2 ± 15.9	2.11 ± 0.53	0.27 ± 0.02
		10	1.20 ± 0.76	0.03 ± 0.01	107.3 ± 46.7	1.00 ± 0.55	0.03 ± 0.02
		50	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
		100	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Pinus contorta	Sand/Salt applied to soil	0	7.79 ± 0.64	0.12 ± 0.01	249.8 ± 6.6	5.93 ± 0.38	0.13 ± 0.01
		10	8.42 ± 0.79	0.09 ± 0.01	202.6 ± 17.4	2.99 ± 0.37	0.34 ± 0.06
		50	8.00 ± 1.04	0.14 ± 0.01	276.6 ± 11.2	4.18 ± 0.23	0.19 ± 0.02
		100	7.95 ± 1.54	0.12 ± 0.01	276.8 ± 15.0	2.52 ± 0.22	0.29 ± 0.04
	$MgCl_2$ applied to soil	0	9.47 ± 0.70	0.20 ± 0.01	280.3 ± 3.80	7.58 ± 0.19	0.13 ± 0.01
		10	3.86 ± 1.05	0.07 ± 0.01	336.2 ± 46.6	2.08 ± 0.34	0.09 ± 0.07
		50	0.46 ± 0.40	-0.01 ± 0.00	273.4 ± 71.4	-0.12 ± 0.08	-0.07 ± 0.14
		100	0.16 ± 0.09	0.01 ± 0.00	86.6 ± 45.2	0.28 ± 0.15	0.01 ± 0.01
	$MgCl_2$ applied to foliage	0	9.18 ± 1.32	0.65 ± 0.17	327. 3 ± 5.3	10.60 ± 0.78	0.08 ± 0.01
		10	-0.06 ± 0.06	0.00 ± 0.00	34.4 ± 34.4	0.09 ± 0.09	0.00 ± 0.00
		50	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
		100	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0

Symbol definitions: [] = concentration level of deicer application in reference to standard roadbed application level; A = net carbon assimilation rate (photosynthesis), (μmol CO_2 m^{-2} s^{-1}); g_s = stomatal conductance to water vapor, (mol H_2O m^{-2} s^{-1}); Ci = intercellular CO_2 concentration, (μmol CO_2 mol^{-1}); E = transpiration rate, (mmol H_2O m^{-2} s^{-1}); WUE = percent water use efficiency, (A x 10^{-6} / E *100)

Post-treatment gas exchange parameters were analyzed with a species by deicer treatment type by concentration level factorial MANOVA. Again, leaf-level gas exchange after exposure to a three-month simulated deicing period varied significantly by species ($F = 59.94$, $p < 0.0001$), deicer treatment type ($F = 50.65$, $p < 0.0001$), and deicer concentration level ($F = 38.53$, $p < 0.0001$). In addition, all interactions of species, treatment type and concentration levels displayed statistical significance.

Average post treatment leaf-level gas exchange characteristics remained significantly higher in *P. contorta* than in *P. ponderosa* according to Bonferroni post hoc comparisons ($\alpha = 0.05$). Overall, observed net carbon assimilation (A), stomatal conductance (g_s), intercellular carbon dioxide content (Ci), and transpiration rates were greater in *P. contorta* saplings, along with the expected associated lower water use efficiency percentage (Table 33.).

Table 33. Bonferroni post hoc determination ($\alpha = 0.05$, n = 144) of mean gas exchange parameters after deicer treatment by species. * denotes means that are statistically different.

Gas exchange parameter	Species	
	P. contorta	*P. Ponderosa*
A (μmol CO_2 m^{-2} s^{-1})	4.60*	3.70*
g_s (mol H_2O m^{-2} s^{-1})	0.12*	0.04*
Ci (μmol CO_2 mol^{-1})	195.3*	143.6*
E (mmol H_2O m^{-2} s^{-1})	3.01*	1.36*
WUE (%)	0.10*	0.25*

Additionally, according to Bonferroni post hoc comparisons ($\alpha = 0.05$), saplings exposed to sand/salt treatments demonstrated higher overall levels of net carbon assimilation (A) than saplings exposed to $MgCl_2$ deicer treatments. Additionally, saplings exposed to soil treatments of $MgCl_2$ deicer maintained higher leaf-level photosynthetic rates than saplings exposed to foliar applications of $MgCl_2$ deicer (Figure 19.).

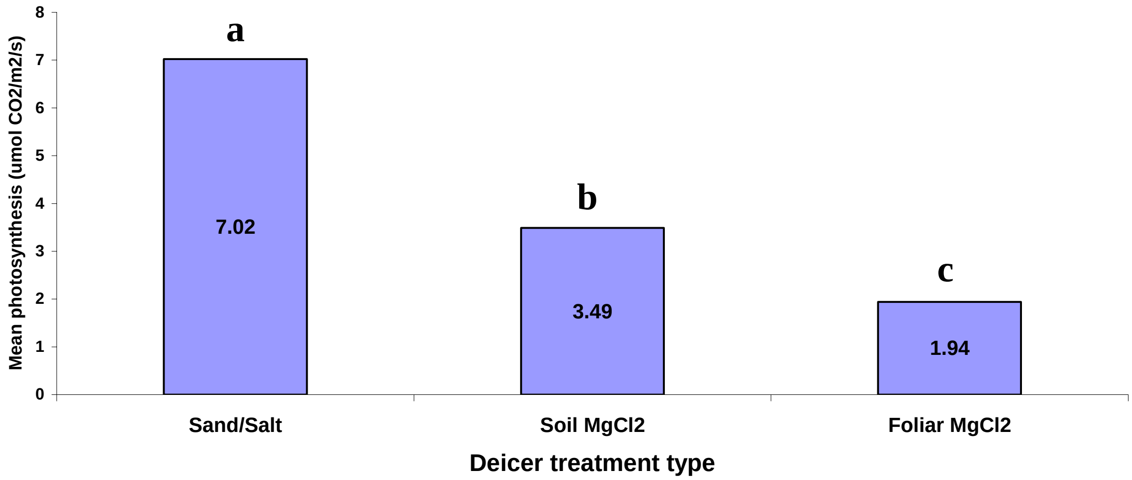


Figure 19. Mean post treatment leaf-level net carbon assimilation in saplings exposed to varying deicer treatment types.

However, after extended exposure to deicers, no significant difference was noted in the levels of stomatal conductance to water vapor (g_s) by treatment type. Significantly depressed levels of intercellular carbon dioxide concentration (Ci) were noted in conifer saplings exposed to foliar applications of $MgCl_2$ deicer compared to other deicer treatment types primarily due to tree mortality. Transpiration rates (E) and water use efficiency (WUE) were significantly higher in saplings exposed to Sand/Salt then any type of $MgCl_2$ deicer treatment, and positively correlated with observed measures of sapling health. Water use efficiency was significantly depressed in saplings treated with aerosolized $MgCl_2$ deicer, again due to tree mortality and inhibited physiology. Table 34. summarizes mean post treatment gas exchange parameters across deicer treatment types.

Table 34. Bonferroni post hoc determination ($\alpha = 0.05$, n = 96) of mean gas exchange parameters by deicer exposure type. Means with the same letter are not statistically different.

Gas exchange parameter	Deicer Treatment Type		
	Sand/Salt	$MgCl_2$ Soil	$MgCl_2$ Foliar
A (µmol CO_2 m^{-2} s^{-1})	7.02 a	3.49 b	1.94 c
g_s (mol H_2O m^{-2} s^{-1})	0.09 a	0.05 a	0.09 a
Ci (µmol CO_2 mol^{-1})	222.4 a	205.3 a	80.64 b
E (mmol H_2O m^{-2} s^{-1})	2.88 a	1.94 b	1.73 b
WUE (%)	0.34 a	0.13 b	0.05 c

Furthermore, saplings exposed to 50 and 100 percent levels of deicer applications exhibited the lowest overall rates of net carbon assimilation (A), via Bonferroni post hoc comparisons. Saplings exposed to 10% deicer concentrations demonstrated higher mean rates of photosynthesis, while saplings in the control treatments (distilled water) displayed the highest (Table 35.). Stomatal conductance (g_s), intercellular carbon dioxide content (Ci), and transpiration rates (E) were significantly inhibited by any level of deicer contact over time (Table 35.). Clear trends of decreasing physiological activity with increasing level of deicer exposure are notable. Water use efficiency (WUE) was variable across concentration levels, depending on respective rates of transpiration and photosynthesis (Table 35.).

Table 35. Bonferroni post hoc comparison (α = 0.05, n = 72) of mean gas exchange parameters by deicer concentration level. Means with the same letter are not statistically different.

Gas exchange parameter	Concentration Level (%)			
	0	10	50	100
A (μmol CO_2 m^{-2} s^{-1})	6.93 a	4.70 b	2.74 c	2.23 c
$\mathbf{g_s}$ (mol H_2O m^{-2} s^{-1})	0.19 a	0.06 b	0.04 b	0.03 b
Ci (μmol CO_2 mol^{-1})	239.2 a	190.9 b	157.5 b	90.1 c
E (mmol H_2O m^{-2} s^{-1})	4.88 a	2.07 b	1.16 c	0.62 d
WUE (%)	0.22 a	0.16 a, b	0.10 b	0.22 a

All interactions of species, deicer treatment type, and concentration level for sapling exposure to deicers over time proved highly significant. These interactions will be discussed in terms of net carbon assimilation (photosynthesis) as the primary physiological variable of concern. Data for interactions were re-evaluated in terms of photosynthesis via a species by deicer treatment type by concentration level factorial ANOVA. This model significantly ($F = 22.59$, $p < 0.0001$) explained post treatment leaf-level photosynthesis as a function of species, deicer treatment type, and concentration level. The model was found to be robust, explaining 66% of the observed variation ($R^2 = 0.663056$). All main effects and interactions of the model maintained statistical significance in reanalysis with photosynthesis as the only dependent variable.

Firstly, the interaction of species and deicer treatment type was demonstrated to be significant ($F = 3.94$, $p = 0.0206$). Graphical comparisons of mean post treatment leaf-level photosynthesis indicated that *P. contorta* is relatively more sensitive physiologically to soil applications of $MgCl_2$ deicer, while *P. ponderosa* is relatively more sensitive to foliar applications of $MgCl_2$ deicer. Mean post treatment leaf-level photosynthesis also differed significantly across the interaction of species and deicer concentration levels ($F = 12.10$, $p < 0.0001$). Graphical evaluation of the interaction indicated that *P. ponderosa* saplings displayed increased physiological tolerance to low concentrations of deicer exposure (10%), but less tolerance to high concentrations (100%) relative to *P. contorta*.

In addition, a deicer treatment type by deicer concentration level interaction was also determined to be significant ($F = 18.24$, $p < 0.0001$). Graphical comparisons of mean post treatment leaf-level photosynthesis demonstrated that even at the 10% deicer concentration level, foliar applications of $MgCl_2$ significantly depressed sapling physiology. Although mean photosynthesis is also depressed by applications of 10% $MgCl_2$ to the soil matrix, higher mean photosynthesis rates were found in saplings exposed to 10% sand/salt treatments. Sapling physiology was negligibly affected by applications of sand/salt, even at 100% roadbed application strength.

Finally, the three-way interaction between species, deicer treatment type, and concentration level displayed statistical significance ($F = 2.18$, $p = 0.0453$). Additional graphical evaluation of the interaction elucidated a post treatment photosynthetic tolerance to foliar and soil applications of $MgCl_2$ deicer in *P. ponderosa* at the 10% level relative to *P. contorta*. *P. ponderosa* also displayed relatively greater mean photosynthesis rates in the 10% concentration of sand/salt applications. *P. contorta* however, demonstrated greater physiological tolerance to higher concentration levels of sand/salt deicers than *P. ponderosa*.

Conclusions

Deicer exposure caused significant foliar injury in saplings of ponderosa and lodgepole pine, with exposure to higher concentrations of the $MgCl_2$ based deicer FreezGard leading to complete sapling mortality (Table 27.). Patterns of tissue necrosis in deicer-exposed saplings were similar between deicers types and corresponded with observed foliar injury at study field sites along Colorado highways. In general, exposed needles became necrotic and chlorotic from their tips, with tissue death advancing to the needle base. Again, these patterns are in accordance with damage occurring in ponderosa pine saplings treated with NaCl solutions (Spotts et al., 1972; Bedunah & Trilca, 1977), mature ponderosa pines in Denver exposed to deicing salts (Staley et al., 1968), and conifers exposed to aerial drift and soil contamination of deicing salts or salinity (Hall et al., 1972; Sucoff et al., 1976; McCune et al., 1977; Townsend, 1983; Dobson, 1991; Kelsey & Hootman, 1992; Kozlowski, 1997; Viskari & Karenlampi, 2000; Bryson & Barker, 2002).

Overall, exposure to the $MgCl_2$ deicer was far more deleterious to sapling health than exposure to sand/salt (Figure 16.). As magnesium has not demonstrated appreciable phytotoxicity nor correlated with foliage damage in the field, the likely cause of sapling injury in this case stems from chloride exposure. In this case, chloride toxicity may be exacerbated due to the heavier concentration of chloride anions per application of FreezGard compared with an application of sand/salt. Future research to investigate Cl ion accumulation in needle tissue in response to varying deicers may provide clarification.

Strikingly, direct foliar contact with the $MgCl_2$ deicer was far more injurious to saplings than exposure to $MgCl_2$ through the soil matrix (Figure 16.). Saplings exposed by direct foliar contact to $MgCl_2$ deicer exhibit severe and ultimately fatal necrosis at even the 10% concentration level (3% $MgCl_2$). This corroborates studies that implicate deicing salt spray as a prime contributor to roadside vegetation damage (Hofstra & Hall, 1971; Lumis et al., 1973; Townsend, 1982; Bryson & Barker, 2002). $MgCl_2$ deicer appears to act equivalently to NaCl spray as a non-selective herbicide, with conifers demonstrating particular sensitivity.

Townsend & Kwolek (1987) in Dobson (1991) classify ponderosa pines (*P. ponderosa*) as salt tolerant to the controlled application of salt spray. In this study, ponderosa pine saplings demonstrated reduced foliar injury across deicer treatment types and concentration levels relative to lodgepole (*P. contorta*) saplings (Table 27.). Ponderosa saplings possessed a greater tolerance to soil applications of $MgCl_2$ deicer and a generally greater tolerance to lower concentrations (10%, 50% roadbed application strength) of deicing chemicals.

Interestingly, greater levels of injury in new foliage growth were seen in the greenhouse study than noted in mature conifers in the field. This injury is likely a product of exposure intensity, and the foliar absorption of salt ions by the trees exposed to salt spray. An exception occurred for saplings exposed to soil applied $MgCl_2$, where older needle growth demonstrated a significantly increased sensitivity to full roadbed application strength (100%) of the deicer compared to new needle growth. This observation might be explained by an excess of mobile chloride ions from soil uptake, which tend to accumulate at the end of the transpiration stream, first in the margins of older tissues and leaves, then in stems, and to a lesser degree in the fruits and seeds (Westing, 1969, Dobson, 1991; White & Broadley, 2001).

Mean photosynthesis rates and other gas exchange parameters recorded after an initial exposure to deicer treatment should be interpreted with caution. Daily fluctuations in ambient temperature, although minimized can effect transpiration and photosynthesis rates. As such, only broad trends in physiological changes are of consequence. For example, although saplings tested after an initial deicer exposure exhibited statistically depressed photosynthesis rates when exposed to $MgCl_2$ deicer compared to sand/salt (Figure 18.), note that *P. contorta* saplings exposed to distilled water in the foliar $MgCl_2$ treatment group also demonstrated lower rates of photosynthesis (Table 28.). Additionally, lower rates of net carbon assimilation, stomatal conductance, and transpiration were present in saplings of *P. ponderosa* exposed only to distilled water through the soil as compared to saplings exposed to soil $MgCl_2$. These data were not representative of a trend, and were likely due to individual physiologies and daily temperature differences in ambient conditions, although exposure to short-term salinity has been shown to stimulate net carbon assimilation in figs (*Ficus carica*) (Golombek & Ludders, 1993).

Overall, two observed physiological changes were likely a consequence of deicer exposure. First, ponderosa pine saplings demonstrated immediate (1 hour) physiological sensitivity to foliar applications of $MgCl_2$ deicer (FreezGard) (Table 28.). Equivalent physiological suppression was not observed with other deicer treatment types or with lodgepole pines. This difference is supported by the significance of the interaction of species and deicer treatment type ($F = 60.8$, $p < 0.01$), where graphical comparisons of mean leaf-level photosynthesis in *P. ponderosa* and *P. contorta* across deicer treatment types revealed increased species sensitivity to foliar applications of $MgCl_2$ deicer in *P. ponderosa* compared to *P. contorta.* Other studies have also found reductions in photosynthesis and stomatal conductance in green ash (*Fraxinus pennsylvanica*) in response to short-term exposure to salt water (Pezeshki & Chambers, 1986).

Net carbon assimilation (photosynthesis), A, and water use efficiency, WUE, in *P. ponderosa* saplings decreased precipitously upon application of any concentration of aerosolized $MgCl_2$ deicer, although a clear concomitant reduction in stomatal conductance, g_s, was not observed. An increase in needle intercellular carbon dioxide concentration, Ci, and transpiration rates, E, in response to deicer application also was detected (Table 28.). That intercellular carbon dioxide concentrations increased while stomatal conductance rates decreased marginally or remained equivalent implies a non-stomatal reduction in the capacity of mesophyll cells to fix carbon or non-heterogeneous stomatal behavior under stress (Farquhar & Sharkey. 1982; Yeo et al., 1985; Brugnoli & Lauteri, 1991). Salt on the needle surface may create osmotic stress in resulting in water loss and cell plasmolysis (Barrick & Flore 1979; Barrick & Davidson, 1980), and this membrane damage might have occurred rapidly enough to affect photosynthetic machinery. Application of NaCl to conifer needles has been demonstrated to induce fragmentation of needle cuticles, disrupted stomata, collapse of cell walls, granulation of the cytoplasm, and disintegrated chloroplasts and nuclei, as well as disorganization of phloem tissues (Kozlowski, 1997). It is not clear if this stress or injury to the stomatal mechanism through specific ion toxicities in needle tissue may lead to correspondingly higher rates of transpiration as observed in this case. In the future, to further partition the stomatal and non-stomatal inhibition of photosynthesis and examine cellular fixation capacity, photosynthetic phytochemistry might be examined through chlorophyll fluorescence measurements.

Secondly, *P. contorta* saplings exposed to full strength $MgCl_2$ deicer through the soil demonstrated a possible physiological inhibition in response to osmotic stress. Depressed levels of net carbon assimilation, stomatal conductance, transpiration, and corresponding higher water use efficiency were observed in these saplings (Table 28.). This finding was supported by the significant interaction of species, deicer treatment type and concentration level ($F = 11.87$, $p < 0.0001$). Graphical evaluation of the interaction clearly revealed an initial depression in photosynthesis rates as a response to soil applications of 100% $MgCl_2$ deicer in *P. contorta*, while photosynthesis in *P. ponderosa* remained unaffected.

Both decreased stomatal conductance and transpiration have been noted with salt exposure (Petersen & Eckstein, 1988; McCune, 1991; Brugnoli and Bjorkman, 1992), and stomatal closure to minimize transpirational water loss may occur in plants in response to increased osmotic stress in salt contaminated soils (Huck et al., 1983; Dobson, 1991). Salt stress can also increase instantaneous water use efficiency (WUE) by reducing stomatal conductance and transpiration to a greater extent than photosynthesis (McCree & Richardson, 1987; Glenn & Brown, 1998). This enhancement is generally regarded as mechanism to avoid salt ions, which may enter plant tissues in proportion to transpiration rates (Brugnoli & Bjorkman, 1992).

As expected, *P. ponderosa* and *P. contorta* differed significantly in their gas exchange characteristics across deicer treatment types and concentration levels (Table 29.).

Overall, saplings of *P. contorta* displayed significantly higher rates of net carbon assimilation (photosynthesis), stomatal conductance, and water use efficiency than saplings of *P. ponderosa*. The two species were comparatively similar in intercellular carbon dioxide concentrations and demonstrated similar rates of transpiration.

Gas exchange in conifer saplings following a three-month treatment period simulating winter roadside exposure to deicers varied significantly by species, deicer treatment type, and concentration level. Depression of gas-exchange parameters with increasing salt concentration exposure clearly occurred, providing evidence that observed physiological effects were a consequence of deicer exposure and sapling mortality (Table 35.). Overall, a decline in physiological gas exchange parameters and foliage health was observed in saplings of *P. contorta* and *P. ponderosa* exposed to higher concentrations of foliar and soil applications of $MgCl_2$ deicer. Even at the 10% deicer concentration level (3% $MgCl_2$), foliar applications of $MgCl_2$ significantly depressed sapling physiology. Trees exposed to sand/salt in contrast, exhibited little to no impact in gas exchange parameters, even at 100% roadbed application strength (Table 32.). Bedunah & Trilca (1977) found no significant differences in photosynthesis rates in seedlings of ponderosa pines treated with NaCl salt spray and distilled water, although a general increasing trend of photosynthetic depression occurred as salt concentration levels increased.

Although saplings exposed to sand/salt treatments demonstrated higher overall levels of net carbon assimilation (A) than saplings exposed to soil and foliar $MgCl_2$ deicer treatments, no significant difference was noted in the levels of stomatal conductance to water vapor (g_s) by treatment type (Table 34.). In this case increases in needle ionic content may be the cause of the reduction in photosynthesis rates rather than stomatal inhibition (Golombek & Ludders, 1993; Kozlowski, 1997). Significantly depressed levels of intercellular carbon dioxide concentration (Ci) were noted in conifer saplings exposed to foliar applications of $MgCl_2$ deicer compared to other deicer treatment types primarily due to tree mortality. Transpiration rates (E) and water use efficiency (WUE) were significantly higher in saplings exposed to Sand/Salt then any type of $MgCl_2$ deicer treatment, and positively correlated with observed measures of sapling health. Water use efficiency was significantly depressed in saplings treated with aerosolized $MgCl_2$ deicer, again due to tree mortality and inhibited physiology (Table 34).

Although mean gas exchange characteristics remained significantly higher in *P. contorta* than in *P. ponderosa* across deicer treatments, interestingly, these differences do not reflect the observed greater necrosis levels in *P. contorta* saplings (Figure 15.). Increased physiological activity may promote the uptake of salt ions both via the soil matrix from higher transpiration rates or through foliar penetration with higher levels of stomatal conductance. In the significant interaction of species and deicer treatment type ($F = 3.94$, $p = 0.0206$), graphical comparisons of mean post treatment leaf-level photosynthesis indicated that *P. contorta* is relatively more sensitive physiologically to soil applications of $MgCl_2$ deicer, while *P. ponderosa* is relatively more sensitive to foliar applications of $MgCl_2$ deicer.

Seed Germination

Introduction

To provide more information about deicer impacts on seed germination, this study included three main objectives:

- To evaluate the impacts of seven commercial deicers and reagent grade magnesium chloride on germination of three grass species, *Festuca idahoensis*, *Pascopyrum smithii*, and *Stipa viridula*. *S. viridula* was then chosen for an in depth assessment of germination and seed viability across deicer types.
- To assess germination recovery from deicer exposure in *Festuca idahoensis*, *Pascopyrum smithii*, and *Stipa viridula*.
- To assess the effects of $MgCl_2$ deicer (FreezGard) on germination in nine native plant species and the effects on germination and viability for six of those species.

Deicers Evaluated: The commercial deicers tested consisted of five liquid deicers, Ice Ban, Caliber M-1000, Caliber M-2000, NC-3000, and $MgCl_2$ used by CDOT (FreezGard). Two solid deicers also were assessed, Ice Slicer and sand/salt. Reagent grade $MgCl_2$ solution and distilled water provided comparative controls. These deicers have been analyzed extensively elsewhere (Lewis, 1999; Lewis, 2001; Fischel, 2001), and therefore only basics are recounted here. Tested deicers can be subdivided based on the primary salt component and its concentration, and the addition of other components, usually organic silage derived additives (Table 36.).

Table 36. Primary salt components and concentrations of tested commercial deicers for seed germination effects.

Deicer	Primary salt component	Salt application concentration level	Other components
Ice Ban	$MgCl_2$	29-31%	Fermented corn derivatives
Ice Slicer	Primarily, NaCl, with $CaCl_2$, KCl, $MgCl_2$	92-98%	Fine soil particulates
Caliber M-1000	$MgCl_2$,	26-28%	Fermented corn derivatives
Caliber M-2000	$MgCl_2$,	30%	Organic additives
$MgCl_2$ CDOT (FreezGard)	$MgCl_2$	29-31%	
NC-3000	None		Processed starch and sugar derivatives
Sand/Salt	NaCl	15%	sand/ gravel
$MgCl_2$ (reagent grade)	$MgCl_2$	30%	

Species Evaluated: A broad assessment of deicer types was undertaken for three Colorado native perennial grasses, *Festuca idahoensis*, *Pascopyrum smithii*, and *Stipa viridula*. These species are widely distributed in the United States and used for re-vegetation by many agencies including the Colorado Department of Transportation. Germination and viability also was evaluated using a range of native plant species in response to $MgCl_2$ deicer. These species included *Gaillardia aristata, Hilaria jamesii, Elymus trachycaulus, Bromus marginatus, Bouteloua gracilis, Picea engelmannii, Rudbeckia hirta, Pinus ponderosa,* and *Chrysothamnus nauseosus*. Ecological characteristics of these species and relevant germination information are listed below. All information was taken from Ogle et al. (2003), Wasser (1982), and Barkworth et al., eds. (2003).

***Festuca idahoensis* (Idaho Fescue):**
Widely distributed, native to Intermountain West and Inland Pacific Northwest; long-lived cool season perennial bunch grass with fine leaves and stems growing primarily from the base; highly palatable for forage; occurs abundantly on north exposures in areas with 14 inches and above in rainfall; tolerant of weakly saline, alkaline, and acid soils; moderately drought and shade tolerant; found commonly in foothills, mountain shrub, and woodlands between 3,000 and 10,000 feet.

***Pascopyrum smithii* (Western Wheatgrass):**
A long-lived, late maturing, winter hardy, strongly rhizomatous grass with coarse blue-green leaves; a widely distributed western native grass of primary importance in the Northern Great Plains; moderately palatable; typified by poor germination and seedling vigor; excellent palatability in spring and early summer, declining as plants mature; very aggressive native sod grass, excellent for erosion control; exhibits moderate to high salt tolerance, thriving on fine textured soils with moderate or higher levels of soil moisture; generally adapted to 14-20" of annual precipitation; tolerant of moderately severe droughts, cold hardy, and grows in sites up to 9,000 feet.

***Stipa viridula* (Green Needlegrass):**
Cool season, moderately tall, perennial, medium fine-leafed bunchgrass native to the Great Plains and portions of the Intermountain West; adapted to a wide range of soils and moderately palatable to livestock and wildlife; deep extensive fibrous root system; good drought tolerance in the 12-20" zone; weakly to moderately tolerant of soil salinity; extremely winter hardy occurring at elevations up to 9,000 feet; germination in *S. viridula* has been shown to be more sensitive to magnesium and potassium salts than to sodium or calcium salts (Ries & Hoffman, 1983).

***Gaillardia aristata* (Rock or Prairie Gaillardia):**
Native, cool season, short-lived perennial forb; widely distributed in western United States in open dry areas or on upper slopes; low palatability; moderately drought tolerant; commonly grows on disturbed areas.

***Hilaria jamesii* (Galleta Grass):**
Perennial, warm season, strongly rhizomatous bunchgrass, endemic to the southwestern United States; forms a loose to dense sod; grows 12 to 14 inches tall; found in deserts, canyons, and dry plains; important component of desert grasslands and pinyon-juniper communities; good for reclamation and used in mining disturbance sites; extensive rooting system; moderate palatability, drought tolerant.

***Elymus trachycaulus* (Slender Wheatgrass):**
Short-lived native bunchgrass with good seedling vigor and moderate palatability; valuable in erosion control due to rapid development; moderate salt tolerance and compatibility with other species; well adapted as a cover species and to increase organic matter in saline sites; tolerates high altitude well and areas receiving 10" or more in annual precipitation.

***Bromus marginatus* (Mountain Brome)**:

A short-lived vigorous cool season bunch grass native to the Intermountain West; establishes quickly on disturbed sites; moderately palatable and valuable for quick cover; shade tolerant; tolerant of fair salinity levels; weakly moderate drought tolerance; common in foothills and up to 10,000 feet.

***Bouteloua gracilis* (Blue Grama):**
A native warm season sod-forming shortgrass; major species of the Western Great Plains and Southwest; dense and tufted, commonly 6-24" tall with grey-green basal leaves; highly palatable year round; tolerant of moderate soil salinity, and common on alkaline soils; highly drought tolerant, with good winter hardiness; sodium chloride and other salts have been found to reduce germination in *B. gracilis* (Neid & Biesboer, 2004; Weiler and Gould, 1983).

***Picea engelmannii* (Engelmann Spruce):**
Native to high mountains of western United States; medium to large sized conifer tree; up to 100' tall and 3' in diameter; root system shallow and spreading; unpalatable to livestock, limited palatability to wildlife; intolerant of saline soils; found in cold humid sub-alpine climates; weak drought tolerance, preferring 25" to over 40" of precipitation.

***Rudbeckia hirta* (Black-eyed Susan):**
Native annual, biennial, or short lived perennial forb; widely distributed throughout the United States from 3,000 to 9,000 feet; moderately palatable; recommended for reclamation of disturbed areas including road cuts and mine sites; moderately drought tolerant.

***Pinus ponderosa* (Ponderosa Pine):**
Most extensively distributed native pine in western North America; medium to very large conifer tree; typically 50' to 150' tall; extensively and moderately deep rooted; palatability low; provides good wildlife and watershed cover and food for birds and small mammals; tolerant of moderately acid and basic soils, but not tolerant of saline or sodic soils; moderately strong drought tolerance especially in the seedling stages due to long taproots; prefers 15" to 25" of annual precipitation.

***Chrysothamnus nauseosus* (Rubber Rabbitbrush):**
Native to western North America; shrub usually 12" to 80" tall but varying from dwarf forms to types over 10' tall; composed of greater than 20 subspecies varying widely in size, stem, leaf, and flower characteristics; widely distributed in plains, valleys, and foothills; vigorous invader of disturbed sites including road cuts; excellent for erosion control due to deep roots, heavy litter, and ability to grow on disturbed sites; commonly used in re-vegetation on roadways and mine sites; value as forage is highly variable; moderate to strong drought tolerance and winter hardy; some varieties adapted to saline soils; species grow from 2,000 to over 9,000 feet in elevation.

Methods

Three species of perennial grasses used in re-vegetation by the Colorado Department of Transportation were monitored for germination response when exposed to a concentration gradient of seven commercial deicers. *Stipa viridula* (green needlegrass), *Festuca idahoensis* (Idaho fescue) and *Pascopyrum smithii* (western wheat grass) were exposed to a logarithmic concentration gradient of deicer beginning at full roadside application strength (100%), decreasing ten fold (10%) and one hundred fold (1%). Germination percentages in all species also were assessed when exposed to reagent grade magnesium chloride ($MgCl_2$) and distilled water controls. Germination was defined as the visible emergence of the radicle from the seed coat.

Two replicate sets of one hundred seeds per deicer type and concentration level were tested for a total of six trays per deicer and five thousand four hundred seeds of each species. A set of one hundred seeds was spread in 5”x 5”x1” germination boxes (Hoffman Manufacturing, Albany, OR) containing blotter paper and 7ml of deicer solution. Six controls per species also were established with 7ml of distilled water. Potassium nitrate was added to deicer solutions and distilled water to create 0.2%KNO_3 solutions to provide seeds with a nitrogen source for germination (AOSA, 2003).

Seeds were incubated and germinated according to the Association of Official Seed Analysts (AOSA) Rules for Testing Seeds (AOSA, 2003). *S. viridula*, *P. smithii*, and *F. idahoensis* were germinated in a Biochemical Oxygen Demand (BOD) incubator in darkness with an alternating temperature cycle of 8h/30°C- 16h/15°C. Final germination counts were made after 28 days for *P. smithii* and *F. idahoensis*, and after 14 days for *S. viridula* (AOSA, 2003).

Upon completion of germination, viability was assessed in ungerminated seeds of *S. viridula* using tetrazolium testing as per AOSA’s Tetrazolium Testing Handbook (AOSA, 2000). *S. viridula* embryos were bisected and stained overnight in 0.1% 2,3,5-triphenyl tetrazolium chloride solution. Stained embryos were then rinsed and evaluated under a dissecting scope for viability based on AOSA guidelines. Additionally, an extra two duplicates of 100 seeds of all species exposed to full application strength deicers were rinsed post-germination period and re-germinated in distilled water following the same incubation and assessment protocols to evaluate germination recovery.

Finally, the germination and viability effects of the magnesium chloride based deicer used by the Colorado Department of Transportation (FreezGard) were assessed on native plant species. *Gaillardia aristata, Hilaria jamesii, Elymus trachycaulus, Bromus marginatus, Bouteloua gracilis, Picea engelmannii, Rudbeckia hirta, Pinus ponderosa,* and *Chrysothamnus nauseosus* were exposed to full application strength (100%), ten fold (10%), and one hundred fold (1%) dilutions of $MgCl_2$ deicer as well as distilled water. Two replicates of one hundred seeds were placed in germination trays where blotter paper in each tray was treated with 7ml of solution. Each tray was treated with Schultz's Garden Safe Fungicide 3 (active ingredient: clarified hydrophobic extract of neem oil). Seeds were germinated at a constant 25°C in a BOD incubator in the dark. Protocols were modified from AOSA standards due to growth chamber space and temperature limitations. Determination of germination final counts followed AOSA guidelines (AOSA, 2003).

E. trachycaulus and *P. ponderosa* were pre-chilled for 5-35 days to break dormancy at 5°C as per AOSA protocols. *P. engelmannii* was germinated with the addition of 0.2% KNO_3 solution to provide a nitrogen source (AOSA, 2003). Viability post deicer exposure was evaluated for *Gaillardia aristata, Elymus trachycaulus, Bromus marginatus, Bouteloua gracilis, Picea engelmannii,* and *Stipa viridula*. Seed embryos were bisected and stained overnight in 0.1% 2,3,5-triphenyl tetrazolium chloride solution. Stained embryos were then rinsed and evaluated for viability based on AOSA protocols (AOSA, 2000).

Statistical analysis of all data utilized SAS version 8.1, SAS Institute Inc., Cary, NC, USA. Germination data were analyzed with a species by deicer type by concentration level factorial ANOVA, while germination and viability data were assessed with a species by deicer type by concentration level factorial MANOVA by Wilks' lambda. In all cases of significance ($\alpha < 0.05$), relationships were compared by Bonferonni post-hoc t-tests with significance levels (α) of 0.05.

Results

Impacts of Deicing Chemical Type and Concentration Level on Germination Percentages in Festuca idahoensis, Pascopyrum smithii, and Stipa viridula: Germination percentages varied by deicer type, salt concentration level, and species. In all cases, as deicer concentration increased, germination decreased. No germination occurred in seeds exposed to deicers at 100% full roadbed application strength, and little germination occurred in species exposed to 10% deicer solutions with the exception of Sand/Salt and reagent grade $MgCl_2$. Table 37. summarizes mean germination percentages across deicers, concentrations, and species.

Table 37. Mean Germination of *Festuca idahoensis, Pascopyrum smithii,* and *Stipa viridula* exposed to seven commercial deicers, reagent grade magnesium chloride, and distilled water.

Species	Deicer Type	Concentration Level (%)	Mean Germination Percentage ± SE
Festuca idahoensis	Distilled Water	0	82 ± 2.3
	Ice Ban	1	78.5 ± 0.5
		10	0
		100	0
	Ice Slicer	1	82 ± 0.0
		10	0
		100	0
	Caliber M-1000	1	41 ± 0.0
		10	0.5 ± 0.5
		100	0
	Caliber M-2000	1	28 ± 28.0
		10	1.5 ± 1.5
		100	0
	$MgCl_2$ CDOT	1	35.5 ± 29.5
		10	0
		100	0
	$MgCl_2$ Reagent	1	76 ± 2.0
		10	0.5 ± 0.5
		100	0
	NC-3000	1	78.5 ± 2.5
		10	0
		100	0
	Sand/Salt	1	85.5 ± 2.5
		10	84 ± 1.0
		100	0

Table 37.

Species	Deicer Type	Concentration (%)	Mean germination ± SE
Pascopyrum smithii	Distilled Water	0	90.2 ± 1.3
	Ice Ban	1	78 ± 6.0
		10	0
		100	0
	Ice Slicer	1	88 ± 5.0
		10	2.5 ± 2.5
		100	0
	Caliber M-1000	1	89.5 ± 0.5
		10	0
		100	0
	Caliber M-2000	1	84 ± 0.0
		10	0
		100	0
	$MgCl_2$ CDOT	1	86.5 ± 1.5
		10	0
		100	0
	$MgCl_2$ Reagent	1	92.5 ± 4.5
		10	63.5 ± 3.5
		100	0
	NC-3000	1	89.5 ± 0.5
		10	5 ± 2.0
		100	0
	Sand/Salt	1	89 ± 3.0
		10	90.5 ± 0.5
		100	0

Table 37.

Species	Deicer type	Concentration (%)	Mean Germination (%) ± SE
Stipa viridula	Distilled Water	0	83.2 ± 2.1
	Ice Ban	1	57.5 ± 24.5
		10	0
		100	0
	Ice Slicer	1	82 ± 0.0
		10	0
		100	0
	Caliber M-1000	1	73 ± 6.0
		10	0
		100	0
	Caliber M-2000	1	74.5 ± 1.5
		10	0
		100	0
	$MgCl_2$ CDOT (FreezGard)	1	80.5 ± 1.5
		10	0
		100	0
	$MgCl_2$ Reagent	1	83.5 ± 2.5
		10	4 ± 1.0
		100	0
	NC-3000	1	84.5 ± 2.5
		10	0
		100	0
	Sand/Salt	1	84 ± 1.0
		10	81 ± 1.0
		100	0

Germination data were analyzed with a species by deicer type by concentration level factorial ANOVA. This model significantly ($F = 58.88$, $p > 0\ .0001$) explained seed germination as a function of species, deicer type, and concentration level. The model was exceedingly robust, explaining 98% of the observed variation ($R^2 = 0.980422$). All main effects of the model including species ($F = 25.81$, $p < 0.0001$), deicer type ($F = 42.81$, $p < 0.0001$), and concentration level ($F = 1301.79$, $p < 0.0001$) proved statistically significant.

Species were found to significantly differ in their germination responses to deicers. Bonferroni post hoc comparisons ($\alpha = 0.05$) demonstrated that *P. smithii* had the greatest deicer tolerance, $\bar{x} = 41.815$, followed by *S. viridula* $\bar{x} = 35.333$, then *F. idahoensis* $\bar{x} = 31.019$ (Figure 20.).

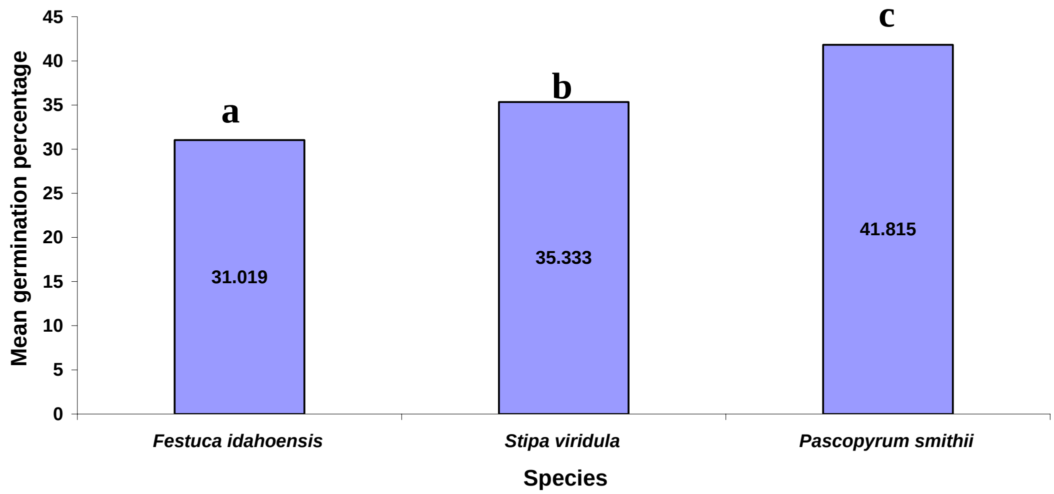


Figure 20. Mean germination percentages across deicer type exposure by species

Germination also differed significantly by deicer type. Distilled water $\bar{x}$ = 85.111 and Sand/Salt $\bar{x}$ =57.111 had significantly lower unique effects on seed germination then other deicing chemicals (Table 38.). The remainder of the deicers tested could be divided into two groups of greater and lesser germination impacts, although it should be noted that not all members of these groups were significantly different from each other (Table 38.). Reagent grade $MgCl_2$, NC-3000, and Ice Slicer had a generally lesser impact on germination percentage, while Ice Ban, Caliber M-1000, Caliber M-2000, and CDOT $MgCl_2$ demonstrated a greater general suppression of germination.

Table 38. Bonferroni post hoc grouping (α = 0.05) of germination percentages by deicer type. Means with the same letter are not significantly different.

Bonferroni grouping		Germination Mean (%)	n	Deicer Type
	A	85.111	18	Distilled Water
	B	57.111	18	Sand/Salt
	C	35.556	18	$MgCl_2$ reagent
D	C	28.611	18	NC-3000
D	C	28.278	18	Ice Slicer
D		23.778	18	Ice Ban
D		22.667	18	Caliber M-1000
D		22.500	18	$MgCl_2$ CDOT
D		20.889	18	Caliber M-2000

Finally, deicer concentration levels all demonstrated unique and significant impacts on germination percentages via Bonferroni post hoc comparisons (α = 0.05). Mean germination percentages of control (0%) groups were 85.111. The mean percentage dropped steadily and significantly with each concentration increase: 1% deicer $\bar{x} = 75.896$, 10% deicer $\bar{x} = 13.875$, and 100% deicer $\bar{x} = 0$ (Figure 21.).

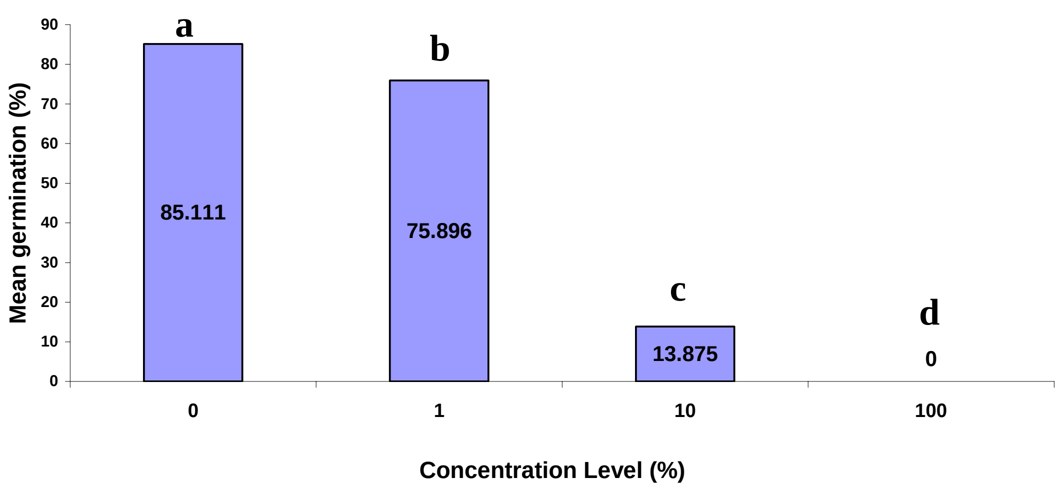


Figure 21. Mean germination percentages of *F. idahoensis*, *P. smithii*, and *S. viridula* by deicer concentration level

All interactions between species, deicer type and concentration level also exhibited statistical significance. The interaction of species and deicer type proved significant (F = 3.35, p = 0.0003), and graphical comparisons of mean germination percentages across species and deicer types indicated a species tolerance in *P. smithii* to reagent grade $MgCl_2$, and a noteworthy sensitivity to Caliber M-1000, Caliber M-2000, and CDOT $MgCl_2$ in *F. idahoensis*. The interaction of species and concentration also proved significant (F = 10.9, p < 0.0001). Graphical evaluation of germination percentages in *P. smithii*, *S. viridula*, and *F. idahoensis* demonstrate a substantial comparative decrease in germination in *F. idahoensis* at the 1% deicer concentration level.

A significant interaction on germination percentages was noted between deicer type and concentration level (F = 27.57, p < 0.0001). Sand/Salt and reagent grade $MgCl_2$ had substantially higher germination percentages at the 10% concentration level than any other tested deicers. Germination rates at the 1% concentration level differed from distilled water for Ice Ban, Caliber M-1000, $MgCL_2$ CDOT, and Caliber M-2000.

Finally, a significant three-way interaction occurred between species, deicer type, and concentration level ($F = 4.08$, $p < 0.0001$). Additional graphical evaluation of the interaction reveals that *P. smithii* is relatively more resistant to a 1% reagent grade solution of $MgCl_2$, *S. viridula* is relatively strongly impacted by 1% solutions of Ice Ban, *F. idahoensis* and *S. viridula* experience relatively depressed germination in 1% Caliber M-1000 compared to *P. smithii*, and germination in *F. idahoensis* is highly impacted by 1% solutions of Caliber M-1000, Caliber M-2000, and CDOT $MgCl_2$. Analyses of 10% solutions demonstrate that *P. smithii* has relatively higher rates of germination in 10% reagent grade $MgCl_2$ and NC-3000 than *F. idahoensis* or *S. viridula*. Seeds in the 100% deicer solutions failed to germinate and were excluded from this analysis.

Impacts of Deicing Chemical Type and Concentration Level on Germination Percentages and Viability in Stipa viridula: *Stipa viridula* was chosen for an in-depth analysis of deicer impact on seed germination and viability. Non-viable seeds did not correlate with increasing deicer concentration, but instead were most prominent in the 10% concentration level. Table 39. summarizes germination and viability data for *S. viridula* across deicer type and concentration level.

A factorial MANOVA was run to assess deicer type and concentration level impact on germination and viability in *S. viridula*. Overall, deicer type ($F = 6.72$, $p < 0.0001$), concentration level ($F = 143.11$, $p < 0.0001$), and the interaction of deicer type and concentration level ($F = 5.53$, $p < 0.0001$) significantly affected germination and viability in *S. viridula*.

Table 39. Mean germination and non-viable seed percentages in *S. viridula* across deicer type and concentration levels

Deicer Type	Concentration Level	Mean Germination Percentage ± SE	Mean Percentage Non-viable Seeds ± SE
Distilled Water	0	83.2 ± 2.1	3.3 ± 0.61
Ice Ban	1	57.5 ± 24.5	7.5 ± 2.5
	10	0	11 ± 0.0
	100	0	4 ± 2.0
Ice Slicer	1	82 ± 0.0	6 ± 1.0
	10	0	16.5 ± 2.5
	100	0	4.5 ± 0.5
Caliber M-1000	1	73 ± 6.0	5.5 ± 1.5
	10	0	9 ± 1.0
	100	0	3.5 ± 0.5
Caliber M-2000	1	74.5 ± 1.5	7.5 ± 2.5
	10	0	11 ± 1.0
	100	0	4 ± 2.0
$MgCl_2$ CDOT	1	80.5 ± 1.5	4.5 ± 2.5
	10	0	11.5 ± 2.5
	100	0	2.5 ± 0.5
$MgCl_2$ Reagent	1	83.5 ± 2.5	4 ± 1.0
	10	4 ± 1.0	8 ± 2.0
	100	0	6 ± 0.0
NC-3000	1	84.5 ± 2.5	4 ± 1.0
	10	0	11.5 ± 2.5
	100	0	4 ± 2.0
Sand/Salt	1	84 ± 1.0	5 ± 0.0
	10	81 ± 1.0	6 ± 0.0
	100	0	14.5 ± 0.5

Both distilled water and sand/salt treatments differed significantly in their effects on germination in *S. viridula* compared to the other deicers tested (Figure 22.). According to Bonferroni post hoc comparisons ($\alpha = 0.05$), sand/salt ($\bar{x} = 55.000$) significantly decreased mean germination percentage from distilled water ($\bar{x} = 83.167$), but was found to be significantly higher in mean germination percentages than the other deicers tested.

In terms of non-viable seed count, only Ice Slicer and Sand/Salt differed significantly with increased counts from distilled water. They did not differ significantly from the other tested deicers, however (Table 40.).

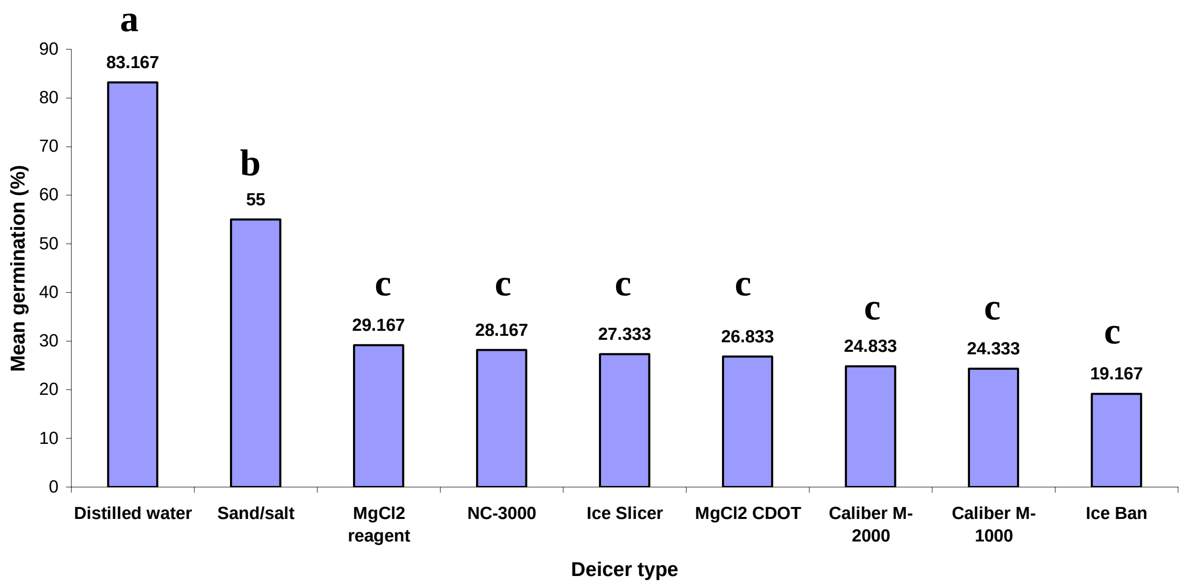


Figure 22. Mean germination in *S. viridula* across deicer type

Table 40. Bonferroni post hoc grouping for non-viable seed count across deicer type ($\alpha = 0.05$). Means with the same letter are not significantly different.

Bonferroni Grouping		Mean Non-Viable Seed (%)	n	Deicer Type
	A	9.000	6	Ice Slicer
	A	8.500	6	Sand/Salt
B	A	7.500	6	Ice Ban
B	A	7.500	6	Caliber M-2000
B	A	6.500	6	NC-3000
B	A	6.167	6	$MgCl_2$ CDOT
B	A	6.000	6	$MgCl_2$ reagent
B	A	6.000	6	Caliber M-1000
B		3.333	6	Distilled Water

Across concentration levels, mean germination of *S. viridula* in distilled water ($\bar{x} =$ 83.167) did not differ significantly from 1% deicer solutions ($\bar{x} = 77.438$). Germination means in 10% deicer solutions ($\bar{x} = 10.625$) and germination in 100% deicer solutions ($\bar{x} = 0$) were significantly different from all other levels however (Figure 23.).

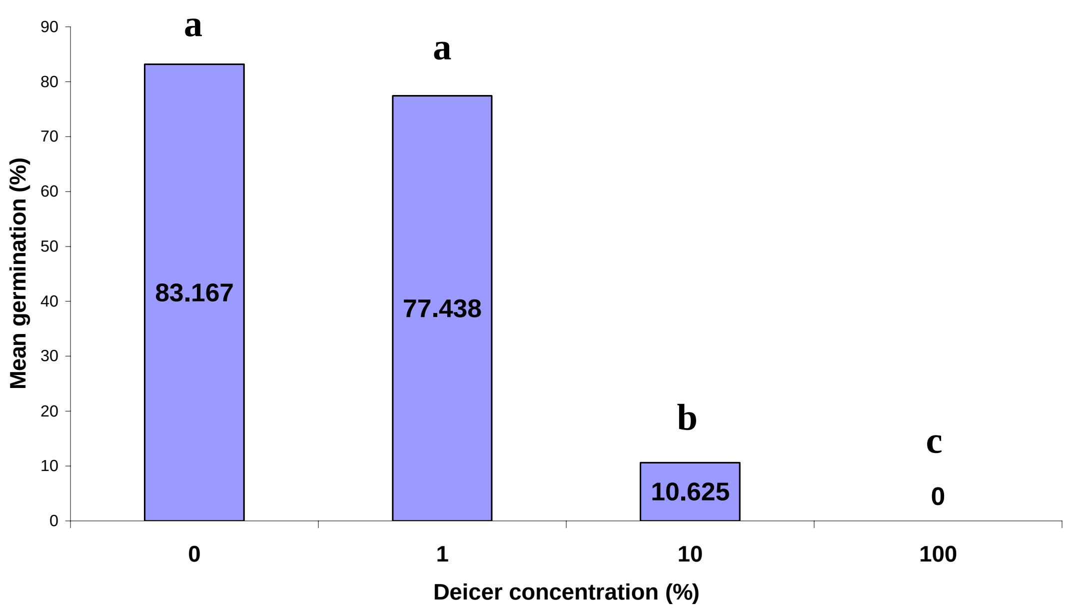


Figure 23. Mean germination percentages in *S. viridula* across a deicer concentration gradient

Viability was only significantly unique in the 10% deicer solutions according to Bonferroni post hoc comparisons (α = 0.05). Mean non-viable seed counts averaged 10.5625, significantly higher than in other deicer concentration levels (Figure 24.).

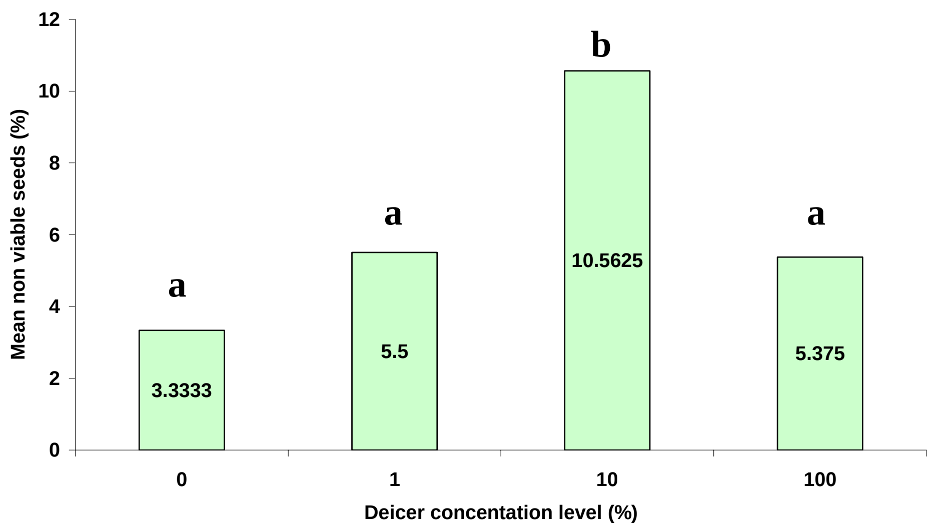


Figure 24. Mean non-viable seed count in *S. viridula* across deicer concentration levels

There was also a significant interaction for both germination and viability across deicer types and concentration levels ($F = 5.53$, $p < 0.0001$). Graphical comparisons of mean germination of *S. viridula* deicer concentration levels across deicer types reveal higher germination percentages in Sand/Salt and reagent grade $MgCl_2$ at the 10% deicer concentration level. A decrease in germination across Caliber M-1000, Caliber M-2000, and Ice Ban at the 1% deicer concentration is also notable. For viability, more non-viable seeds were seen in reagent grade $MgCl_2$ and Sand/Salt at the 100% level than for any other tested deicers. An increase in non-viable seeds also was noted in reagent grade $MgCl_2$, NC-3000, Ice Slicer, and CDOT $MgCl_2$, at the 10% deicer concentration level.

Impact of Previous Deicer Type Exposure on Re-germination Percentages in Festuca idahoensis, Pascopyrum smithii, and Stipa viridula: Seeds of *F. idahoensis*, *P. smithii*, and *S. viridula* failed to germinate in full deicer application strengths (100%). To assess whether these seeds were capable of germination recovery, they were rinsed with distilled water and placed in new germination trays, where they underwent an identical incubation period and cycle with exposure to distilled water rather than deicers. "Re-germination" percentages were compared across species and previous deicer type exposure. Table 41. summarizes mean re-germination percentages of tested species across deicer types.

A species by previous deicer type exposure factorial ANOVA was used to analyze germination recovery percentages. This model significantly ($F= 27.65$, $p > 0 .0001$) explained seed re-germination as a function of species ($F = 92.88$, $p < 0.0001$), previous deicer type exposure ($F = 38.27$, $p < 0.0001$), and their interaction ($F = 12.55$, $p < 0.0001$). Additionally, the model was especially robust, explaining 96% of the observed variation ($R^2 = 0.963690$).

Table 41. Mean germination recovery percentages of *F. idahoensis, P. smithii,* and *S. viridula* across previous deicer type exposure

Species	Previous Deicer Exposure Type	Mean Re-germination Percentage ± SE
Festuca idahoensis	Distilled Water	82 ± 2.7
	Ice Ban	61 ± 5.0
	Ice Slicer	1.5 ± 1.5
	Caliber M-1000	64 ± 4.0
	Caliber M-2000	64 ± 1.0
	$MgCl_2$ CDOT	76 ± 2.0
	$MgCl_2$ Reagent	54.5 ± 7.5
	NC-3000	17 ± 10.0
Pascopyrum smithii	Distilled Water	90.2 ± 0.5
	Ice Ban	78.5 ± 0.5
	Ice Slicer	75 ± 4.0
	Caliber M-1000	86.5 ± 0.5
	Caliber M-2000	72.5 ± 4.5
	$MgCl_2$ CDOT	87.5 ± 2.5
	$MgCl_2$ Reagent	60 ± 7.0
	NC-3000	75.5 ± 0.5
Stipa viridula	Distilled Water	83.2 ± 1.5
	Ice Ban	70 ± 2.0
	Ice Slicer	55.5 ± 1.5
	Caliber M-1000	80.5 ± 0.5
	Caliber M-2000	75 ± 3.0
	$MgCl_2$ CDOT	75 ± 6.0
	$MgCl_2$ Reagent	72 ± 1.0
	NC-3000	54 ± 4.0
	Sand/Salt	58 ± 1.0

Bonferroni post hoc comparisons ($\alpha = 0.05$) demonstrated that *F. idahoensis, P. smithii*, and *S. viridula* all significantly differed from one another in germination recovery percentages. *P. smithii* had the greatest amount of germination recovery $\bar{x} = 78.213$, followed by *S. viridula* $\bar{x} = 69.244$ and *F. idahoensis* $\bar{x} = 52.500$ (Figure 25.).

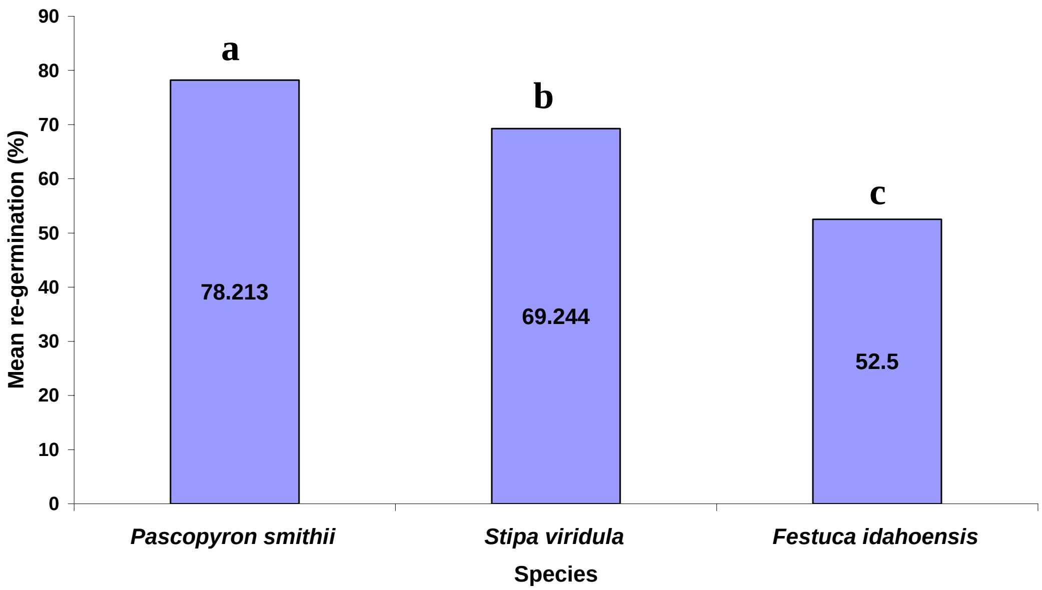


Figure 25. Mean germination recovery in *P. smithii*, *S. viridula*, and *F. idahoensis*

Germination recovery varied significantly by previous deicer type exposure ($F = 38.27$, $p < 0.0001$). Table 42. gives Bonnferroni post hoc groupings ($\alpha = 0.05$) of germination recovery across previous deicer type exposure. Seeds exposed to distilled water, CDOT $MgCl_2$, and Caliber M-1000 had the highest re-germination percentages, while seeds exposed to NC-3000 and Ice Slicer demonstrated the lowest.

The interaction of species and previous deicer type exposure also proved significant ($F = 12.55$, $p < 0.0001$). Graphical comparisons of mean germination recovery of all three species across previous deicer exposure types reveal relatively higher mean germination percentages in *S. viridula* previously exposed to Caliber M-1000, as well as higher mean germination of *P. smithii* previously exposed to Ice Ban. *P. smithii* and *S. viridula* also proved to have notably more germination recovery than *F. idahoensis* after exposure to NC-3000 and Ice Slicer.

Table 42. Bonferroni post hoc grouping (α = 0.05) of mean germination recovery percentages by previous deicer type exposure. Means with the same letter are not significantly different.

Bonferroni Grouping		Re-germination Mean (%)	n	Previous Deicer Type Exposure
	A	85.133	6	Distilled Water
B	A	79.500	6	$MgCl_2$ CDOT
B	A	77.000	6	Caliber M-1000
B	C	70.500	6	Caliber M-2000
B	C	69.833	6	Ice Ban
	C	62.167	6	$MgCl_2$ reagent
D	C	58.000	2	Sand/Salt
D	E	48.833	6	NC-3000
	E	44.000	6	Ice Slicer

Impacts of $MgCl_2$ Deicer Concentration Levels on Germination Percentages in Gaillardia aristata, Hilaria jamesii, Elymus trachycaulus, Bromus marginatus, Bouteloua gracilis, Picea engelmannii, Rudbeckia hirta, Pinus ponderosa, and Chrysothamnus nauseosus: A survey of germination responses in plant species to a concentration gradient of CDOT magnesium chloride deicer (FreezGard) demonstrated that germination varied by salt concentration level as well as by species. In all cases, as deicer concentration increased, germination decreased. No germination occurred in seeds exposed to $MgCl_2$ deicer at 100% or 10% of full roadbed application strength. Table 43. summarizes mean germination percentages across concentrations and species.

Germination data were analyzed with a species by concentration level factorial ANOVA. This model significantly ($F = 80.50$, $p < 0 .0001$) explained seed germination as a function of species ($F = 9.87$, $p < 0.0001$), deicer concentration level ($F = 1149.78$, $p < 0.0001$), and their interaction ($F = 6.84$, $p < 0.0001$). The model was also especially robust, explaining 98% of the observed variation ($R^2 = 0.987472$).

Table 43. Mean germination percentages of plant species across a concentration gradient of $MgCl_2$ deicer.

Species	Concentration Level (%)	Mean Germination Percentage ± SE
Bouteloua gracilis	0	95 ± 1.0
	1	90 ± 2.0
	10	0
	100	0
Bromus marginatus	0	95.5 ± 1.5
	1	97 ± 1.0
	10	0
	100	0
Chrysothamnus nauseosus	0	76.5 ± 0.5
	1	68.5 ± 3.5
	10	0
	100	0
Elymus trachycaulus	0	94 ± 3.0
	1	39.5 ± 1.5
	10	0
	100	0
Festuca idahoensis	0	84.5 ± 1.5
	1	35.5 ± 29.5
	10	0
	100	0
Gaillardia aristata	0	70 ± 3.0
	1	42.5 ± 4.5
	10	0
	100	0
Hilaria jamesii	0	58.5 ± 0.5
	1	58 ± 3.0
	10	0
	100	0
Pascopyrum smithii	0	90.5 ± 0.5
	1	86.5 ± 1.5
	10	0
	100	0
Picea engelmannii	0	88 ± 2.0
	1	77.5 ± 5.5
	10	0
	100	0
Pinus ponderosa	0	85.5 ± 0.5
	1	86.5 ± 1.5
	10	0
	100	0

Table 43.

Species	Concentration (%)	Mean Germination (%) ± SE
Rudbeckia hirta	0	86.5 ± 1.5
	1	43 ± 1.0
	10	0
	100	0
Stipa viridula	0	85 ± 1.0
	1	80.5 ± 1.5
	10	0
	100	0

Germination differed significantly between species ($F = 9.87$. $p < 0.0001$). Seeds of *Bromus marginatus*, *Bouteloua gracilis*, *Pascopyrum smithii*, *Pinus ponderosa*, *Picea engelmannii,* and *Stipa viridula* germinated at higher percentages than other species in the lab and when exposed to CDOT $MgCl_2$ (Table 44.). Seeds of *Chrysothamnus nauseosus*, *Elymus trachycaulus*, *Rudbeckia hirta*, *Festuca idahoensis*, *Hilaria jamesii*, and *Gaillardia aristata* germinated at lower overall percentages in the lab and when exposed to CDOT $MgCl_2$ (FreezGard) (Table 44.).

Mean germination percentages also differed significantly across concentration levels of $MgCl_2$ deicer ($F = 1149.78$, $p < 0.0001$). No seeds of any kind germinated in 10% or 100% deicer solutions. Seeds also germinated at a significantly reduced rate in the 1% deicer solution ($\bar{x} = 67.083$) compared to distilled water ($\bar{x} = 84.125$) (Table 45.).

A species by deicer concentration level interaction also was significant ($F = 6.84$, $p < 0.0001$), indicating species sensitivity to $MgCl_2$ deicer. Graphical comparisons of mean germination percentages of seeds in distilled water and 1% CDOT $MgCl_2$ (FreezGard) demonstrate several notable differences. Seeds of *P. engelmannii*, *E. trachycaulus, R. hirta*, *F. idahoensis,* and *G. aristata* were prominently more sensitive to the deicer than other seeds tested, and germinated at reduced rates even in 1% CDOT $MgCl_2$. Seeds exposed to 10% and 100% deicer solutions were excluded as they failed to germinate entirely.

Table 44. Bonferroni post hoc grouping (α = 0.05) of mean germination percentages by species. Means with the same letter are not significantly different.

Bonferroni grouping					Germination Mean (%)	n	Species
			A		48.125	8	*Bromus marginatus*
	B		A		46.250	8	*Bouteloua gracilis*
	B		A	C	44.250	8	*Pascopyrum smithii*
	B	D	A	C	43.000	8	*Pinus ponderosa*
E	B	D	A	C	41.375	8	*Picea engelmannii*
E	B	D	A	C	41.375	8	*Stipa viridula*
E	B	D	F	C	36.250	8	*Chrysothamnus nauseosus*
E		D	F	C	33.375	8	*Elymus trachycaulus*
E		D	F		32.375	8	*Rudbeckia hirta*
E			F		30.000	8	*Festuca idahoensis*
			F		29.125	8	*Hilaria jamesii*
			F		28.125	8	*Gaillardia aristata*

Table 45. Bonferroni post hoc grouping (α = 0.05) of mean germination percentages of plant species by $MgCl_2$ deicer concentration. Means with the same letter are not significantly different.

Bonferroni Grouping	Germination Mean (%)	n	$MgCl_2$ Concentration Level (%)
A	84.125	24	0
B	67.083	24	1
C	0.000	24	10
C	0.000	24	100

Impacts of $MgCl_2$ Deicer Concentration Levels on Germination Percentages and Viability in Gaillardia aristata, Elymus trachycaulus, Bromus marginatus, Bouteloua gracilis, Picea engelmannii, and Stipa viridula: Six plant species, *Gaillardia aristata*, *Elymus trachycaulus*, *Bromus marginatus*, *Bouteloua gracilis*, *Picea engelmannii*, and *Stipa viridula* were chosen for an in-depth evaluation of germination and viability in response to a concentration gradient of CDOT $MgCl_2$ deicer. Again, non-viable seeds did not correlate with increasing deicer concentration, but instead were most prominent in the 10% concentration level. *G. aristata* proved an exception to this trend, however. Table 46. summarizes germination and viability data for the above species along a logarithmic concentration gradient of $MgCl_2$ deicer.

Table 46. Mean germination and non-viable seed percentages of six plant species along a concentration gradient of $MgCl_2$ deicer (FreezGard).

Species	Concentration Level (%)	Mean Germination Percentage ± SE	Mean Percentage Non-viable seeds ± SE
Gaillardia aristata	0	70 ± 3.0	7.5 ± 2.5
	1	42.5 ± 4.5	14 ± 3.0
	10	0	25 ± 4.0
	100	0	36.5 ± 2.5
Elymus trachycaulus	0	94 ± 3.0	2.5 ± 0.5
	1	39.5 ± 1.5	21 ± 4.0
	10	0	26 ± 0.0
	100	0	6.5 ± 3.5
Bromus marginatus	0	95.5 ± 1.5	4.5 ± 1.5
	1	97 ± 1.0	2.5 ± 0.5
	10	0	65 ± 1.0
	100	0	9 ± 6.0
Bouteloua gracilis	0	95 ± 1.0	5 ± 1.0
	1	90 ± 2.0	10 ± 2.0
	10	0	56 ± 6.0
	100	0	14 ± 5.0
Picea engelmannii	0	88 ± 2.0	11.5 ± 1.5
	1	77.5 ± 4.5	22.5 ± 4.5
	10	0	77.5 ± 0.5
	100	0	16.5 ± 2.5
Stipa viridula	0	85 ± 1.0	3.5 ± 0.5
	1	80.5 ± 1.5	4.5 ± 2.5
	10	0	11.5 ± 2.5
	100	0	2.5 ± 0.5

A factorial MANOVA was run to assess species and concentration level impact on germination and viability in *Gaillardia aristata, Elymus trachycaulus, Bromus marginatus, Bouteloua gracilis, Picea engelmannii,* and *Stipa viridula*. Overall, species ($F = 54.83$, $p < 0.0001$), concentration level ($F = 689.54$, $p < 0.0001$) and the interaction of species and concentration level ($F = 33.46$, $p < 0.0001$) were found to significantly effect germination and viability in the six plant species.

Tested species could be placed into four significant groups based on their mean germination response to $MgCl_2$ deicer. Bonferroni post hoc comparisons ($\alpha = 0.05$) demonstrated that *Bromus marginatus* and *Bouteloua gracilis* had higher overall mean germination percentages ($\bar{x} = 48.125$) and ($\bar{x} = 46.250$), respectively, followed by *Picea engelmannii* ($\bar{x} = 41.375$) and *Stipa viridula* ($\bar{x} = 41.375$). *Elymus trachycaulus* ($\bar{x} = 33.375$) demonstrated a much lower mean germination percentage, and *Gaillardia aristata* had the lowest overall mean germination percentage ($\bar{x} = 28.125$) (Figure 26.).

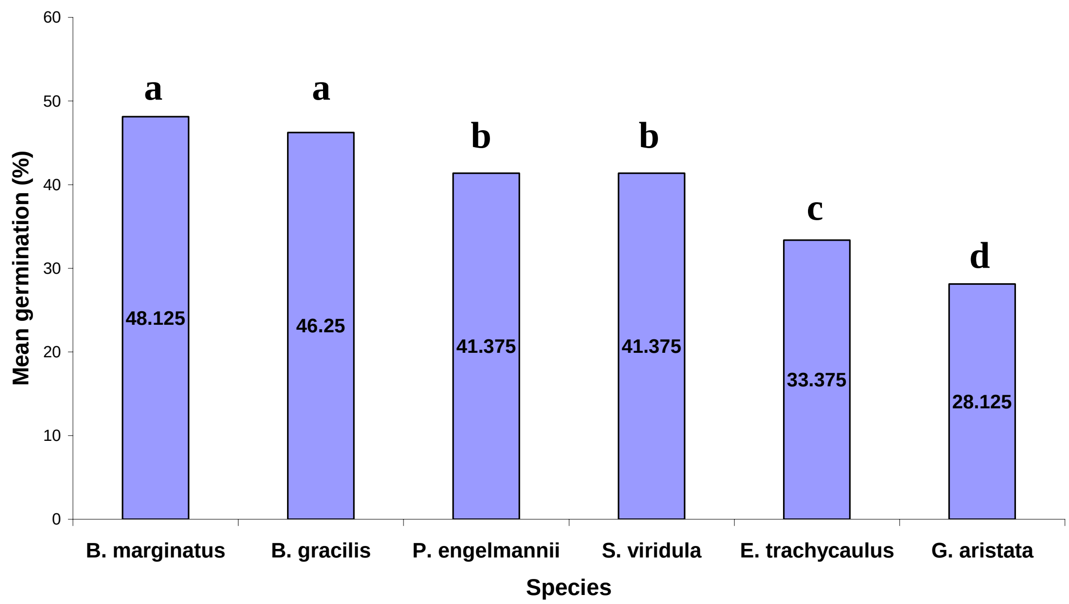


Figure 26. Mean germination percentage of six plant species in response to $MgCl_2$ deicer

Picea engelmannii was significantly different from the other species tested, having the most non-viable seeds ($\bar{x}$ = 32.00). *Stipa viridula* demonstrated the least amount of non-viable seeds ($\bar{x}$ = 5.500), with the other tested species falling into significant groupings in between (Table 47.).

Table 47. Bonferroni post hoc grouping (α = 0.05) of mean non-viable seed percentages by species. Means with the same letter are not significantly different.

Bonferroni Grouping		Mean Non-viable Seed (%)	n	Species
	A	32.000	8	*Picea engelmannii*
	B	21.250	8	*Bouteloua gracilis*
C	B	20.750	8	*Gaillardia aristata*
C	B	20.250	8	*Bromus marginatus*
C		14.000	8	*Elymus trachycaulus*
	D	5.500	8	*Stipa viridula*

Mean germination and viability in the six species tested also varied significantly across concentration levels of CDOT $MgCl_2$ (F = 689.54, $p < 0.0001$). Bonferroni post hoc comparisons (α = 0.05) indicate that the mean germination percentage of seeds in distilled water ($\bar{x}$ = 87.917) was significantly different than for seeds in the 1% deicer solution ($\bar{x}$ =71.167). Seeds exposed to 10% percent and 100% deicer were significantly different as they failed to germinate at all (Table 48.).

Table 48. Bonferroni post hoc grouping (α = 0.05) of mean germination percentages by $MgCl_2$ deicer concentration level. Means with the same letter are not significantly different.

Bonferroni Grouping	Mean germination (%)	n	Concentration Level (%)
A	87.917	12	0
B	71.167	12	1
C	0.000	12	10
C	0.000	12	100

Viability in seeds also differed significantly across $MgCl_2$ deicer concentration levels. Non-viable seeds were found in significantly higher percentages in 10% $MgCl_2$ deicer solution than at any other concentration level via Bonferroni post hoc comparisons (α = 0.05). The lowest percentages of non-viable seeds were found in seeds exposed to distilled water ($\bar{x}$ = 5.750) (Figure 27.).

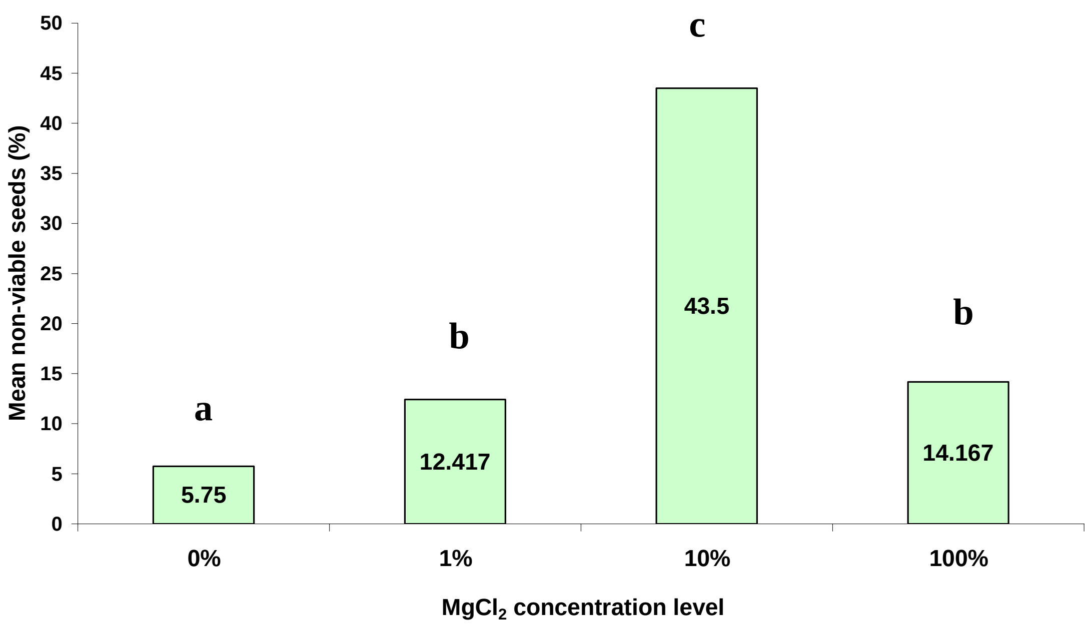


Figure 27. Mean non-viable seed percentages of six plant species across a $MgCl_2$ deicer concentration gradient

The interaction of species and concentration level also proved significant for both mean germination and viability (F = 33.46, $p < 0.0001$). Graphical comparisons of mean species germination in 0% and 1% $MgCl_2$ deicer solutions indicate that germination is relatively depressed in *P. engelmannii* in 1% deicer solutions, and significantly depressed in 1% deicer solutions for *E. trachycaulus* and *G. aristata*. Seeds in the 10% and 100% $MgCl_2$ deicer solution were excluded from this analysis because they failed to germinate. The percentage of non- viable seeds was notably higher for *B. marginatus, B. gracilis,* and *P. engelmannii* in the 10% $MgCl_2$ deicer solution according to graphical comparisons. *B. gracilis* and *E. trachycaulus* demonstrated an elevated number of non-viable seeds in 1% $MgCl_2$ deicer solution, while *G. aristata* demonstrated an elevated number of non-viable seed in 100% $MgCl_2$ deicer solution.

Conclusions

Impacts of Deicing Chemical Type and Concentration Level on Germination Percentages in Festuca idahoensis, Pascopyrum smithii, and Stipa viridula:

Germination percentages significantly ($F = 58.88$, $p > 0 .0001$) varied by deicer type, salt concentration level, and species. In all cases, as deicer concentration increased, germination decreased. Mean germination percentages of control (0%) groups were 85.111, and the mean percentage dropped steadily and significantly with each concentration increase: 1% deicer $\bar{x} = 75.896$, 10% deicer $\bar{x} = 13.875$, and 100% deicer $\bar{x} = 0$. As expected from the published literature, no germination was observed in seeds of any species exposed to full roadbed application strength of any tested deicer. Halophytes, or salt tolerant plants, have been found to tolerate salinities of up to approximately 3% salt solutions (Rubio-Casal et al., 2002), roughly equivalent to the 10% deicer solution used in this experiment (with the exception of Sand/Salt). Full application strength deicers were tested to provide information on viability at an upper limit of potential environmental exposure.

Of the three species evaluated, *P. smithii* has been shown to exhibit moderate to high salt tolerance (Wasser, 1982). This was supported by our data where *P. smithii* demonstrated the highest overall deicer germination tolerance of the evaluated species. Both *F. idahoensis* and *S. viridula*, known to be weakly or moderately tolerant of saline soils (Wasser, 1982), germinated at significantly lower overall percentages across deicer types. *F. idahoensis* proved to be the least salt tolerant of the evaluated species to deicer stress during germination.

As expected, seeds exposed to deicing chemicals germinated at significantly lower percentages than conspecific seeds in distilled water. Germination percentages varied by deicer type with the least germination seen in Ice Ban, Caliber M-1000, Caliber M-2000, and CDOT $MgCl_2$ (FreezGard). These results support the findings of Roosevelt and Fitch (2000), where concentrations of the deicer Ice Ban were found to suppress germination in turf grass seeds more than concomitant concentrations of sodium and magnesium chloride.

The deicing chemicals with the greatest germination suppression all contain a salt base of $MgCl_2$, while Caliber M-1000, Caliber M-2000, and Ice ban contain silage-derived anti-corrosives. The solutes in these additives may have contributed to higher osmotic inhibition in seeds leading to an increased suppression of germination, because seeds in the equivalent salt concentration of reagent grade $MgCl_2$ solution germinated at significantly higher percentages than all deicers tested, except Sand/Salt. Additionally, it is possible that toxic effects from unknown proprietary chemicals are occurring. This idea is further supported by the significant interaction between deicer type and concentration level ($F = 27.57$, $p < 0.0001$). Sand/Salt and reagent grade $MgCl_2$ had substantially higher germination percentages at the 10% concentration level than any other tested deicers.

Although seeds exposed to Ice Slicer and NC-3000 had relatively higher germination percentages, these deicers were not significantly different from the others tested or reagent grade $MgCl_2$, again with the exception of Sand/Salt. Seeds exposed to Sand/Salt had significantly higher germination than any other salts tested, as would be expected considering the lower level of salinity of the deicer.

The interaction of species and deicer type proved significant ($F = 3.35$, $p = 0.0003$). *P. smithii* exhibited a relatively greater tolerance to reagent grade $MgCl_2$, while *F. idahoensis* demonstrated a noteworthy sensitivity to Caliber M-1000, Caliber M-2000, and CDOT $MgCl_2$ (FreezGard). The interaction of species and concentration also proved significant ($F = 10.9$, $p < 0.0001$). *F. idahoensis* demonstrated a substantial comparative decrease in germination at the 1% deicer concentration level.

The significant interaction between deicer type and concentration level ($F = 27.57$, $p < 0.0001$) further isolated the deicers with the greatest effect on germination. Germination percentages at the 1% deicer concentration level differed from distilled water for Ice Ban, Caliber M-1000, $MgCL_2$ CDOT, and Caliber M-2000.

Finally, a significant three-way interaction occurred between species, deicer type, and concentration level ($F = 4.08$, $p < 0.0001$). *P. smithii* was relatively more resistant to a 1% reagent grade solution of $MgCl_2$, *S. viridula* was relatively strongly impacted by 1% solutions of Ice Ban, *F. idahoensis* and *S. viridula* exhibited relatively depressed germination in 1% Caliber M-1000 compared to *P. smithii*, and germination of *F. idahoensis* was highly impacted by 1% solutions of Caliber M-1000, Caliber M-2000, and CDOT $MgCl_2$ (Freezgard). Analyses of 10% solutions demonstrate that *P. smithii* has relatively higher rates of germination in 10% reagent grade $MgCl_2$ and NC-3000 than *F. idahoensis* or *S. viridula*. These responses may be indicative of individual species salinity tolerances as well as tolerances to specific salt ion toxic effects.

Impacts of Deicing Chemical Type and Concentration Level on Germination Percentages and Viability in Stipa viridula: Overall, deicer type, concentration level, and the interaction of deicer type and concentration level significantly affected germination and viability in *S. viridula* ($p < 0.0001$). The analysis of germination and viability in *S. viridula* supported the germination results of the first germination only analysis, with the exception of germination across deicer concentration levels. Mean germination of *S. viridula* in distilled water ($\bar{x} = 83.167$) did not differ significantly from 1% deicer solutions ($\bar{x} = 77.438$), indicating a greater capacity for salt tolerance during germination.

Surprisingly, non-viable seeds did not correlate with increasing deicer concentration but instead were only significantly higher at the intermediate or 10% deicer concentration level. This suggests that germination suppression by deicers is not a function of toxicity, but is due instead to osmotic inhibition. However, in this case, a confounding factor of fungal contamination may explain these results. Germination trays of *S. viridula* developed fungal growth mid-way through the germination cycle, with the exception of seeds in the 100% deicing solution. This growth, however, did not impact seed viability in the distilled water or the 1% deicer solutions. We hypothesize that the osmotic concentration of 10% deicer solutions prevented seed germination but did not prevent fungal growth as was observed in the full strength deicer solutions. Seeds in this concentration level, unable to imbibe and begin the metabolic processes of germination, became vulnerable to fungal parasitism. During embryo evaluation for viability, most non-viable seeds displayed evidence of fungal contamination. This occurrence may provide an interesting corollary for seeds in natural environments. If seeds are prevented from germination in saline soils, it is possible that they may become susceptible to salt tolerant fungal pathogens.

Only Ice Slicer and Sand/Salt differed significantly with increased percentages of non-viable seeds from those observed in distilled water, although they did not differ significantly from the other tested deicers. Once again, fungal contamination was clearly evident in the Sand/Salt concentrations and is the likely culprit for embryo damage. In the Ice Slicer concentrations the fungal presence was much more tenuous, and a toxic ion response of *S. viridula* to the deicer is possible.

Higher percentages of non-viable seeds were seen in reagent grade $MgCl_2$ and Sand/Salt at the 100% level than for any other tested deicers. An increase in non-viable seeds was also noted in reagent grade $MgCl_2$, NC-3000, Ice Slicer, and CDOT $MgCl_2$ (FreezGard), at the 10% deicer concentration level. Due to the aforementioned fungal contamination, speculation on the cause of this interaction remains tenuous, and the experiment would need to be repeated in order to elucidate these relationships.

Impact of Previous Deicer Type Exposure on Re-germination Percentages in Festuca idahoensis, Pascopyrum smithii, and Stipa viridula: Information on germination recovery can clarify the source of germination suppression. If seeds are capable of "re-germination" than suppression is largely a consequence of osmotic stress (Baji et al., 2002). If re-germination fails to occur, it is possible that a toxic ion effect has disrupted the integrity of the seed (Al-Ansari, 2003). "Re-germination" percentages in rinsed seeds of *F. idahoensis*, *P. smithii*, and *S. viridula* previously exposed to full roadbed application strengths (100%) of deicers were compared across species and previous deicer type exposure. Seed germination recovery was found to be a function of species and previous deicer type exposure ($F= 27.65$, $p > 0 .0001$). Seeds previously exposed to $MgCl_2$ deicer (FreezGard) and Caliber M-1000 underwent full germination recovery, being statistically the same as seeds exposed only to distilled water. Seeds previously exposed to Caliber M-2000, Ice Ban, reagent grade $MgCl_2$, and Sand/Salt had a significantly lower germination percentage than seeds exposed only to distilled water. Seeds previously exposed to NC-3000 and Ice Slicer displayed the least amount of germination recovery. These data suggest that the suppression of seed germination by $MgCl_2$ deicer (FreezGard) and Caliber M-1000 is a function of osmotic inhibition, whereas germination suppression by other tested deicers may be more related to an associated toxicity.

Of the species tested, *P. smithii* exhibited the greatest percentage of germination recovery $\bar{x}$ = 78.2%, followed by *S. viridula* $\bar{x}$ = 69.2% and *F. idahoensis* $\bar{x}$ = 52.5%. This relationship supports the initial conclusion of the germination data, that *P. smithii* also displays the greatest deicer tolerance, followed by *S. viridula* then F. *idahoensis*.

Salt tolerances and recovery varied by species and previous deicer type exposure (F = 12.55, $p < 0.0001$). *S. viridula* displayed relatively higher tolerance to Caliber M-1000, and a relatively higher tolerance of Ice Ban was observed in *P. smithii*. *P. smithii* and *S. viridula* also demonstrated notably more germination recovery than *F. idahoensis* after exposure to NC-3000 and Ice Slicer.

Impacts of $MgCl_2$ deicer (FreezGard) Concentration Levels on Germination Percentages in Gaillardia aristata, Hilaria jamesii, Elymus trachycaulus, Bromus marginatus, Bouteloua gracilis, Picea engelmannii, Rudbeckia hirta, Pinus ponderosa, and Chrysothamnus nauseosus: Germination was found to vary significantly (F = 80.50, $p > 0 .0001$) by deicer concentration level as well as by species. In all cases, as deicer concentration increased, germination decreased. No germination occurred in seeds exposed to $MgCl_2$ deicer (FreezGard) at 100% or 10% of full roadbed application strength. Seeds of the assessed plant species germinated at a significantly reduced rate in the 1% deicer solution ($\bar{x}$ =67.083) compared to distilled water ($\bar{x}$ = 84.125). These results suggest that even highly dilute environmental exposures of $MgCl_2$ deicer is enough to suppress germination in the glycophytic species evaluated.

Native species displayed significant variability in their tolerance to salinity during germination. Seeds of *P. engelmannii*, *E. trachycaulus*, *R hirta*, *F. idahoensis*, and *G. aristata* were prominently more sensitive to the deicer than other seeds tested, and germinated at reduced rates even in 1% CDOT $MgCl_2$ (FreezGard). For additional clarity, germination percentage differences were compared between seeds in distilled water and seeds in 1% deicer solution. For seeds of *Bromus marginatus*, *Pinus ponderosa*, and *Hilaria jamesii*, germination was not significantly different in 1% deicer solution (Table 49.). For the other species evaluated germination declined significantly and progressively in *Pascopyrum smithii*, *Stipa viridula*, *Bouteloua gracilis*, *Chrysothamnus nauseosus*, *Picea engelmannii*, *Gaillardia aristata*, *Rudbeckia hirta*, *Festuca idahoensis*, and *Elymus trachycaulus* (Table 49.).

Table 49. Germination percentage difference between seeds of tested species in distilled water and 1% $MgCl_2$ deicer (FreezGard) solution. * denotes a difference that exceeds the standard error.

Species	Percent Germination Change
Bromus marginatus	+ 1.5
Pinus ponderosa	+1
Hilaria jamesii	-0.5
Pascopyrum smithii	-4*
Stipa viridula	-4.5*
Bouteloua gracilis	-5*
Chrysothamnus nauseosus	-8*
Picea engelmannii	-10.5*
Gaillardia aristata	-27.5*
Rudbeckia hirta	-43.5*
Festuca idahoensis	-49*
Elymus trachycaulus	-54.5*

Bromus marginatus is reported to be tolerant of fair salinity levels (Wasser, 1982), and this would also seem to hold true for germination. *Hilaria jamesii* is an important component of desert grasslands and pinyon-juniper woodlands. These environments often contain saline soil and water conditions, and *Hilaria jamesii* would seem to be tolerant of $MgCl_2$ deicer during germination *Pinus ponderosa*, although tolerant of moderately acid and basic soils, is not tolerant of saline or sodic soils (Wasser, 1982). Although germination is readily suppressed in *P. ponderosa* by deicers, the species demonstrated full germination recovery when removed from a saline environment (Table 49.).

Of species heavily impacted by $MgCl_2$ deicer (FreezGard), *Picea engelmannii* is known to be intolerant of saline soils (Wasser, 1982). *Festuca idahoensis*, although tolerant of weakly saline, alkaline, and acid soils was heavily impacted by $MgCl_2$ deicer with germination reduced by 49% in a 1% solution. Although reportedly of moderate salt tolerance (Wasser, 1982), *Elymus trachycaulus* experienced the most $MgCl_2$ deicer germination suppression (54.5%). Germination *Gaillardia aristata* and *Rudbeckia hirta* also were heavily impacted by $MgCl_2$ deicer. Thus, these species may not be the best choice for re-vegetation where $MgCl_2$ contamination is of concern.

Impacts of $MgCl_2$ Deicer (FreezGard) Concentration Levels on Germination Percentages and Viability in Gaillardia aristata, Elymus trachycaulus, Bromus marginatus, Bouteloua gracilis, Picea engelmannii, and Stipa viridula: Germination and viability were examined in six of the above plant species demonstrating a range of germination tolerance to $MgCl_2$: *Gaillardia aristata, Elymus trachycaulus, Bromus marginatus, Bouteloua gracilis, Picea engelmannii,* and *Stipa viridula*. Overall, species, concentration level, and the interaction of species and concentration level were found to significantly affect germination and viability in the six species ($p < 0.0001$).

Mean germination percentage of seeds in distilled water ($\bar{x} = 87.9$) remained significantly different than for seeds in the 1% deicer solution ($\bar{x} = 71.2$). *Bromus marginatus* and *Bouteloua gracilis* maintained higher overall mean germination percentages, followed by *Picea engelmannii*, *Stipa viridula*, *Elymus trachycaulus* and

Gaillardia aristata. Again, mean species germination in 0% and 1% $MgCl_2$ deicer solutions indicate that germination is relatively depressed in *P. engelmannii* and severely depressed in 1% deicer solutions for *E. trachycaulus* and *G. aristata*.

As for the analysis with *S. viridula*, non-viable seeds overall did not correlate with increasing deicer concentration, but instead were most prominent in the 10% concentration level. This suggests that germination suppression by deicers is not a function of toxicity but is due instead to osmotic inhibition. However, once again fungal contamination proved a confounding factor in spite of anti-fungal treatments administered during the germination cycle. This renders interpretation of causes of non-viability suspect.

Two points are clear, however. In *G. aristata*, non-viable seeds increased as deicer concentration levels increased. This included the 100% deicer solution where no fungal growth was present, and indicates a potentially toxic reaction to the deicer. Additionally, in all cases non-viable seed percentages were lowest in seeds exposed to distilled water in spite of fungal growth. This suggests that deicer stress may synergistically act with environmental pathogens to impact seed viability.

Picea engelmannii was significantly different from the other species tested, having the most non-viable seeds ($\bar{x} = 32.0$). *Stipa viridula* demonstrated the least amount of non-viable seeds ($\bar{x} = 5.5$). The percentage of non- viable seeds was notably higher for *B. marginatus*, *B. gracilis*, and *P. engelmannii* in the 10% $MgCl_2$ deicer solution. *B. gracilis* and *E. trachycaulus* demonstrated an elevated number of non-viable seeds in 1% $MgCl_2$ deicer solution. The experiment should be repeated with better fungal control to elucidate the variation and causes of non-viability and species sensitivity to $MgCl_2$ deicer.

Overall, deicers clearly negatively impacted seed germination in these environmental chamber studies. The level of germination suppression varied significantly by species, deicer type, and concentration level. Even one hundred-fold dilutions of certain deicers were found to significantly depress germination in vulnerable species. Sand/salt, NC-3000, and Ice Slicer had the least impact on germinating species, while $MgCl_2$ based deicers including those with organic additives such as Ice Ban, Caliber M-1000, and M-2000 had the greatest.

While deicer applications have the potential to negatively affect seedling recruitment in roadside populations of plants, species variation in salinity tolerance during germination should allow for the selection of more tolerant species in re-vegetation and roadside plantings where deicer impact is problematic. Timing also may be critical, as salinity in roadside environments varies by season and precipitation (Biesboer & Jacobson, 1994). Species that naturally germinate after dilution of environmental salinity through snowmelt and spring rains may be more successful in roadside environments.

It is also interesting to note that it has been well established that calcium significantly relieves salt stress in plants (Rengel, 1992, Suhayda et al., 1992; Kinraide, 1999). In plant cells, plasma membrane bound Ca^{2+} ions are thought to be displaced by other metal cations in salts, destroying membrane integrity and permeability (Cramer et al., 1985; Lynch et. al, 1987; Marschner, 1995). The addition of calcium is thought to assuage this displacement. It has been hypothesized that the reason magnesium chloride salts have been found to be more toxic to plants is due to the similar valence structure of the Mg^{2+} ion, which allows easily displacement of membrane bound Ca^{2+} ions (Tobe et. al, 2003; Hyder & Yasmin, 1972).

Calcium has been used to successfully alleviate germination suppression (Bliss et al., 1986; Hamada, 1984), and $CaCl_2$, a primary ingredient in certain deicers, has been successfully used in alleviating germination suppression and radicle damage by a variety of other salts (Tobe, et. al, 2003). It would be very interesting to compare the effect of a calcium chloride based deicer on germination and viability in plant species. Remediation of soils with gypsum ($CaSO_4$) also has been shown to alleviate germination salinity stress (Myers & Morgan, 1989; Neid & Biesboer, 2004) and may provide a practical solution in roadside areas impacted by deicer salinity.

OBJECTIVE FOUR: EVIDENCE OF DROUGHT STRESS AND DEICER EFFECTS IN COLORADO ROADSIDE CONIFERS

Introduction

In order to establish whether drought stress accounts for foliar injury in Colorado roadside conifers, assessment of pre-dawn leaf water status was undertaken across the eight field study sites to determine if leaves failed to recover from diurnal water stress. At each field site, five conifers along the roadside, and five conifers of equivalent trunk diameter and stand structure away from the roadside, were evaluated for needle tissue water potentials (ψ_w). One round of measurements within designated plots took place during the deicing season or soon after in winter/spring of 2004, and a second round followed prior to the deicing season in the subsequent late summer and fall of 2004. Leaf water potentials were recorded in conjunction with leaf-level gas exchange measurements.

Methods

Measurements were carried out using fully expanded current year needle fascicles detached from branches in the lower third of the canopy, on which leaf-level gas exchange assessments were being made. Three needles from separate fascicles on each tree were sampled, and immediately placed in a sealed plastic bag to minimized water loss. Samples were evaluated on site and as soon as possible after detachment. Measurements were performed before sunrise, between 0100 to 0430 hours. Leaf water potential (ψ_w) in Mega Pascals (Mpa) was evaluated using a Scholander-type pressure chamber, the 3000 series plant water status console, Soilmoisture Equipment Corporation, Goleta, CA.

Statistical analysis of all data utilized SAS version 8.1, SAS Institute Inc., Cary, NC, USA. Differences in leaf water potentials (ψ_w) between roadside and control (off-roadside) conifers were assessed using a site by exposure factorial ANOVA. Significant relationships ($p < 0.05$) were evaluated through Bonferroni post hoc comparisons with significance levels (α) of 0.05. Pearson correlation coefficients were calculated to find relationships between leaf water potentials, salt presence, foliage health and physiology variables, and distance of conifers from the roadside.

Results

Average leaf tissue water potentials in the late winter and spring did not differ appreciably between trees adjacent to and away from the roadside environment although site location differences were observed (Table 50.). Winter and spring leaf water potentials were analyzed via a site location by tree exposure (roadside vs. off-road) factorial ANOVA. This model significantly ($F = 7.60$, $p < 0 .0001$) explained leaf tissue water potentials as a function of site location ($F = 14.88$, $p < 0.0001$). The model was also robust, explaining 64% of the observed variation ($R^2 = 0.640384$). Winter water potentials did not vary significantly between roadside and off-road trees or by the interaction of site location and exposure, however.

Table 50. Mean leaf water potential (ψ_w) in MPa and standard error in roadside and off- roadside conifers at eight field sites, winter and spring, 2004.

Site	Mean leaf water potential (MPa) ± SE	
	Roadside	Off-road
111D (I-70)	-1.58 ± 0.13	-1.83 ± 0.30
112H (I-70)	-1.72 ± 0.12	-2.22 ± 0.11
113H (I-70)	-1.94 ± 0.31	-1.67 ± 0.27
114D (I-70)	-1.14 ± 0.12	-1.49 ± 0.21
121H (Hwy 34)	-1.20 ± 0.07	-1.29 ± 0.09
122D (Hwy 34)	-1.25 ± 0.09	-1.32 ± 0.09
131H (Metro Denver)	-0.59 ± 0.04	-0.58 ± 0.02
132D (Metro Denver)	-1.10 ± 0.06	-1.11 ± 0.16

According to Bonferroni post hoc t-tests, more negative leaf tissue water potentials were found along the I-70 corridor, with the worst drought stress observed at sites 112H and

113H (Table 51.). Lower levels of drought stress were observed at the Hwy 36 sites 121H and 122D, while the least drought stress was seen in the Denver metro sites 131H and 132D (Table 51.). In general, sites with ponderosa pine (*P. ponderosa*) trees (Denver and Hwy 36) exhibited less negative overall leaf tissue water potentials.

Table 51. Bonferroni post hoc grouping for winter leaf water potentials (MPa) across site locations (α = 0.05, n = 10). Means with the same letter are not significantly different.

Bonferroni Grouping			Mean ψ_w (MPa)	Site ID
	A		-1.97	112H (I-70)
B	A		-1.81	113H (I-70)
B	A	C	-1.70	111D (I-70)
B	D	C	-1.31	114D (I-70)
B	D	C	-1.28	122D (Hwy 36)
	D	C	-1.25	121H (Hwy 36)
E	D		-1.10	132D (Denver)
E			-0.58	131H (Denver)

Late summer and early fall leaf water potentials were analyzed via a site location by tree exposure (roadside vs. off-road) factorial ANOVA. This model significantly ($F = 10.87$, $p < 0 .0001$) explained leaf tissue water potentials as a function of site location ($F = 21.69$, $p < 0.0001$). The model was also robust, explaining 72% of the observed variation ($R^2 = 0.718061$). As seen over the winter months, leaf tissue water potentials did not vary significantly between roadside and off-road trees or by the interaction of site location and exposure.

According to Bonferroni post hoc t-tests, water stress over the growing season was in general higher along the I-70 corridor at sites 111D and 112H. The least amount of drought stress was observed at sites 121H and 122D along Hwy 36, with the Denver metro sites falling in between (Table 53.). Consistent with winter measurements, sites with ponderosa pine (*P. ponderosa*) trees exhibited less negative average needle water potentials on the whole.

Table 52. Mean leaf water potential (ψ_w) in MPa and standard error in roadside and off- roadside conifers at eight field sites, summer and fall, 2004.

Site	Mean leaf water potential (MPa) ± SE Roadside	Off-road
111D (I-70)	-1.81 ± 0.10	2.03 ± 0.10
112H (I-70)	-1.57 ± 0.15	1.70 ± 0.08
113H (I-70)	-1.63 ± 0.10	1.28 ± 0.14
114D (I-70)	-0.96 ± 0.12	1.05 ± 0.10
121H (Hwy 34)	-0.83 ± 0.01	0.83 ± 0.07
122D (Hwy 34)	-0.76 ± 0.06	0.66 ± 0.02
131H (Metro Denver)	-1.11 ± 0.21	1.31 ± 0.18
132D (Metro Denver)	-1.21 ± 0.15	1.53 ± 0.20

Table 53. Bonferroni post hoc grouping for winter leaf water potentials (MPa) across site locations ($\alpha = 0.05$, n = 10). Means with the same letter are not significantly different.

Bonferroni Grouping			Mean ψ_w (MPa)	Site ID
	A		-1.92	111D (I-70)
B	A		-1.63	112H (I-70)
B	C		-1.46	113H (I-70)
B	C	D	-1.37	132D (Denver)
E	C	D	-1.21	131H (Denver)
E	F	D	-1.01	114D (I-70)
E	F		-0.83	121H (Hwy 36)
	F		-0.71	122D (Hwy 36)

Neither winter and spring or summer and fall needle tissue water potentials significantly correlated with any measure of observed foliar injury, or with tree distance from the roadbed. Summer and fall needle tissue water potentials also did not significantly correlate with presence of salt ions in soils or plant tissues. However, summer and fall water potentials correlated significantly but weakly with years of needle growth retained by the tree ($R^2 = 0.111$, $p < 0.01$), and negatively but weakly with leaf-level photosynthesis rates ($R^2 = 0.113$, $p < 0.01$).

Conclusions

Drought stress in the roadside environment could not be linked to foliage injury in Colorado roadside conifers. No significant differences were observed in water stress between trees adjacent to roadside or distant from the roadside in either the winter or throughout the growing season. Although roadside trees may experience higher levels of insolation due to vegetative cover loss, these results indicate that water stress is not directly contributing to tissue death in roadside vegetation. While significant differences were seen in water stress by site location, water stress failed to significantly correlate with distance from the roadside or any measure of foliar injury. Leaf tissue pre-dawn water potentials also did not correlate with measures of salt exposure, although some evidence of reduced leaf xylem potentials has been noted with exposure to root zone NaCl (Mickelbart & Marler, 1996).

The more negative pre-dawn leaf tissue water potentials reported for I-70 sites is likely a product of the physiology of lodgepole pine (*P. contorta*) as the dominant tree species. In general, ponderosa pines have been known to demonstrate less negative water pre-dawn leaf tissue potentials than lodgepole pines (Korol, 2001).

Ultimately, levels of precipitation and weather conditions over time definitively influence deicer impact and tree foliage health (Simini & Leone, 1982; Viskari & Karenlampi, 2000). Seasonal drought stress may exacerbate salt symptoms and foliar injury in trees by increasing soil osmotic stress or ion penetration into plant tissues. Salt levels in roadside soils can be ameliorated by high levels of precipitation and correspondingly aggravated by a decrease in precipitation (Jones et al, 1992; Environment Canada, 2000).

Future research might monitor patterns of foliar injury, annual precipitation, temperature fluctuation, and salt accumulation in roadside conifers to determine the extent of this interaction.

OBJECTIVE FIVE: EVALUATION OF OTHER FACTORS POTENTIALLY DELETERIOUS TO ROADSIDE VEGETATION INCLUDING: NUTRIENT AVAILABILITY, POLLUTION, DISEASE, AND INSECT IMPACTS

Introduction

Roadside vegetation may be exposed to a variety of biotic and abiotic stresses that can impact plant health. An assessment of the presence and potential impacts of nutrient deficiencies, pollution, disease, insects, and abiotic damage was carried out at each field study site to provide further insight into the causes of foliar injury.

In the summer and fall of 2004, pine needle tissue, twig tissue and soil 1m from the base of the study site trees were analyzed for nutrient deficiencies through levels of nitrogen (TKN), calcium (Ca), potassium (K), phosphorus (P), and total organic carbon (TOC). Levels of soil organic matter were also evaluated. Pollutant exposure was assessed through the presence of the heavy metals silver (Ag), cadmium (Cd), chromium (Cr), copper (Cu), nickel (Ni), lead (Pb), and zinc (Zn). Pollutant exposure was also evaluated through the presence of sulfur (S) in plant tissues, sulfate (SO_4-S) in soils, and through overall nitrogen exposure (TKN). Although the erosion of needle epicuticular waxes has been associated with exposure to air pollutants (Turunen & Huttunen, 1990; Grodzinska-Jurczak & Szarek-Lukaszewska, 1999), degradation of waxes was not investigated due to the prevalence of needle surface deposits on roadside trees. Finally, study site trees were appraised for the presence and severity of disease, as well as insect, animal, and abiotic damage.

Evidence of biotic and abiotic plant stress factors was compared between roadside and off-road environments at each study site. Data were then examined for significant correlations between these stress factors, overall crown necrosis, photosynthesis rates, presence of needle surface deposits, and tree distance from the roadside.

Methods

Sampling: Needle tissue, twig tissue and soil samples were collected at each field study site from mid-September and early October 2004, prior to the beginning of deicing applications. Samples were obtained from five pine trees adjacent to the roadside and five pine trees located off roadside at each individual site for a total of eighty trees. Three soil cores up to 12” deep were taken at random locations one meter from the trunk each tree and homogenized. Needle and twig tissue representative of overall current year and previous years foliage was recovered with a tree trimming head and separated into primary photosynthetic tissue (needles) and secondary lignified tissue (twigs).

Chemical Analyses: All chemical analyses were carried out by Weld Laboratories, Inc., Greeley, CO, USA. Soil total organic carbon was assessed via the Rather method, soil organic matter via the Walkley-Black method, and total nitrogen by the Kjeldahl method in *Methods of Soil Analysis*; A.L. Page, et al., 1982. Soil phosphorus levels were evaluated via Olson’s Bicarb method, soil sulfate turbidimetrically, and soil calcium and potassium content were quantified using exchangeable atomic emission methods also as described in *Methods of Soil Analysis*; A.L. Page, et al., 1982.

Soil heavy metals were evaluated through atomic absorption methods for silver (7760), cadmium (7130), chromium (7190), copper (7210), nickel (7520), lead (7420), and zinc (7950) as described in the EPA publication SW-846, 3rd edition, *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods*.

Total organic carbon in needle and twig tissues was evaluated via the Rather method in *Methods of Soil Analysis*; A.L. Page, et al., 1982. Plant tissue nitrogen content was quantified by the Kjeldahl method 978.04, tissue potassium content by atomic emission method 3.2.05, and tissue phosphorus photometrically (4.8.14) through methods outlined in *Official Methods of Analysis of AOAC International*; Dr. William Horwitz, editor; 17^{th}

Ed., 2000. Plant tissue calcium levels were measured by the atomic absorption method 3.2.05 described in the same volume, as were the metals silver, cadmium, chromium, copper, nickel, lead, and zinc.

Assessment of Disease, Insect, Animal, and Abiotic Damages: Sites were examined in October of 2004 by independent evaluator Dr. William R. Jacobi, a professor and tree pathologist at Colorado State University. At each site, study trees were assessed for common Colorado conifer diseases including dwarf mistletoes, fungal needle casts, *Elytroderma* needle disease, western gall rust, stem and branch internal decay, and root diseases such as *Armillaria*. Trees also were examined for animal related damage such as gnawing by rodents or deer/elk. Insect assessments included evaluation of any injury related to needle miners, bark beetles such as Ips and the mountain pine beetle, wood boring insects, bark aphids, twig beetles, and pine needle scale. Finally, an appraisal of damage from abiotic sources such as frost, snow breakage, drought, and chemical damage was undertaken at each study site.

Statistical analysis of all data utilized SAS version 8.1, SAS Institute Inc., Cary, NC, USA. Differences in plant stress factors in plant tissues and soils were evaluated between roadside and off-road conifers across sites via site location by exposure factorial ANOVAs for each analyte. Significant relationships ($p < 0.05$) were evaluated through Bonferroni post hoc comparisons with significance levels (α) of 0.05. Pearson correlation coefficients were then calculated to find relationships between stress factors, overall crown necrosis, photosynthesis rates, presence of needle surface deposits, and distance from the roadside.

Results

Nutrient Availability: Overall, roadside soils exhibited significantly lower levels of total nitrogen, organic matter, total organic carbon, potassium, calcium, and phosphorus than soils away from the roadside environment. In conifer needle tissue however, only total organic carbon was significantly lower in roadside trees compared to their off-road counterparts. Roadside conifer needle tissue also demonstrated higher levels of total nitrogen and phosphorus than trees away from the roadbed.

Between site differences in nutrient availability were readily observable. In general, levels of soil potassium, phosphorus and calcium tended to be higher at sites 131H and 132D in the Denver metro area. These Denver sites and sites 122D and 121H along Hwy 36 also exhibited greater levels of soil nitrogen, soil organic matter, and twig calcium than sites along the I-70 corridor. In contrast, needle and twig total organic carbon content was depressed in Denver metro sites relative to the other sites tested.

On the whole, soil total organic carbon was relatively higher at sites along Hwy 36, while soil total organic carbon and organic matter were uniquely higher at site 113H along I-70. Needle and twig potassium, needle calcium, and needle and twig phosphorus levels were variable by site. However, site 111D demonstrated the lowest overall levels of needle and twig potassium and phosphorous, but the highest overall levels of needle calcium.

Tables 54., 56., 60., 64., 68., and 72. summarize soil, needle, and twig nitrogen, total organic carbon, potassium, calcium, and phosphorus content, as well as soil organic matter, by site location and tree exposure. Statistical analyses follow all data.

Total nitrogen content of conifer needle tissue, twig tissue and adjacent soils:

Table 54. Mean and standard error of percent nitrogen (TKN) content in needle tissue (N) and twig tissue (T), and nitrogen content in soils (S) in ppm, by tree exposure across study sites.

Site	Mean TKN content (%, ppm) ± SE	Exposure Roadside	Off-road
111D (I-70)	N	1.06 ± 0.05	0.82 ± 0.03
	T	0.27 ± 0.03	0.34 ± 0.08
	S	600.0 ± 26.3	336.0 ± 46.2
112H (I-70)	N	1.21 ± 0.06	1.01 ± 0.06
	T	0.34 ± 0.03	0.31 ± 0.02
	S	290.0 ± 31.5	196.0 ± 45.3
113H (I-70)	N	1.60 ± 0.36	1.00 ± 0.03
	T	0.32 ± 0.02	0.35 ± 0.01
	S	212.0 ± 20.6	2888.0 ± 588.9
114D (I-70)	N	1.05 ± 0.05	0.94 ± 0.02
	T	0.37 ± 0.01	0.33 ± 0.01
	S	252.0 ± 54.1	788.0 ± 33.5
121H (Hwy 36)	N	1.11 ± 0.07	1.03 ± 0.05
	T	0.41 ± 0.01	0.36 ± 0.07
	S	860.0 ± 137.2	1604.0 ± 86.5
122D (Hwy 36)	N	1.15 ± 0.10	0.93 ± 0.03
	T	0.36 ± 0.03	0.36 ± 0.01
	S	954.0 ± 133. 4	1308.0 ± 470.9
131H (metro Denver)	N	1.09 ± 0.07	0.92 ± 0.03
	T	0.45 ± 0.05	0.45 ± 0.08
	S	774.0 ± 209.7	972.0 ± 479.8
132D (metro Denver)	N	1.09 ± 0.05	1.05 ± 0.09
	T	0.34 ± 0.02	0.31 ± 0.06
	S	610.0 ± 129.1	1290.0 ± 155.9

Total Kjeldahl nitrogen content of conifer needle tissue was analyzed with a site location by tree exposure factorial ANOVA. This model significantly ($F = 2.68$, $p < 0.01$) explained variation in needle nitrogen levels as a function of tree exposure ($F = 15.46$, $p < 0.001$). The model explained 39% of the observed variation ($R^2 = 0.386142$). Overall, nitrogen content in needle tissue was significantly elevated in roadside trees ($\bar{x}$ = 1.17%) compared to trees away from the roadbed ($\bar{x}$ = 0.96%). No significant differences were observed in twig total nitrogen levels by site location or tree exposure.

Total Kjeldahl nitrogen soil content was also analyzed with a site location by tree exposure factorial ANOVA. This model significantly ($F = 8.01$, $p < 0 .0001$) explained variation in soil nitrogen as a function of site location ($F = 6.55$, $p < 0.0001$), tree exposure ($F = 24.87$, $p < 0.0001$), and the interaction of site and exposure ($F = 7.05$, $p < 0.0001$). The model explained 65% of the observed variation ($R^2 = 0.652423$).

Total soil nitrogen levels were generally elevated at sites along Hwy 36 and in Denver compared to I-70 sites with the notable exception of site 113H (Table 55.). Total soil nitrogen also was significantly higher in soils distant from the roadbed ($\bar{x}$ = 1172.8ppm) than soils adjacent to the road ($\bar{x}$ = 569.0ppm). Graphical analyses of the interaction of site and exposure revealed significantly higher levels of soil nitrogen distant from the roadbed at sites 113H, 114D, 121H, and 132D and in roadside soil at site 111D (Table 54.).

Table 55. Bonferroni post hoc comparison of soil total Kjeldahl nitrogen (TKN) levels by site location, n = 10. Means with the same letter are not statistically different.

Bonferroni grouping			Mean soil TKN (ppm)	Site
	A		1550.0	113H
B	A		1232.0	121H
B	A		1131.0	122D
B	A	C	950.0	132D
B	A	C	873.0	131H
B		C	520.0	114D
B		C	468.0	111D
		C	243.0	112H

Total organic carbon content of conifer needle tissue, twig tissue and adjacent soils:

Table 56. Mean and standard error of percent total organic carbon (TOC) content in needle tissue (N), twig tissue (T), and soils (S), by tree exposure across study sites.

Site	Mean TOC content (%) ± SE	Exposure Roadside	Off-road
111D (I-70)	N	50.00 ± 0.27	52.00 ± 0.22
	T	50.38 ± 0.68	51.76 ± 0.47
	S	0.65 ± 0.07	0.50 ± 0.05
112H (I-70)	N	50.94 ± 0.36	51.40 ± 0.48
	T	51.74 ± 0.33	50.88 ± 0.49
	S	0.88 ± 0.05	0.57 ± 0.05
113H (I-70)	N	50.86 ± 0.52	52.62 ± 0.78
	T	53.60 ± 0.73	53.10 ± 0.67
	S	0.61 ± 0.08	12.07 ± 1.70
114D (I-70)	N	50.60 ± 0.52	51.70 ± 0.32
	T	51.32 ± 0.57	50.88 ± 0.49
	S	0.79 ± 0.33	2.19 ± 0.33
121H (Hwy 36)	N	50.76 ± 0.80	49.94 ± 0.60
	T	51.64 ± 0.48	51.34 ± 0.45
	S	2.23 ± 0.34	2.86 ± 0.23
122D (Hwy 36)	N	50.66 ± 0.53	50.88 ± 0.35
	T	52.10 ± 0.41	51.84 ± 0.77
	S	2.90 ± 0.37	3.17 ± 1.14
131H (metro Denver)	N	50.90 ± 0.29	50.30 ± 0.98
	T	50.92 ± 0.56	49.56 ± 0.66
	S	1.90 ± 0.10	2.15 ± 0.34
132D (metro Denver)	N	48.24 ± 1.09	50.30 ± 0.45
	T	50.14 ± 0.87	51.44 ± 0.06
	S	1.10 ± 0.20	1.69 ± 0.17

Total percentage of needle organic carbon was analyzed with a site location by tree exposure (roadside or off-road) factorial ANOVA. This model significantly ($F = 2.77$, $p < 0.01$) explained variation in needle carbon levels as a function of site location ($F = 3.09$, $p < 0.01$) and tree exposure ($F = 6.98$, $p < 0.05$). The model explained 39% of the observed variation ($R^2 = 0.393505$).

In general, needle total organic carbon levels were higher at sites with lodgepole pines along the I-70 corridor than sites with ponderosa pines along Hwy 36 and in metro Denver (Table 57.). Needle total organic carbon was significantly higher in trees away from the roadbed ($\bar{x}$ = 51.15%) compared to trees adjacent to the road ($\bar{x}$ = 50.37%).

Table 57. Bonferroni post hoc comparison of average percent total needle organic carbon content by site location, n = 10. Means with the same letter are not statistically different.

Bonferroni grouping		Mean needle total organic carbon content (%)	Site
	A	51.74	113H
B	A	51.17	112H
B	A	51.15	114D
B	A	51.00	111D
B	A	50.77	122D
B	A	50.62	131H
B	A	50.35	121H
B		49.27	132D

Total twig organic carbon content was again analyzed with a site location by tree exposure (roadside or off-road) factorial ANOVA. This model also significantly (F = 3.08, p < 0 .001) explained variation in twig carbon levels as a function of site location (F = 5.16, p < 0.0001). The model explained 42% of the observed variation (R^2 = 0.419390). Overall, Denver metro sites 132D and 131H demonstrated the lowest averages of twig organic carbon (Table 58.).

Table 58. Bonferroni post hoc comparison of average percent twig organic carbon content by site location, n = 10. Means with the same letter are not statistically different.

Bonferroni grouping		Mean twig organic carbon content (%)	Site
	A	53.35	113H
B	A	51.97	122D
B	A	51.49	121H
B		51.31	112H
B		51.10	114D
B		51.07	111D
B		50.79	132D
B		50.24	131H

Percent soil total organic carbon content was analyzed with a site location by tree exposure (roadside or off-road) factorial ANOVA. This model significantly ($F = 25.00$, $p < 0 .0001$) explained variation in total soil organic carbon levels as a function of site location ($F = 22.27$, $p < 0.0001$), tree exposure ($F = 40.77$, $p< 0.0001$), and the interaction of site and exposure ($F = 25.49$, $p < 0.0001$). The model was robust, explaining 85% of the observed variation ($R^2 = 0.854223$).

As seen with soil organic matter, soil total organic carbon levels were significantly and uniquely higher at site 113H along the I-70 corridor, and generally higher along Hwy 36 than Denver metro and other I-70 sites (Table 59.). Soil total organic carbon was also significantly higher in soils distant from the roadbed ($\bar{x} = 3.15\%$) than soils adjacent to the road ($\bar{x} = 1.38\%$). Graphical analyses of the interaction of site and exposure revealed significantly higher levels of soil total organic carbon distant from the roadbed at sites 113H and 114D, and in roadside soil at site 112H (Table 56.).

Table 59. Bonferroni post hoc comparison of average percent soil organic carbon content by site location, n = 10. Means with the same letter are not statistically different.

Bonferroni grouping		Mean soil organic carbon content (%)	Site
	A	6.34	113H
	B	3.04	122D
	B	2.54	121H
C	B	2.02	131H
C	B	1.49	114D
C	B	1.40	132D
C		0.73	112H
C		0.58	111D

Potassium content of conifer needle tissue, twig tissue and adjacent soils:

Table 60. Mean and standard error of percent potassium (K) content in needle tissue (N) and twig tissue (T), and potassium content of soils (S) in ppm, by tree exposure across study sites.

Site	Mean K content (%, ppm) ± SE	Exposure	
		Roadside	Off-road
111D (I-70)	N	0.15 ± 0.01	0.12 ± 0.00
	T	0.05 ± 0.00	0.06 ± 0.00
	S	120.0 ± 9.3	157.4 ± 22.8
112H (I-70)	N	0.55 ± 0.03	0.56 ± 0.03
	T	0.33 ± 0.02	0.21 ± 0.02
	S	111.8 ± 7.4	129.0 ± 8.8
113H (I-70)	N	0.44 ± 0.10	0.32 ± 0.10
	T	0.25 ± 0.01	0.26 ± 0.01
	S	94.6 ± 7.3	279.0 ± 8.7
114D (I-70)	N	0.55 ± 0.05	0.49 ± 0.03
	T	0.25 ± 0.03	0.23 ± 0.00
	S	113.0 ± 4.8	225.6 ± 20.8
121H (Hwy 36)	N	0.13 ± 0.01	0.15 ± 0.01
	T	0.10 ± 0.02	0.07 ± 0.01
	S	197.4 ± 50.5	265.0 ± 23.5
122D (Hwy 36)	N	0.58 ± 0.04	0.50 ± 0.02
	T	0.24 ± 0.02	0.26 ± 0.01
	S	170.2 ± 25.7	148.6 ± 5.5
131H (metro Denver)	N	0.26 ± 0.09	0.16 ± 0.01
	T	0.14 ± 0.02	0.21 ± 0.10
	S	419.8 ± 33.8	358.0 ± 10.8
132D (metro Denver)	N	0.19 ± 0.08	0.16 ± 0.01
	T	0.07 ± 0.01	0.09 ± 0.01
	S	296.8 ± 56.2	322.4 ± 10.3

Percent needle potassium content was analyzed with a site location by tree exposure (roadside or off-road) factorial ANOVA. This model significantly ($F = 13.12$, $p < 0.0001$) explained variation in leaf potassium levels as a function of site location ($F = 27.14$, $p < 0.0001$). The model was also robust, explaining 75% of the observed variation

(R^2 = 0.754616). Needle potassium content was variable by site, with the highest levels seen at site 112H (I-70), and the lowest at site 111D (I-70) (Table 61.).

Table 61. Bonferroni post hoc comparison of percent needle potassium (K) content by site location, n = 10. Means with the same letter are not statistically different.

Bonferroni grouping		Mean needle K content (%)	Site
	A	0.55	112H
B	A	0.54	122D
B	A	0.52	114D
B		0.38	113H
	C	0.21	131H
	C	0.17	132D
	C	0.14	121H
	C	0.13	111D

Percent potassium content in twig tissues was analyzed with a site location by tree exposure (roadside or off-road) factorial ANOVA. This model significantly ($F = 8.72$, $p < 0.0001$) explained variation in shoot potassium levels as a function of site location ($F = 17.24$, $p < 0.0001$). The model explained 67% of the observed variation (R^2 = 0.671578). As with needle potassium levels, twig potassium content was variable by site, with the highest levels seen at site 112H (I-70), and the lowest at site 111D (I-70) (Table 62.).

Table 62. Bonferroni post hoc comparison of percent twig potassium (K) content by site location, n = 10. Means with the same letter are not statistically different.

Bonferroni grouping		Mean twig K content (%)	Site
	A	0.27	112H
B	A	0.25	113H
B	A	0.25	122D
B	A	0.24	114D
B	C	0.17	131H
D	C	0.08	121H
D	C	0.08	132D
D		0.06	111D

Soil potassium content in ppm was analyzed with a site location by tree exposure (roadside or off-road) factorial ANOVA. This model significantly ($F = 16.54$, $p < 0.0001$) explained variation in soil potassium levels as a function of site location ($F = 28.56$, $p < 0.0001$), tree exposure ($F = 13.61$, $p < 0.001$), and the interaction of site and exposure ($F = 4.93$, $p < 0.001$). The model was also robust, explaining 79% of the observed variation ($R^2 = 0.794928$).

Soil potassium levels were significantly and generally higher at site 132D and site 131H in the Denver metro area (Table 63.). Soil potassium was also significantly higher in soils distant from the roadbed ($\bar{x} =$ 235.7ppm) than soils adjacent to the road ($\bar{x} =$ 190.5ppm). Graphical analyses of the interaction of site and exposure revealed significantly higher levels of potassium in soil distant from the roadbed at sites 113H, and 114D along the I-70 corridor (Table 60.).

Table 63. Bonferroni post hoc comparison of soil potassium (K) content in ppm by site location, n = 10. Means with the same letter are not statistically different.

Bonferroni grouping		Mean soil K content (ppm)	Site
	A	388.9	131H
B	A	309.6	132D
B	C	231.5	121H
D	C	186.8	113H
D	C	169.3	114D
D	C	159.4	122D
D		138.7	111D
D		120.4	112H

Calcium content of conifer needle tissue, twig tissue and adjacent soils:

Table 64. Mean and standard error of percent calcium (Ca) content in needle tissue (N) and twig tissue (T), and Ca content in soils (S) in ppm, by tree exposure across study sites.

Site	Mean Ca content (% and ppm) ± SE	Exposure Roadside	Off-road
111D (I-70)	N	0.34 ± 0.07	0.49 ± 0.05
	T	0.10 ± 0.03	0.26 ± 0.16
	S	507.2 ± 71.7	892.0 ± 48.3
112H (I-70)	N	0.25 ± 0.06	0.22 ± 0.03
	T	0.21 ± 0.06	0.19 ± 0.06
	S	220.8 ± 17.5	401.8 ± 42.8
113H (I-70)	N	0.08 ± 0.04	0.25 ± 0.06
	T	0.07± 0.03	0.12 ± 0.04
	S	253.6 ± 38.9	2364.0 ± 555.7
114D (I-70)	N	0.24 ± 0.09	0.33 ± 0.09
	T	0.12 ± 0.04	0.19 ± 0.07
	S	208.8 ± 61.3	1255.0 ± 169.6
121H (Hwy 36)	N	0.31 ± 0.02	0.34 ± 0.09
	T	0.40 ± 0.04	0.57 ± 0.01
	S	1142.0 ± 113.9	1282.0 ± 59.7
122D (Hwy 36)	N	0.10 ± 0.05	0.21 ± 0.07
	T	0.21 ± 0.04	0.20 ± 0.06
	S	823.0 ± 128.7	894.0 ± 80.6
131H (metro Denver)	N	0.34 ± 0.06	0.28 ± 0.05
	T	0.45 ± 0.06	0.50 ± 0.05
	S	2010.0 ± 176.5	1977.0 ± 107.3
132D (metro Denver)	N	0.43 ± 0.10	0.26 ± 0.05
	T	0.69 ± 0.049	0.48 ± 0.03
	S	3350.0 ± 608.5	2742.0 ± 132.1

The percentage of calcium in conifer needle tissue was analyzed with a site location by tree exposure (roadside or off-road) factorial ANOVA. This model significantly ($F = 2.84$, $p < 0.01$) explained variation in needle calcium levels as a function of site location ($F = 4.19$, $p < 0.001$). The model explained 40% of the observed variation (R^2 =

0.399506). Needle calcium content was variable by site, with the highest levels seen at site 111D (I-70), and the lowest at site 122D (Hwy 36) (Table65.).

Table 65. Bonferroni post hoc comparison of percent needle calcium (Ca) content by site location, n = 10. Means with the same letter are not statistically different.

Bonferroni grouping		Mean needle Ca content (%)	Site
	A	0.42	111D
B	A	0.35	132D
B	A	0.33	121H
B	A	0.31	131H
B	A	0.28	114D
B	A	0.23	112H
B		0.16	113H
B		0.16	122D

Twig tissue calcium levels were analyzed with a site location by tree exposure (roadside or off-road) factorial ANOVA. This model significantly ($F = 10.17$, $p < 0.0001$) explained variation in twig calcium levels as a function of site location ($F = 19.56$, $p < 0.0001$). The model explained 70% of the observed variation ($R^2 = 0.704428$). Overall, twig calcium content was higher in the Denver metro and Hwy 36 sites compared to sites along the I-70 corridor (Table 66.).

Table 66. Bonferroni post hoc comparison of percent twig calcium (Ca) content by site location, n = 10. Means with the same letter are not statistically different.

Bonferroni grouping	Mean twig Ca content (%)	Site
A	0.59	132D
A	0.48	121H
A	0.47	131H
B	0.20	122D
B	0.20	112H
B	0.18	111D
B	0.15	114D
B	0.10	113H

Soil calcium content in ppm was analyzed with a site location by tree exposure (roadside or off-road) factorial ANOVA. This model significantly ($F = 17.94$, $p < 0.0001$) explained variation in soil calcium levels as a function of site location ($F = 29.94$, $p < 0.0001$), tree exposure ($F = 13.18$, $p < 0.001$), and the interaction of site and exposure ($F = 6.63$, $p < 0.0001$). The model was also robust, explaining 81% of the observed variation ($R^2 = 0.807899$).

Soil calcium levels were significantly and generally higher at site 132D and site 131H in the Denver metro area, similar to levels of soil potassium (Table 67.). Soil calcium content was also significantly higher in soils distant from the roadbed ($\bar{x}$ = 1476.0ppm) than soils adjacent to the road ($\bar{x}$ = 1064.4ppm). Graphical analyses of the interaction of site and exposure revealed significantly higher levels of calcium in soil distant from the roadbed at all sites along the I-70 corridor: 111D, 112H, 113H, and 114D (Table 64.).

Table 67. Bonferroni post hoc comparison of soil calcium (Ca) content in ppm by site location, n = 10. Means with the same letter are not statistically different.

Bonferroni grouping		Mean soil Ca content (ppm)	Site
	A	3046.0	132D
	B	1993.5	131H
C	B	1308.8	113H
C		1212.0	121H
C	D	858.5	122D
C	D	731.9	114D
C	D	699.6	111D
	D	311.3	112H

Phosphorus content of conifer needle tissue, twig tissue and adjacent soils:

Table 68. Mean and standard error of percent phosphorus (P) content in needle tissue (N) and twig tissue (T), and phosphorus content in soils (S) in ppm, by tree exposure across study sites.

Site	**Mean P content (%, ppm) ± SE**	**Exposure** Roadside	Off-road
111D (I-70)	N	0.14 ± 0.00	0.13 ± 0.00
	T	0.10 ± 0.00	0.10 ± 0.00
	S	3.98 ± 0.49	5.78 ± 0.87
112H (I-70)	N	0.14 ± 0.00	0.14 ± 0.00
	T	0.12 ± 0.01	0.11 ± 0.00
	S	5.14 ± 0.32	9.12 ± 1.22
113H (I-70)	N	0.16 ± 0.00	0.13 ± 0.00
	T	0.11 ± 0.00	0.11 ± 0.00
	S	6.30 ± 0.67	13.40 ± 2.20
114D (I-70)	N	0.14 ± 0.00	0.14 ± 0.00
	T	0.11 ± 0.00	0.11 ± 0.00
	S	4.46 ± 0.62	26.96 ± 3.71
121H (Hwy 36)	N	0.14 ± 0.01	0.13 ± 0.00
	T	0.11 ± 0.00	0.11 ± 0.00
	S	30.82 ± 20.33	15.86 ± 3.67
122D (Hwy 36)	N	0.15 ± 0.01	0.13 ± 0.00
	T	0.10 ± 0.00	0.11 ± 0.00
	S	13.40 ± 1.92	8.76 ± 0.90
131H (metro Denver)	N	0.14 ± 0.01	0.13 ± 0.00
	T	0.11 ± 0.00	0.12 ± 0.01
	S	53.40 ± 16.40	87.58 ± 12.61
132D (metro Denver)	N	0.14 ± 0.01	0.13 ± 0.00
	T	0.11 ± 0.00	0.11 ± 0.00
	S	27.16 ± 10.65	80.92 ± 23.45

Needle tissue phosphorus percentage was analyzed with a site location by tree exposure (roadside or off-road) factorial ANOVA. This model significantly ($F = 3.47$, $p < 0.001$) explained variation in needle phosphorus as a function of site location ($F = 2.33$, $p <$

0.05) and tree exposure (F = 24.22, $p < 0.05$). The model explained 45% of the observed variation ($R^2 = 0.448524$).

Needle phosphorus levels were significantly higher at site 113H (I-70) than site 111D (I-70), with other sites sharing significance in between (Table 69.). Needle phosphorus also was significantly higher in trees near the roadbed ($\bar{x}$ = 0.143%) than trees distant from the road ($\bar{x}$ = 0.133%).

Table 69. Bonferroni post hoc comparison of percent needle phosphorus (P) by site location, n = 10. Means with the same letter are not statistically different.

Bonferroni grouping		Mean needle P content (%)	Site
	A	0.144	113H
B	A	0.141	112H
B	A	0.140	122D
B	A	0.138	114D
B	A	0.137	131H
B	A	0.137	121H
B	A	0.133	132D
B		0.131	111D

Percent twig tissue phosphorus content was analyzed with a site location by tree exposure (roadside or off-road) factorial ANOVA. This model significantly (F = 3.15, $p < 0.001$) explained variation in twig phosphorus levels as a function of site location (F = 5.55, $p < 0.0001$). The model explained 42% of the observed variation ($R^2 = 0.424779$).

Twig phosphorus levels were variable between sites, with the highest levels found at site 131H (Denver) and the lowest at site 111D (I-70) (Table 70.).

Table 70. Bonferroni post hoc comparison of percent twig phosphorus (P) by site location, n = 10. Means with the same letter are not statistically different.

Bonferroni grouping		Mean twig P content (%)	Site
	A	0.114	131H
	A	0.114	112H
	A	0.110	121H
	A	0.109	113H
B	A	0.108	132D
B	A	0.106	114D
B	A	0.106	122D
B		0.101	111D

Soil phosphorus content in ppm was analyzed with a site location by tree exposure (roadside or off-road) factorial ANOVA. This model significantly ($F = 7.41$, $p < 0.0001$) explained variation in soil phosphorus levels as a function of site location ($F = 12.27$, $p < 0.0001$), tree exposure ($F = 6.96$, $p< 0.05$), and the interaction of site and exposure ($F = 2.61$, $p < 0.05$). The model explained 63% of the observed variation ($R^2 = 0.634667$).

Soil phosphorus levels were significantly higher at sites 132D and site 131H in the Denver metro area (Table 71.). Soil phosphorus was also significantly higher in soils distant from the roadbed ($\bar{x}$ = 31.05ppm) than soils adjacent to the road ($\bar{x}$ = 18.08ppm). Graphical analyses of the interaction of site and exposure revealed significantly higher levels of phosphorus in soil distant from the roadbed at sites 112H, 113H, and 114D along the I-70 corridor (Table 68.).

Table 71. Bonferroni post hoc comparison of soil phosphorus (P) levels in ppm by site location, n = 10. Means with the same letter are not statistically different.

Bonferroni grouping		Mean soil P content (ppm)	Site
	A	70.49	131H
B	A	54.04	132D
B	C	23.34	121H
	C	15.71	114D
	C	11.08	122D
	C	9.85	113H
	C	7.13	112H
	C	4.88	111D

Total soil organic matter content:

Table 72. Mean and standard error of percent soil organic matter (SOM) content by tree exposure across study sites.

	Exposure	
Site	Roadside	Off-road
111D (I-70)	2.12 ± 0.09	1.62 ± 0.13
112H (I-70)	1.66 ± 0.08	1.15 ± 0.25
113H (I-70)	1.54 ± 0.311	20.08 ± 2.60
114D (I-70)	1.60 ± 0.62	3.68 ± 0.35
121H (Hwy 36)	3.65 ± 0.56	4.73 ± 0.33
122D (Hwy 36)	4.62 ± 0.77	5.97 ± 2.02
131H (Denver)	3.99 ± 0.23	4.11 ± 0.36
132D (Denver)	2.19 ± 0.35	4.26 ± 0.37

Soil organic matter content was analyzed with a site location by tree exposure (roadside or off-road) factorial ANOVA. This model significantly ($F = 24.71$, $p < 0.0001$) explained variation in soil organic matter content as a function of site location ($F = 21.65$, $p < 0.0001$), tree exposure ($F = 45.17$, $p < 0.0001$), and the interaction of site and exposure ($F = 24.85$, $p < 0.0001$). The model was also robust, explaining 85% of the observed variation ($R^2 = 0.852772$).

Soil organic matter was significantly and uniquely higher at site 113H along the I-70 corridor, and generally higher along Hwy 36 and at the Denver metro sites than other I-70 sites (Table 73.). Soil organic matter content was also significantly higher in soils distant from the roadbed ($\bar{x} = 5.70\%$) than soils adjacent to the road ($\bar{x} = 2.67\%$). Graphical analyses of the interaction of site and exposure revealed significantly higher levels of organic matter in soil distant from the roadbed at sites 113H, 114D, 132D, and in roadside soil at site 111D (Table 72.).

Table 73. Bonferroni post hoc comparison of mean percent soil organic matter by site location, n = 10. Means with the same letter are not statistically different.

Bonferroni grouping		Mean % soil organic matter	Site
	A	1407.0	113H
	B	1262.0	122D
C	B	876.0	121H
C	B	857.0	131H
C	B	698.0	132D
C	B	690.0	114D
C		569.0	111D
C		554.0	112H

Nutrient Availability, Leaf-level Photosynthesis Rates, and Foliar Injury: Needle and soil nitrogen contents demonstrated opposing relationships to foliar injury. Although total needle nitrogen levels correlated significantly and positively with overall crown necrosis, soil nitrogen levels correlated negatively but weakly with foliar injury (Table 74.). In addition, needle nitrogen levels significantly decreased as sampling distance from the roadside increased, while soil total nitrogen levels increased. Needle nitrogen levels also correlated significantly but weakly with the presence of needle surface deposits (Table 74.).

Soil organic matter and total organic carbon content in soil and needle tissue correlated positively but weakly with distance from the roadside (Table 74.). Additionally, needle total organic carbon content correlated negatively but weakly with the presence of needle surface deposits. Soil organic matter, soil total organic carbon, and twig tissue total organic carbon also formed positive but weak correlations with photosynthesis rates. As needle total organic content and soil organic matter increased across sites, observed levels of crown necrosis significantly decreased (Table 74.).

Increased soil potassium and phosphorus content as well as increased needle, twig, and soil calcium levels all correlated significantly but weakly with reduced rates of fall leaf-level photosynthesis (Table 74.). In contrast, increased needle potassium content correlated with increased photosynthesis rates. Soil potassium also formed a weak negative correlation with overall crown necrosis, while needle phosphorus levels formed a weak positive correlation with foliar injury even while increasing significantly with distance from the roadbed (Table 74.).

Table 74. Significant correlations between nutrient availability, distance from the roadside, leaf-level photosynthesis, and overall crown necrosis. * indicates a negative correlation.

Significantly correlated variables		R^2	p value
Needle total N content (%)	Crown necrosis (%)	0.203	< 0.0001
	Needle surface deposits	0.049	< 0.05
	Distance from roadbed* (m)	0.091	< 0.01
Soil total N content (%)	Crown necrosis* (%)	0.053	< 0.05
	Distance from roadbed (m)	0.239	< 0.0001
Needle total organic C content (%)	Crown necrosis* (%)	0.229	< 0.0001
	Needle surface deposits*	0.097	< 0.01
	Distance from roadbed (m)	0.067	< 0.05
Twig total organic C content (%)	Fall photosynthesis rates (μmol CO_2 m^{-2} s^{-1})	0.073	< 0.05
Soil total organic C content (%)	Fall photosynthesis rates (μmol CO_2 m^{-2} s^{-1})	0.069	< 0.05
	Distance from roadbed (m)	0.261	< 0.0001
Needle K content (ppm)	Fall photosynthesis rates (μmol CO_2 m^{-2} s^{-1})	0.067	< 0.05
Soil K content (ppm)	Crown necrosis* (%)	0.072	< 0.05
	Fall photosynthesis rates* (μmol CO_2 m^{-2} s^{-1})	0.114	< 0.01
Needle Ca content (ppm)	Fall photosynthesis rates* (μmol CO_2 m^{-2} s^{-1})	0.063	< 0.05
Twig Ca content (ppm)	Fall photosynthesis rates* (μmol CO_2 m^{-2} s^{-1})	0.147	< 0.001
Soil Ca content (ppm)	Fall photosynthesis rates* (μmol CO_2 m^{-2} s^{-1})	0.118	< 0.05
Needle P content (ppm)	Crown necrosis (%)	0.237	< 0.0001
	Distance from roadbed* (m)	0.129	< 0.01
Soil P content (ppm)	Fall photosynthesis rates* (μmol CO_2 m^{-2} s^{-1})	0.175	< 0.0001
Soil organic matter (%)	Crown necrosis* (%)	0.051	< 0.05
	Fall photosynthesis rates (μmol CO_2 m^{-2} s^{-1})	0.049	< 0.05
	Distance from roadbed (m)	0.275	< 0.0001

Pollutant Exposure: Colorado conifer exposure to environmental pollutants varied significantly by tree proximity to the roadside and site location. Significantly elevated levels of sulfur in needle and twig tissue, copper in needle tissue, and lead in twig tissue and soils were observed in samples from tree tissues and soils adjacent to the roadbed compared to samples collected away from the roadside environment.

In general, trees and soils in the Denver metro sites 132D and 131H exhibited the highest pollutant and heavy metal exposure levels. Needle and twig sulfur contents, needle, twig, and soil cadmium contents, soil copper, nickel, and lead levels, and soil and needle zinc contents were elevated in the Denver metro area sites compared to other study site locations. Sites 122D and 121H along Hwy 36 also tended to demonstrate elevated soil lead levels relative to sites along I-70. In contrast, needle and twig tissues exhibited elevated levels of copper along the I-70 corridor relative to other study sites.

Tables 75., 78., 79., 83., 84., 88., 90., and 92. summarize soil sulfate levels, needle and twig sulfur content, and levels of silver, cadmium, chromium, copper, nickel, lead and zinc in tree tissues and soils by site location and tree exposure. Statistical analyses follow all data.

Needle and twig sulfur content and soil sulfate levels:

Table 75. Mean and standard error of sulfur (S) content in needle (N) and twig (T) tissues, and sulfate (SO_4-S) content soils in ppm, by tree exposure across study sites.

Site	Mean S or SO_4-S content (ppm) ± SE	Exposure Roadside	Off-road
111D (I-70)	N	910.0 ± 53.6	804.0 ± 53.0
	T	500.0 ± 30.5	478.0 ± 19.1
	Soil	8.475 ± 0.908	10.509 ± 3.561
112H (I-70)	N	748.0 ± 39.2	632.0 ± 25.4
	T	702.0 ± 56.4	560.0 ± 130.5
	Soil	26.959 ± 2.818	24.351 ± 3.192
113H (I-70)	N	614.0 ± 89.8	524.0 ± 53.7
	T	568.0 ± 61.3	434.0 ± 49.3
	Soil	13.265 ± 0.862	23.948 ± 1.870
114D (I-70)	N	740.0 ± 52.2	656.0 ± 35.3
	T	444.0 ± 29.1	372.0 ± 23.3
	Soil	23.526 ± 6.956	24.975 ± 1.524
121H (Hwy 36)	N	888.0 ± 77.2	864.0 ± 52.1
	T	588.0 ± 99.8	502.0 ± 34.3
	Soil	31.024 ± 7.996	29.106 ± 2.539
122D (Hwy 36)	N	622.0 ± 42.1	486.0 ± 65.7
	T	386.0 ± 25.6	394.0 ± 15.7
	S	20.451 ± 2.835	25.023 ± 4.173
131H (metro Denver)	N	1360.0 ± 145.6	1164.0 ± 108.3
	T	732.0 ± 98.6	870.0 ± 142.5
	Soil	20.108 ± 1.893	25.895 ± 2.923
132D (metro Denver)	N	1662.0 ± 104.0	1152.0 ± 70.0
	T	1114.0 ± 154.5	724.0 ± 26.2
	Soil	47.627 ± 24.104	20.853 ± 3.961

Needle sulfur content was analyzed with a site location by tree exposure (roadside or off-road) factorial ANOVA. This model significantly ($F = 19.40$, $p < 0.0001$) explained variation in needle sulfur content as a function of site location ($F = 36.83$, $p < 0.0001$) and tree exposure ($F = 18.48$, $p < 0.0001$). The model was also robust, explaining 82% of the observed variation ($R^2 = 0.819720$).

Needle sulfur content was significantly and uniquely higher in the Denver metro study sites than any other sites examined according to Bonferroni post hoc comparisons (α = 0.05) (Table 76.). Needle sulfur content was also significantly higher in roadside trees ($\bar{x}$ = 943.0ppm) than off road trees ($\bar{x}$ = 785.25ppm).

Table 76. Bonferroni post hoc comparison of needle sulfur (S) content in ppm by site location, n = 10. Means with the same letter are not statistically different.

Bonferroni grouping		Mean needle S content (ppm)	Site
	A	1407.0	132D
	A	1262.0	131H
	B	876.0	121H
	B	857.0	111D
C	B	698.0	114D
C	B	690.0	112H
C		569.0	113H
C		554.0	122D

Twig sulfur content also significantly ($F = 6.76$, $p < 0.0001$) varied by site location ($F = 11.82$, $p < 0.0001$) and tree exposure ($F = 5.12$, $p < 0.05$). The model explained 61% of the observed variation ($R^2 = 0.612947$). Again, twig sulfur content was significantly elevated in the Denver metro study sites relative to other study sites (Table 77.). Twig sulfur content was also significantly higher in roadside trees ($\bar{x}$ = 6.29.25ppm) than off road trees ($\bar{x}$ = 541.75ppm).

Soil sulfate content did not differ significantly between sites or by proximity to the roadside (Table 75.).

Table 77. Bonferroni post hoc comparison of twig sulfur (S) content in ppm by site location, n = 10. Means with the same letter are not statistically different.

Bonferroni grouping		Mean twig S content (ppm)	Site
	A	1407.0	132D
B	A	1262.0	131H
B	C	876.0	112H
	C	857.0	121H
	C	698.0	113H
	C	690.0	111D
	C	569.0	114D
	C	554.0	122D

Needle, twig, and soil silver (Ag) content:

Table 78. Mean and standard error of silver (Ag) content in needle tissue (N), twig tissue (T), and soils (S) in ppm, by tree exposure across study sites.

Site	Mean Ag content (ppm) ± SE	Exposure Roadside	Exposure Off-road
111D (I-70)	N	0.27 ± 0.07	0.24 ± 0.01
	T	0.36 ± 0.22	0.18 ± 0.05
	S	0.34 ± 0.04	0.40 ± 0.05
112H (I-70)	N	6.22 ± 4.40	2.90 ± 1.80
	T	7.09 ± 5.93	4.57 ± 3.99
	S	0.42 ± 0.02	0.43 ± 0.05
113H (I-70)	N	3.79 ± 2.97	4.60 ± 2.91
	T	3.85 ± 1.05	5.07 ± 4.56
	S	0.32 ± 0.03	0.67 ± 0.05
114D (I-70)	N	0.33 ± 0.06	0.48 ± 0.12
	T	1.45 ± 1.16	17.38 ± 9.18
	S	0.38 ± 0.04	0.46 ± 0.04
121H (Hwy 36)	N	0.17 ± 0.04	0.27± 0.04
	T	0.26 ± 0.04	0.03 ± 0.03
	S	0.32 ± 0.03	0.28 ± 0.03
122D (Hwy 36)	N	6.01 ± 4.03	5.12 ± 3.62
	T	0.87 ± 0.54	1.41 ± 0.54
	S	0.31 ± 0.03	0.34 ± 0.04
131H (metro Denver)	N	0.47 ± 0.08	2.67 ± 2.16
	T	0.30± 0.05	0.39 ± 0.11
	S	1.01 ± 0.06	0.72 ± 0.05
132D (metro Denver)	N	0.29 ± 0.15	0.35 ± 0.06
	T	0.33 ± 0.05	1.44 ± 1.11
	S	1.37 ± 0.88	0.39 ± 0.02

Levels of silver in conifer needle and twig tissues and adjacent soils did not differ significantly between sites or by proximity to the roadside (Table 78.).

Needle, twig, and soil cadmium (Cd) content:

Table 79. Mean and standard error of cadmium (Cd) content in needle tissue (N), twig tissue (T), and soils (S) in ppm, by tree exposure across study sites.

Site	Mean Cd content (ppm) ± SE	Exposure Roadside	Off-road
111D (I-70)	N	0.18 ± 0.02	0.21 ± 0.02
	T	0.18 ± 0.04	0.16 ± 0.02
	S	0.19 ± 0.06	0
112H (I-70)	N	0.24 ± 0.02	0.18 ± 0.01
	T	0.22 ± 0.02	0.28 ± 0.03
	S	0.26 ± 0.04	0.27 ± 0.02
113H (I-70)	N	0.16 ± 0.01	0.24 ± 0.03
	T	0.22 ± 0.01	0.20 ± 0.01
	S	0.53 ± 0.13	0.53 ± 0.04
114D (I-70)	N	0.29 ± 0.02	0.30 ± 0.02
	T	0.27 ± 0.07	0.21 ±0.03
	S	0.33 ± 0.04	0.48 ± 0.02
121H (Hwy 36)	N	0.28 ± 0.02	0.20 ± 0.01
	T	0.26 ± 0.03	0.42 ± 0.03
	S	0.03 ± 0.02	0.04 ± 0.03
122D (Hwy 36)	N	0.14 ± 0.04	0.15 ± 0.02
	T	0.18 ± 0.01	0.22 ± 0.03
	S	0.35 ± 0.04	0.45 ± 0.01
131H (metro Denver)	N	0.22 ± 0.02	0.31 ± 0.07
	T	0.21 ± 0.02	0.20 ± 0.04
	S	0.79 ± 0.04	0.47 ± 0.03
132D (metro Denver)	N	0.31 ± 0.03	0.22 ± 0.09
	T	0.56 ± 0.17	0.16± 0.01
	S	1.91 ± 0.88	1.39 ± 0.19

Needle cadmium content in ppm was analyzed with a site location by tree exposure (roadside or off-road) factorial ANOVA. This model significantly ($F = 2.48$, $p < 0.01$) explained variation in needle cadmium content as a function of site location ($F = 3.51$, $p < 0.01$). The model explained 37% of the observed variation ($R^2 = 0.367406$). Needle cadmium levels were variable by site, although relatively higher levels were observed in both Denver metro sites 131H and 132D (Table 80.).

Table 80. Bonferroni post hoc comparison of needle cadmium (Cd) content in ppm by site location, n = 10. Means with the same letter are not statistically different.

Bonferroni grouping		Mean needle Cd content (ppm)	Site
	A	0.291	114D
	A	0.264	131H
	A	0.264	132D
B	A	0.239	121H
B	A	0.211	112H
B	A	0.200	113H
B	A	0.191	111D
B		0.145	122D

Twig cadmium content in ppm was also analyzed via a site location by tree exposure (roadside or off-road) factorial ANOVA. This model significantly ($F = 4.13$, $p < 0.0001$) explained variation in twig cadmium content as a function of site location ($F = 3.56$, $p < 0.01$) and the interaction of site location and tree exposure ($F = 5.10$, $p < 0.0001$). The model explained 49% of the observed variation ($R^2 = 0.491725$).

Twig cadmium levels were variable by site, with the highest levels observed in site 132D (Denver) and the lowest in site 111D (I-70) (Table 81.). Graphical analyses of the interaction of site and exposure revealed significantly higher levels of twig cadmium in trees distant from the roadbed at site 121H along Hwy 36 and higher cadmium in roadside trees in site 132D in metro Denver (Table 79.).

Table 81. Bonferroni post hoc comparison of twig cadmium (Cd) content in ppm by site location, n = 10. Means with the same letter are not statistically different.

Bonferroni grouping		Mean twig Cd content (ppm)	Site
	A	0.36	132D
	A	0.34	121H
B	A	0.25	112H
B	A	0.24	114D
B	A	0.21	113H
B	A	0.20	131H
B	A	0.20	122D
B		0.17	111D

Soil cadmium content was analyzed with a site location by tree exposure (roadside or off-road) factorial ANOVA. This model significantly ($F = 4.91$, $p < 0.0001$) explained variation in soil cadmium content as a function of site location ($F = 9.90$, $p < 0.0001$). The model explained 53% of the observed variation ($R^2 = 0.534847$).

Soil cadmium levels were significantly and uniquely higher in the Denver metro site 132D than any other sites examined according to Bonferroni post hoc comparisons ($\alpha = 0.05$) (Table 82.).

Table 82. Bonferroni post hoc comparison of soil cadmium (Cd) content in ppm by site location, n = 10. Means with the same letter are not statistically different.

Bonferroni grouping	Mean soil Cd content (ppm)	Site
A	1.65	132D
B	0.63	131H
B	0.53	113H
B	0.40	114D
B	0.40	122D
B	0.26	112H
B	0.09	111D
B	0.03	121H

Needle, twig, and soil chromium (Cr) content:

Table 83. Mean and standard error of chromium (Cr) content in needle tissue (N), twig tissue (T), and soils (S) in ppm, by tree exposure across study sites.

Site	Mean Cr content (ppm) ± SE	Exposure Roadside	Off-road
111D (I-70)	N	0	0
	T	0	0
	S	9.01 ± 1.74	13.44 ± 3.34
112H (I-70)	N	0	0
	T	0.20 ± 0.20	0
	S	12.71 ± 1.40	15.58 ± 2.62
113H (I-70)	N	0	0
	T	0	0
	S	9.46 ± 1.22	8.15 ± 0.63
114D (I-70)	N	0	0
	T	0	0.22 ± 0.22
	S	9.54 ± 1.74	11.20 ± 1.72
121H (Hwy 36)	N	0	0
	T	0	0
	S	14.46 ± 3.52	8.68 ± 1.13
122D (Hwy 36)	N	0	0
	T	0	0
	S	6.84 ± 1.05	19.81 ± 3.24
131H (metro Denver)	N	0	0
	T	0	0
	S	8.25 ± 1.48	8.60 ± 1.35
132D (metro Denver)	N	0	0
	T	0	0
	S	15.68 ± 3.00	10.10 ± 1.15

With the exception of a few isolated cases, only trace levels of chromium were present in study conifer needles and twig tissues. Therefore, no significant differences were detectable between sites or tree exposure levels.

Soil chromium content was analyzed with a site location by tree exposure (roadside or off-road) factorial ANOVA. This model significantly ($F = 2.92$, $p < 0.01$) explained variation in soil chromium content as a function of the interaction of site location and tree exposure ($F = 4.12$, $p < 0.001$). The model explained 41% of the observed variation ($R^2 = 0.406450$). Graphical analyses of the interaction of site and exposure revealed significantly higher levels of soil chromium distant from the roadbed at site 122D along Hwy 36 (Table 83.).

Needle, twig, and soil copper (Cu) content:

Copper levels in conifer needle tissue were analyzed with a site location by tree exposure (roadside or off-road) factorial ANOVA. This model significantly ($F = 3.94$, $p < 0.0001$) explained variation in needle copper levels as a function of site location ($F = 5.97$, $p < 0.0001$) and tree exposure ($F = 6.61$, $p < 0.05$). The model explained 48% of the observed variation ($R^2 = 0.480151$).

Needle copper levels were elevated in the I-70 lodgepole pine sites compared to the Hwy 36 and Denver metro sites according to Bonferroni post hoc comparisons ($\alpha = 0.05$) (Table 85.). Needle copper levels were also significantly elevated in roadside trees ($\bar{x}$ = 4.15ppm) compared to off-road trees ($\bar{x}$ = 3.34ppm).

Copper levels in conifer twig tissue were also analyzed with a site location by tree exposure (roadside or off-road) factorial ANOVA. This model significantly ($F = 2.55$, $p < 0.01$) explained variation in twig copper levels as a function of site location ($F = 2.82$, $p < 0.05$) and the interaction of site location and tree exposure ($F = 2.65$, $p < 0.05$). The model explained 37% of the observed variation ($R^2 = 0.374330$).

Twig copper levels were variable by site location with a more general elevation seen in sites along I-70 compared to the Hwy 36 and Denver metro sites (Table 86.). Graphical analyses of the interaction of site and exposure revealed significantly elevated copper content in roadside woody tree tissue at site 111D along the I-70 corridor (Table 84.).

Table 84. Mean and standard error of copper (Cu) content in needle tissue (N), twig tissue (T), and soils (S) in ppm, by tree exposure across study sites.

Site	Mean Cu content (ppm) ± SE	Exposure Roadside	Off-road
111D (I-70)	N	4.07 ± 0.89	2.98 ± 0.32
	T	4.55 ± 0.32	2.25 ± 0.20
	S	1.83 ± 0.13	2.27 ± 0.17
112H (I-70)	N	4.90 ± 0.50	5.12 ± 0.31
	T	4.07 ± 0.27	4.65 ± 0.46
	S	1.78 ± 0.54	2.13 ± 0.50
113H (I-70)	N	5.06 ± 1.02	2.45 ± 0.61
	T	4.48 ± 0.41	5.49 ± 0.62
	S	1.62 ± 0.10	2.89 ± 0.43
114D (I-70)	N	5.42 ± 0.77	6.14 ± 0.72
	T	4.11 ± 0.45	3.79 ± 0.53
	S	2.67 ± 0.62	3.67 ± 0.18
121H (Hwy 36)	N	3.29 ± 0.42	2.82 ± 0.54
	T	3.92 ± 0.55	3.67 ± 0.60
	S	2.68 ± 0.40	1.65 ± 0.09
122D (Hwy 36)	N	3.74 ± 1.20	2.59 ± 0.44
	T	3.58 ± 0.58	4.88 ± 0.67
	S	1.33 ± 0.12	2.38 ± 0.42
131H (metro Denver)	N	3.10 ± 0.37	2.90 ± 0.22
	T	3.66 ± 0.23	3.95 ± 0.59
	S	5.47 ± 0.19	3.62 ± 0.27
132D (metro Denver)	N	3.62 ± 0.43	1.71 ± 0.34
	T	3.43 ± 0.73	2.77 ± 0.19
	S	6.38 ± 2.04	2.21 ± 0.67

Table 85. Bonferroni post hoc comparison of needle copper (Cu) levels in ppm by site location, n = 10. Means with the same letter are not statistically different.

Bonferroni grouping			Mean needle Cu content (ppm)	Site
	A		5.78	114D
B	A		5.01	112H
B	A	C	3.76	113H
B		C	3.53	111D
B		C	3.16	122D
B		C	3.05	121H
B		C	3.00	131H
		C	2.67	132D

Table 86. Bonferroni post hoc comparison of twig copper (Cu) levels in ppm by site location, n = 10. Means with the same letter are not statistically different.

Bonferroni grouping		Mean twig Cu content (ppm)	Site
	A	4.99	113H
B	A	4.36	112H
B	A	4.23	122D
B	A	3.95	114D
B	A	3.81	131H
B	A	3.80	121H
B	A	3.40	111D
B		3.09	132D

Soil copper levels were also analyzed with a site location by tree exposure (roadside or off-road) factorial ANOVA. This model significantly ($F = 5.03$, $p < 0.0001$) explained variation in soil copper content as a function of site location ($F = 6.04$, $p < 0.0001$) and the interaction of site location and tree exposure ($F = 4.53$, $p < 0.001$). The model explained 54% of the observed variation ($R^2 = 0.540873$).

Soil copper levels were significantly elevated in the Denver metro sites 132D and 131H compared to all other sites except 114D (I-70) according to Bonferroni post hoc comparisons ($\alpha = 0.05$) (Table 87.). Graphical analyses of the interaction of site and exposure revealed significantly higher levels of soil copper distant from the roadbed at site 113H along I-70 and site 122D along Hwy 36. In addition, elevated copper content was observed in roadside soils at site 121H along Hwy 36, and 131H in metro Denver (Table 85.).

Table 87. Bonferroni post hoc comparison of average soil copper (Cu) content in ppm by site location, n = 10. Means with the same letter are not statistically different.

Bonferroni grouping		Mean soil Cu content (ppm)	Site
	A	4.54	131H
	A	4.29	132D
B	A	3.17	114D
B		2.25	113H
B		2.17	121H
B		2.05	111D
B		1.95	112H
B		1.85	122D

Needle, twig, and soil nickel (Ni) content:

Table 88. Mean and standard error of nickel (Ni) content in needle tissue (N), twig tissue (T), and soils (S) in ppm, by tree exposure across study sites.

Site	**Mean Ni content (ppm) ± SE**	**Exposure** Roadside	Off-road
111D (I-70)	N	0	0
	T	0.48 ± 0.48	0
	S	17.15 ± 2.05	20.90 ± 1.45
112H (I-70)	N	0	0.54 ± 0.54
	T	0	1.28 ± 1.28
	S	13.71 ± 1.48	17.81 ± 2.26
113H (I-70)	N	0	0
	T	0.45 ± 0.45	0.79 ± 0.79
	S	7.38 ± 0.33	12.68 ± 0.70
114D (I-70)	N	0.72 ± 0.72	1.89 ± 1.20
	T	0	0
	S	15.62 ± 1.10	19.63 ± 0.12
121H (Hwy 36)	N	0.87 ± 0.54	2.71 ± 0.80
	T	0	0
	S	27.29 ± 7.53	15.93 ± 0.81
122D (Hwy 36)	N	0	0.46 ± 0.46
	T	0	0.42 ± 0.42
	S	9.96 ± 0.97	23.00 ± 1.13
131H (metro Denver)	N	0	3.49 ± 2.18
	T	0.78 ± 0.23	0
	S	14.65 ± 2.93	20.53 ± 2.98
132D (metro Denver)	N	0	3.34 ± 3.34
	T	0.27 ± 0.27	0.47 ± 0.29
	S	20.51 ± 1.60	23.22 ± 2.12

No significant differences were seen in nickel levels in conifer needle or twig tissues across study site locations or tree exposure (Table 88.).

Soil nickel levels were analyzed with a site location by tree exposure (roadside or off-road) factorial ANOVA. This model significantly ($F = 4.33$, $p < 0.0001$) explained variation in soil nickel as a function of site location ($F = 4.51$, $p < 0.001$), tree exposure ($F = 7.56$, $p < 0.01$), and the interaction of site and exposure ($F = 3.70$, $p < 0.01$). The model explained 50% of the observed variation ($R^2 = 0.503958$).

Soil nickel content was greatest at site 132D in metro Denver and site 121H along Hwy 36. Nickel levels were lowest at sites 112H and 113H along I-70 (Table 89.). Soil nickel content also was significantly higher in soils away from the roadbed ($\bar{x} =$ 19.21ppm) than soils adjacent to the road ($\bar{x} =$ 15.78ppm). Graphical analyses of the interaction of site and exposure revealed significantly higher levels of soil nickel distant from the roadbed at sites 113H, 114D, and 122D (Table 88.).

Table 89. Bonferroni post hoc comparison of average soil nickel (Ni) content in ppm by site location, n = 10. Means with the same letter are not statistically different.

Bonferroni grouping		Mean soil Ni content (ppm)	Site
	A	4.54	132D
	A	4.29	121H
	A	3.17	111D
B	A	2.25	114D
B	A	2.17	131H
B	A	2.05	122D
B	A	1.95	112H
B		1.85	113H

Needle, twig, and soil lead (Pb) content:

Table 90. Mean and standard error of lead (Pb) content in needle tissue (N), twig tissue (T), and soils (S) in ppm, by tree exposure across study sites.

Site	Mean Pb content (ppm) ± SE	Exposure Roadside	Off-road
111D (I-70)	N	0.77 ± 0.32	0.29 ± 0.29
	T	1.54 ± 0.43	0.59 ± 0.36
	S	11.21 ± 2.03	8.62 ± 0.79
112H (I-70)	N	1.39 ± 0.75	0
	T	0.22 ± 0.22	1.59 ± 0.45
	S	11.08 ± 1.55	4.48 ± 0.43
113H (I-70)	N	1.09 ± 0.75	1.13 ± 0.52
	T	0.29 ± 0.29	1.08 ± 0.32
	S	13.65 ± 1.07	16.51 ± 1.76
114D (I-70)	N	0.56 ± 0.34	0.33 ± 0.33
	T	0.26 ± 0.26	1.16 ± 0.44
	S	13.26 ± 4.08	13.81 ± 1.01
121H (Hwy 36)	N	0.49 ± 0.30	0
	T	0.22 ± 0.22	0.50 ± 0.31
	S	34.83 ± 6.15	9.98 ± 0.74
122D (Hwy 36)	N	0.37 ± 0.37	0
	T	0.67 ± 0.41	1.46 ± 0.47
	S	56.92 ± 8.00	10.19 ± 1.98
131H (metro Denver)	N	0.77 ± 0.33	0
	T	0.24 ± 0.24	0.49 ± 0.49
	S	75.60 ± 3.74	34.52 ± 1.42
132D (metro Denver)	N	0.98 ± 0.44	0.86 ± 0.41
	T	1.23 ± 0.52	1.85 ± 0.52
	S	23.74 ± 2.04	32.94 ± 3.37

No significant differences were seen in the lead content of conifer needle tissue across study site locations or tree exposure. However an analysis of lead content in twig tissue with a site location by tree exposure factorial ANOVA demonstrated significant ($F = 2.19$, $p < 0.05$) explained variation as a function of tree exposure ($F = 6.95$, $p < 0.05$).

Study site trees away from the roadsides exhibited elevated levels of lead in twig tissues ($\bar{x}$ = 1.09ppm) compared to roadside trees ($\bar{x}$ = 0.58ppm).

Soil lead levels were analyzed with a site location by tree exposure (roadside or off-road) factorial ANOVA. This model significantly (F = 33.60, $p < 0.0001$) explained variation in soil lead levels as a function of site location (F = 43.06, $p < 0.0001$), tree exposure (F = 65.23, $p < 0.0001$), and the interaction of site and exposure (F = 19.62, $p < 0.0001$). The model also was robust, explaining 89% of the observed variation (R^2 = 0.887316).

Soil lead content was greatest at sites 131H and 132D in metro Denver, as well as site 122D along Hwy 36. Lead levels were lowest at sites along the I-70 corridor (Table 91.). Soil lead content was significantly higher in roadside soils ($\bar{x}$ = 30.04ppm) than soils distant from the roadbed ($\bar{x}$ = 16.38ppm). Graphical analyses of the interaction of site and exposure revealed significantly higher levels of soil lead in roadbed soils at sites 112H, 121H, 122D, and 131H (Table 90.).

Table 91. Bonferroni post hoc comparison of average soil lead (Pb) content in ppm by site location, n = 10. Means with the same letter are not statistically different.

Bonferroni grouping		Mean soil Pb content in ppm	Site
	A	55.06	131H
	B	33.56	122D
C	B	28.34	132D
C	D	22.41	121H
E	D	15.08	113H
E	D	13.54	114D
E		9.92	111D
E		7.78	112H

Needle, twig, and soil zinc (Zn) content:

Table 92. Mean and standard error of zinc (Zn) content in needle tissue (N), twig tissue (T), and soils (S) in ppm, by tree exposure across study sites.

Site	Mean Zn content (ppm) ± SE	Exposure Roadside	Exposure Off-road
111D (I-70)	N	4.34 ± 0.62	5.00 ± 0.88
	T	2.83 ± 0.16	2.12 ± 0.33
	S	3.60 ± 0.54	4.86 ± 0.38
112H (I-70)	N	2.20 ± 0.97	0.90 ± 0.23
	T	5.01 ± 2.96	2.16 ± 0.43
	S	3.35 ± 0.53	3.55 ± 0.12
113H (I-70)	N	1.96 ± 0.28	2.62 ± 0.23
	T	2.35 ± 0.23	8.43 ± 5.23
	S	5.53 ± 1.21	4.63 ± 0.42
114D (I-70)	N	4.06 ± 1.39	3.71 ± 0.80
	T	1.46 ± 0.11	1.73 ± 0.22
	S	3.43 ± 1.08	6.19 ± 0.26
121H (Hwy 36)	N	2.82 ± 0.34	1.89 ± 0.13
	T	2.64 ± 0.39	2.78 ± 1.03
	S	5.23 ± 0.66	4.42 ± 1.09
122D (Hwy 36)	N	1.64 ± 0.41	0.80 ± 0.27
	T	4.42 ± 3.45	2.03 ± 0.69
	S	9.71 ± 6.41	4.17 ± 0.30
131H (metro Denver)	N	4.55 ± 0.40	3.35 ± 0.48
	T	3.94 ± 0.34	3.76 ± 0.40
	S	14.05 ± 1.38	10.20 ± 1.60
132D (metro Denver)	N	4.60 ± 0.18	11.39 ± 4.74
	T	5.57 ± 0.19	3.55 ± 0.60
	S	11.77 ± 4.63	6.28 ± 0.37

Zinc levels in conifer needle tissue were analyzed via a site location by tree exposure (roadside or off-road) factorial ANOVA. This model significantly ($F = 3.54$, $p < 0.001$) explained variation in needle zinc levels as a function of site location ($F = 5.49$, $p < 0.0001$). The model explained 45% of the observed variation ($R^2 = 0.453659$).

Needle zinc levels were variable by site location, although both Denver metro sites 131H and 132D demonstrated elevated levels of zinc in tree tissues (Table 93.). In contrast, levels of zinc in twig tissues did not express significant differences across study sites or tree exposure.

Table 93. Bonferroni post hoc comparison of mean needle zinc (Zn) content in ppm by site location, n = 10. Means with the same letter are not statistically different.

Bonferroni grouping		Mean needle Zn content in ppm	Site
	A	8.00	132D
B	A	4.67	111D
B	A	3.95	131H
B	A	3.89	114D
B		2.35	121H
B		2.29	113H
B		1.55	112H
B		1.22	122D

Soil zinc content was analyzed with a site location by tree exposure (roadside or off-road) factorial ANOVA. This model significantly ($F = 2.41$, $p < 0.05$) explained variation in soil zinc content as a function of site location ($F = 3.79$, $p < 0.01$). The model explained 36% of the observed variation ($R^2 = 0.360521$). Overall, soil zinc levels were higher in metro Denver sites than most other sites along Hwy 36 and I-70, according to Bonferroni post hoc comparisons ($\alpha = 0.05$) (Table 94.).

Table 94. Bonferroni post hoc comparison of average soil zinc (Zn) content in ppm by site location, n = 10. Means with the same letter are not statistically different.

Bonferroni grouping		Mean soil Zn content in ppm	Site
	A	12.13	131H
B	A	9.03	132D
B	A	6.94	122D
B		5.08	113H
B		4.83	121H
B		4.81	114D
B		4.23	111D
B		3.45	112H

Pollutant Exposure, Leaf-level Photosynthesis Rates, and Foliar Injury: Of the pollutants tested, only needle and twig tissue sulfur content and needle tissue lead content correlated weakly but significantly with observed levels of foliar necrosis (Table 95.). Pollutant exposure in general correlated much more often with decreased rates of fall leaf-level photosynthesis. Needle and twig sulfur contents, needle and soil cadmium contents, soil copper levels and needle zinc contents all formed negative correlations with conifer photosynthesis rates (Table 95.). In contrast, levels of copper in twig tissue correlated positively but weakly with photosynthesis rates. Finally, levels of sulfur and copper in needle tissue and levels of lead in soil significantly negatively correlated with distance from the roadbed (Table 95.).

Table 95. Significant correlations between pollutant exposures, distance from the roadside, leaf-level photosynthesis and overall crown necrosis. * indicates a negative correlation.

Significantly correlated variables		R^2	p value
Needle sulfur content (%)	Crown necrosis (%)	0.056	< 0.05
	Fall photosynthesis rates* (µmol CO_2 m^{-2} s^{-1})	0.387	< 0.0001
	Distance from roadbed* (m)	0.061	< 0.05
Twig sulfur content (%)	Crown necrosis (%)	0.082	< 0.05
	Fall photosynthesis rates* (µmol CO_2 m^{-2} s^{-1})	0.259	< 0.0001
Needle cadmium (Cd) content (ppm)	Fall photosynthesis rates* (µmol CO_2 m^{-2} s^{-1})	0.077	< 0.05
Soil cadmium (Cd) content (ppm)	Fall photosynthesis rates* (µmol CO_2 m^{-2} s^{-1})	0.100	< 0.01
Needle copper (Cu) content (ppm)	Distance from roadbed*(m)	0.056	< 0.05
Twig copper (Cu) content (ppm)	Fall photosynthesis rates (µmol CO_2 m^{-2} s^{-1})	0.112	< 0.01
Soil copper (Cu) content (ppm)	Fall photosynthesis rates* (µmol CO_2 m^{-2} s^{-1})	0.055	< 0.05
Needle lead (Pb) content (ppm)	Crown necrosis (%)	0.052	< 0.05
Soil lead (Pb) content (ppm)	Distance from roadbed* (m)	0.138	< 0.001
Needle zinc (Zn) content (ppm)	Fall photosynthesis rates* (µmol CO_2 m^{-2} s^{-1})	0.153	< 0.001

Assessment of Disease, Insect, Animal, and Abiotic Damages: Study site trees exhibited only minor damage attributable to disease, insect, animal and abiotic damage. Needle banding, tip burn, branch dieback, chlorosis and mottling contributing to crown necrosis however, were again observed on study plot trees (Figure 2.).

Insect damage included minor damage by tip moths, scale insects, gray and wooly aphids, parasitic wasps, twig beetles, bark roughing attributable to cicada or tree-hopper activity, and needle chewing attributable to a wood boring beetle or other defoliator. Bark beetle and stem borer damage was not observed in any study site trees, although four to five pines at Denver metro site 132D within 500 feet of the study plot off road trees exhibited yellow needles in the spring and mortality by fall. This damage was ascribed to bark beetles and borers, as well as potential past drought stress.

Western gall rust was the only fungal pathogen noted, present on a roadside ponderosa pine at site 121H along Hwy 36. Non-critical parasitism by dwarf mistletoe occurred on a roadside ponderosa at site 122D, and a more serious instance on an off-road ponderosa at site 121H. This tree exhibited a dwarf mistletoe rating of around three. Noted abiotic damages included branch cracking from heavy snows, needle mottling from weather fleck, trunk mechanical damage, and needle twisting, a sign of potential insect or herbicide impact.

Appendix B encompasses the fall tree assessment and conclusions of CSU tree pathologist Dr. William Jacobi, and provides a damage assessment of each individual study plot tree.

Conclusions

The surface profile of Colorado roadside soils is of relatively poor quality compared to soils further away from the roadside environment. Roadside study site soils exhibited significantly lower levels of major plant nutrients including total nitrogen, potassium, calcium, and phosphorus. Additionally, soil organic matter and total organic carbon content was significantly reduced adjacent to the roadbed than in soils further away. In general, levels of increased soil total nitrogen, total organic carbon, and soil organic matter correlated moderately with increased distance from the roadside (Table 74.). Soil organic matter provides the major pool of carbon and nutrients for vegetation and greatly influences the physical, chemical, and biological properties of the soil. Reductions in soil organic carbon, phosphorous and total nitrogen levels have correlated with reduced herbaceous biomass and diversity of perennial plant species in India (Panchal & Pandey, 2002).

Increases in the percentage of Na in the cation exchange capacity of a soil has been shown to leach out the base cations K, Ca, and Mg, which can in turn result in nutrient deficiencies in certain soil types (Norrstrom & Bergstedt, 2001). This phenomenon was noted across study sites. Sodium levels were significantly elevated in roadside soils ($\bar{x}$ = 184.8ppm) compared to soils away from the road ($\bar{x}$ = 114.6ppm), while soils adjacent to the roadbed did in fact exhibit significantly reduced levels of magnesium (Table 14.), potassium (Table 60.) and calcium (Table 64.).

Decreases in soil organic matter, total nitrogen, and potassium levels correlated significantly but very weakly with increased overall crown necrosis levels (Table 74.). Overall, changes in these factors explained only up to seven percent of the variation in crown necrosis, and therefore are highly unlikely to be prime causative agents in foliar injury. In addition, soil organic matter and total organic carbon content formed weak positive correlations with fall leaf-level photosynthesis rates (Table 74.), indicating that nutrient availability in this case may potentially affect net carbon assimilation. In contrast, as soil potassium, calcium, and phosphorous levels increased, a corresponding decrease in photosynthesis rates was observed (Table 74.). Significant negative correlations were also formed between conifer needle and twig calcium contents and fall leaf-level photosynthesis rates. This depression may be related to overall soil salinity as leaf-level photosynthesis rates were also reduced in relation to the overall levels of total soluble salts in roadside soils (Table 26.). Floodwater salinity has been linked to the excessive accumulation of Na, K, Ca, and Mg, in leaf tissues, and this increase in the overall ionic content the primary cause of a reduction in tree photosynthesis rates (Pezeshki et al., 1987.).

Although significant degradation of the nutrient status was observed in roadside soils, concomitant differences in nutrient status between the tissues of roadside and off-road study trees was not observed. Only total organic carbon in conifer needle tissue was significantly lower in roadside trees compared to their off-road counterparts. This suggests that roadside soils although relatively nutrient depleted, still offer a sufficiency of most mineral nutrients for vegetation growth and physiology. Reduced organic carbon content in needle tissue correlated moderately (R^2 = 0.229, $p < 0.0001$) with increased foliar injury, and may be related to reduced total canopy photosynthesis in roadside trees. Fall leaf-level photosynthesis rates correlated positively but very weakly with twig total organic carbon content (R^2 = 0.073, $p < 0.05$) and soil total organic carbon content (R^2 = 0.069, $p < 0.05$).

These data suggest that salinity in Colorado roadside soils does not for the most part appreciably affect nutritional balance in the shoot and leaf tissues of lodgepole and ponderosa pines. Similarly, while macronutrient concentrations were markedly modified in root tissues, no deficiencies or toxicities were noted among three provenances of maritime pines (*Pinus pinaster*) treated with exposure to nutrient solutions containing NaCl (Saur et al., 1995). Hall et al (1973) also reported no evidence that sodium and chloride caused leaf injury in roadside sugar maples by inducing deficiencies in the essential elements nitrogen, potassium, or phosphorus.

Although salinity may alter the nutritional balance of plants through the osmotic effects of salts, competitive interactions among ions, and alterations on cell membrane selectivity (Kozlowski, 1997), the effect of saline particles on mineral elements plant tissues is dependent on the individual element, the degree of exposure, and the species of plant (McCune, 1991). The effects of salinity on nutritional balance may be profoundly variable by species. For example, overall changes in nitrogen and phosphorus were not seen consistently among six tree species exposed to root zone gradient of NaCl (Townsend, 1980).

Finally, roadside conifer needle tissue demonstrated higher levels of total nitrogen and phosphorus than trees away from the roadbed. Needle total nitrogen content correlated moderately with overall crown necrosis (Table 74.). This relationship is potentially a product of atmospheric nitrous oxide exposure. Other studies have established that needle N concentrations in conifer species have been elevated by dry or wet deposition of atmospheric nitrous oxides (Grodzinska-Jurczak & Szarek-Lukaszewska, 1999; Manninen & Huttunen, 2000). Evidence for this is further reinforced by a weak correlation between needle total N content and needle surface deposits ($R^2 = 0.049$, $p < 0.05$) and negative correlation between needle N content and distance from the roadside ($R^2 = 0.091$, $p < 0.01$). Needle phosphorus content also correlated positively with tree necrosis, and negatively but weakly with distance from the roadbed (Table 74.), suggesting some phosphorus toxicity may be contributing to plant damage.

Overall, the generally elevated levels of soil potassium, nitrogen, phosphorus and calcium at sites 131H and 132D in the Denver metro area may reflect the addition of fertilizer to the artificial plantings that encompassed the study sites. Although some limited and conflicting evidence exists that increases in salt tolerance may be induced in vegetation by increased N and P levels (Bernstein, 1975), this finding was not supported in this study. The Denver metro sites and sites 122D and 121H along Hwy 36 also tended to exhibit greater levels of soil organic matter than sites along I-70, probably reflecting elevation and soil type differences. The uniquely high levels of soil organic matter, total organic carbon, and total nitrogen at site 113H along I-70 corridor can be attributed to the clay rich soil in the riparian floodplain that characterized that site.

Trees and soils along Colorado roadsides exhibited increased levels of pollutants and trace metals than their counterparts away from the roadside environment. Specifically, significantly elevated levels of sulfur in needle and twig tissue, nitrogen and copper in needle tissue, and lead in twig tissue and soils were observed. Needle total S concentrations have been linked to stomatal uptake of sulfur dioxides, and needle N concentrations elevated by dry or wet deposition of atmospheric nitrous oxides (Grodzinska-Jurczak & Szarek-Lukaszewska, 1999; Manninen & Huttunen, 2000). Roughly equivalent needle concentrations of S and N in study site needle tissues were seen in Scots pine and Norway spruce exposed to sulfur and nitrogen dioxides in Poland (Grodzinska-Jurczak & Szarek-Lukaszewska, 1999). These levels were considered to exceed levels considered normal by 100-400%. Reductions in leaf carbon content and increases in nitrogen and sulfur content have also been noted in trees of the evergreen oak *Quercus ilex* exposed to urban air pollutants (Alfani et al., 2000).

Needle and twig tissue sulfur content and needle tissue nitrogen content correlated weakly but significantly with observed levels of foliar necrosis (Table 74. and Table 95.). Overall, changes in these factors explained only a small amount of the variation in crown necrosis compared to the accumulation of salt ions in plant tissues, although a contribution to foliar injury is highly likely. Additionally, unlike reported patterns of salt injury, SO_2 injury is concentrated in new needle growth due to increased levels of foliar absorption (Manninen & Huttunen, 2000). Needle sulfur and nitrogen content also decreased as distance from the roadbed increased.

Although needle copper content did not significantly correlate with observed foliar injury in study site trees, needle lead content formed a very weak positive correlation with overall crown necrosis ($R^2 = 0.052$, $p < 0.05$). Although the phytotoxicity of lead in vegetation has been well documented, the concern usually involves the movement of the heavy metal into the food chain (Foy et al., 1978).

Plant tissue sulfur and trace metal contents formed weak negative correlations with fall leaf-level photosynthesis rates. Photosynthetic efficiency was also negatively correlated with airborne concentrations of Cu, Ni, and SO_2 in exposed vegetation, although not in Scots pine (*Pinus sylvestris*) (Odasz-Albrigtsen et al., 2000). Needle and twig sulfur contents, needle and soil cadmium contents, soil copper levels and needle zinc contents all formed weak negative correlations with conifer photosynthesis rates (Table 95.). In contrast, levels of copper in twig tissue correlated positively but weakly with photosynthesis rates. These data suggest that pollutant exposure may contribute to some degree to physiological depression in roadside conifers.

Overall, levels of copper, zinc, and chromium in Colorado study site roadside soils were generally much lower than those reported for roadside soils collected from Donner Pass, CA, Albany and Buffalo, NY, Sparta NJ, Lansing MI, and Cape Cod, MA, all areas representative of high traffic and heavy salt use in the late 1980's (Amrhein & Strong, 1990). In contrast, soil lead, nickel, and cadmium levels were generally equivalent at similar sampling distances from the roadbed. Observed levels of soil Cd, Cr, Cu, and Zn in this study were also lower than those reported for analyses of Greeley, Denver, and Longmont soils in 2001 (Keane et al., 2001). Again, soil levels of nickel and lead at roadside study sites were equivalent or slightly elevated in comparison (Keane et al., 2001).

Uptake of trace metals is also species and environment dependent, and levels of heavy metals reported in Colorado soils in dandelion leaves (*Taraxacum officinale*) were generally higher than those observed in study site pine tissues (Keane et al, 2001). Lombardo et al. (2001) reported generally lower levels of accumulated Cd, and higher levels of Cu, Pb, and Zn in needle tissues of *Pinus spp*. exposed to vary levels traffic and urbanization in Palermo, Italy.

Not surprisingly given their urban environment, trees and soils in the Denver metro sites 132D and 131H exhibited the highest pollutant and heavy metal exposure levels. Needle and twig sulfur contents, needle, twig, and soil cadmium contents, soil copper, nickel, and lead levels, and soil and needle zinc contents were elevated in the Denver metro area sites compared to other study site locations. Sites 122D and 121H along Hwy 36 also tended to demonstrate elevated soil lead levels relative to sites along I-70. In contrast, needle and twig tissues exhibited elevated levels of copper along the I-70 corridor relative to other study sites.

Although not directly quantified, some inferences are possible regarding the effects of ozone exposure on Colorado conifers. Symptoms of foliar injury in ponderosa pine in response to ozone exposure are highly similar to symptoms of foliar injury in response to salt stress. 'Weather fleck' and leaf mottling has been linked to ozone damage in deciduous species (Langebartels et al., 2002), and chlorotic mottling and abscission of older needle growth as well as tip dieback in current year needles have been reported in ponderosa pines in response to ozone fumigation (Miller et al., 1963).

Given these damage patterns and the elevated levels of tree tissue nitrogen attributable to nitrous oxide deposition, it is likely that ozone contributes to damage in roadside vegetation. It should be noted however, that although ozone damage patterns are similar to salt damage patterns, ozone is a widely distributed pollutant that will often occur at greater concentrations in rural locations than urban locations, and is capable of forest impact on a regional scale (Samuelson & Kelly, 2001). That foliar injury is significantly concentrated in the roadside environment points instead to a localized causative agent.

Finally, study site trees exhibited only minor damage attributable to disease, insect, animal and abiotic damage, unlikely to impact tree health and physiology (Appendix B). Previous examinations of sodium-damaged ponderosa pines in Denver also exposed no fungi, insects or nematodes that could be implicated as causal agents of foliar injury (Staley et al., 1968). In the conclusion of the pathology assessment, Dr. William Jacobi comments:

- The occasional needles that were partially removed/chewed are probably from maturation feeding by an insect such as a wood boring beetle, or some defoliator.

This damage, although interesting biologically, is not a damage that could affect the tree's health.

- There were some parasitic wasp pupa seen and some ladybeetle larva- probably associated with the aphids. The aphids should not cause a major dieback or needle loss unless they are persistent over the year and over years and in high populations.
- On only one tree was there a significant disease that could affect tree health and physiology- the tree with dwarf mistletoe (Off road tree, site 121H). However, it was a class three in the Dwarf Mistletoe Rating system and thus the impact of the parasite would be just starting to impact growth and water status of the tree. It will be interesting to see if there was any difference in water potentials between that tree and others on the plot. (No notable differences were observed in water potentials or leaf-level gas exchange in the study tree).

In conclusion, although some degree of pollutant exposure and alterations of nutrient balance no doubt impact Colorado roadside conifers, the correlations formed with measures of tree health and physiology explained very little of the observed variation. In contrast, accumulation of salt ions in plant tissue formed robust correlations with conifer foliar injury (Figures 10. through 13.). Observed disease, insect, animal, and other abiotic damages could not be linked to reductions in tree physiology or foliar injury.

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APPENDIX A: DEFINITION OF FIELD SITE DESCRIPTORS

Slope Position: Records the study plot position on the landscape. Slope position definitions are from: National Soil Survey Handbook (Title 430-VI). USDA Soil Conservation Service, 1993.

Table A1. slope position definitions

Code	Description
1	**Summit/Ridgetop/Plateau**. The topographically highest hillslope position of a hillslope profile and exhibiting a nearly level surface.
2	**Shoulder**. The hillslope position that forms the uppermost inclined surface near the top of a hillslope. It comprises the transition zone from backslope to summit.
3	**Backslope**. The hillslope position that forms the steepest inclined surface and principal element of many hillslopes. In profile, backslopes are commonly steep, linear, and bounded by a convex shoulder above and descending to concave footslope. They may or may not include cliff segments. Backslopes are commonly erosional forms produced by mass movement and running water.
4	**Footslope**. The hillslope position that forms the inner, gently inclined surface at the base of a hillslope. In profile, footslopes are commonly concave. It is a transition zone between upslope sites of erosion and transport.
5	**Toeslope**. The hillslope position that forms the gently inclined surface at the base of a hillslope. Toeslopes in profile are commonly gentle and linear, and are constructional surfaces forming the lower part of a hillslope continuum that grades to valley bottom.
6	**Valley Bottom**. Wide valley bottom beyond influence of toeslope.

Figure A-1: Slope Position

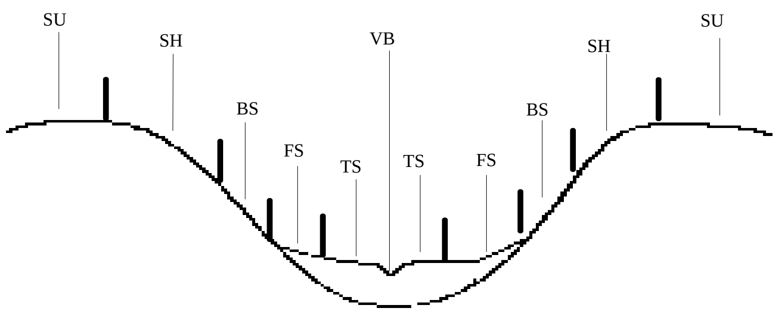

Table A-2: Topographic Configuration: Records the micro-site configuration of the study plot.

Code	Description
1	**Broken**. Cliffs, knobs and/or benches interspersed with steeper slopes generally characterized by sharp, irregular breaks. A marked variation of topography, or an irregular and rough piece of ground.
2	**Concave.** The gradient decreases down the slope. Runoff tends to decelerate as it moves down the slope, and if it is loaded with sediment the water tends to deposit the sediment on the lower parts of the slope. The soil on the lower part of the slope also tends to dispose of water less rapidly than the soil above it.
3	**Convex**. The gradient increases down the slope and runoff tends to accelerate as it flows down the slope. Soil on the lower part of the slope tends to dispose of water by runoff more rapidly than the soil above it. The soil on the lower part of a convex slope is subject to greater erosion than that on the higher parts.
4	**Linear or Planar.** Substantially a straight line when seen in profile at right angles to the contours. The gradient does not increase or decrease significantly with distance (level or little relief).
5	**Undulating**. One or more low relief ridges or knolls and draws within the plot area.

Stand Structure: Structure is a description of the distribution of tree height classes within the stand. Structure descriptions are as follows:

Closed Canopy Single-story - A single even canopy characterizes the stand. The greatest number of trees are in a height class represented by the average height of the stand; there are substantially fewer trees in height classes above and below this mean.

Closed Canopy Multi-storied - At least two height size classes are commonly represented in the stand. Generally, the canopy is broken and uneven although multiple canopy levels may be distinguishable. The various size classes tend to be uniformly distributed throughout the stand.

Open Canopy Multi storied– Woodland, open canopy, trees are dispersed throughout stand, two distinct age or height classes commonly represented. Generally, the canopy is broken and uneven although multiple canopy levels may be distinguishable. The various size classes tend to be uniformly distributed throughout the stand.

Open Canopy Single Storied– Woodland, open canopy, trees are dispersed throughout stand, the greatest number of trees are in a height class represented by the average height of the stand; there are substantially fewer trees in height classes above and below this mean.

Mosaic - At least two distinct height size classes are represented and these are not uniformly distributed, but are grouped in small repeating aggregations, or occur as stringers less than two chains wide, throughout the stand.

APPENDIX B: STUDY SITE TREE PATHOLOGY AND DAMAGE ASSESSMENT

Report and Invoice:

University of Northern Colorado
Contract: Tree Assessment at Road Salt Study Plots

Dr. William R. Jacobi
2725 McKeag Drive
Fort Collins, CO 80526
970-206-1746
November 7, 2004

Report and Invoice: **November 7, 2004**

- University of Northern Colorado
- Contract: Tree Assessment at Road Salt Study Plots
- Dr. William R. Jacobi, 2725 McKeag Drive, Fort Collins, CO 80526
- November 7, 2004
- For tree health assessments at research sites near Estes Park, Denver CO and along I-70 east and west of the Eisenhower Tunnel.
- Amount: $1,500

Report:

Assessment Dates: October 6, 2004 9 am to 7 pm
October 12, 2004 1 pm to 6 pm

Research Sites:
October 12, 2004: Two research sites on Rt 36 south east of Estes Park CO.

Plot 121H (Hwy 36), Ponderosa Pine Trees along the road

P1 Needle banding occurred on a few 2&3 yr-old needles, two western gall rust galls, one on dead branch, one branch had dieback. No other biotic damages seen.
P2 Limited needle tip burn and tip dieback, 5% branch dieback through out tree, a dead branch with obvious decay. No other biotic damages seen.
P3 < 5% of branches had dieback in lower crown. Rest of crown is in good condition, no banding or tip burn. A couple of branches cracked from heavy snows. No other biotic damages noted.
P4 Limited tip burn on 2 or 3 branches. Two branches dying in lower crown. No other biotic damages noted.
P5 75% defoliation of crown. Tip burn on 1, 2 and 3-year needles. No biotic damages seen.

Site 121H (Hwy 36) Control Plot: Trees down hill from road.

P1 2-3 branch tip attacked by tip moths, minor mottling of needles, and 2 newly dead branches in lower crown. No other biotic damages noted.
P2 < 1% small branch dieback. No other biotic damages noted.
P3 < 1% small branch dieback, and two scale insects. No other major damages
P4 Sooty mold on some needles indicating probable aphids but no other damages noted.
P5 Limited mottling on needles and dwarf mistletoe rating of about 3. No other biotic damages.

Plot 122D (Hwy 36), Ponderosa Pine Trees along road,

P1 75% foliage missing except for current years needles. 25-35% branch dieback
Needle tip burn on this year's needles, No biotic damages noted.

P2. Straw colored needle tips on current and 1-year needles, 50-75% needles missing stem infection of dwarf mistletoe, about three visible plants, not a serious damage to the tree.
P3. No mistletoe or other biotic damages, 2 and 3 yr needles have some limited tip burn, 15% missing needles.
P4. Lower branches have needle mottling, banding and tip burn, good needle retention of 95%, upper crown looks good, no beetles or other biotic damages
P5. Good needle retention (100%), some needle mottle and banding on lower branches. No biotic damages noted.

Site 122D (Hwy 36)- away from road:

P1. Good needle retention, not biotic damages, and very few needles with some mottle.
P2. No biotic damages, limited needle mottle on a few branches, 3 branches with limited dieback, an understory tree so needle retention is less than a more dominant tree.
P3. Occasional chewed needle (see comments), some limited needle mottling, needle density about 75% of max. No other biotic damages noted.
P4. No biotic damages noted, needle density about 85% of normal, a few needles with limited mottling.
P5. Crown about 90% of maximum density, limited needle mottling. No other biotic damages noted.

October 6, 2004 I-70 sites:

Plot 132D (Denver) , Mouse Trap area, Ponderosa Pine Trees:

P1. Only tip dieback on older needles, look for sucking insects in July and August or earlier none noted now except for sooty mold. No other biotic damages noted.
P2. Better tree, no biotic damages
P3. Tree removed
P4. Tip burn on 2-year needles, pupal case on needle of a parasitic wasp. No other biotic damages noted.
P5. Minor physical bark roughing on top of branch- cicada, treehopper damage? Banding on 2-3 year old needles, no damage on 1 yr needles. No other biotic damages noted.

Plot 132D (Denver), away from road:

P1 Tip burn 3 and 4 yr old needle, current needles ok, no biotic damages noted.
P2 Little weather fleck/mottleing on 3 and 4 year old needles. No other biotic damages noted.
P3. Hanging on 1 and 2 year old needles, no biotic damages.
P4. A few needle scales noted, 3 yr of needles retained, no biotic damages,
P5. Current needles OK, some older needles have tip burn, but over all crown looks healthy

Some (4-5) pines within 500 feet of second plot had yellow needles in the spring are now dead. Bark beetles and borers appear to have killed the trees. These trees may have been stressed by the two years of drought.

Plot 131H (Denver) Wadsworth Ponderosa Pine near west bound on ramp:

P1. Occasional needle ends chewed by defoliator/maturation feeding, took sample of needle spots (did not find any evidence of a fungus), mottling on 1,2,3 yr needles, a few needle scales, not other abiotic damages. No other biotic damages noted.
P2. No major biotic damages, 3 tips with tip moth damage, some flecking on 1,2,3 yr needles
P3. Two-tip moth damaged twigs, some flexing and twisting of needles, some flecking seen on 2 and 3 yr old needles. No other biotic damages noted.
P4. No biotic damage or abiotic issues noted.
P5. Twisted current needles, upper surface needle flex and mottling on 2 and 3 yr needles, occasional needle chewed. No other biotic damages noted.

131H (Denver), Wadsworth and I-70 intersection, Ponderosa Pines away from the road:

P1. Very little needle flecking and a few twisted needles, no biotic damages noted.
P2. Limited flecking on 1 year needles, mottling on 2 & 3 yr needles, 4 yr needles with tip burn, and a few twisted needles, no biotic damages noted.
P3. Grey aphids on a few twigs, some needle chewing, and 2-tip moth damaged tips, no biotic damages noted.
P4. Limited needle mottle, 2 and 4-year needles with yellowing, no major biotic damages noted.
P5. An old wound on the stem, some mottling on 2 and 3 yr needles and fleck on current year needles, no biotic damages noted.

Plot 112H (I-70), Roadside Lodgepole pine at mile marker 224, west of Silver Plume on I 70

P1. Needle tip burn on last years needles. No other biotic damages noted.
P2. No twig beetles, missing interval of needles, needle banding on last years needles. No other biotic damages noted.
P3. Not biotic damages noted, only 2 yr of needles present, not much needle banding or tip burn.
P4. No major flecking or mottling. No other biotic damages noted.
P5. Some minor tip burn, longer needles in 2004 than the short needles in 2003. No other biotic damages noted.

Plot 112H (I-70) Upper site away from road, lodgepole pine.

P1. Some flecking on 3-4 yr needles, no biotic damages noted.
P2. Minor amount of wooly aphids on 10% of the branch tips. No other biotic damages noted.
P3. Scale insects, general needle chlorosis on 4 and 5 yr old needles. No other biotic damages noted.
P4. Tip moth damage on 4 branches, some needle scales, nothing important and no other biotic damages noted.
P5. A few needle scales but no biotic issues of importance.

Plot 114D (I-70), roadside lodgepole pine:

P1. Tip burn on 2 and 3 yr needles, chlorotic 2 and top of tree is dead, no other biotic damages seen.
P2. Chlorotic 2 and 3 yr needles, tip burn on these needles also, missing branches on roadside of trees, no biotic damages noted.
P3. Tip branch dieback at top of tree, needle tip burn on 2 and 3 yr needles, no biotic damages seen.
P4. Lower 1/3 of crown no needles, "dead branches" are flexible, needles present are chlorotic and have tip burn on 2 and 3 yr needles, not biotic damage noted.
P5. Tip burn on 2 yr needles, and yellowing on current needles, and branches without needles are flexible, not biotic damages noted.

Plot 114D (I-70) Up hill away from road- lodgepole pine:

P1. Little chewing on <1% needles, a little needle mottle on 2 and 3 yr needles, no biotic damages noted.
P2. Nothing major noted, other than two twig beetle damaged twig tips.
P3. Minor mottling of needles, no biotic damages noted.
P4. Sides chewed of a few needles, no other biotic damages.
P5. No tip burn on needles, a little mottle on 2 and 3 yr needles. No other biotic damages noted.

Plot 113H (I-70), East bound I-70,roadside lodgepole pine.

P1. Tip burn on most 2 and 3 yr needles, branch dieback, no biotic damages noted.
P2. Sparse foliage, dead branches over the entire crown, no biotic damages noted.
P3. Branch dieback over whole crown, flexible defoliated branches, no biotic damages noted.
P4. Chlorotic needles and tip burn on 2 and 3 yr needles, no biotic damages noted.
P5. Roots covered with road base, sparse foliage and tip burn on 2 yr needles, no other biotic damages noted.
Could these trees be damaged by snow blowers during the winter in some fashion that kills needles but allows the branch to stay alive longer than normal? A branch usually dies within a year of foliage loss. It will be interesting to hear what the chloride content of these trees was.

Plot 113H, East bound I-70. lodgepole pine, lower site away from the road.

P1. Two twig beetle damaged twigs, no other damages noted.
P2. Limited needle fleck on 2 and 3 yr needles, chlorotic on 4 yr needles, no other biotic damages noted.
P3. A few old physical wounds on the stem, limited flecking on top of needles, no other biotic damages noted.
P4. About 1% twig damage to tips, some upper surface needle fleck, no other biotic damages seen.
P5. Chlorotic 2 and 3 yr old needles, 6-twig beetle damaged tips, and no other biotic damages.

Plot 111D, Lodgepole pine next to I-70:

P1. Tip burn on 3 yr needles, mid-crown dieback at 10%, no other biotic damages noted.
P2. Some needle flecking, midcrown dieback 5%, lower crown 15% dead, no biotic damages noted.
P3. Lower 25% of crown dead and no biotic damages noted.
P4. Mechanical damage to base of stem of about 25% girdle, mid crown dieback on road side, some twig beetles in branch tips, and no other biotic damages.
P5. Many dead branches, 70% of needles missing making sparse foliage with tip burn on the remaining needles, no biotic damages noted.

Plot 111D, upper site away from the road:

P1. A little upper needle flecking, some minor chlorotic issues with 4 yr needles. No other biotic damages noted.
P2. A little upper needle flecking, a little less foliage since the tree is in a swampy area. No other biotic damages noted.
P3. No biotic damages and a bit of weather fleck on needles, not biotic damages noted.
P4. Upper needle surface fleck and not other biotic damages.
P5. No dieback or upper surface fleck and no biotic damages.

Diseases and Insects assessed for at all sites:

Diseases:
- Dwarf Mistletoes
- Fungal Needle Casts
- Elytroderma needle disease
- Western gall rust
- Stem and branch- internal decay
- Root disease such as Armillaria root disease

Animal Damage: Gnawing by rodents or deer/elk

Abiotic Damage: Frost, snow breakage, drought, or chemical damage.

Insects:
- Needle Miners
- Bark beetles – Ips and Mt pine beetle
- Wood boring insects
- Bark aphids
- Twig beetles
- Pine needle scale

Comments:

The occasional needles that were partially removed/chewed is probably from maturation feeding by an insect such as a wood boring beetle, or some defoliator. This damage, although interesting biologically, is not a damage that could affect the tree's health

There were some parasitic wasp pupa seen and some ladybeetle larva- probably associated with the aphids. The aphids should not cause a major dieback or needle loss unless they are persistent over the year and over years and in high populations.

On only one tree was there a significant disease that could affect tree health and physiology- the tree with dwarf mistletoe. However, it was a class three in the Dwarf Mistletoe Rating system and thus the impact of the parasite would be just starting to impact growth and water status of the tree. It will be interesting to see if there was any difference in water potentials between that tree and others on the plot.

APPENDIX C: GLOSSARY OF TERMS

Abiotic stress: Nonliving environmental factors (such as drought, extreme cold or heat, high winds) that can have harmful effects on plants.

Abscission: The normal shedding from a plant of an organ that is mature or aged, e.g. a ripe fruit, an old leaf, or in this case, conifer needles.

Aerobic cellular respiration: The conversion within the cell of nutrients (such as carbohydrates) into chemical energy in the form of adenosine triphosphate or ATP, by reacting the nutrients with oxygen until the food has completely been degraded into carbon dioxide and water.

Anion: A negatively-charged ion.

Biotic stress: Living organisms that can harm plants, such as viruses, fungi, bacteria, and insects.

Carbon Fixation: The process by which photosynthetic organisms such as plants turn inorganic carbon (carbon dioxide) into organic compounds (carbohydrates).

Cation: A positively-charged ion.

Chlorosis: Abnormal condition of plant foliage characterized by absence of green pigments; often caused by poor soil conditions and/or malnutrition. Foliage exhibits a yellowed or pale green appearance.

Germination: The process where a seed begins to sprout, grow, or develop, usually after it has been dormant for a time while waiting for growing conditions.

Heavy metals: Metallic elements that become toxic even at low concentrations, including those required for plant and animal nutrition in trace concentrations. These metals tend to remain in the environment and accumulate in living organisms. Examples include mercury (Hg), selenium (Se), molybdenum (Mo), cadmium (Cd), and lead (Pb).

Insolation: Solar radiation received at the earth's surface.

Ion: An atom or molecule that has gained or lost electrons and thus has a net positive or negative charge.

Leaf-level gas exchange: The movement of carbon dioxide, oxygen, and water vapor between the plant leaves (needles) and the atmosphere. Leaves take up carbon dioxide and release water vapor and oxygen during photosynthesis. Leaves also take up oxygen and release carbon dioxide through the process of aerobic cellular respiration.

Mesophyll: the photosynthetic tissue of a leaf located within the leaf beneath the leaf surfaces.

Necrosis: Death of living tissues due to infection or injury.

Net carbon assimilation (A): The amount of carbon fixed by leaves during photosynthesis less the carbon lost through aerobic cellular respiration.

Non-viable: Not alive or able to reproduce.

Osmosis: The diffusion of water through a selectively permeable membrane such as the membrane of a living cell; water moves from a region of higher concentration to an area of lower concentration.

Osmotic stress: Depression or inhibition of metabolic processes such as germination or photosynthesis through the creation of a water deficit due to osmosis. For example, seeds can be prevented from germinating when an external concentration of salts or other molecules exceeds the concentration of these molecules within the cells of the seed. In this case, the seed will be unable to absorb water.

pH: System of measuring the acidity or alkalinity of a substance; refers to the negative logarithm of the hydrogen ion content of the solution. pH values run from 1 to 14; a pH of 7 indicates that a substance is neutral. A value of more than 7 indicates the substance is basic (alkaline) and a value of 11 or more indicates it is very basic and is likely to cause corrosion and/or tissue damage. Likewise, a value of less than 7 indicates that the substance is acidic, and a value of 3 or less indicates it is a strong acid.

Photosynthesis: Process through which light energy, water, and carbon dioxide are converted to carbohydrates and oxygen in plant cells.

Phytotoxicity: Having properties that are poisonous or toxic to plants.

Salinity: the amount of chemical salts (compounds that include sodium, potassium, magnesium, and calcium) contained in a solution or the soil matrix.

Sodicity: Refers to soil containing levels of sodium that affect its stability. Sodic soils are dispersible and are thus vulnerable to erosion.

Soil organic matter: The part of the soil that includes carbon compounds derived from decomposing remains of plants and animals. Soil organic matter improves soil structure and fertility.

Soluble: Capable of being dissolved; in this case, the characteristic of soil minerals that leads them to be carried away in solution by water.

Stomata: pores in the surface or epidermis of a leaf, providing access for gaseous exchange between plant tissues and the atmosphere.

Stomatal conductance/diffusion (gs): A plant physiology property related to the ease with which water vapor escapes from plant leaves through stomata. If the conductance is high, the plant loses water through transpiration, which potentially places the plant in water stress. However if conductance is low, photosynthesis is reduced through reduced carbon dioxide exchange with the atmosphere. Therefore, plants tend to maximize efficiency between these two constraints.

Transpiration: The evaporation of water from the surfaces of leaves through stomates (pores).

Water potential: A measure of xylem sap tension which is an indicator of plant water stress. More negative water potential measurements reflect increasing plant water or moisture stress in the plant.

Water use efficiency (WUE): Percentage measure of the carbon assimilated through photosynthesis over the amount of water transpired.

Xylem: Tissues within the plant body that conduct water absorbed by the roots to all other parts of the plant.

Appendix C.

Winter Maintenance Meeting Minutes

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I-70 PEIS Winter Maintenance and Water Quality Trends Meeting
Location: Mountain Residency
July 13, 2009 1:00 to 4:30 pm

MEETING MINUTES
16 July, 2009

Water quality monitoring

An in-stream water quality monitoring program was initiated in 2000 for Black Gore Creek, Straight Creek, and Clear Creek. The water quality program was initiated to assess pollutants associated with the operation and maintenance of I-70 that may be considered a threat to aquatic habitat or public water supplies. The constituents of concern from maintenance activities are traction sand derived sediment (particulate phosphorous), and salts (sodium and magnesium chloride) that are used on I-70 to maintain traction and mobility.

Salt concentrations are measured directly through water sampling and indirectly from continuous conductivity readings taken in the I-70 streams. A background sample from Miller Creek showed chloride level of less than 2 milligrams/liter (mg/L). Monitoring data from 2000 to 2006 from Black Gore Creek, Straight Creek and upper Clear Creek showed a range of 20 to over 200 mg/L. The chronic aquatic water quality standard is 230 mg/L over a 4 day average that cannot be exceeded more than once in every 3 years. The drinking water standard is 250 mg/L. Monitoring data from 2000 to 2003 were reported in a 2004 technical report and draft PEIS. This report was updated in 2008 with data through 2006.

Regulatory requirements for the Straight Creek TMDL are to pick up 25 percent of the traction sand applied.

Winter maintenance operations

The percentage of rock salt in the sand mix varies by patrol from 5 to 15 percent. A 12 percent mixture is used at Silverthorne and Floyd Hill. The ratio of the sand mix stays constant and is not changed in relationship to storm events.

The handout of data graphs and tables on winter maintenance material usage showed a decrease in the use of sand and an increase in the use of liquid deicers beginning in 2002 at Black Gore Creek and in Straight Creek and Clear Creek. Since 2003 patrol 44 MP 180-188 has primarily used a sand-slicer mix. The application rate is adjusted to control melting so that the melting does not result in ice conditions. The use of a solid deicer has been greatly reduced on the east slopes in favor of a sand slicer mix. The use of a solid deicer has remained more constant on the west slope and is used the most during early spring storm events.

The usage of sand mix and deicers is dependent upon several factors such as air temperature, pavement temperature, amount of snow, storm characteristics. Bridges require more frequent treatment but the percentage of sand and deicer mix remains the same.

The graph showing solid usage for each patrol was discussed, which included salt-sand mixture, solid deicer/ice slicer, and sand-slicer mix. There was a change starting in 2003 from primarily salt-sand mix to sand-slicer mix in all patrols except 41. The ice slicer is more concentrated than rock salt.

Trend in Water Quality

The trend in water quality reflects CDOT maintenance practice of using less traction sand and more liquid and solid deicer salts. This change has resulted in higher chloride loading and a similar or slightly lower sediment loading since 2002. The sodium and magnesium chloride used in the liquid deicer are highly soluble and, therefore the concentration in the runoff is high. The in-stream chloride concentration is the greatest in February, March, and April when there is little dilution from snow melt. Conversely the chloride concentration is the lowest in May and June due to greater runoff and dilution of the chloride from snow melt.

The chloride from rock salt is still a contributing factor to chloride entering the streams. However, the change to ice-slicer may have resulted in higher stream chloride concentrations. Salt washes out of the sand very quickly. The sand can be picked up but there is no proven method for picking up the rock salt before it is washed out of the sand. Sand is needed for traction and will therefore continue to be a concern for water quality.

The chloride concentration is the greatest in Black Gore Creek ranging from 50 to 400 mg/L and in Upper Clear Creek below Herman Gulch which ranges from 30 to 400 mg/L. There is a slight increasing trend in concentration in these watersheds. The concentration in Straight Creek ranges from 30 to 250 mg/L but the increasing trend is a much higher than in either Black Gore Creek or Upper Clear Creek. The chloride concentration in West Tenmile Creek is much lower than the other streams with a high in the early spring months of around 100 mg/L. The West Tenmile watershed is larger than Black Gore Creek which provides a greater dilution factor and the stream is much further distance from I-70.

Operational mitigation measures

Early Closure- There is increasing support from the communities for early road closure if the storm is expected to be severe. This would reduce overall material use since no material would be applied until the storm plays out. Operational efficiency can also be achieved by clearing snow and applying chemicals before opening the road where traffic interferes with maintenance operations.

Speed management-Use signage to control speed to driving condition and reducing speeds before areas where traffic begins to back up.

Reservoir storage for water dilution-It may be possible to build small reservoirs where water could be collected, stored, and then released into the streams to dilute high spikes in chloride concentrations. CDOT has water rights for 3CFS in Straight Creek. Assumption is any water collected from I-70 would have to be returned to the normal receiving stream. Drainage separation would be needed for water runoff storage.

Management of sand and deicer materials

The top three factors indicated on the questionnaire were 1) heavy traffic, 2) training, and 3) experience.

<u>Heavy traffic</u>-The general philosophy has been to keep the road open. Possible mitigation measures would include early road closure.

<u>Training / education</u>-In general the operators tend to use more material than is needed and material application is sprayed outside the travel lane. Training has to be balanced with getting the job done and determining what is the balance between training and the actual reduction in volume of sand and deicer material used.

Possible mitigation measures would include initial planning for storm events. Some of the variables discussed in the meeting include:

- It is possible to manage the amount of sedimentation by pickup sand, however it is not possible to manage salt going into the stream except for percentage used in the mix.
- Ice slicer is more concentrated than rock salt; therefore consideration needs to be given to the type of salt used in the mix.
- Magnesium chloride is more effective than salt but does not work in all conditions.
- Chloride concentration varies among the different products and some type of conversion table would be useful in determining how much of a product is needed.

<u>Other management considerations</u>

- Additional weather stations are needed to plan application amount. Problem exists with receiving weather signals in parts of the corridor.
- HD equipment needs to be installed in more of the trucks. Only 10 percent of the trucks are equipped with these instruments.
- Calibrated spreaders would eliminate guess work.
- Consistent data needed on truck loads to determine effectiveness of the program. Driver fills out log book but it is based upon his estimate rather than any direct measurement. Automatic data recorder could be used for bucket loader size. A scale for the loader buckets would provide a better means for tracking material usage. Weight scale for the truck could be used however this needs to consider condition of the truck and material being loaded if either is covered with snow or frozen material.
- Sand recovery currently only captures a small percent of the sand applied. Contractor removal of the sand has proven to be very expensive. Cost benefit of increasing CDOT maintenance sand cleanup costs needs to be evaluated as trade off against contractor costs.
- Options need to be evaluated for present value and in a consistent manner.

Maintenance of future auxiliary lanes
Tim provided a map that shows the auxiliary lanes for the preferred alternative. Auxiliary lane construction is estimated to be 5 to 7 years out.

Auxiliary Lane Locations

Location	Eastbound	Westbound
West Vail Pass	MP 180-190	MP 180-190
Frisco to Silverthorne	MP 203-205	
EJMT	MP 216- 218.5	MP 216-221
Empire to Downieville	MP 232-234	MP 232-234
Mount Vernon Canyon		MP 252-258

In areas where auxiliary lanes are present the fast lane would be plowed with little or no sand or deicer material applied. Material would be applied to the other two lanes to keep them open to vehicles that can not handle snow condition or drivers who prefer to take less risk because of the road conditions.

Adding a third lane does not result in a direct correlation for an additional 33 percent of sand or deicer material. The actual factor may be closer to a 10 percent increase.

Appendix D.

United States Fish and Wildlife Species List

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United States Department of the Interior

FISH AND WILDLIFE SERVICE
Ecological Services
Colorado Field Office
P.O. Box 25486, DFC (65412)
Denver, Colorado 80225-0486

IN REPLY REFER TO:
ES/CO: T&E/Species List
TAILS: 65412-2010-SL-0486

JUL - 6 2010

Jeff Peterson
Colorado Department of Transportation
4201 East Arkansas Avenue, Shumate Building
Denver, Colorado 80222

Dear Mr. Peterson:

Based on the authority conferred to the U.S. Fish and Wildlife Service (Service) by the Fish and Wildlife Act of 1956 (916 U.S.C. 742(a)-754); Fish and Wildlife Coordination Act (FWCA - 16 U.S.C. 661-667(e)); National Environmental Policy Act of 1969 (NEPA - 42 U.S.C. 4321-4347); Department of Transportation Act (49 U.S.C. 1653(f)), and; Endangered Species Act of 1973, as amended (ESA - 50 CFR §402.14), as well as multiple Executive Orders, policies and guidelines, and interrelated statutes to ensure the conservation and enhancement of fish and wildlife resources (e.g., Migratory Bird Treaty Act (MBTA - 16 U.S.C. 703), and Bald and Golden Eagle Protection Act (BGEPA - 16 U.S.C. 668)), the Service reviewed your June 10, 2010, request for information on the Service's trust resources in the vicinity of your proposed **Interstate 70 (I-70) West Corridor PEIS in Jefferson, Clear Creek, Summit, Eagle, and Garfield counties**. The proposed highway improvements would occur from mile marker 260 (I-70/C-470 intersection in Golden) to mile marker 116 (Glenwood Springs). We responded to your requests for species lists in February and December 2006, as well as in August 2008, and you are now requesting an update.

Threatened and Endangered Species

Following is a list of Federal endangered, threatened, proposed and candidate species for Jefferson, Clear Creek, Summit, Eagle, and Garfield counties, which may be used as a basis for determining additional listed species potentially present in the project area. While other species could occur at or visit the project area, endangered or threatened species most likely to be affected include:

Birds:
*Least tern, interior population (*Sternula antillarum*), Endangered
*Piping plover (*Charadrius melodus*), Threatened
*Whooping crane (*Grus americana*), Endangered
Mexican spotted owl (*Strix occidentalis lucida*), Threatened

Mammals: Black-footed ferret (*Mustela nigripes*), Endangered
Preble's meadow jumping mouse (*Zapus hudsonius preblei*), Threatened
Canada lynx (*Lynx canadensis*) Threatened

Fishes: *Pallid sturgeon (*Scaphirhynchus albus*), Endangered
© ** Razorback sucker (*Xyrauchen texanus*) Endangered
**Bonytail (*Gila elegans*) Endangered
© ** Colorado pikeminnow (*Ptychocheilus lucius*) Endangered
**Humpback chub (*Gila cypha*) Endangered
Greenback cutthroat trout (*Oncorhynchus clarki stomias*) Threatened

Plants : Colorado butterfly plant (*Gaura neomexicana* ssp. *coloradensis*), Threatened
Colorado hookless cactus (*Sclerocactus glaucus*), Threatened
DeBeque phacelia (*Phacelia submutica*), Threatened
Parachute beardtongue (*Penstemon debilis*), Threatened
Ute ladies'-tresses orchid (*Spiranthes diluvialis*), Threatened
*Western prairie fringed orchid (*Platanthera praeclara*), Threatened

Invertebrates: Uncompahgre fritillary butterfly (*Boloria acrocnema*), Endangered

* Since 1978, the Service has consistently taken the position in its section 7 consultations that Federal agency actions resulting in existing or new water depletions to the Platte River system may affect these species as well as designated critical habitat for the whooping crane in the central Platte River in Nebraska. Depletions include evaporative losses and/or consumptive use less return flows. Project elements that could be associated with depletions to the Platte River system include, but are not limited to, ponds (detention/recreation/irrigation storage), lakes (recreation/ irrigation storage/municipal storage/power generation), reservoirs (recreation/irrigation storage/municipal storage/power generation), pipelines, and water treatment facilities, dust control, and compaction.

** Water depletions in the Upper Colorado River and San Juan River basins may affect these species in Summit and Eagle counties.

© These species are present and there is also designated critical habitat in Garfield County.

The Service also is interested in the protection of species which are candidates for official listing as threatened or endangered (Federal Register, Vol. 61, No. 40, February 28, 1996). While these species presently have no legal protection under the Act, it is within the spirit of this Act to consider project impacts to potentially sensitive candidate species. It is the intention of the Service to protect these species before human-related activities adversely impact their habitat to a degree that they would need to be listed and, therefore, protected under the Act. Additionally, we wish to make you aware of the presence of Federal candidates should any be proposed or listed prior to the time that all Federal actions related to the project are completed. If any candidate species will be unavoidably impacted, appropriate mitigation should be proposed and discussed with this office.

Mammals: Gunnison's prairie dog (*Cynomys gunnisoni*)

Birds: Yellow-billed cuckoo (*Coccyzus americanus*)

Migratory Birds

Under the MBTA construction activities in grassland, wetland, stream, and woodland habitats, and those that occur on bridges (e.g., which may affect swallow nests on bridge girders) that would otherwise result in the take of migratory birds, eggs, young, and/or active nests should be avoided. Although the provisions of MBTA are applicable year-round, most migratory bird nesting activity in eastern Colorado occurs during the period of April 1 to August 30. However, some migratory birds are known to nest outside of the aforementioned primary nesting season period. For example, raptors can be expected to nest in woodland habitats during February 1 through July 15. If the proposed construction project is planned to occur during the primary nesting season or at any other time which may result in the take of nesting migratory birds, the Service recommends that the project proponent (or construction contractor) arrange to have a qualified biologist conduct a field survey of the affected habitats and structures to determine the absence or presence of nesting migratory birds. Surveys should be conducted during the nesting season. In some cases, such as on bridges or other similar structures, nesting can be prevented until construction is complete. It is further recommended that the results of field surveys for nesting birds, along with information regarding the qualifications of the biologist(s) performing the surveys, be thoroughly documented and that such documentation be maintained on file by the project proponent (and/or construction contractor) for potential review by the Service (if requested) until such time as construction on the proposed project has been completed. The Service's Colorado Field Office should be contacted immediately for further guidance if a field survey identifies the existence of one or more active bird nests that cannot be avoided by the planned construction activities. Adherence to these guidelines will help avoid the unnecessary take of migratory birds and the possible need for law enforcement action.

Wetlands

FWCA provides the basic authority for the Service's involvement in evaluating impacts to fish and wildlife "whenever the waters of any stream or other body of water are proposed or authorized to be impounded, diverted, the channel deepened, or the stream or other body of water otherwise controlled or modified **for any purpose whatever**...by any department or agency of the United States, or by any public or private agency under Federal permit or license," including water crossings and wetland impacts, whether or not those wetlands are under the jurisdiction of the U.S. Army Corps of Engineers [16 U.S.C. 661(1), emphasis added]. It requires that fish and wildlife resources "receive equal consideration...to other project features...through the effectual and harmonious planning, development, maintenance, and coordination of wildlife conservation and rehabilitation," and requires Federal agencies to consult with the Service during the planning process to help "prevent the loss of or damage to such resources as well as providing for the development and improvement thereof" (16 U.S.C. 661 *et seq*). Full consideration is to be given to Service recommendations.

If the Service can be of further assistance, please contact Alison Deans Michael of my staff at 303 236-4758.

Sincerely,

ACTING FOR Adam Misztal

Susan C. Linner
Colorado Field Supervisor

ec: CDOT, R1 (Wendy Wallach)
CDOT, R6 (Jane Hann)
JF Sato (Tim Tetherow, Sarita Douglas)
Michael

Ref: Alison\H:\My Documents\I-70\I-70 West Corridor spplist update.doc

Appendix E

United States Forest Service Species List and Colorado Department of Wildlife State Species of Concern List

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WRNF Management Indicator Species List

American Elk (roads and recreation)
Cave Bats (no caves will be effected)
American Pipit (management of alpine habitat) We probably won't impact alpine.
Brewer's Sparrow (management of sagebrush habitat)
Virginia's Warbler (management of dense shrub habitat primarily oak brush)
Aquatic Macroinvertebrates
All Trout (includes brook, brown, rainbow and Colorado River (CR) cutthroat trout)

I added the references to what management each species is an indicator for. Each species that would have habitat effected by the project would be selected as an MIS so Elk Brewer's Sparrow and Virginia's Warbler would probably be the MIS that would be chosen.

Comments on T&E list for I-70 PEIS
White River National Forest

Birds: The only bird species that occurs on the White River is Mexican Spotted Owl.

Mexican Spotted Owl: Occurs on the White River NF list from USFWS for the Eagle District (which is in Glenwood Canyon). The only habitat that occurs for this species is in Glenwood Canyon and surveys have been done with no detection of these owls. Since the PEIS ends at the east end of the canyon this species would not be impacted.

Mammals: The only mammals that occurs on the White River is Canada Lynx

Fishes: Potential downstream impacts (primarily from water depletions) on Colorado pikeminnow, humpback chub, razorback sucker, and bonytail chub. Local impacts to greenback cutthroat.

Plants: Leave that for botanist to respond

Invertebrates: UFB is on the White River list although none of the interstate is at a high enough elevation to impact alpine habitat where this butterfly lives.

Candidates: Yellow Bill Cuchoo: this bird is not known to occur east of Rifle and would be only in riparian corridors along the Rivers which would be on private lands.

Candidate Plants: Leave that for Botanist to respond

ARP T&E/SS/MIS Lists
Species in bold occur within the I-70 Corridor, have habitat within the corridor, or are potentially affected by the project.
5-14-09

<u>Federal T&E:</u>
Mexican spotted owl
Canada lynx
Preble's meadow jumping mouse
Whooping crane*
Piping plover*
Least tern*
***downstream species**
Yellow-billed cuckoo (candidate spp)
Greenback cutthroat trout

<u>R2 Sensitive</u>:
White-tailed prairie dog
Black -tailed prairie dog
N. American wolverine
River otter
American marten
Fringed myotis
Rocky Mtn bighorn sheep
Townsend's big-eared bat
Pygmy shrew
Swift fox

<u>Birds:</u>
N. Goshawk
Boreal owl
Cassin's sparrow
Grasshopper sparrow
Burrowing owl
American bittern
Ferruginous hawk
McCown's longspur
Chestnut-collared longspur
Greater sage grouse
Mountain plover
Black tern
Northern harrier
Olive-sided flycatcher
Black swift
American peregrine falcon
Bald eagle

White tailed ptarmigan
Loggerhead shrike
Lewis' woodpecker
Long-billed curlew
Flammulated owl
American three-toed woodpecker
Purple martin
Brewer's sparrow

Amphibians:
Boreal toad
Northern leopard frog
Wood frog

Insects:
Hudsonian emerald

Molluscs:
Rocky Mountain capshell

Fishes:
Colorado River cutthroat trout

MIS (Management Indicator Species):
Elk
Mule deer
Bighorn sheep
Hairy woodpecker
Pygmy nuthatch
Golden-crowned kinglet
Mountain bluebird
Warbling vireo
Wilson's warbler
Boreal toad
Brook trout
Brown trout
Greenback cutthroat trout
Colorado River cutthroat trout

Pawnee National Grassland:
Black-tailed prairie dog
Mule deer
Ferruginous hawk
Burrowing owl
Mountain plover
Lark bunting

R2 Regional Forester's Sensitive Species

THOSE HIGHLIGTED IN YELLOW ARE WHITE RIVER NF SPECIES. GREEN HIGHLIGHTING ADDED TI SENSITIVE FISH SPECIES OCCURRING ON THE WRNF. (Those not highlighted do not occur, do not have ranges that overlap the WRNF or do not have habitat on the WRNF)

ANIMALS

MAMMALS

Conepatus leuconotus	American hog-nosed skunk
Cynomys gunnisoni	Gunnison's prairie dog
Cynomys leucurus	white-tailed prairie dog
Cynomys ludovicianus	black-tailed prairie dog
Euderma maculatum	spotted bat
Gulo gulo	wolverine
Lontra canadensis	river otter
Martes americana	American marten
Microtus richardsoni	water vole
Myotis thysanodes	fringed myotis
Ovis canadensis canadensis	Rocky Mountain bighorn sheep
Ovis canadensis nelsoni	desert bighorn sheep
Plecotus townsendii	Townsend's big-eared bat
Sorex hoyi	pygmy shrew
Thomomys clusius	Wyoming pocket gopher
Ursus arctos horribilis	grizzly bear
Vulpes macrotis	kit fox
Vulpes velox	swift fox
Zapus hudsonius luteus	New Mexico meadow jumping mouse
Zapus hudsonius preblei (Wyoming SPR)	Preble's meadow jumping mouse

BIRDS

Accipiter gentilis	northern goshawk
Aegolius funereus	boreal owl
Aimophila cassinii	Cassin's sparrow
Ammodramus savannarum	grasshopper sparrow
Amphispiza belli	sage sparrow
Asio flammeus	short-eared owl
Athene cunicularia	burrowing owl
Botaurus lentiginosus	American bittern
Buteo regalis	ferruginous hawk
Calcarius mccownii	McCown's longspur
Calcarius ornatus	chestnut-collared longspur
Centrocercus minimus	Gunnison sage-grouse
Centrocercus urophasianus	greater sage-grouse
Charadrius montanus	mountain plover
Chlidonias niger	black tern

Circus cyaneus	northern harrier
Coccyzus americanus	yellow-billed cuckoo
Contopus cooperi	olive-sided flycatcher
Cygnus buccinator	trumpeter swan
Cypseloides niger	black swift
Falco peregrinus anatum	American peregrine falcon
Haliaeetus leucocephalus	bald eagle
Histrionicus histrionicus	harlequin duck
Lagopus leucura	white-tailed ptarmigan
Lanius ludovicianus	loggerhead shrike
Melanerpes lewis	Lewis's woodpecker
Numenius americanus	long-billed curlew
Otus flammeolus	flammulated owl
Picoides arcticus	black-backed woodpecker
Picoides dorsalis	American three-toed woodpecker
Progne subis	purple martin
Spizella breweri	Brewer's sparrow
Tympanuchus cupido	greater prairie-chicken
Tympanuchus pallidicinctus	lesser prairie-chicken
Tympanuchus phasianellus columbianus	Columbian sharp-tailed grouse

AMPHIBIANS

Anaxyrus boreas boreas	boreal toad
Lithobates blairi	Plains leopard frog
Lithobates luteiventris	Columbia spotted frog pop. 4 (Bighorn Mountain spotted frog)
Lithobates pipiens	northern leopard frog
Lithobates sylvatica	wood frog

REPTILES

Sistrurus catenatus edwardii	desert massasauga rattlesnake
Storeria occipitomaculata pahasapae	Black Hills red-bellied snake

FISHES

Catostomus discobolus	bluehead sucker
Catostomus latipinnis	flannelmouth sucker
Catostomus platyrhynchus	mountain sucker
Catostomus plebeius	Rio Grande sucker
Couesius plumbeus	lake chub
Gila pandora	Rio Grande chub

Gila robusta	roundtail chub
Hybognathus placitus	Plains minnow
Macrhybopsis gelida	sturgeon chub
Margariscus margarita	pearl dace

Nocomis biguttatus	hornyhead chub
Oncorhynchus clarkii pleuriticus	Colorado River cutthroat trout
Oncorhynchus clarkii virginalis	Rio Grande cutthroat trout
Oncorhynchus clarkii bouvieri	Yellowstone cutthroat trout
Phoxinus eos	northern redbelly dace
Phoxinus erythrogaster	southern redbelly dace
Phoxinus neogaeus	finescale dace
Platygobio gracilis	flathead chub

INSECTS

Hesperia ottoe	Ottoe skipper
Ochrotrichia susanae	Susan’s purse-making caddisfly
Somatochlora hudsonica	Hudsonian emerald
Speyeria idalia	regal fritillary
Speyeria nokomis nokomis	Nokomis fritillary or Great Basin silverspot

MOLLUSCS

Acroloxus coloradensis	Rocky Mountain capshell
Oreohelix pygmaea	pygmy mountainsnail
Oreohelix strigosa cooperi	Cooper’s Rocky Mountainsnail

Colorado Department of Wildlife, State Listed Species

COMMON NAME	SCIENTIFIC NAME	STATUS*
AMPHIBIANS		
Boreal Toad	Bufo boreas boreas	SE
Northern Cricket Frog	Acris crepitans	SC
Great Plains Narrowmouth Toad	Gastrophryne olivacea	SC
Northern Leopard Frog	Rana pipiens	SC
Wood Frog	Rana sylvatica	SC
Plains Leopard Frog	Rana blairi	SC
Couch's Spadefoot	Scaphiopus couchii	SC
BIRDS		
Whooping Crane	Grus americana	FE, SE
Least Tern	Sterna antillarum	FE, SE
Southwestern Willow Flycatcher	Empidonax traillii extimus	FE, SE
Plains Sharp-Tailed Grouse	Tympanuchus phasianellus jamesii	SE
Piping Plover	Charadrius melodus circumcinctus	FT, ST
Bald Eagle	Haliaeetus leucocephalus	SC
Mexican Spotted Owl	Strix occidentalis lucida	FT, ST
Burrowing Owl	Athene cunicularia	ST
Lesser Prairie-Chicken	Tympanuchus pallidicinctus	ST
Western Yellow-Billed Cuckoo	Coccyzus americanus	SC
Greater Sandhill Crane	Grus canadensis tabida	SC
Ferruginous Hawk	Buteo regalis	SC
Gunnison Sage-Grouse	Centrocercus minimus	SC
American Peregrine Falcon	Falco peregrinus anatum	SC
Greater Sage Grouse	Centrocercus urophasianus	SC
Western Snowy Plover	Charadrius alexandrinus	SC
Mountain Plover	Charadrius montanus	SC
Long-Billed Curlew	Numenius americanus	SC
Columbian Sharp-Tailed Grouse	Tympanuchus phasianellus columbianus	SC
FISH		

Colorado Department of Wildlife, State Listed Species

COMMON NAME	SCIENTIFIC NAME	STATUS*
Bonytail	Gila elegans	FE, SE
Razorback Sucker	Xyrauchen texanus	FE, SE
Humpback Chub	Gila cypha	FE, ST
Colorado Pikeminnow	Ptychocheilus lucius	FE, ST
Greenback Cutthroat Trout	Oncorhynchus clarki stomias	FT, ST
Rio Grande Sucker	Catostomus plebeius	SE
Lake Chub	Couesius plumbeus	SE
Plains Minnow	Hybognathus placitus	SE
Suckermouth Minnow	Phenacobius mirabilis	SE
Northern Redbelly Dace	Phoxinus eos	SE
Southern Redbelly Dace	Phoxinus erythrogaster	SE
Brassy Minnow	Hybognathus hankinsoni	ST
Common Shiner	Luxilus cornutus	ST
Arkansas Darter	Etheostoma cragini	ST
Mountain Sucker	Catostomus playtrhynchus	SC
Plains Orangethroat Darter	Etheostoma spectabile	SC
Iowa Darter	Etheostoma exile	SC
Rio Grande Chub	Gila pandora	SC
Colorado Roundtail Chub	Gila robusta	SC
Stonecat	Noturus flavus	SC
Colorado River Cutthroat Trout	Oncorhynchus clarki pleuriticus	SC
Rio Grande Cutthroat Trout	Oncorhynchus clarki virginalis	SC
Flathead Chub	Platygobio gracilus	SC
MAMMALS		
Gray Wolf	Canis lupus	FE, SE
Black-Footed Ferret	Mustela nigripes	FE, SE
Grizzly Bear	Ursus arctos	FT, SE
Preble's Meadow Jumping Mouse	Zapus hudsonius preblei	FT, ST
Lynx	Lynx canadensis	FT, SE
Wolverine	Gulo gulo	SE
River Otter	Lontra canadensis	ST

Colorado Department of Wildlife, State Listed Species

COMMON NAME	SCIENTIFIC NAME	STATUS*
Kit Fox	Vulpes macrotis	SE
Townsend's Big-Eared Bat	Corynorhinus townsendii pallescens	SC
Black-Tailed Prairie Dog	Cynomys ludovicianus	SC
Botta's Pocket Gopher	Thomomy bottae rubidus	SC
Northern Pocket Gopher	Thomomys talpoides macrotis	SC
Swift fox	Vulpes velox	SC
REPTILES		
Triploid Checkered Whiptail	Cnemidophorus neotesselatus	SC
Midget Faded Rattlesnake	Crotalus viridis concolor	SC
Longnose Leopard Lizard	Gambelia wislizenii	SC
Yellow Mud Turtle	Kinosternon flavescens	SC
Common King Snake	Lampropeltis getula	SC
Texas Horned Lizard	Phrynosoma cornutum	SC
Roundtail Horned Lizard	Phrynosoma modestum	SC
Massasauga	Sistrurus catenatus	SC
New Mexico Thread Snake	Leptotyphlops dissectus	SC
MOLLUSKS		
Rocky Mountain Capshell	Acroloxus coloradensis	SC
Cylindrical Papershell	Anodontoides ferussacianus	SC

*Status Codes:

FE = Federally Endangered
FT = Federally Threatened
SE = State Endangered
ST = State Threatened
SC = State Special Concern (not a statutory category)
Last Updated: 10/15/2007

Note that a more recent list has been recently produced and is available on CDOW’s website (7/7/2010). This list has three changes. The following two species were added:

COMMON NAME	SCIENTIFIC NAME	STATUS*

Colorado Department of Wildlife, State Listed Species

COMMON NAME	SCIENTIFIC NAME	STATUS*
Texas Blind Snake	Leptotyphlops dulcis	SC
Common Garter Snake	Thamnophis sirtalis	SC

The following species has been deleted from the list:

COMMON NAME	SCIENTIFIC NAME	STATUS*
New Mexico Thread Snake	Leptotyphlops dissectus	SC

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Appendix F.

Colorado Natural Heritage Program Species List

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Colorado Natural Heritage Program Species List

CNHP Species Not Identified on Federal Lists as Special Status
Found in Jefferson, Clear Creek, Summit, Eagle, or Garfield Counties

Major Group	Scientific Name	Common Name	Rank	
Birds	*Bucephala islandica*	Barrow's Goldeneye	G5	S2B
	Tympanuchus phasianellus columbianus	Columbian Sharp-tailed Grouse	G4T3	S2
	Buteo regalis	Ferruginous Hawk	G4	S3B,S4N
	Vireo vicinior	Gray Vireo	G4	S2B
	Grus canadensis tabida	Greater Sandhill Crane	G5T4	S2B,S4N
	Melanerpes lewis	Lewis's Woodpecker	G4	S4
	Seiurus aurocapilla	Ovenbird	G5	S2B
	Centrocercus urophasianus	Sage Grouse	G4	S4
	Asio flammeus	Short-eared Owl	G5	S2B
	Plegadis chihi	White-faced Ibis	G5	S2B
	Lagopus leucura	White-tailed Ptarmigan	G5	S4
	Conimitella williamsii	Williams bishop's cap	G3?	S1
Insects	*Agapema homogena*	A Giant Silkmoth	G4	S2
	Doa ampla	A Moth	GNR	S1
	Cicindela nebraskana	A Tiger Beetle	G4	S1?
	Grammia sp. 1	A Tiger Moth	G2G3	SNR
	Atrytone arogos	Arogos Skipper	G3	S2
	Polites origenes	Cross-line Skipper	G5	S3
	Celastrina humulus	Hops Feeding Azure	G2G3	S2
	Callophrys mossii schryveri	Moss's Elfin	G4T3	S2S3
	Erynnis martialis	Mottled Dusky Wing	G3	S2S3
	Hesperia ottoe	Ottoe Skipper	G3G4	S2
	Oeneis polixenes	Polixenes Arctic	G5	S3
	Speyeria idalia	Regal Fritillary	G3	S1
	Oeneis jutta reducta	Rocky Mountain Arctic Jutta	G5T4	S1
	Sympetrum costiferum	Saffron-bordered Meadowfly	G5	S1?
	Erebia pawloskii	Theano Alpine	G5	S3
Mammals	*Salix drummondiana / Mesic Forbs Shrubland*	Drummonds Willow/Mesic Forb	G4	S4
	Corynorhinus townsendii pallescens	Townsend's Big-eared Bat Subsp	G4T4	S2
	Gulo gulo	Wolverine	G4	S1
Mollusks	*Valvata sincera*	Mossy Valvata	G5	S3
Reptiles	*Urosaurus ornatus*	Tree Lizard	G5	S4
	Coluber constrictor mormon	Western Yellowbelly Racer	G5T5	S3
	Malaxis brachypoda	white adder's-mouth	G4Q	S1
Vascular Plants	*Crepis nana*	dwarf hawksbeard	G5	S2

Major Group	Scientific Name	Common Name	Rank	
	Cirsium perplexans	adobe thistle	G2G3	S2S3
	Aster alpinus var. *vierhapperi*	alpine aster	G5T5	S1
	Braya humilis	alpine braya	G5	S2
	Ribes americanum	American currant	G5	S2
	Draba fladnizensis	arctic draba	G4	S2S3
	Physaria bellii	Bell's twinpod	G2G3	S2S3
	Sisyrinchium demissum	blue-eyed grass	G5	S2
	Astragalus bodinii	Bodin milkvetch	G4	S2
	Pellaea breweri	Brewer's cliff-brake	G5	S2
	Carex leptalea	bristle-stalk sedge	G5	S1
	Platanthera sparsiflora var. *ensifolia*	Canyon bog-orchid	G4G5T4?	S3
	Cypripedium fasciculatum	clustered lady's-slipper	G4	S3
	Delphinium alpestre	Colorado larkspur	G2	S2
	Salix exigua / Barren Shrubland	Coyote Willow/Bare Ground	G5	S5
	Astragalus debequaeus	Debeque milkvetch	G2	S2
	Castilleja puberula	downy indian-paintbrush	G2G3	S2S3
	Amorpha nana	dwarf wild indigo	G5	S2S3
	Astragalus musiniensis	Ferron milkvetch	G3	S1
	Aristida basiramea	forktip three-awn	G5	S1
	Heuchera hallii	Front Range alum-root	G3	S3
	Liatris ligulistylis	gay-feather	G5?	S1S2
	Ipomopsis globularis	globe gilia	G2	S2
	Eriogonum contortum	grand buckwheat	G3	S2
	Penstemon mensarum	Grand Mesa penstemon	G3	S3
	Asplenium trichomanes-ramosum	green spleenwort	G4	S1S2
	Sullivantia hapemanii var. purpusii	Hanging Garden sullivantia	G3T3	S3
	Telesonix jamesii	James' telesonix	G2	S2
	Thelypodiopsis juniperorum	juniper tumble mustard	G2	S2
	Iliamna grandiflora	large-flower globe-mallow	G3?Q	S1
	Agastache foeniculum	lavender hyssop	G4G5	S1
	Astragalus molybdenus	Leadville milkvetch	G3	S2
	Saxifraga foliolosa	leafy saxifrage	G4	S1
	Botrychium simplex	least moonwort	G5	S1
	Erigeron humilis	low fleabane	G4	S1
	Carex concinna	low northern sedge	G4G5	S1
	Mentzelia multicaulis	many-stem stickleaf	G3	S3
	Astragalus argophyllus var. *martinii*	meadow milkvetch	G5T4	S1
	Botrychium minganense	Mingan's moonwort	G4	S1
	Cystopteris montana	mountain bladder fern	G5	S1
	Monardella odoratissima	mountain wild mint	G4G5	S2
	Carex limosa	mud sedge	G5	S2

Major Group	Scientific Name	Common Name	Rank	
	Botrychium lineare	narrowleaf grapefern	G2?	S1
	Astragalus naturitensis	Naturita milkvetch	G2G3	S2S3
	Allium nevadense	Nevada onion	G4	S2
	Botrychium pinnatum	northern moonwort	G4?	S1
	Draba borealis	northern rockcress	G4	S2
	Botrychium pallidum	pale moonwort	G3	S2
	Penstemon debilis	Parachute penstemon	G1	S1
	Oxytropis parryi	Parry's crazy-weed	G5	S1
	Lesquerella parviflora	Piceance bladderpod	G2	S2
	Draba porsildii	Porsild's whitlow-grass	G3G4	S1
	Ptilagrostis porteri	Porter feathergrass	G2	S2
	Viola pedatifida	prairie violet	G5	S2
	Pellaea atropurpurea	purple cliff-brake	G5	S2S3
	Botrychium echo	reflected moonwort	G3	S3
	Mentzelia rhizomata	Roan Cliffs blazing star	G2	S2
	Draba globosa	rockcress draba	G3	S1
	Aquilegia saximontana	Rocky Mountain columbine	G3	S3
	Carex saximontana	Rocky Mountain sedge	G5	S1
	Cryptantha rollinsii	Rollins' cat's-eye	G3	S2
	Townsendia rothrockii	Rothrock townsend-daisy	G2G3	S2S3
	Carex capitata ssp. *arctogena*	round-headed sedge	G5T4?	S1
	Pellaea glabella ssp. *simplex*	smooth cliff-brake	G5T4?	S2
	Phippsia algida	snow grass	G5	S2
	Potentilla ambigens	southern Rocky Mountain cinquefoil	G3	S1S2
	Cryptantha mensana	southwestern cat's-eye	G3	S1
	Dryopteris expansa	spreading wood fern	G5	S1
	Lymnaea stagnalis	Swampy Lymnaea	G5	S2
	Draba crassa	thick-leaf whitlow-grass	G3	S3
	Carex torreyi	Torrey sedge	G4	S1
	Ranunculus karelinii	tundra buttercup	G4G5	S2
	Festuca dasyclada	Utah fescue	G3	S3
	Ceanothus martinii	Utah mountain lilac	G4	S1
	Saussurea weberi	Weber saussurea	G2G3	S2
	Draba weberi	Weber's draba	G1	S1
	Botrychium hesperium	western moonwort	G4	S2
	Draba oligosperma	woods draba	G5	S2
	Gypsoplaca macrophylla		G3G4	S1
	Lepidium crenatum		G2	S2

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Appendix G.

Lynx Update

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Lynx Update
May 25, 2009

INTRODUCTION

In an effort to establish a viable population of Canada lynx (*Lynx canadensis*) in Colorado, the Colorado Division of Wildlife (CDOW) initiated a reintroduction effort in 1997 with the first lynx released in February 1999. From 1999-2006, 218 lynx were released in southwestern Colorado.

REINTRODUCTION

Effort

From 1999 through 2006 218 lynx were reintroduced into southwestern Colorado (Table 1). Lynx released were captured in Alaska, British Columbia, Manitoba, Quebec and Yukon. All lynx were released in the Core Release Area of southwestern Colorado. Lynx were released with dual VHF/satellite radio collars so they could be monitored for movement, reproduction and survival. The CDOW did not release any additional lynx in 2007, 2008 or 2009 and there are no plans to release any additional animals in the near future.

Table 1. Lynx released in Colorado from February 1999 through May 25, 2009.

Year	Females	Males	TOTAL
1999	22	19	41
2000	35	20	55
2003	17	16	33
2004	17	20	37
2005	18	20	38
2006	6	8	14
TOTAL	115	103	218

Mortality Factors

Of the total 218 adult lynx released, we have 115 known mortalities as of May 25, 2009 (Table 2). Starvation was a significant cause of mortality in the first year of releases only. Mortalities occurred throughout the areas through which lynx moved. The primary known causes of death included 30.4% human-induced deaths which were confirmed or probably caused by collisions with vehicles or gunshot. Malnutrition and disease/illness accounted for 18.3% of the deaths. Other mortality factors included predation or probable predation by mountain lions, bobcat and lynx as well as other trauma-caused deaths. An additional 37.4% of known mortalities were from unknown causes.

Table 2. Causes of death for lynx released into southwestern Colorado from 1999-2006 as of May 25, 2009.

Cause of Death	Number of Mortalities
Unknown	43
Shot	16
Hit by Vehicle	14
Starvation	11
Other Trauma	8
Plague	7
Probable Shot	5
Predation	5
Probable Predation	3
Illness	3
Total Mortalities	115

Current Status

Reintroduced Lynx

We are currently tracking 42 of the 103 reintroduced lynx still possibly alive. We have 62 reintroduced lynx that we have not heard signals on since at least May 25, 2008 and list these animals as 'missing' (Table 3). One of these missing lynx is the unknown mortality, thus only 61 are truly missing. A number of these lynx are now missing because their collar batteries have died and we can no longer pick up radio signals. Some of the missing lynx may still have functioning collars but are outside the research area. Our expanded flights outside the research area during the summer and fall months may yield locating these missing lynx.

Table 3. Status of adult lynx reintroduced to Colorado as of May 25, 2009.

	Females	Males	Unknown	TOTALS
Released	115	103		218
Known Dead	63	51	1	115
Possible Alive	52	52		103 [a]
Missing	29	33		62[a]
Tracking	23	19		42

[a] 1 is unknown mortality

Colorado Lynx

Through trapping efforts to either replace malfunctioning or old radio collars on reintroduced lynx or collar Colorado-born lynx, we have captured 16 Colorado-born lynx as adults and fitted them with dual VHF-satellite transmitter collars (Table 4). These animals were identified by the PIT-tags placed subcutaneously at the back of the neck when found as kittens in their dens. Of these 16 we are currently tracking 7; 7 are known dead and 2 are missing (signals not heard since May 25, 2008).

Table 4. Status of Colorado-born telemetry collared lynx as of May 25, 2009.

	Females	Males	TOTALS
Collared	9	7	16
Known Dead	5	2	7
Possible Alive	4	5	9
Missing	1	1	2
Tracking	3	4	7

In addition, 3 young adult (< 3 years old) lynx were captured that did not have either a telemetry collar or a PIT-tag. These animals could be from litters of reintroduced lynx that we did not find, they could be native Colorado lynx, or immigrants from naturally occurring northern population outside of Colorado. They include 2 females and 1 male, all currently being tracked.

Reproduction

Reproduction was first documented in 2003 when 6 dens and a total of 16 kittens were found in the lynx Core Release Area in southwestern Colorado. Reproduction was also documented in 2004, 2005 and 2006. No dens were found in 2007 or 2008 (Table 5). We are just beginning our search for dens for 2009. Two of the Colorado-born females that we are tracking in the 2009 reproduction season were paired during breeding season with Colorado-born and telemetered-collared males. A third Colorado-born radio-telemetered male is paired with one of the radio-telemetered females captured in Colorado but of unknown origin.

Field crews weighed, photographed, PIT-tagged the kittens and checked body condition. Beginning in 2005, we also collected blood samples from the kittens for genetic work in an attempt to confirm paternity Kittens were processed as quickly as possible (11-32 minutes) to minimize the time the kittens were without their mother. While working with the kittens the females remained nearby, often making themselves visible to the field crews. The females generally continued a low growling vocalization the entire time personnel were at the den. In all cases, the female returned to the den site once field crews left the area. At all dens the females appeared in excellent condition, as did the kittens. The kittens weighed from 270-500 grams. Lynx kittens weigh approximately 200 grams at birth and do not open their eyes until they are 10-17 days old.

Females tracked in any given year include reintroduced females, telemeter-collared Colorado-born females and the 2 telemter-collared females of unknown origin (see above). The percent of tracked females during May and June found with litters in 2006 was lower (0.095) than in the 3 previous years (0.413, SE = 0.032, Table 5). However, all demographic and habitat characteristics measured at the 4 dens that were found in 2006 were comparable to all other dens found. Mean number of kittens per litter from 2003-2006 was 2.78 (SE = 0.05) and sex ratio of females to males was equal ($\bar{x}$ = 1.14, SE = 0.14).

Table 5. Lynx reproduction summary statistics for 2003-2008.

Year	# Females Tracked	# Dens Found in May/June	% Tracked Females with Kittens	Additional Litters Found in Winter	Mean # Kittens/Litter (SE)	Total Kittens Found	Sex Ratio M/F (SE)
2003	17	6	0.353	0	2.67 (0.33)	16	1.0
2004	26	11	0.462	2	2.83 (0.24)	39	1.5
2005	40	17	0.425	1	2.88 (0.18)	50	0.8
2006	42	4	0.095	0	2.75 (0.47)	11	1.2
2007	34	0	0.0	0		0	
2008	28	0	0.0	0		0	
2009	22						
TOTAL						116	1.14 (0.14)

Den Sites.--A total of 37 dens were found from 2003-2006. All of the dens except one were scattered throughout the high elevation areas of Colorado, south of I-70. In 2004, 1 den was found in southeastern Wyoming, near the Colorado border. Dens were located on steep ($\bar{x}_{slope} = 30^o$, SE=2^o), north-facing, high elevation ($\bar{x}$ = 3354 m, SE = 31 m) slopes. The dens were typically in Engelmann spruce/subalpine fir forests in areas of extensive downfall of coarse woody debris. All dens were located within the winter use areas used by the females.

Distribution and Movement Patterns

The majority of surviving lynx from the entire reintroduction effort continue to use high elevation (> 2900 m), forested areas from New Mexico north to Independence Pass, west as far as Taylor Mesa and east to Monarch Pass. Most movements away from the Core Release Area were to the north.

Numerous travel corridors have been used repeatedly by more than one lynx. These travel corridors include the Cochetopa Hills area for northerly movements, the Rio Grande Reservoir-Silverton-Lizardhead Pass for movements to the west, and southerly movements down the east side of Wolf Creek Pass to the southeast through the Conejos River Valley. Lynx appear to remain faithful to an area during winter months, and exhibit more extensive movements away from these areas in the summer. Such movement patterns have also been documented by native lynx in Wyoming and Montana.

Home Range

Reproductive females had the smallest 90% utilization distribution annual home ranges ($\bar{x}$ = 75.2 km^2, SE = 15.9 km^2, n = 19), followed by attending males ($\bar{x}$ = 102.5 km^2, SE = 39.7 km^2, n = 4). Non-reproductive females had the largest annual home ranges ($\bar{x}$ = 703.9 km^2, SE = 29.8 km^2, n = 32) followed by non-reproductive males ($\bar{x}$ = 387.0 km^2, SE = 73.5 km^2, n = 6). Combining all non-reproductive animals yielded a mean annual home range of 653.8 km^2 (SE = 145.4 km^2, n = 38).

HABITAT USE

Landscape-scale daytime habitat use was documented from 10,935 aerial locations of lynx collected from February

1999-August 27, 2008. Throughout the year Engelmann spruce / subalpine fir was the dominant cover used by lynx. A mix of Engelmann spruce, subalpine fir and aspen (*Populus tremuloides*) was the second most common cover type used throughout the year. Various riparian and riparian-mix areas were the third most common cover type where lynx were found during the daytime flights. Use of Engelmann spruce-subalpine fir forests and Engelmann spruce-subalpine fir-aspen forests was similar throughout the year. There was a trend in increased use of riparian areas beginning in July, peaking in November, and dropping off December through June.

Site-scale habitat data collected from snow-tracking efforts indicate Engelmann spruce and subalpine fir were also the most common forest stands used by lynx for all activities during winter in southwestern Colorado. Comparisons were made among sites used for long beds, dens, travel and where they made kills. Little difference in aspect, mean slope and mean elevation were detected for 3 of the 4 site types including long beds, travel and kills where lynx typically use gentler slopes ($\bar{x}$ = 15.7°) at an mean elevation of 3173 m, and varying aspects with a slight preference for north-facing slopes.

Mean percent total overstory was higher for long bed and kill sites than travel or den sites. Engelmann spruce provided a mean of 35.87% overstory for kills and long beds, with travel sites averaging 28% and den sites having the lowest mean percent overstory of 23% . Mean percent subalpine fir or aspen overstory did not vary across use sites. Willow overstory was highly variable and no dens were located in willow overstory.

A total of 1841 site-scale habitat plots were completed in winter from December 2002 through April 2005. The most common understory species at all 3 height categories above the snow (low = 0-0.5m, medium = 0.51 - 1.0 m, high = 1.1 - 1.5 m) was Engelmann spruce, subalpine fir, willow (*Salix* spp.) and aspen. Various other species such as Ponderosa pine (*Pinus ponderosa*), lodgepole pine (*Pinus contorta*), cottonwood (*Populus sargentii*), birch (*Betula* spp.) and others were also found in less than 5% of the habitat plots. If present, willow provided the greatest percent cover within a plot followed by Engelmann spruce, subalpine fir, aspen and coarse woody debris for long beds, kills and travel sites. Areas documented in willow used by lynx are typically on the edge of willow thickets as tracks are quickly lost within the thicket. Den sites had significantly higher percent understory cover for all three height categories. Understory at den sites was primarily made up of coarse woody debris.

The most common tree species documented in the site-scale habitat plots was Engelmann spruce. Subalpine fir and aspen were also present in >35% of the plots. Most habitat plots were vegetated with trees of DBH < 6". As DBH increased, percent occurrence decreased within the plot. Although decreasing in abundance as size increased, most lynx use sites had trees in each of the DBH categories, indicating mature forest stands except for dens. Den sites had a broad spectrum of Engelmann spruce tree sizes, including > 18" but no large subalpine fir or aspen trees. While Engelmann spruce and subalpine fir occurred in similar densities for kills, long beds and travel sites, den sites had twice the density of subalpine firs found at all other sites.

DIET AND HUNTING BEHAVIOR

Winter diet of lynx was documented through detection of kills found through snow-tracking. Prey species from failed and successful hunting attempts were identified by either tracks or remains. Scat analysis also provided information on foods consumed. A total of 604 kills were located from February 1999-April 2009. We collected over 1000 scat samples from February 1999-April 2009 that will be analyzed for content. In each winter from 1999-2007-08 the most common prey item was snowshoe hare, followed by red squirrel. During these years, the percent of snowshoe hare kills found however, varied annually from a low of 55.56% in 1999 to a high of 90.77% in winter 2002-2003. During the 2008-09 winter, the percent of red squirrel kills found (66%, *n* = 56 kills) exceeded the percent snowshoe hare kills found (30%).

A comparison of percent overstory for successful and unsuccessful snowshoe hare chases indicated lynx were more successful at sites with slightly higher percent overstory, if the overstory species were Englemann spruce, subalpine fir or willow. Lynx were slightly less successful in areas of greater aspen overstory. This trend was repeated for percent understory at all 3 height categories except that higher aspen understory improved hunting success. Higher density of Engelmann spruce and subalpine fir increased hunting success while increased aspen density decreased hunting success.

LYNX IDENTIFICATION NUMBERS

The nomenclature for the lynx are 2 letters to note area of origin (YK = Yukon, AK = Alaska, BC = British Columbia, QU = Quebec and MT = Manitoba), 2 numbers to demarcate year released (99 = 1999, 00 = 2000 etc.), 1 letter for sex (M, F) and then animal number for each year and location. So, for example, lynx YK00F02 was the second female lynx captured in the Yukon and released in Colorado in spring 2000. Lynx known to be born in Colorado are denoted by the first 2 letters 'CO' the next 2 numbers denote the year of their birth '05', then sex, then the order of each individual by sex as found that year (e.g.., CO05F01). Lynx first captured as adults in Colorado with no PIT-tags or telemeter-collars are denoted by the first 2 letters 'CO' the next 2 numbers denote the year of their first capture '07', then an 'A' for adult, then either 'F'or 'M' for sex, then the order of each individual by sex as found that year (e.g., CO07AF01).

WEB SITE

These updates and other lynx reports are being posted on the CDOW web site http://wildlife.state.co.us/WildlifeSpecies/SpeciesOfConcern/Mammals/Lynx/LynxOverview.htm.

SIGHTINGS

Thanks again to all of you who have called or e-mailed in sightings - these really help us when we fly for lynx. We now have a standardized sighting form that can be used to report sightings. The form is found on our website. Please know that even if we do not contact you, we follow-up on all these sightings, usually with flights in the area of the sighting as soon as possible. Please contact me if you have specific questions or concerns. My office phone number is 970 472-4310 and my e-mail address is tanya.shenk@state.co.us.