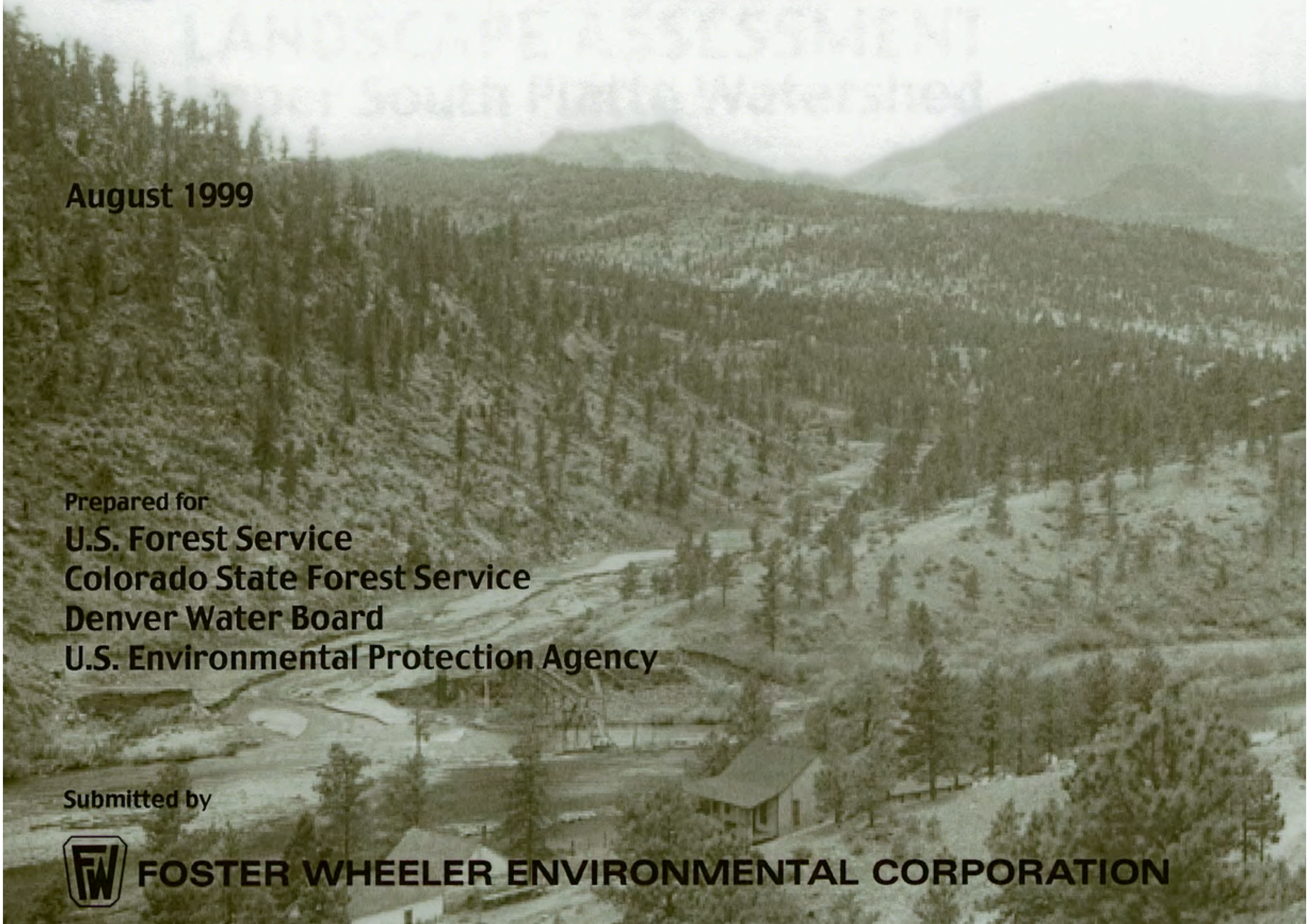
LANDSCAPE ASSESSMENT
Upper South Platte Watershed



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U.S. Forest Service
Colorado State Forest Service
Denver Water Board
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Submitted by

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INTRODUCTION

The intent of this Assessment is to study ecological processes and develop recommendations to restore and maintain the health of the Upper South Platte Watershed. The Upper South Platte Watershed provides the City of Denver with 70 percent of its drinking water supply. The Watershed was identified by the Colorado Unified Watershed Assessment (Colorado Department of Public Health and Environment and USDA NRCS) as a critical watershed in need of restoration because it is not meeting clean water and other natural resource goals. Additionally, a fire in the Buffalo Creek drainage in 1996 resulted in a loss of several houses and forest cover on 12,000 acres. Two large summer storms in the area of the burn caused catastrophic erosion and sediment deposition into the watershed's streams, and one human death. The Denver Water Board has had to extensively dredge the Strontia Springs Reservoir because of sediment from the Buffalo Creek Fire that was transported and deposited into the reservoir. Future large fires and subsequent erosion in the watershed could threaten property and human life, and exacerbate soil and water quality problems.

The Upper South Platte Watershed Protection and Restoration Project was initiated in August 1998 to develop a strategy for watershed restoration and protection. The Project involves an interagency partnership between the US Forest Service, Colorado State Forest Service, Denver Water Board, and Environmental Protection Agency. These partners are concerned with continued soil and water problems from the Buffalo Creek Fire of 1996 and the potential for future fires to cause problems in other parts of the watershed. The partners intend to use watershed restoration as a guideline for management and project planning.

This landscape assessment is a first step in a larger restoration project. The goal for the assessment is to identify and prioritize restoration opportunities that can be used to plan management of the watershed's resources. Because forest vegetation appears to not be in a sustainable condition in some portions of the Upper South Platte Watershed, the landscape assessment will focus on identifying areas where forest vegetation restoration opportunities exist. The next step is to recommend forest restoration to maintain or restore watershed functions, particularly to reduce the extent and intensity of disturbances such as the Buffalo Creek fire and to strengthen the resilience of the watershed if such events should occur.

The focus for the identification of restoration opportunities will be to look for areas that are not functioning in a manner that could be sustained as evidenced by their historical, or pre-European condition. These areas may currently be less regulated by the type of disturbances under which the ecosystem developed and more influenced by disturbances altered by human intervention. The result may be landscapes that are at a high risk of significant loss to events that are more extreme than typically occurred prior to European settlement. Identification of these areas will be combined with an evaluation of current watershed conditions to identify areas where forest restoration could be used to lessen the potential of extreme or catastrophic events. The goals of the recommended management strategies would be to reduce the extent and impacts of catastrophic events, prevent excessive erosion and to both protect and improve the current watershed conditions. Ultimately, the end result would be to move the forest towards a condition that is more sustainable over time.

The Upper South Platte Watershed Landscape Assessment will focus on issues that have been defined by the interagency partners as most critical to protection of the watershed. These issues are concerned with the relationship between the existing forest vegetation, soil erosion and transport to streams, as well as future risks of catastrophic disturbances that could increase soil erosion and transport. The assessment is limited to these concerns and not intended to fully address all resource issues that are managed and studied within the watershed. The issues to be studied in detail include:

A. Landscape pattern of forest vegetation

B. Soil development and movement

C. Water quality, quantity and aquatic habitats

The assessment consists of six steps (see also Appendix A):

Step 1. **Characterization of the Watershed.** This step characterizes the processes and features of the watershed that affect watershed health and the potential for catastrophic disturbance. Step 1 also involves the identification and review of management plans from local, state and federal agencies that apply to this study. Management objectives, land use allocations and other regulatory constraints will be discussed.

Step 2. **Issues and Key Questions.** This step defines the issues listed above including the goals of the study. Questions are presented that need to be answered by the study in order to explain the existing condition, compare current conditions with those that existed prior to European settlement and develop recommendations for management.

Step 3. **Current Condition.** This step presents an assessment of the current condition of the physical, biological and human aspects of the ecosystem for each issue.

Step 4. **Reference Condition.** This step develops a description of the pre-European or reference condition that can be compared to the current condition. This will provide an explanation of how ecological conditions have changed over time due to human influences and natural disturbances. It will also provide a measuring tool to determine how far the existing condition differs from what could be considered a sustainable condition based on historical information.

Step 5. **Synthesis.** This step synthesizes the information for the three issues previously presented. The discussion includes a comparison of the current and reference condition where significant differences, similarities, trends and their causes should be identified. This step also evaluates the capability of the system to achieve management objectives or to be restored to sustainable watershed conditions. Watersheds in need of restoration management are prioritized.

Step 6. **Recommendations.** This step provides management recommendations that could restore important ecological functions or processes if they are implemented. Recommendations are prioritized by watershed that have the highest potential for, or need of, restoration.

STEP 1. CHARACTERIZATION OF THE WATERSHED

The Upper South Platte Watershed is a large, important watershed in Colorado (Exhibit 1). The watershed is a critical water supply for the City of Denver. Because it is very close to Denver (Exhibit 2), it contains a large area of urban-wildlands interface and provides easily accessible fishing, hiking and other outdoor experiences. There are portions of two wilderness areas (Lost Creek and Mt. Evans) in the Assessment Area. Portions of the South Platte River are a gold medal trout fishery and will likely be designated as a Wild and Scenic River in the near future.

Exhibit 1. Colorado Location Map

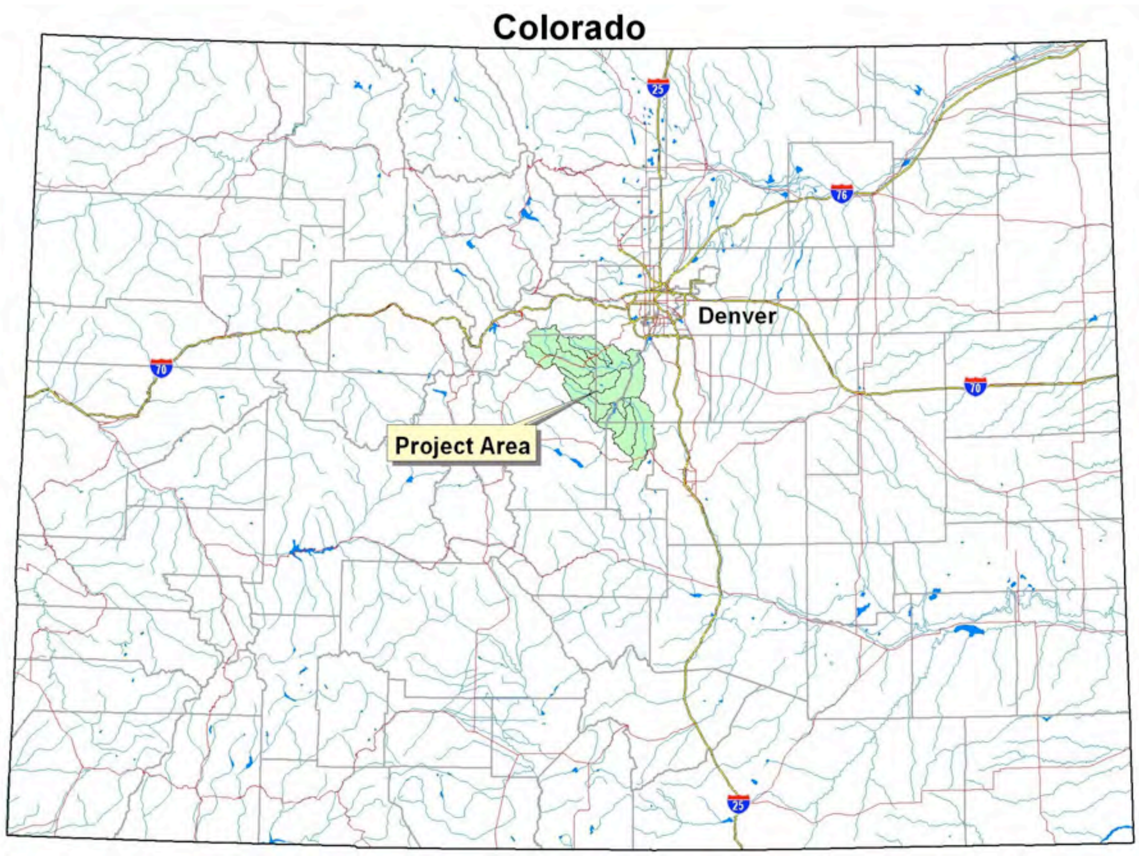
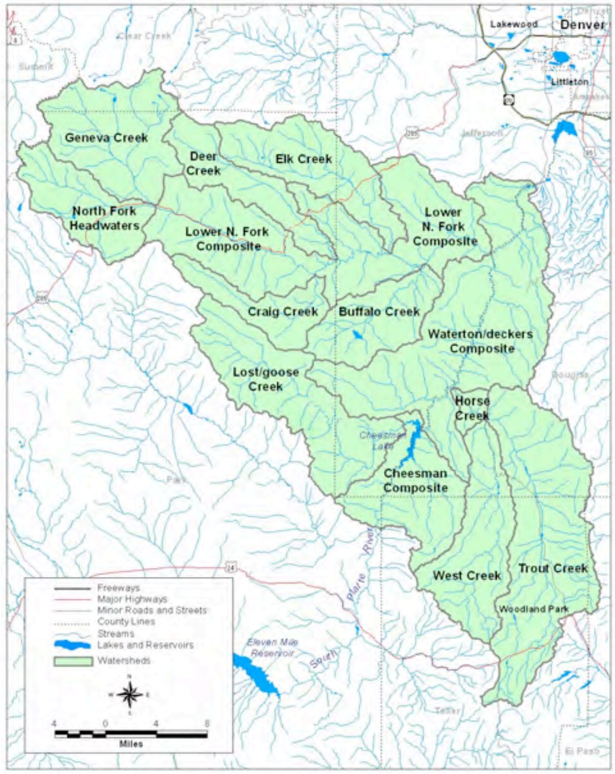


Exhibit 2. Project Location Map



The structure, composition, and landscape pattern of vegetation in the Upper South Platte Watershed have been altered from its pre-European conditions by cumulative human impacts. These impacts include extensive grazing, likely human use of fire, extensive logging between 1870 and 1900, and fire suppression since the early 1900s. The result is an alteration of the disturbance processes that dominated the ecosystem prior to European settlement.

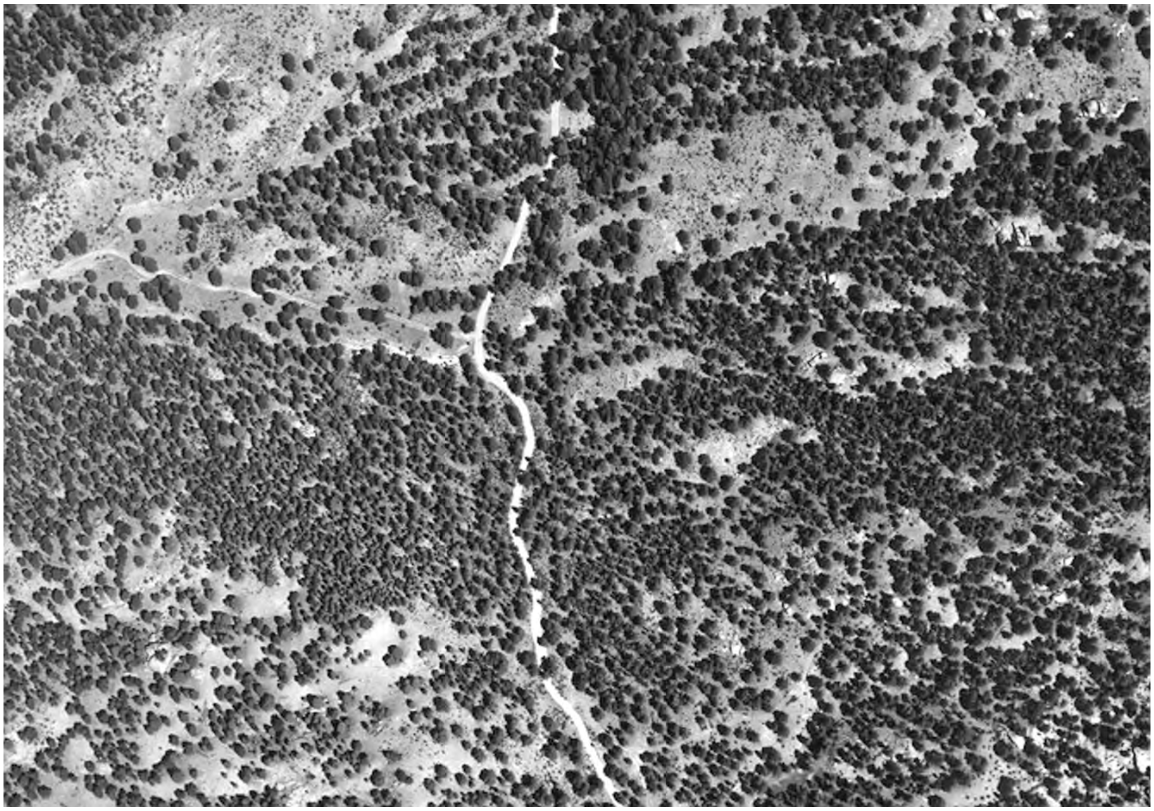
The pre-European ponderosa pine forest was likely quite open with fewer trees, greater age diversity, and larger openings than the area displays today. City of Denver land surrounding Cheesman Lake has been studied extensively (Brown, et al., in press, and Kaufmann, et al., submitted) and provides evidence that the ponderosa pine forests from 1000 to 1870 were characterized by frequent fires. The frequent fires usually killed some trees (and sometimes many) by spreading into the crowns. Crown fires played a critical role in maintaining the open structure of the forest.

The open forest was also somewhat protected from extensive fires because of the distance between tree crowns and large openings. That forest structure is very appropriately called a mosaic. The mosaic consisted of many ages from seedlings to over 400 year old trees (Exhibit 3). Many snags (standing dead trees) and cavities in live trees provided prime wildlife habitat. The forest mosaic was sustainable because of the diversity and openness.

The ponderosa pine forests today are more dense, even-aged, younger and more homogeneous than the pre-European condition. Large areas of ponderosa pine have interconnected crowns that could sustain a catastrophic fire. The recent Buffalo Creek fire is an example of the type of event that could become frequent throughout the montane forest zone. These types of disturbances could lead to excessive soil erosion, and transport and deposition into area streams such as happened following the Buffalo Creek fire.

This would be detrimental to the health of the watershed. Wildlife habitat, fish habitat and water quality would suffer greatly if extensive fires would consume large portions of the ponderosa pine forest.

Exhibit 3. Aerial View of the Mosaic Forest Condition at Cheesman Lake



Historic photographs were collected and some of the sites were revisited to document the changes. The best historic photographs are circa 1900 and therefore do not document the reference (pre-European) condition. These photographs do document what conditions existed in 1900 following extensive logging but before fire suppression. The current conditions developed from the conditions documented in the historic photographs. Exhibit 4 shows a comparison of Buffalo Park near the confluence of Buffalo Creek and North Fork South Platte River. Exhibit 5 shows a comparison of Deckers and the South Platte River below Cheesman. A small cabin appearing near the left center edge of the circa 1900 photograph can also be seen in the 1999 photograph. These photographs document the change in forest structure and density that other photographs also show for other areas in the Assessment Area.

Exhibit 4. Buffalo Park circa 1900 and 1999

Exhibit 5. Deckers circa 1900 and 1999

Management Plans and Regulatory Constraints

The majority of the Assessment Area is National Forest land managed by the Pike-San Isabel National Forest. The Pike-San Isabel Land and Resource Management Plan (USDA 1984a) and associated Environmental Impact Statement (USDA 1984b) contains many standards and guidelines for managing National Forest land in the Assessment Area. Revisions to the Land and Resource Management Plan have started, therefore some of the current standards and guidelines may not apply to restoration projects undertaken in targeted watersheds, because they will be revised before project implementation. There also may be a need to revise some of the standards and guidelines in the process of implementing a restoration project.

Some Pike-San Isabel Forest Direction Goals that can be used to direct restoration activities include;

- Provide a cost-effective level of fire protection to minimize the combined costs of protection and damages, and prevent loss of human life.
- Increase diversity for wildlife and habitat improvement
- Improve fish habitat on suitable streams
- Improve age class and species distribution of tree stands forest-wide
- Maintain or improve water quality to meet Federal and State standards and increase average annual water yield
- Protect riparian areas and wetlands from degradation
- Conserve water and soil resources and prevent significant or permanent impairment of land productivity.

There are 12 Management Areas of the Pike-San Isabel National Forests within the Assessment Area. The Management Areas and their direction are listed in Exhibit 6. Vegetation restoration activities would be compatible with US Forest Service direction in Management Areas 2A, 2B, 3A, 7A, and 7D. Management Area direction would substantially reduce the area of consideration for forest restoration activities in the following watersheds: Craig Creek, Geneva Creek, North Fork Headwaters, Lost/Goose Creek, Lower North Fork, and a large portion of Trout Creek. Watersheds with Management Area direction that would be most suitable for forest restoration activities would be Buffalo Creek, Cheesman, Horse Creek, Waterton/Deckers and West Creek.

There are portions of two wilderness areas (Lost Creek and Mt. Evans) in the Assessment Area. These wilderness areas would likely be excluded from restoration projects. Additionally, some segments of the South Platte River are being considered for inclusion in the Wild and Scenic River program. Activities in those segments would need to fit within the management direction of the specific designations. The Federal Wildland Fire Management Policy (USDI and USDA, 1995) gives specific direction for managing fires on Federal lands.

The State of Colorado has listed several segments of streams within the Assessment Area on the 303(d) list, as mandated by the Federal Clean Water Act. Activities in those watersheds would have to go through or comply with the total maximum daily load (TMDL) process. Two new State of Colorado laws (SB 145 and HB 1351) regulate smoke from prescribed fires.

There is a large section of private land in the northern portion of the Assessment Area. Jefferson and Douglas Counties have management plans that cover portions of the Assessment Area. The Douglas County Master Plan (July 1997) presents guidelines for wildlife and fire hazards. The Conifer/285 Corridor Area Community Plan (Jefferson County, 1987) provides direction for reducing fire risk in the area.

Exhibit 6. Management Areas and direction in the Assessment Area

Mgmt. Area	Management Area Direction (Emphasis)	Watersheds
1B-1	Downhill skiing on existing downhill ski sites.	Geneva Creek
1B-2	Maintenance of selected sites for future downhill skiing recreation opportunities.	Geneva Creek
2A	Semiprimitive motorized recreation opportunities.	Cheesman, Elk Creek, Horse Creek, Lost/Goose Creek, Trout Creek, Waterton/Deckers
2B	Rural and roaded-natural recreation opportunities.	Buffalo Creek, Cheesman, Craig Creek, Deer Creek, Elk Creek, Geneva Creek, Horse Creek, Lower North Fork, North Fork Headwaters, Trout Creek, Waterton/Deckers, West Creek
3A	Semiprimitive nonmotorized recreation in both roaded and unroaded areas.	Cheesman, Lost/Goose Creek, Lower North Fork, North Fork Headwaters, Waterton/Deckers, West Creek
4B	Habitat needs of one or more management indicator species.	Cheesman, Geneva Creek, Lower North Fork, North Fork Headwaters, Trout Creek, Waterton/Deckers
5B	Forage and cover on big game winter range.	Lower North Fork, North Fork Headwaters, Waterton/Deckers
6B	Livestock grazing	Lost/Goose Creek
7A	Wood-fiber production and utilization of large roundwood.	Buffalo Creek, Cheesman, Lost/Goose Creek, Lower North Fork, North Fork Headwaters, Trout Creek, Waterton/Deckers, West Creek
7D	Production and utilization of forest products other than sawtimber.	Elk Creek, Lost/Goose Creek, Waterton/Deckers, West Creek
8B	Providing the protection and perpetuation of wilderness areas.	Buffalo Creek, Cheesman, Craig Creek, Deer Creek, Elk Creek, Geneva Creek, Lost/Goose Creek, Lower North Fork, Waterton/Deckers
8C	Semiprimitive recreation opportunities	Buffalo Creek, Craig Creek, Deer Creek, Elk Creek, Geneva Creek, Lost/Goose Creek, Lower North Fork, Waterton/Deckers
10A	Research, study, observations, monitoring, and educational activities for Research Natural Areas.	Trout Creek

There are numerous recovery plans for wildlife species in the Assessment Area. The State of Colorado's Department of Wildlife and the US Fish and Wildlife Service should be consulted regarding protection, recovery or reintroduction plans for special status wildlife species. The Colorado Weed Management Act and the Environmental Assessment for Management of Noxious Weeds prepared by the Pike-San Isabel National Forests should be consulted for management of exotic plants.

STEP 2. ISSUES AND KEY QUESTIONS

The Upper South Platte Watershed Landscape Assessment focuses on issues that have been defined by the interagency partners as most critical to protection of the watershed condition. The watershed condition is dependent on the relationship between forest condition, soil erosion and subsequent deposition into the streams, and transport of these sediments by the stream. The long term health of the watershed can be affected by future risks of catastrophic disturbances that could increase soil erosion, transport and deposition. Therefore, this assessment primarily examines the following issues and their interrelationships:

1. Landscape pattern of vegetation

2. Soil development and movement

3. Water quality, quantity and aquatic habitats

This step of the study sets up the issues that need to be examined in detail and lays out the study's goals and process for analysis. Each of the issues is discussed from a perspective of past, current, and future trends. The issues are discussed in terms of what needs to be considered in order to develop the landscape assessment. Questions are presented for each issue that need to be answered in order to guide the study from examining historical trends to presenting recommendations for management of specific watersheds. The questions were developed to help describe the current conditions, to describe historical or reference conditions, to compare and synthesize the reference with the current condition, and finally, to develop recommendations and prioritize watersheds by restoration need. These questions follow the Steps 3 through 6 outlined in the introduction.

ISSUE A. LANDSCAPE PATTERN OF VEGETATION

The structure, composition, and landscape pattern of vegetation in the Upper South Platte Watershed may be altered from its pre-European conditions by cumulative human impacts. These impacts stem from changes in land use such as grazing and timber harvesting, and in land management policies such as fire suppression. The result of these activities may be an alteration of the disturbance processes that dominated the ecosystem prior to European settlement. The current types, amount and pattern of vegetation cover may increase the potential for catastrophic disturbances over the reference or pre-European (or reference) condition. These types of disturbances could lead to excessive soil erosion, and transport and deposition into area streams. This would be detrimental to the health of the watershed.

Background

In the forests of the Colorado Front Range a combination of the effects of logging, grazing and fire suppression may have altered the distribution, ages and types of trees and associated plants in these forests. Much of the Assessment Area is in the montane forest zone where Front Range ponderosa pine and Douglas-fir forests are generally considered to be more dense, younger, and more homogeneous than they were prior to European settlement. Currently, these areas may be less regulated by processes reflecting historic or sustainable disturbance patterns and more influenced by extreme events. The 1996 catastrophic Buffalo Creek fire is an example of a fire event that may occur in the Assessment Area. The potential for such events may be increased by the current vegetation condition.

Key Questions

The questions that are asked to guide the assessment are presented below. The questions are organized according to the step of the process that they are used.

Step 3. Current condition questions for landscape patterns of forest vegetation

A-1. What are the existing patterns and distribution of the types and ages of the forest's vegetation?

A-2. What disturbance processes are primarily responsible for the patterns and distribution of the forest's vegetation?

A-3. What are the patterns of fire hazard in the Assessment Area? Where are areas of uniformity in forest cover that may reflect an increased risk of fire spread?

A-4. How does the current composition and pattern of the forest vegetation (overstory and understory) contribute to the risk of catastrophic disturbance that may lead to excessive soil erosion? How do these factors contribute to the risk of excessive soil erosion resulting from sparse vegetation cover?

A-5. What are the current patterns of distribution of weedy or invasive plant species in the Assessment Area? Where in the area are invasive species most likely to be of concern for restoration management?

A-6. Where are known populations of terrestrial (flora and fauna) species of special interest or concern located within the Assessment Area? Where is potential habitat for these species in the Assessment Area?

Step 4. Reference condition questions for landscape patterns of forest vegetation

A-7. What were the key pre-European disturbances (e.g. fire, insects, disease) that contributed to patterns of vegetation development in the Assessment Area?

A-8. How were historical fires characterized (frequency, intensity, extent)? What was the historical occurrence of intense, large fires?

Step 5. Synthesis questions for landscape patterns of forest vegetation

A-9. How do existing conditions of forest vegetation (composition, age, distribution and landscape pattern) differ from historical or reference conditions?

Step 6. Recommendations to manage landscape patterns of forest vegetation

A-10. What distribution and patterns of forest vegetation conditions across the landscape would lessen the risks of catastrophic disturbance that might lead to extreme soil erosion? What would be considered a sustainable forest vegetation composition and landscape pattern?

A-11. Given the current vegetation patterns, as well as distributions of invasive species and critical terrestrial species, where are the high priority restoration needs or opportunities?

A-12. What are feasible ways to change areas of unsustainable vegetation condition to sustainable vegetation condition?

Step 3. Current Condition

Variation in Vegetation Structure and Composition

Question A-1: What are the existing patterns and distribution of the types and ages of the forest's vegetation?

There are three major vegetation zones in the Assessment Area and they are dependent primarily on elevation. The montane zone ranges from 6,500 to 10,000 feet in elevation. The predominant current vegetation types within the montane zone are ponderosa pine, Douglas-fir, and in the upper portions of the montane zone, lodgepole pine. The subalpine zone ranges from 10,000 to 12,000 feet in elevation. In this zone, lodgepole pine, aspen, Engelmann spruce and subalpine fir are currently the predominant vegetation types. Finally, there is the alpine zone, which is areas above treeline that are primarily composed of alpine meadows, shrubland, rock, and pockets of bristlecone pine. Exhibit 7 and Map V-1 present the vegetation types across the watershed. Both the map and the table illustrate the widespread extent of the ponderosa pine and Douglas-fir vegetation types. A detailed table, which breaks the vegetation types down by subwatershed, can be found in Appendix B.

Map V-1. Distribution of Vegetation Types. Geneva Creek and North Fork Headwaters have basically no ponderosa pine, Douglas-fir. Craig and Lost/Goose Creeks have small amounts of ponderosa pine, Douglas-fir. Ponderosa pine and Douglas-fir are generally found intermixed as displayed in the southwest portion of the Assessment Area. The large block of ponderosa pine in the north central portion is likely an area of intermixed stands of ponderosa pine and Douglas-fir but data were not available to separate those stands and therefore a large area was classified as ponderosa pine.

Exhibit 7. Vegetation Types in the Assessment Area

Vegetation Type	Percent of Watershed
Ponderosa pine	36
Douglas-fir	23
Engelmann spruce/subalpine fir	13
Lodgepole pine	11
Shrub	5
Grasslands/meadows	5
Aspen	3
Rock	2
Other (bristle cone, limber, pinyon juniper)	1
Other (water, urban)	Less than 0.5 percent of watershed each

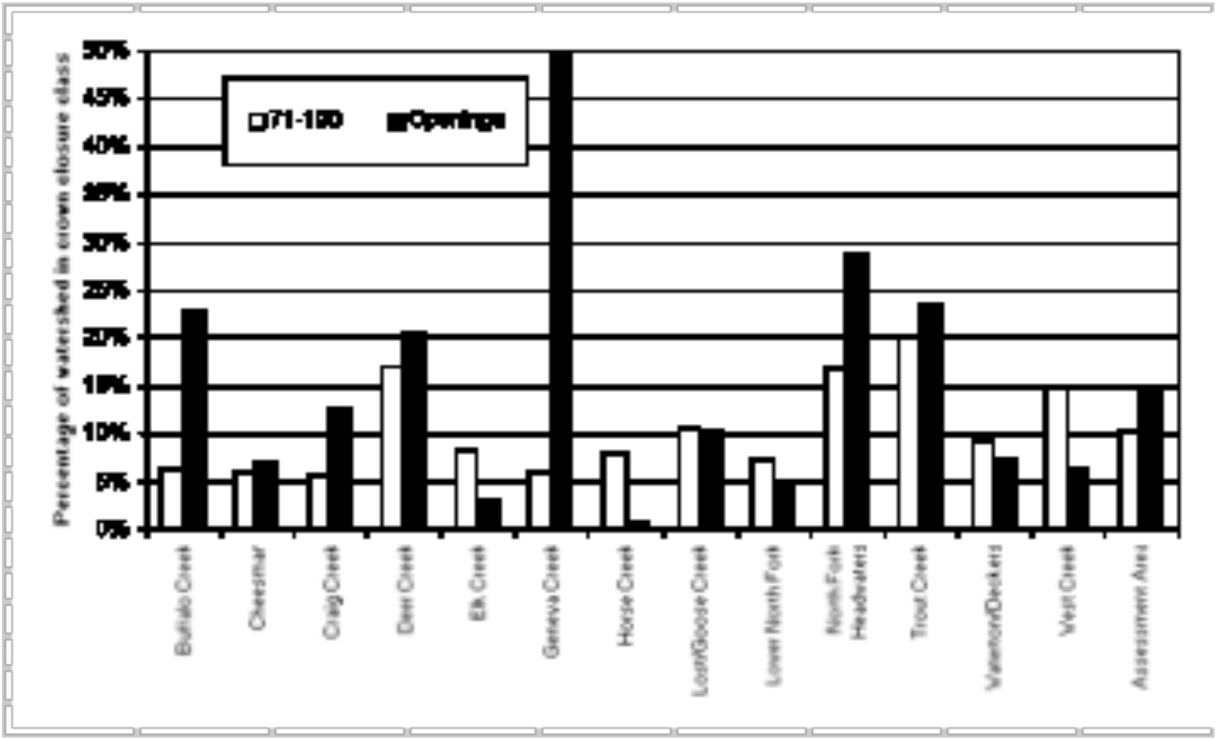
In addition to the tree dominated vegetation types, approximately 10 percent of the Assessment Area is non-forested and covered with grasslands, meadows, shrublands and rock. Riparian areas occur in areas with high water tables, both in forested and non-forested areas. Forest grasslands and meadows occur throughout the higher elevation areas and small pockets are interspersed with other vegetation types. The grasslands can support perennial grasses and forbs. It is possible that some of these open areas are the result of fire. The shrublands are dominated by one or more of the following species: current, bitterbrush, rabbit-brush, snowberry and mountain mahogany.

Riparian zones are found in approximately nine percent of the area, and occur in all vegetation areas. Riparian areas are typically located adjacent to streams and around springs, lakes or bogs. The riparian areas are delicate and important resources and contain some of the most productive sites in the Assessment Area. They also often have the most diverse age structure. Vegetation in these areas depend on aspect and elevation. Plants that are typically found in this ecosystem include willows, alder, cottonwood and sedges.

Crown closure of the forested areas in the Assessment Area was used to assess the density of the landscape. If an aerial view (looking straight down) of the forest shows that 30 percent of the ground is visible then the crown closure is estimated to be 70 percent. The forest stands in the Assessment Area are primarily 41-70 percent crown closure classification. Openings, which were classified as 0-10 percent crown closure and shrublands, vary widely throughout the Assessment Area. The percentage of watersheds in openings ranges from 1 percent (Horse Creek) to 50 percent (Geneva Creek). There are six watersheds that have less than 10 percent openings; Cheesman, Elk Creek, Horse Creek, Lower North Fork, Waterton/Deckers and West Creek. The watersheds in the Assessment Area that are dominated by ponderosa pine/Douglas-fir montane forest are the watersheds with the lowest percentages of openings. Exhibit 8 shows the openings and 71-100 percent crown closure for all watersheds in the Assessment Area.

Map V-2. Distribution of Crown Closure. This map shows that the majority of the landscape is in the 41-70 percent crown cover category. The crown cover data was taken directly from the US Forest Service RMRIS GIS data. For the majority of private land crown closure was estimated from aerial photos (other portions did not have adequate photography). This map also identifies old growth on US Forest Service land in the Assessment Area.

Exhibit 8. Selected Crown Closure Classes by Watershed



Major Forested Vegetation Types

A summary of the major vegetation types as they exist in the Assessment Area is given below. The discussion here concentrates on the vegetation types of most importance to the study. A more detailed discussion can be found in Appendix B.

Ponderosa Pine Type

In the Assessment Area, the ponderosa pine vegetation type occurs in the montane zone, primarily between 6,500 and 10,000 feet, occupying approximately 36 percent of the area. Typical species that may be associated with the ponderosa pine vegetation type include aspen, piñon pine, juniper and oakbrush. Ponderosa pine can grow in pure stands, but is more generally associated with Douglas-fir. It is considered a climax species on many of the sites on which it occurs. Major disturbances such as high-intensity fires, heavy logging or widespread mortality from insect or disease infestations may cause these sites to revert to an early seral species. Mountain pine beetle is common in the area, killing individual trees and clumps of trees in some stands.

The ponderosa pine reproduces by seed. Natural regeneration requires conditions that coincide rather infrequently in the Assessment Area including a good seed crop, ample moisture the spring following seed fall, and favorable seedbed conditions. Because of management activities such as logging and fire suppression, the majority of the ponderosa pine is mature to over-mature: 83 percent is late seral. The ponderosa pine sites are also densely stocked.

Douglas-fir

This vegetation type occurs in the montane zone in the Assessment Area and covers approximately 23 percent of the area. It is frequently the major conifer in a large area. It is a long-lived species that, in the Assessment Area, has not been heavily harvested, resulting in mostly mature to over mature stands and very few areas of early seral stages. Approximately 79 percent of the area is late seral. Like ponderosa pine, it is a climax species that reproduces by seed.

Engelmann Spruce/Subalpine Fir

This vegetation type occupies 13 percent of the Assessment Area in the subalpine zone, primarily in moist areas. Like ponderosa pine and Douglas-fir, it is considered a climax plant community on most of the sites that is occupies. These species are long-lived, spruce living to 300 years and fir to 250 years and the stands often have dense forest growth and a layered appearance. Unless a stand originates from a stand replacing fire, spruce/fir stands tend to be multi-aged as different areas are affected by insect attack or windthrow. In the Assessment Area, 83 percent of the stands are late seral.

As the stands mature they do become susceptible to insect and disease infestations. The trees are also susceptible from blowdown in windstorms which create conditions that lead to higher insect populations and increased mortality. There have been beetle outbreaks in the Assessment Area that have affected the old growth spruce and fir stands. Many of the trees killed in these attacks are still standing. Without fire or logging, spruce/fir readily reproduce.

Lodgepole Pine

The lodgepole vegetation type occurs in the Assessment Area in the upper portions of the montane zone and in the subalpine zone, covering 11 percent of the area. It occurs mostly in even-aged stands that were created by stand replacing fires. Lodgepole will cede to more shade tolerant species such as spruce/fir in the long term absence of fire. On sites that lack seed sources or proper conditions for the establishment of spruce/fir, lodgepole pine will form a virtual climax plant community. In the Assessment Area, 30 percent of the lodgepole stands is late seral, 67 percent mid-seral and six percent early seral.

"Ever since this part of the country was first settled by ranchmen, about forty years ago, the business of cutting lumber from the territory now included within the boundaries of the reserve has been unremittingly prosecuted, although during the earlier years most of the timber cut was for strictly local use. With the advent of railroads and the development of mining the shipping of lumber became important, and numerous sawmills have been almost steadily at work taking timber from private or public lands, legally and illegally. Beginning with the supplies available nearest to market or shipping station, portable sawmills have been moved gradually to the farthest and least accessible of the timbered parts of the mountains, until now they have reached Lost Park, where is located the last of any considerable area of timber land which has not had the best picked from it or been totally destroyed by fire." (Jack, 1900)

Lodgepole pine is an aggressive invader of disturbed sites. Natural regeneration is often so prolific that the stand becomes too dense and may not grow vigorously unless thinned. Overmature or crowded stands are susceptible to beetle infestations and disease. Stands with high proportions of beetle killed trees are susceptible to wildfire. More information on this species can be found in Appendix B.

Other Types

Other vegetation types occurring in the Assessment Area include aspen, shrub, grasslands/ meadows and riparian. Detailed descriptions of these vegetation types can be found in Appendix B.

Disturbance Processes and the Current Condition

Question A-2: What disturbance processes are primarily responsible for the current patterns and distribution of the forest's vegetation?

The current forest vegetation condition is a result of a sequence of disturbances beginning with European settlement of the area in the mid-1800s. Settlers introduced grazing and began harvesting timber through selective logging. The logging effort increased substantially between 1880 and 1890 when logging operations moved into the area. This logging had a significant effect on the forests.

"There are a very few thousand acres of merchantable timber where the ax has not been used with evident effect. The best of the remaining timber cannot be called large, but it is greedily sought by the lumbermen, who take any kind of sufficient dimensions without much discrimination regarding species." (Jack, 1900).

The Assessment Area at the turn of the century was very open and contained few large trees (see Exhibits 4 and 5). The forests of today started growing around that time period. The even-aged structure of many of the ponderosa and Douglas-fir stands today was setup by the disturbances between 1850 and 1900, and the regrowth that has occurred since that time.

The exclusion of fire from the Assessment Area since the early 1900s has allowed the ponderosa pine/Douglas-fir stands to mature into relatively homogeneous, dense stands compared to what likely existed before 1850. This has been due to a combination of factors including fire suppression, competition and grazing. The removal of the large trees and elimination of grasses from grazing would have lessened competition for water and nutrients for the newly growing trees. Fire suppression kept natural fires from reducing their growth or eliminating them. Therefore, a larger proportion of seedlings have grown to maturity due to the change in disturbance factors.

"As this ground has nearly all been cut over at various times during the past thirty years, some of it having been twice or even three times searched for suitable sawmill trees, there are a few trees of large size remaining." (Jack, 1900).

Fire suppression has also allowed Douglas-fir to occupy a larger portion of the montane area. Ponderosa pines have bark that allows it to survive some fires while Douglas-fir is not as fire tolerant. Therefore, frequent fires reduced the proportion of Douglas-fir compared to ponderosa pine. Fire suppression also reduced or eliminated the creation of openings that were a more dominant characteristic of the forest before 1850. With the older trees removed by harvesting, the oldest trees are now the remnants that were not harvested about 100 years ago.

The current disturbance regime in the Assessment Area contains no or little disturbances for 100+ years, followed one large fire, Buffalo Creek, and likely larger fires in the future. The Assessment Area is now setup for a series of large catastrophic fires due to the large areas of homogenous, even-aged stands with connected crowns. The fire breaks (openings and widely spaced large trees) that existed before are not present in the current condition.

The relatively dense, even-aged stands that characterize the current condition favor fires that consume all of the trees over large areas (Buffalo Creek fire). This disturbance regime can repeat itself through large catastrophic fires that reset the montane area and start the process over again. The density of the ponderosa pine/Douglas-fir forest (as evidenced by crown closure) is generally dense enough to sustain a substantial crown fire. The evidence is that the crown closure that existed before the Buffalo Creek Fire was nearly identical to that existing in the majority of the ponderosa pine/Douglas-fir forest (predominate crown closure classification of 41-70 percent). The result is a high fire risk throughout the ponderosa pine/Douglas-fir forest.

Fire Hazard Patterns

> Question A-3: What are the patterns of fire hazard in the Assessment Area? Where are areas of uniformity in forest cover that may reflect an increased risk of fire spread?

Fire hazard patterns are determined by the likelihood of a fire starting in an area, the likelihood of it spreading after an initial start, and the likelihood of a spreading fire to be severe. All of these factors are influenced by natural and human factors. The major causes of ignition are lightning and people. Lightning-caused fires are a natural part of the ecosystem in the Assessment Area. Topography and weather patterns make certain portions of the area particularly prone to lightning strikes. Fires caused by people have a variety of origins including camping, smoking, use of vehicles or equipment, or arson. These fires are more likely in areas that people can access through roads and therefore, the presence of roads is a risk factor for ignition.

Once ignited, factors that cause a fire to spread and determine its severity include the amount of fuel near the point of ignition, the structure of the forest at the point of ignition, and weather conditions, such as the strength of the wind and the amount of moisture in the fuels and in the air. Weather conditions vary widely and are difficult to quantify. However, the amount of forest fuels can be quantified by estimating the amount and types of woody debris. The forest structure affects the ability of the fire to spread. A fire started in a forest with a continuum of low to canopy level trees would, given the proper weather conditions, be likely to spread along the ground with the fuels and then move into the canopy through the lower level trees (called the "ladder effect"). Once in the canopy, the fire can move quickly from treetop to treetop, establishing a crown fire. The more dense and more even-aged the stand and adjacent stands the more quickly and intensely the fire will burn.

The fire hazard of the Assessment Area has been mapped by combining the risk of ignition with the risk of spread. Areas at high risk for ignition have been identified based on historic lightning patterns and proximity to roads. A fuel hazard map was developed by relating stand conditions to fuel loads. Exhibit 9 ranks the watersheds by fire hazard. Map V-5 provides a fire hazard ranking by watershed and Map V-4 provides a detailed view throughout the Assessment Area. The areas of high hazard coincide with the large areas of ponderosa pine/Douglas-fir stands. The areas of medium high hazard are also primarily in those vegetation types but there are also pockets in the lodgepole pine and spruce-fir areas.

Map V-4. Fire Hazard. This map combines high-risk areas, which are based on historic lightning patterns and proximity to roads, with fuel hazard areas, those that have both high fuel loads and a continuum of low to canopy level trees (the ladder effect). The map shows two large blocks of high fire hazard separated by the Buffalo Creek fire area.

Map V-5. Fire Hazard by Watershed. This map uses the ratings for Map V-4 but composites the data into a watershed ranking. Cheesman, Horse Creek, Trout Creek, West Creek and Waterton/ Deckers watersheds all are rated high and are adjacent.

Map V-5 illustrates the connectivity of the areas of high to medium high hazard. The watersheds that are ranked as high hazard are all adjacent to one another and create a block of high hazard that is close to half of the Assessment Area. The upper portion of this block is adjacent to the watersheds ranked at medium high hazard creating a continuum for all watersheds ranked as high or medium high hazard. There is a potential fire break created by the Buffalo Creek Fire, but as can be seen on Map V-4, fingers of high to medium high hazard still provide connections.

Exhibit 9. Fire Hazard Class for the Assessment Area Watersheds

Fire Hazard	Watershed
High	Cheesman, Horse Creek, Trout Creek, Waterton/Deckers, West Creek
Medium High	Elk Creek, Lower North Fork
Medium	Buffalo Creek, Deer Creek, Geneva Creek
Low	Lost/Goose Creek, Craig Creek, North Fork Headwaters

Risk of Catastrophic Disturbance

Question A-4: How does the current composition and pattern of the forest vegetation (overstory and understory) contribute to the risk of catastrophic disturbance that may lead to excessive soil erosion? How do these factors contribute to the risk of excessive soil erosion resulting from sparse vegetation cover?

In the ponderosa pine/Douglas-fir forest, current conditions are a continuous, dense, and relatively homogeneous forest with heavy fuels. Many of these areas have low-level trees that encourage surface to canopy movement of fire. The dense and homogeneous nature of the surrounding forest could lead to crown fires that can kill vast proportions of the trees over thousands of acres. There are few openings in these forests that can act as fire breaks. This type of event can lead to soil erosion on a massive scale. The Buffalo Creek Fire of 1996 is an example of this type of event. The intense burn of that fire altered soil conditions and drastically increased soil erosion rates in that area.

Map V-6. Risk of Disturbances other than Fire by Watershed. This map rates watersheds on the risk of disturbance by insects and disease. The areas ranked as medium risk (the highest rating) are the watersheds that are not rated as high or medium-high fire hazard on Map V-5.

Map V-7. Risk for Long-Term Sustainability of the Vegetation Condition by Watershed. This map shows a watershed ranking that combines Maps V-4 and V-6. This ranking combines the risks for fire and other vegetation disturbances.

In portions of the Assessment Area outside the ponderosa pine/Douglas-fir forests, particularly the higher elevation areas that are cooler and wetter, fires are less frequent and the forests often experience extended (300+ years) fire-free periods. These areas are more at risk from other disturbance factors such as insects and wind (see Map V-6). Maturing trees in these areas become increasingly susceptible to insect attack. Heavy mortality from insects can create large amounts of fuels, which can eventually lead to large, stand replacing fires. Windthrow can also cause mortality over a large area and also lead to insect epidemics. Both of these mechanisms lead to overstory mortality that, in combination with fire, can result in stand replacing events that affect soil erosion rates. The discussion of Issue B - Soil Development and Movement provides more detail regarding the effect of disturbances of the Assessment Area's soils and potential erosion.

Existing Distribution of Invasive Plants

Question A-5: What are the current patterns of distribution of weedy or invasive plant species in the Assessment Area? Where in the area are invasive species most likely to be of concern for restoration management?

Characterization of Invasive Plants

Exotic and invasive plants, known as noxious weeds, are alien species that are deemed detrimental to an environmentally sound ecosystem. They are usually introduced to an area, often from a different continent, and would not occur there naturally. Once in the area they can be further spread by people, cars and trucks, and domestic animals. Noxious weeds usually compete aggressively with native plants and can take over entire native plant communities. They are very adaptable species and therefore, very difficult to control once introduced into the ecosystem. There is currently a management plan for the Pike and San Isabel National Forests which identifies the preferred methods of control of these species.

Map V-8. Distributions of Exotic or Invasive Plant Species. This map shows known locations and potential habitats of exotic and invasive plants.

Occurrence and Distribution in the Assessment Area

Exotic and invasive plant species that occur or are likely to occur in the Assessment Area were identified as target species for this study. Exhibit 10 presents the species and their preferred habitat and elevation range. Appendix G discusses the methodology for identification of these species. Map V-8 shows the distributions of potential and known locations.

Exhibit 10.Noxious Weeds of Concern in the Assessment Area

Noxious Weed Species	Place of Origin	Elevation Range (ft)	Examples of Preferred Habitat
Canada Thistle	Eurasia and North Africa	4,000-9,500	Open meadows, ponderosa pine savannas, roadsides, fields, pastures and other disturbed areas. Prefers rich, heavy and dry soils. Does not tolerate water-logged or poorly aerated soils
Dalmation Toadflax	Southeastern Europe - Mediterranean Region. Introduced to North America as an ornamental	5,000 - 6,500	Oak, aspen, sagebrush, mountain brush, and riparian communities on roadsides, rangeland, waste places, cultivated fields, and semi-arid regions. Tolerates low temperatures and coarse textured soils
Diffuse Knapweed	Eurasia	NA	Readily colonizes a wide range of soils
Downy Broam	Eurasia and Mediterranean	4,000 - 9,000	Roadsides, waste areas, pastures, rangelands. Also occurs in open slopes, sagebrush, pinyon/juniper, and less commonly, aspen and conifer communities. Does not tolerate heavy soils
Field Bindweed	Europe - thought to have been introduced in wheat from Turkey	4,000 - 10,000	Common on roadsides, very adaptable. Prefers rich somewhat sandy and basic soils
Houndstongue	Europe	5,000 - 9,000	Usually found in pastures, waste fields, and bare and disturbed patches of stony or sandy ground. Prefers gravely, somewhat limey soils
Kochia	Europe	up to 8,500	Roadsides, waste places, fields
Leafy Spurge	Europe	5,000 - 6,500	Prefers open habitats, roadsides, waste areas, pastures, cultivated fields, irrigation ditches, disturbed sites, rangelands, fields etc. Tolerant of wide range of conditions
Musk Thistle	Southern Europe and western Asia	NA	Disturbed sites along roads, fields, pastures spreading into sagebrush, pinyon juniper and mountain brush communities.

Noxious Weed Species	Place of Origin	Elevation Range (ft)	Examples of Preferred Habitat
			Prefers dry, gravely soils and very abundant on fertile soils
Russian Knap-weed*	Europe	4,500 - 7,500	Roadsides, waste areas, cultivated fields, fence rows, ditch banks. Very adaptable and difficult to control
Russian Thistle	Eurasia	up to 8,500	Wide variety of habitats. Dry plains, cultivated fields, waste places, roadsides. Adapted to disturbed land
Salt Cedar	Eurasia and Africa - introduced as an ornamental shrub in early 1800s	NA	Disturbed and undisturbed streams, waterways, bottom-lands, banks, and drainage washes. Also moist rangelands and patures. Seedlings require saturated soils. Tolerates highly saline soils and alkali conditions.
Spotted Knapweed	Europe - Introduced as contaminant of alfalfa and clover seed	NA	Includes habitats dominated by ponderosa pine and Doug-las-fir as well as foothill prairie habitats. Found in light, porous fertile, well-drained and often calcareous soils in warm areas.
Hoary Cress	Europe - Introduced in alfalfa seed	3,500 - 8,500	Waste places, cultivated fields, pastures. Vigorous growth on irrigated alkaline soils
Yellow Toadflax	Eurasia - escaped as an ornamental	6,000 - 8,500	Waste places, pastures, roadsides, cultivated fields, mead-ows and gardens. Occurs in a wide variety of habitats but is limited in wet or dark conditions. Occurs mostly on sandy/gravely soils, but also common on chalky soils.

* Considered a serious noxious weed due to difficulty of control and eradication and is one of four plants that must be managed in accordance with the Colorado Weed Management Act.

Several of the species listed in Exhibit 10 have become common invasive plants in burned areas (Buffalo Creek Fire), out-competing native plants and reducing forage value. There have been extensive efforts to combat their spread. The species that have been noted in burned areas include leafy spurge, kochia, salt cedar, defuse knapweed, Canada thistle, musk thistle, yellow toad flax, and Russian thistle. See Appendix G for a discussion of current distribution of invasive plants.

Existing Terrestrial Species, Sensitive Vegetation and Wildlife

Question A-6: Where are known populations of terrestrial (flora and fauna) species of special interest or concern located within the Assessment Area? Where is potential habitat for these species in the Assessment Area?

This study identifies specific target terrestrial species and their habitats within the Assessment Area. Target species are those listed as threatened or endangered, those occurring on the USFS Region 2 sensitive species list, or those identified as management indicator species in the Pike-San Isabel National Forest Plan. Species on these lists that are not likely to occur in the Assessment Area were removed from the target list for this assessment (see Appendix C for further discussion). Exhibit 11 presents the target species and identifies their status. Map V-9 displays the distribution of habitat throughout the Assessment Area.

Map V-9. Vegetation Restoration Ranking Considering Target Terrestrial Species. This map shows a watershed ranking for terrestrial habitat for target species. All watersheds that provided at least 20 percent of their area as habitat for target species were assigned one rating point. The result is that watersheds ranked in the >20 category had more than 20 percent of the watershed area providing habitat for greater than 20 target species. The categorization shows that Buffalo Creek, Cheesman, Lower North Fork, Trout Creek and Waterton/Deckers watersheds provide habitat for the largest number of target species.

The target species occurring within the Assessment Area were divided into the following categories: alpine tundra, forest and mountain meadows (including ponderosa pine/Douglas-fir, and aspen groves), and lakes and riparian habitats. Appendix C presents a discussion of each target species, emphasizing those that occur in the forested habitats where future management activities would be likely to occur. A series of maps have been prepared to show the habitat distribution of the target species. These are included in Appendix D. Appendix C also provides a discussion of the distribution of habitat of each target species and maps for many of them. The discussion below provides a brief description of the existing habitat types.

Alpine Tundra

Alpine tundra is the treeless landscape above timberline. Elevation ranges from 11,500 to 14,400 feet. This highest ecosystem is dominated by a cold, windy climate. As a result, the plants adapted to this environment, usually sedges and grasses, grow low to the ground for protection. Dwarf shrubs and low herbs may also be present (Mutel and et al., 1992). The target species identified as alpine tundra species are discussed in Appendix C.

Forest and Mountain Meadows

The forest habitat emphasized in this assessment is that comprised of ponderosa pine, Douglas-fir, and aspen. The forest habitat extends from the foothills (6,000 to 8,000 feet in elevation) through the montane zone (8,000 to 10,000 feet in elevation) into the subalpine zone (10,000 to 11,500 feet in elevation). In the foothills, ponderosa pine, Douglas-fir and aspen form open woodlands, although the area is dominated by scrub oak, mountain mahogany, three-leaf sumac, and common juniper. In the montane zone, the open woods become a tighter, more cohesive forest. Lodgepole and limber pines are added to ponderosa pine/Douglas-fir; aspen groves are larger. In the subalpine zone, the forest is dominated by dense groves of Engelmann spruce and subalpine fir. Grasslands and pockets of meadow are also found in this ecosystem. They can be recognized by dominance of herbs as opposed to trees or shrubs, although widely scattered trees and shrubs may be present (Mutel et al., 1992). The target species identified as forest and mountain meadow species are discussed in Appendix C.

Lakes and Riparian Habitat

Riparian ecosystems occur along the banks of rivers, streams, and other bodies of water. They include floodplain woodlands and marshes with various associations of grasses, herbs, shrubs, and trees that depend on a more or less continuous and accessible water supply. The target species identified as lakes and riparian species are discussed in Appendix C.

Exhibit 11.Target Species

Species	Scientific Name	State Status	Federal Status	Forest Status
MAMMALS				
Abert's squirrel	*Sciurus aberti*			MIS
Beaver	*Castor canadensis*			MIS
Bighorn sheep	*Ovis canadensis*			MIS
Dwarf shrew	*Sorex nanus*			R2-SS
Elk	*Cervus elaphus*			MIS
Fringed-tailed myotis	*Myotis thysanodes pahasapensis*			R2-SS
Lynx	*Felis lynx canadensis*	E		
Mule deer	*Odocoileus hemionus*			MIS
North American wolverine	*Gulo gulo luscus*	E		R2-SS
Pine marten	*Martes americanus*			MIS R2-SS
Prebles' meadow jumping mouse	*Zapus hudsonius preblei*	T	T	
Ringtail	*Bassariscus astutus*			R2-SS
Spotted bat	*Euderma maculatum*			R2-SS
Towsend's big-eared bat	*Plecotus townsendii*			R2-SS
Wet Mountians yellow-bellied marmot	*Marmota flaviventris notioros*			R2-SS
AMPHIBIANS AND REPTILES				
Boreal toad	*Bufo boreas boreas*	E		R2-SS
Milk snake	*Lampropeltis triangulum*			R2-SS
Nothern leopard frog	*Rana pipiens*			R2-SS
Tiger salamader	*Ambystoma tigrinum*			R2-SS
Wood frog	*Rana sylvatica*	T		
BIRDS				
American bittern	*Botaurus lentiginosus*			R2-SS
Bald eagle	*Haliaeetus leucocephalus*	T	T	
Black swift	*Cypseloides niger*			R2-SS
Black tern	*Chlidonias niger*			R2-SS
Black-throated gray warbler	*Dendroica nigrescens*			MIS
Boreal owl	*Aegolius funereus*			R2-SS
Common loon	*Gavia immer*			R2-SS
Eskimo curlew	*Numenius borealis*		E	R2-SS
Flammulated owl	*Otus flammeolus*			R2-SS
Fox sparrow	*Passerella iliaca*			R2-SS
Golden-crowned kinglet	*Regulus satrapa*			R2-SS
Greater sandhill crane	*Crus canadensis*	T		R2-SS
Harlequin duck	*Histrionicus histrionicus*			R2-SS
Lewis' woodpecker	*Melanerpes lewis*			MIS R2-SS
Mallard	*Anas platyrhynchos*			MIS
Merlin	*Falco columbarius*			R2-SS
Mexican spotted owl	*Strix occidentalis lucida*	T	T	R2-SS
Mountain bluebird	*Sialia currocoides*			MIS
Northern goshawk	*Accipiter gentilis*			R2-SS
Olive-sided flycatcher	*Contopus borealis*			R2-SS
Osprey	*Pandion haliaetus*			R2-SS

Species	Scientific Name	State Status	Federal Status	Forest Status
Peregrine falcon	*Falco peregrinus*	T	E	MIS
Purple martin	*Progne subis*			R2-SS
Pygmy nuthatch	*Sitta pygmaea*			R2-SS
Red-naped Sapsucker*	*Sphyrapicus nuchalis*			MIS
Southwestern willow flycatcher	*Empidonax trillii extimus*	E	E	R2-SS
Three-toed woodpecker	*Picoides tridactylus*			MIS R2-SS
Turkey	*Meleagris gallopavo merriami*			MIS
Virginia's warbler	*Vermivora virginiae*			MIS
Water pipit	*Anthus spinoletts*			MIS
Wilson's warbler	*Wilsonia pusilla*			MIS
INVERTEBRATES				
Pawnee Montane Skipper	*Hesperia leonardus montana*		T	
Rocky Mountain capshell snail	*Ferrissia fagilis*			R2-SS
Uncompahgre fritillary butterfly	*Boloria acrocnema*		E	
PLANTS				
Addersmouth	*Malaxis brachyopoda*			R2-SS
Altai cottongrass	*Eriophorum altaicum*			R2-SS
Colorado false needle grass	*Ptilagrostis mongholica*			R2-SS
Colorado tansy-aster	*Machaeranthera coloradoensis*			R2-SS
Degener's penstemon	*Penstemon degeneri*			R2-SS
Globe gilia	*Ipomopsis globularis*			R2-SS
Great-spurred violet	*Viola selkirkii*			R2-SS
Greenland primrose	*Primula egaliksensis*			R2-SS
Hall fescue	*Festuca hallii*			R2-SS
Livid sedge	*Carex livida*			R2-SS
Molybdenum milk-vetch	*Astragalus molybdenus*			R2-SS
Myrtle-leaf willow	*Salix myrtillifolia*			R2-SS
Narrow-leaved moonwort	*Botrychium lineare*			R2-SS
Northern blackberry	*Rubus arcticus*			R2-SS
Pale moonwort	*Botrychium pallidum*			R2-SS
Penland eutrema	*Eutrema penladii*		T	
Reflected moonwort	*Botrychium echo*			R2-SS
Rolland's bulrush	*Scirpus rollandii*			R2-SS
Sea pink	*Armeria maritima siberica*			R2-SS
Smith's whitlow-grass	*Draba smithii*			R2-SS
Smooth rockcress	*Braya glabella*			R2-SS
Ute ladies' tresses orchid	*Spiranthes diluvialis*		T	
Weber's monkey-flower	*Mimulus genniparus*			R2-SS
Wooly willow	*Salix lanata*			R2-SS

MIS = Forest Management Indicator Species
R2-SS = Region 2 Forest Sensitive Species
T = Threatened
E = Endangered
*Formerly a subspecies of the yellow-bellied sapsucker, Sphyrapicus varius.

General Condition of the Forested Habitat for Wildlife

The forested habitat in the montane area is dominated by ponderosa pine/Douglas-fir. This habitat provides primary habitat for 29 of the target species. The current habitat is characterized by even-aged, homogeneous areas of ponderosa pine/Douglas-fir, and a lack of openings. There are also few large trees with cavities and snags. An increase in the proportion of Douglas-fir from the historic condition has created more habitat for some species, however, many montane species would benefit from increased numbers of snags, large trees with cavities, openings and increased age class diversity. This is particularly true in the ponderosa pine forest.

Step 4. Reference Condition

There has been some research conducted on the key pre-European disturbance processes and patterns within the Assessment Area. Recent ongoing research being conducted within the Assessment Area by the USDA Forest Service, Rocky Mountain Research Station has documented centuries-long patterns of fire events in a 10,000-acre portion of the Assessment Area (Brown et al., in press; Kaufmann et al., submitted). This area includes about 8,000 acres around Cheesman Lake that has not been logged and has been fenced to exclude grazing for nearly a century. This research presents a picture of the pre-European ponderosa pine forest as quite open with 10-20 of the forest in openings.

Other research confirms that fire is the dominant disturbance process in other ponderosa pine forests in the Colorado Front Range; including Estes Park (USDA 1910), Fourmile Canyon (Goldblum and Veblen 1992), and Manitou Experimental Forest (USFS current). The research at Cheesman Lake indicates that the fire regime was characterized by long mean fire intervals with “mixed and variable” fires. Other research provides additional evidence of long mean fire intervals in Front Range ponderosa pine forests (Goldblum and Veblen 1992, and Laven et al. 1980). The pre-European forest structure described by Brown et al. and Kaufmann et al. at Cheesman Lake is confirmed by other research of forest structure resulting from “mixed severity” fire regimes in the Colorado Front Range (Turner and Romme 1994, and Brown 1995). This fire regime could be classified as a combination of frequent, low-intensity surface fires and short-return interval, stand-replacement fires (Brown 1994).

Additional evidence of the open stand conditions and the importance of fire are contained a 1900 Forest Reserve report (Jack 1900) and GLO field notes (examined by Laurie Huckaby, Paula Fornwalt and Merrill Kaufmann) obtained from the United States Geological Survey in Lakewood, Colorado. These data sources are not scientific studies but provide additional evidence to support the view of the landscape mosaic described at Cheesman Lake for the ponderosa pine forest in the Assessment Area.

Pre-European Disturbance Processes and Patterns

> Question A-7: What were the key pre-European disturbances (e.g. fire, insects, disease) that contributed to patterns of vegetation development in the Assessment Area?
>
> Question A-8: How were historical fires characterized (frequency, intensity, extent)? What was the historical occurrence of intense, large fires?

The Montane Forest

Disturbance Processes

> “Probably at least 75 per cent of the total area of the reserves clearly shows damage by fire, much of it within the last half century or since the advent of white settlers in the region; and a great deal of ground shows traces of fires, which must have occurred prior to that time,” (Jack, 1900)

The key pre-European disturbance to the primary montane forests, ponderosa pine/Douglas-fir, was fire. In areas that have been logged in the post-settlement era, insects have killed large numbers of trees. However, there have not been any epidemic level outbreaks in the unlogged portions of the Assessment Area. In 1900, the US Geological Survey published a report in which they state “the forest appears to be in a healthy condition and seem to be subject to few diseases caused by insects or fungi” (Jack, 1900). Patches of dwarf mistletoe infections were relatively common and killed some trees in infected areas, however, the parasite was not generally distributed throughout the area. Evidence indicates that, while insects and disease did play a part in the forest's ecosystem and in the development of individual stands, fire was the predominant disturbance factor in the ponderosa pine/Douglas-fir forests.

Characterization of Historical Fires

Fire patterns across the landscape varied both in size and intensity. Some fires were low-intensity surface fires that killed or damaged only a few trees. Large-scale fires occurred on an average 60 year cycle (Brown et al., in press). The large fires were often a mixture of surface and crown fires. It appears that these fires typically occurred following a wetter period during which understory vegetation had become established. This created a ladder effect that enabled winds to push a surface fire from the understory into the canopy and then move through the crowns. In these types of events, the fire would have burned intensely in some locations, killing all trees in that area. In other areas of the same fire event, the fire may have remained a surface fire, killing only some and mostly smaller trees. Other areas would have been missed completely. This would create a varied burn pattern. The mosaic that was created would continue to be maintained as the patch like variation of age classes, densities and openings would result in fires that would skip around rather than killing all trees over several thousand acres.

Vegetation Patterns

The vegetation patterns across the landscape were primarily determined by the frequency and types of fires. The fire patterns would have created and maintained a complex mosaic of openings and patches of different age classes, tree densities, and persistent openings. Some stands may have been nearly even-aged due to stand replacing fire followed by even-aged regeneration patterns. Douglas-fir would have been the major species on north facing slopes. On other aspects, many of the stands would have contained several age classes, ranging from saplings to old growth ponderosa pine and some Douglas-fir.

Openings may have covered 10 to 20 percent of the area. Many of the individual openings may have persisted for decades because trees were not able to establish themselves until a good seed crop coincided with favorable climatic conditions. This was particularly true on south-facing slopes. In other areas, regeneration began immediately. Therefore, post-fire patterns of regrowth were highly variable in both time and space, contributing to the complexity of the landscape.

The Subalpine Forests

Disturbance Processes and Characterization of Historical Fires

Fire has long been considered the major large-scale disturbance process in the subalpine zone (Clements, 1910). However, insects, mistletoe, windthrow and snow breakage were also common, and sometimes significant, disturbance factors. Windthrow in particular is believed to have been an important disturbance factor. Windstorms have been documented that blew down extensive patches of subalpine forest. In 1939, a significant blowdown event was followed by the largest recorded epidemic of spruce beetles of this century. Windthrow followed by insect-caused mortality may have been the dominant disturbance pattern in some areas. Insect outbreaks, without windthrow, may also have contributed to disturbance patterns. Areas of insect caused mortality would increase fuel in the forest and at times lead to a stand replacing fire.

Characterization of Historical Fires

Most fires in these forests were typically catastrophic stand replacing crown fires that caused extensive mortality and exposure of mineral soil. Fire frequency is largely unknown but it appears that areas often would remain unburned for 300 or more years. Blowdown and outbreaks of beetle infestations would increase the forest's fuels, which in turn could lead to large stand-replacing fires.

Vegetation Patterns

The disturbance regimes in these forests, fire, windthrow and beetles, created a complex mosaic across the landscape. Large, catastrophic fires would have led to the establishment of large stands, primarily even-aged, of lodgepole pine, aspen or spruce because these species are better able to grow on the harsh burned sites. The long periods between fires would have led to the establishment of spruce/fir as these species are longer lived. Therefore, depending on fire patterns across the landscape, there were likely larger areas of lodgepole pine combined with areas that escaped fire for an extended period that would be dominated by spruce /fir. Within these large areas, windthrow and insects would have created smaller scale patterns of disturbance with pockets of blowdown or insect killed trees. The windthrow and insect damage would have created uneven-aged stands of shade tolerant species (primarily spruce/fir). In these stands, areas of standing dead trees may have persisted for decades.

Distribution of Invasive Plants

Exotic and invasive plants (noxious weeds) are typically inadvertently introduced to an area, often from a different continent. All of the target species identified in the current conditions originated in Africa, Asia or Europe. The pre-European reference condition was that the Assessment Area did not contain any of the target exotic species because they were introduced following European settlement.

Step 5. Synthesis

Question A-9. How do existing conditions of forest vegetation (composition, age, distribution and landscape pattern) differ from historical or reference conditions?

Question A-10. How do current patterns of fire hazard compare to the reference condition?

Differences Between Existing and Historical Conditions

Map V-10. Restoration Ranking Based on Vegetation Condition and Terrestrial Species. This map shows a watershed ranking for restoration based upon both vegetation condition and terrestrial habitat for target species. Maps V-7 and V-9 were combined to create this map.

The effects of logging, grazing and fire suppression in the Assessment Area have created conditions that differ markedly from pre-European settlement conditions. The changes occurred on a landscape scale and therefore, the character of nearly the entire forest as been altered. The ponderosa pine/Douglas-fir forests have undergone the most significant changes from a historical condition. Logging eliminated a large portion of the old growth in the ponderosa and Douglas-fir forests and some of the old growth in the lodgepole and spruce/fir forests (Jack, 1900). Across the landscape, trees growing in the openings created by the logging did not have to compete with large trees because those had been removed by selective harvesting. Fire suppression kept natural fires from reducing their growth or eliminating them. The survival of the new trees may also have been aided by grazing which eliminated most of the grasses with which they historically would have competed for water and nutrients, and which were needed to carry ground fires. Therefore, conditions were created to bring a larger proportion of the new trees to maturity than would have been possible without the intervening factors. These factors created a forest that is more uniform and dense that the historical mosaic of patches with different aged trees and tree densities.

Montane Forests

The structure of the ponderosa pine and Douglas-fir forests changed from a mosaic of patches with different aged trees and varying density of trees to a more uniform dense forest. Map V-3 compares the existing condition to the expected reference or pre-European condition. Exhibit 12 and Map V-3 show the degree of departure of the existing condition from pre-European conditions (listed by watershed). The greatest degree of departures are found in watersheds with dense ponderosa pine and Douglas-fir. Except for the protected research area, the Cheesman Lake watershed shows some of the greatest difference. This watershed is covered by dense ponderosa pine and Douglas-fir. There is also probably a greater proportion of Douglas-fir because fires that were suppressed would have kept down the Douglas-fir. Douglas-fir is also more shade tolerant and can become established in the understory and become the site's climax species unless a fire comes through, burning the understory trees.

Map V-3. Degree of Departure of Existing Vegetation Conditions from Reference Conditions by Watershed. This map categorizes the watersheds by how different the current vegetation condition (age, density, and age diversity) is from the historic or reference condition. Cheesman, Horse and West Creek are rated as very high.

The period without fire in these forests is now 148 years (1851 to present). This is much longer than the average period between fires (60 years) and the previous longest period (128 years), before fire suppression was a factor. The Buffalo Creek Fire of 1996 initially appears to have a different pattern than what would have been expected historically due to the extent of intense stand-replacing fire. However, other evidence (Jarrett 1999) suggests that fires the magnitude of the Buffalo Creek Fire have occurred several times in the past. The conditions that have been created by logging and fire suppression include a continuous, dense, and relatively homogeneous forest with heavy fuels. This was evident in the Buffalo Creek Fire as throughout the area of the fire there was a ladder effect and crown fire that killed nearly every tree across 7,500 acres. The forest mosaic pattern described at Cheesman Lake could include areas like Buffalo Creek before the fire. However, it appears that large portions of the ponderosa pine/Douglas-fir forest in the Assessment Area are similar to Buffalo Creek before the fire and few areas are characterized as forest mosaic.

Exhibit 12.Degree of Departure of the Existing Condition from the Reference Condition

Degree of Departure	Watershed
Very High	Horse Creek, West Creek, Cheesman
High	Waterton/Deckers, Trout Creek, Lower North Fork, Buffalo
Medium	Lost/Goose Creek, Elk Creek, Deer Creek
Low	Craig Creek, North Fork Headwaters, Geneva Creek

Lodgepole Pine and Spruce/Fir Forests

Lodgepole pine and spruce/fir forests typically had longer periods between fires than did ponderosa pine and Douglas-fir stands. Indications are than areas often went over 300 years between fires. When fires did occur, they were usually stand-replacing events. Therefore, the existing lodgepole pine and spruce/fir forests are more altered by logging and grazing than by fire suppression (see above). However, it is possible that fires would have replaced some of the existing lodgepole pine stands had all fires not been suppressed during this century. Watersheds that are more influenced by lodgepole pine and spruce/fir stands show less variance between the reference and existing condition.

Existing Distribution of Invasive Plants

Prior to European settlement, the invasive plants in this area had not been introduced. Therefore, the difference between the current condition and the reference condition, is the current condition. Without intervention, these species will continue to spread to new areas, affecting native plant communities.

Habitat for Terrestrial Wildlife

Question A-11: How does wildlife habitat differ from the historical or pre-European condition.

Many montane species would benefit from increased numbers of snags, large trees with cavities, openings, and increased age class diversity in the ponderosa pine and Douglas-fire forests. Exhibit 13 shows the montane species and their expected population trends between the current condition and reference condition.

Exhibit 13.Population Trends from Current to Reference Conditions in Assessment Area

Positive Population Trend	Negative Population Trend	Neutral Population Trend
Abert's Squirrel Bighorn Sheep Elk Flammulated Owl Merlin Milk Snake Mountain Bluebird Mule Deer North American Wolverine Northern Goshawk Purple Martin Pygmy Nuthatch Turkey Virginia's Warbler	Boreal Owl Golden-crowned Kinglet Olive-sided Flycatcher Three-toed Woodpecker	Black Swift Black-throated Gray Warbler Dwarf Shrew Fringed-tailed Myotis Lynx Mexican Spotted Owl Pawnee Montane Skipper Peregrine Falcon Pine Marten Red-naped Sapsucker Spotted Bat Townsend's Big-eared Bat

Footnote: please refer to Table C-3 in Appendix C for more detail.

ISSUE B. SOIL DEVELOPMENT AND MOVEMENT

Soil development and movement in the Upper South Platte Watershed may be changed significantly due to human influences on disturbance processes. The lack of natural disturbances may cause negative long-term loss impacts through an increase in catastrophic events such as fire. Similarly the high level of human activity within the Assessment Area may be causing conditions that are also detrimental to soil health and quality. The development and movement of soils is dependent upon the factors of climate, parent material, time, vegetation, and disturbance. The parent material of most of these watersheds is granite. Granite weathers to gruss which is essentially a coarse gravel to fine sand crystalline regolith. Casual inspection of the gruss will reveal that it is composed of individual crystals of potassium feldspar, quartz, weathered biotite and muscovite and hornblende. The gruss provides an acidic substrate for soil development which generally tends to be thinly developed and sandy to gravelly (sandy loams). Gruss and the soils that subsequently develop on it are all highly erodible when exposed to direct impact of rain, sheetwash (overland flow), rilling or gullying.

Background

During the past 100 years the disturbance and vegetation factors have been significantly controlled by human use and management of the landscape. Consequently, soil development and movement may be much different spatially and temporally in the past 100 years than the thousands of years before significant human control. There is likely an imbalance of soil development processes that may have potential long-term detrimental effects to the health and integrity of the landscape. This assessment focuses on categorizing the watersheds within the Upper South Platte Watershed that are at risk due to changes in disturbance regimes.

Key Questions

The questions that are asked to guide the assessment are presented below. The questions are organized according to the Step of the process that they are used. In the following section the term watersheds refers to watersheds targeted for the study in the Upper South Platte Watershed.

Step 3. Current condition questions for soil development and movement

B-1. How do land use, road and trail networks contribute to current soil erosion patterns?

B-2. What watersheds in the study currently have high erosion hazards?

B-3. What watersheds are characterized by geologic instability?

B-4. What watersheds have the highest potential for soil loss following a wildfire? What is the potential for problems associated with hydrophobic soils?

Step 4. Reference condition questions for soil development and movement

B-6. Historically, what were the primary types and patterns of disturbances that contributed to soil erosion in the Assessment Area?

B-7. What was the soil loss due to erosion that could be attributed to these historic patterns?

B-8. Did erosional events such as those occurring after the Buffalo Creek fire occur in the pre-European era? If so, how often might they have occurred?

B-5. What is the importance of microbiotic crusts to ecosystem function and soil retention in the Assessment Area?

Step 5. Synthesis questions for soil development and movement

B-9. What watersheds have patterns of soil distribution that are farthest from what would be expected from pre-European disturbance patterns?

B-10. What watersheds are currently characterized by soil erosion patterns and processes that are farthest from the historic erosion patterns?

B-11. What watersheds have the greatest need for restoration based upon soil integrity and sustainability.

Step 3. Current Condition

Question B-1. How do land use, roads and trails contribute to current soil erosion patterns?

Road and trail networks cause detrimental soil compaction, which reduces or eliminates infiltration of surface water into the soil column. The result of decreased infiltration is the increase of sheet erosion that can lead to rill and gully erosion during periods of rainfall or snowmelt. The network of roads and trails acts to re-focus overland flow, rills and streamlets into artificial flow networks that move water downslope. The poor maintenance of road drainage ditches can lead to hypersaturation of road fill in areas and may result in slope failure for certain finer-textured fills. Although Rice and Lewis (1991) found in a California study that logging and road building is responsible for erosion problems, these specific problems occur only on a small fraction of managed areas. However, these authors fail to mention the cumulative effect of degradation over time. Land uses such as timber harvests, grazing, suburban and rural development, mining and farming are all activities that can increase the surface erosion and soil loss. Each activity may for period of time expose detrimentally compacted, displaced or fragmented surface organic and mineral layers to erosion. The net effect of these conditions may leave surface soil layers in an unstable or unprotected state from whence they can be eroded and deposited in streams and reservoirs.

Question B-2. What watersheds in the Assessment Area currently have high erosion hazards?

The ranking of the watersheds by current high erosion hazard used the guidelines in National Forestry Manual. The National Forestry Manual published by the USDA Natural Resource Conservation Service (NRCS) in 1997 systematically employs the K factor (represents soil erodibility) from RUSLE and breaks out four slope categories which are combined to develop a soil rating for potential erosion hazard. The National Forestry Manual guidelines were chosen because of its standardized national application, availability of data, and ability to manipulate it within a GIS framework on a watershed basis.

Map S-2 displays the post-European erosion hazard potential for the watersheds in the Upper South Platte Watershed. This condition is based on inherent soil erodibility, slope and road density to factor in the enhanced condition for compacted soils (reduced infiltration and permeability), channeling of water, exposed soil, and the fragmentation of surface vegetation and organic matter.

Question B-3. What watersheds are characterized by geologic instability?

Information on the geologic setting of Upper South Platte Watershed is summarized from large scale maps and reports, which are compilations of many, much more detailed individual works. This geologic discussion is intended to provide a broad summary of the overall conditions of major subdivisions of the basin.

Map S-2. Current High Soil Erosion Hazard. The map is based on soil erodibility, land slope and road density. There is an area in the northern central portion of the Assessment Area that is rated as extreme erosion hazard. The soils in the Assessment Area are highly erodible, the classifications used here are only relative.

Unconsolidated deposits are generally considered less stable than bedrock, and also can be destabilized more readily by a change in conditions. Examples of changes which could influence unconsolidated deposits and lead to more geologic instability include extensive over-steepening or undercutting of a slope brought on by erosion, or a change in groundwater quantity or flow, which alters the cohesiveness of underlying materials. In addition to instability attributable to natural changes or processes, man-caused alterations such as roads, dams, ditches or other landscape modifications can lead to local instabilities.

Unconsolidated landslide deposits are present in the Geneva Creek, North Fork Headwaters, and Deer Creek Watersheds (Map S-5). Typically, these deposits are on steeper slopes in headwaters areas or subalpine zones, and more frequently are located on or near northfacing slopes. The landslide deposits recognized in Upper South Platte Watersheds also frequently coincide with the presence of fault zones and fractures in bedrock (USGS, 1981).

Map S-5. Geologic Instability and Hazards. This map shows the geology of the Assessment Area. Generally there are few geologic hazards at the landscape scale. Unconsolidated landslide deposits are present in the Geneva Creek, North Fork Headwaters, and Deer Creek Watersheds.

Other unconsolidated deposits such as Quaternary alluvium and alluvial fans and colluvium, typically are found in extended stream reaches as valley fill. The more extensive deposits of alluvium and colluvium are found in the Trout Creek, Lost/Goose Creek and Lower North Fork watersheds.

Relative to many other areas of Colorado with similar watersheds, the Upper South Platte Watershed has fewer unconsolidated deposits and geographic features that are indicative of geologic instability distributed over the area. In general, it can be considered a relatively stable geologic environment for a mountain setting compared to other watersheds in Colorado. This can be attributed to the predominance of crystalline bedrock types and the style of structural geology of the area. In general, the bedrock is relatively competent, which gives the area a strong underpinning. Mineralogically, the rocks contain a low percentage clays and do not weather to create substantial amounts of clay minerals in the soils which are geologically unstable. The bedrock weathers to materials that form soils that are relatively granular, remain permeable, and drain well. All are characteristics that promote geologic stability in unconsolidated materials. Coincidentally, the mineralogical characteristics of the rock weathering that creates the relatively stable unconsolidated deposits, also makes the soils and unconsolidated deposits granular with relatively low cohesion, which in turn makes them susceptible to erosion.

The faults and fractures that are present are such that, while influencing local topography and stream locations, their density, type, and orientation do not create significant weaknesses that lead to large zones of mass movement and instability.

Question B-4. What watersheds have the highest potential for soil loss following a wildfire?

Map S-3. Potential for Soil Movement following Wildfire. This map combines the erosion potential from Map S-2 with fire hazard, Map V-4, and risk factors for formation hydrophobic soils (coarse textured soils). The map shows that the areas of high potential soil movement following wildfire correspond to the ponderosa pine/Douglas-fir montane forest.

Analysis of the potential for soil loss following a wildfire utilized current erosion potential combined with the fire hazard (developed for the vegetation analysis) to develop a hazard and risk for soil loss. Coarse textured soils (soils with >65% sand) were added as a factor in the potential for the formation of hydrophobic soil layers. Following catastrophic wildfire (which is factored in as a risk), areas of high soil erosion potential combined with the removal of forest cover and presence of coarse soil textures (which are susceptible to hydrophobic layer formation) will lead to an increased soil loss (the hazard). The hazard rating is displayed on Map S-3.

What is the potential for problems associated with hydrophobic soils?

Hydrophobicity is the phenomenon by which intense surface fires result in the destructive distilliation of organic matter and its translocation from the burning layer to the underlying soil (DeBano et al., 1976). The term hydrophobicity refers to the water-repellent layers that are formed when polarized organic molecules are formed as they diffuse down into the soil, then cool and condense forming a compound that coats soil particles, and fills pore spaces. Hydrophobicity interferes with and reduces the soils infiltration characteristics. The specific mechanism is not fully understood, however, it is accepted that soil physical properties such as texture, moisture content and soil temperature play a role in this process. DeBano (1975) has found that water repellent layers may be thicker and more intense in coarser soils under coniferous forests since there is less surface area to coat, and the molecules can more easily penetrate the pores quickly. For the Colorado Front Range, Morris and Moses (1987) found that 75 percent of their monitoring sites exhibited some level of hydrophobicity. However that report and others (DeBano and Rice 1973) indicate that soil water repellency is short lived following fire and may be limit the extent of erosion. In a qualitative sense hydrophobic soils probably increase the net surface erosion of soils by retarding infiltration and thereby increasing sheet wash. It may be that once the organic carbon deposits are eroded away the rate of infiltration will increase and sheet wash and erosion will be reduced.

Step 4. Reference Condition

Question B-6. Historically, what were the primary types and patterns of disturbances that contributed to soil erosion in the Assessment Area?

From a soil perspective, the key processes controlling soil disturbance processes contributing to soil erosion in the Assessment Area are eolian (the effects of wind) and fluvial (the effects of water). Both of these mechanisms are a function of local climate, topography, parent material and time. These natural processes that currently effect the surface soil existed in the pre-European (reference) condition. The influence of humans on the landscape has been extensive in some areas. It may be an over-simplification to limit this discussion to pre- and post-European influences on the landscape since it is well known that Native American communities practiced fire management of the landscape to enhance wildlife habitat and harvesting. It can be estimated that most of this Native American management was ended by 1870. The effect of the post-European condition has been to reduce soil disturbance through extensive and rigorous fire suppression. Soil formation and erosion during this post-European incursion is a function of climate, topography, parent material, fire suppression and time. To fully assess the effects of human management of fire on the forest and forest soils some reference to archaeological and anthropological data sources could be of value, specifically in reference in assessing Pre-European impacts.

Wind and water erosion on agricultural and non-agricultural lands is estimated to remove 4 billion tons of soil annually in the United States (Brown and Wolf 1984). Two thirds of this amount is estimated to be moved by water, and one-third by wind. Of primary concern in forest management (especially on National Forest lands) is water erosion which acts to detach and transport sediment to streams resulting in detrimental impacts to water quality, aquatic habitat, and aesthetics. Soil erosion in forests is generally attributed to forest use and management including road construction, timber harvest, mineral extraction and recreation impacts.

Wildland fire also can have negative impacts on soils and expose soil to the forces of erosion. Lower intensity/severity prescribed fire will have less impact on soils than high intensity and severity wildfires. However, soil should be viewed as both a habitat and selective growth medium when analyzing the effect of fire. Soils and duff layers under dense vegetation contain the seeds of prior successional stands. Severe fires tend to kill a very high percentage of these dormant seeds, while lower intensity fires merely scarify seed coats of many fire adapted species allowing them to germinate during the next growing season. Also, both low intensity and severe fires alter the soils towards mineral soils providing habitat for desirable colonizing species and the rare and possibly endangered species of the understory.

Question B-7. What was the soil loss due to erosion that could be attributed to these historic patterns?

It is likely that in the past soil erosion patterns varied temporally and spatially. Patterns of disturbance relative to time are difficult to reconstruct historically, but are probably correlated to long-term climatic events such as 50-, 100- and 500-year storms and the frequency of disturbance of the vegetation with fire. From a spatial standpoint, Bovis (1974, 1978) examined the spatial variation of soil movement rates along the Colorado Front Range and found that:

1) maximum soil movement rates within the forest area of the Front Range occurred during the summer months due to intense summer rainstorms;
2) maximum soil loss occurs in sparsely vegetated lower montane woodlands, and;
3) within-site variability in soil mobilization rates are often great, suggesting that microscale controls are important

Thus it is likely that these same mechanisms historically were the natural or pre-European soil erosion patterns. Our projection of potential soil erosion areas for the pre-European condition suggests that the area of the Upper South Platte Watershed has a tendency toward a highly erosional landscape and that human modifications have increased the erosion potential in some areas.

Question B-8. Did erosional events such as those occurring after the Buffalo Creek fire occur in the pre-European era? If so, how often might they have occurred?

Undoubtedly, the answer is yes from ecologic inference that large catastrophic fires and subsequent erosional events occurred. The evidence is the even-aged stands of pine forest throughout the Front Range where exposed mineral soils are required for the successful germination and viability of the species. These stands required fire and exposure of the mineral soil. A broad base of geomorphic support for such a conclusion would require some additional research.

Geomorphic investigations in the Buffalo Creek area (Jarrett, 1999) in the burned and unburned areas indicate at least 10 fire/flood sequences in the past 2,500 years have occurred prior to the 1996 Buffalo Creek fire. At least one event was larger than the July 12, 1996 flood, and runoff evidenced by much thicker alluvial deposits produced by several of the prehistoric fires than following the 1996 fire. Hill-slope erosion following wildfire and high rainfall events appears to be a major source of sediment to the drainage network. In the Buffalo Creek area, it was estimated approximately 10 mm of erosion from the hillslopes occurred based upon a hundred hillslope erosion measurements in the affected area (Jarrett, 1999).

Morris and Moses (1987) documented soil movement following forest fires for five ponderosa pine forested catchments along the Colorado Front Range. They found that the sediment flux rates following forest fires was elevated by three orders of magnitude in comparison to control catchments of undisturbed forest. The two most significant variables controlling this were the formation of water-repellency and the tendency for the surficial debris to become detachment limited. They concluded that forest fire disturbances might account for a large portion of the long-term sediment yield from Front Range hillslopes.

Other literature suggests that high-severity wildfires can increase post-fire erosion rates by one or more orders of magnitude. This increase in erosion has been documented in pine forests in South Africa (Scott, 1993), eucalyptus forests in Australia (Prosser and Williams, 1998), chaparral in the southwestern U.S. (Rice, 1974; Laird and Harvey, 1986; Wells and Wohlgemuth, 1987), coniferous forests in Yellowstone

National Park and central Washington (Meyer et al., 1995; Helvey, 1980), and ponderosa pine in the Colorado Front Range (Morris and Moses, 1987). The precise cause of the observed increases is generally not well documented. Contributing processes include the pulverization of the soil due to the burning of the soil organic matter and accompanying breakdown of soil aggregates, increased rain-splash due to the loss of the protective litter layer, destruction of the microbial crust, soil sealing, increased dry ravel, and development of a less permeable hydrophobic layer 1-10 centimeters below the surface. Many of these processes interact to change the hydrologic regime from little or no surface runoff in the unburned condition to large amounts of overland flow from moderate- to high-intensity rainfall events.

Removal or reduction in surface vegetation cover, formation of less permeable soils can lead to increased surface runoff and overland flow which acts as a force to cause the detachment and transport of sediment. These sediment-laden flows may then induce sheetwash, rill and gully erosion, and cause mass movements such as debris torrents and flows. As mass movements travel through the channel network they can cause areas of intense deposition, burial of riparian communities, other areas intense bank scour and erosion which increases the volume of sediment delivered further downstream. Ultimately, the increased surface flow relative to infiltration and subsurface flow can result in downstream flooding and damage to life and property.

Sediment deposition occurs when there is a reduction in transport capacity, and this adversely affects most of the designated beneficial uses of water, including reservoir storage, fish habitat, and domestic water supply. This sequence of wildfire, increased runoff, erosion, and downstream sedimentation is of great concern because past land management practices have created excessive fuel loading in many areas of the western U.S. (Covington et al., 1994). The Buffalo Creek fire is simply one of the most recent and dramatic examples of the problem facing land and water resource managers.

The literature suggests that, in contrast to intense wildfires, low or moderate intensity burns generally do not result in a corresponding increase in runoff and erosion (e.g., Robichaud and Waldrop, 1994). Thus a reduction in existing fuel loadings by prescribed fire or other treatments should greatly reduce the threat of high-intensity wildfires and the associated risks of flooding, erosion, and downstream sedimentation.

Question B-5. What is the importance of microbiotic crusts to ecosystem function and soil retention in the Assessment Area?

Microphytic crusts are composed of algae, mosses and lichens. In many rangelands they are often the only cover that provide the soil protection from erosion (Eldridge 1993, Belnap and Gillette 1997). Microphytic bound soils are a dominant feature of plant communities in semiarid regions (Metting 1991). Microbiotic crusts may represent the last defense against extensive soil loss in arid regions (Williams et al. 1995a). There is some evidence that more stable sites (i.e., those dominated by vascular plants) have had a higher amount of moss and lichen cover in the past than less stable sites (Eldndge 1993). Microphytic crusts are often pioneers of vegetation in disturbed landscapes (Metting 1991, Harper and Pendelton 1993, Eldridge and Greene 1994) and constituents of well developed stable landscapes (West 1990, Metting 1991, Eldridge and Greene 1994, Eldridge and Tozer 1996). Additionally, microphytes can potentially indicate some aspects of the degree of land stability, condition and post disturbance recovery rates (West 1990, Eldridge and Tozer 1996). Several researchers have speculated on what might be expected in the different successional stages of plant communities. There also has been some work on their use as an indicator of soil stability and productivity (Eldridge et al. I 995), and as a monitor of surface disturbances (Belnap 1995). However, the chronology of the crusts' successional development has not been well documented. Different studies indicate that specific studies of erodibility in crusted and uncrusted soils of one region should not be generalized to crusts from all regions (Evans and Johansen 1999). However, because of the evidence of their importance, microphytic crusts are being used as an indicator for rangeland condition in the United States (Grazing Lands Technology Institute 1999).

Microphytic soil crusts play an important role in moisture and nutrient availability within the landscape. They contribute to soil stabilization (Anantani and Marathe 1974, Kleiner and Harper 1977, Belnap and Gillette 1997, Eldridge and Kinnell 1997), moisture retention (Brotherson et al. 1983, Williams et al. 1995a, Eldridge and Kinnell 1997), nitrogen fixation (Belnap 1995), vascular plant seedling establishment (Harper and Marble 1988, West 1990, Eldridge et al. 1991, Lesica and Shelly 1992), and biodiversity of arid and semiarid landscapes. Microphytic crusts' greatest contributions to an ecosystem are soil stabilization and the addition of nutrients to the soil surface (Eldridge 1993, Williams et al. 1995a and 1995b). Soil surface stability on disturbed sites has been shown to be enhanced through the physical binding of aggregates by microphytic crusts (Rogers 1989, West 1990, Belnap 1995, Eldridge and Kinnell 1997).

The role of micrphytic crusts is unclear, but it is probable that their soil stabilizing role is lost during and intense fire. There have been conflicting results reported on the effect of microphytic crusts on the process of infiltration. Studies have demonstrated reductions, increases, or no influence on infiltration rates by microphytic crust cover (Brotherson et al. 1983, Graetz and Tongway 1986, Williams et al. 1995a). An increase or reduction in infiltration may be related to the underlying soil type, the closing of the soil pores by microphytic cover, or differences among developmental stages of the crusts (West 1990, Eldridge and Greene 1994).

Step 5. Synthesis

Question B-9. What watersheds have patterns of soil disturbance that are farthest from what would be expected from pre-European disturbance patterns?

Map S-1 depicts a ranking of watersheds outside natural disturbance patterns. The ranking assumed that human land use promotes soil disturbance patterns resulting in a condition outside the natural soil disturbance regime. Based on the availability of geographic data, human land use was defined as evidence of current or past timber harvest, presence of roads, and human ignited wildfire within the Upper South Platte Watershed. This analysis attempted to determine which soil types by watershed are currently or have been historically (post-European settlement) disturbed by these human related activities and to what extent.

Map S-1. Ranking of Departure from Reference Soil Disturbance Patterns by Watershed. The watersheds were ranked for both the pre- and post-European periods for soil disturbance patterns. The change in rankings were given a direction and magnitude. The watersheds with the greatest change from reference conditions are Deer, Elk and Trout Creeks, which contain the highest human populations.

Question B-10. What watersheds are currently characterized by soil erosion patterns and processes that are farthest from the historic erosion patterns?

Map S-1 displays the difference between the pre-European and post-European erosion hazard potential for the watersheds in the Upper South Platte Assessment Area. These assessments were made based on inherent soil erodibility and slope classes. The road density factor was added for the post-European condition as it incorporates the enhanced condition for compacted soils (reduction in infiltration capacity and permeability), channeling of water, exposed soil, and the fragmentation of surface vegetation and organic matter. The percent of the watershed in each condition class was calculated and then categorized. Map S-1 displays the direction and magnitude of change for potential soil erosion hazard between the pre and post-European condition for each watershed.

The analysis of potential soil erosion hazard hinges on the variable road density as a reliable indicator of increasing human presence in the landscape. Paved roads in more urban centers with the Assessment Area are impervious to rain and can result in runoff where drainage is inadequate or not engineered properly. In more rural settings, non-paved roads can lead to considerable erosion especially when not properly maintained. The change of potential soil erosion hazard between pre- and post-European conditions was ranked by comparing the movement in rankings.

> Question B-11. What watersheds have the greatest need for restoration based upon soil integrity and sustainability.

Map S-4 is the culmination of risks and hazards identified on Maps S-1 through S-3. Exhibit 14 shows the ranking for watersheds that are outside natural disturbance patterns, have areas of high erosion hazards, and are susceptible to potential soil loss following fire. In each assessment and in Map S-4, criteria that are essential to the healthy functioning of soil systems and processes are used.

Map S-4. Risk for Sustaining Long-term Soil Health and Reference Disturbance Processes by Watershed. Map S-4 shows the ranking for watersheds that are outside natural disturbance patterns, have areas of high erosion hazards, and are susceptible to potential soil loss following fire. Horse Creek is the only watershed that is identified as extreme risk. Buffalo Creek, Deer Creek, Elk Creek, Cheesman, Lower North Fork, and Waterton/Deckers watersheds are all identified as high risk.

Exhibit 14.Risk by Watershed for Sustaining Long-Term Health and Natural Disturbance

		% of Watershed in Condition Class				
Watershed Name	**Overall Rating**	**% not rated**	**% Low**	**% Moderate**	**% High**	**% Extreme**
Horse Creek	Extreme	23.7	12.5	21.9	41.9	0.0
Elk Creek	High	47.1	1.4	27.3	11.0	13.3
Cheesman	High	39.7	12.2	23.3	24.8	0.0
Lower North Fork	High	47.4	5.5	17.7	20.0	9.4
Waterton/Deckers	High	46.9	9.6	15.1	28.4	0.0
Buffalo Creek	High	56.3	7.7	13.7	21.3	1.1
Deer Creek	High	61.5	0.0	23.6	5.7	9.2
West Creek	Moderate	59.4	13.7	16.3	10.6	0.0
Trout Creek	Moderate	66.6	7.2	16.7	8.3	1.2
Geneva Creek	Low	85.4	1.9	2.1	10.6	0.0
Lost/Goose Creek	Low	86.8	0.9	3.2	9.1	0.0
Craig Creek	Low	95.0	0.0	1.7	1.5	1.8
North Fork Headwaters	Low	96.0	0.7	0.6	2.6	0.0

ISSUE C. WATER QUALITY AND QUANTITY AND AQUATIC HABITAT

The Upper South Platte Watershed is a valuable drainage system to the city of Denver and the surrounding communities. Of particular concern is the quality and quantity of water produced by this watershed. Recent catastrophic events have resulted in the movement of large amounts of sediment into the streams, causing harmful impacts to water quality, aquatic habitat, and valuable water systems.

Background

The Upper South Platte Watershed is important to local communities, sensitive aquatic species and the public. The Buffalo Creek Fire burned a sizeable portion of the forest in the watershed. This fire moved along the tree tops (a crown dominated fire) and it burned with a high intensity. Shortly after the fire there was a strong thunderstorm over the burned area. Flooding from this storm moved large amounts of sediment, destroyed homes and bridges, and decreased soil stability within the burn area. Following the fire there were intensive efforts to rehabilitate the burned area. In some cases this effort was successful, however, in 1998 there was another flood in the burned area, this one causing a human death. This storm also moved a large amount of sediment. The sediments moved by these storms have settled in reservoirs that supply municipal water. Another effect of the fire and storms is damage to aquatic habitat.

There is now a concerted effort to protect and restore the landscape to more sustainable conditions in order to reduce the potential for catastrophic events that dramatically effect water quality and aquatic habitat. The intent of these efforts is to move watershed conditions and functions towards a more sustainable condition.

Key Questions

The questions that are asked to guide the assessment are presented below. The questions are organized according to the step of the process where they are used. In the following section the term watersheds refers to watersheds targeted for the study within the Upper South Platte Watershed.

Step 3. Current condition questions for water quality, quantity and aquatic habitat

C-1. What are the physical structures of the streams in the watershed and how do those structures affect the movement and quantity of sediment in the streams?

C-2. Where are the most sensitive and highly erodible soils and how do they relate to the watershed's streams? Where are the critical sources of sediment and how do they relate to the watershed's streams?

C-3. What are the sources and causes of water quality impairments as they relate to the state water quality rules and regulations and the Clean Water Act?

C-4. Where are the known populations of aquatic species of special interest located in the Assessment Area? Where is potential habitat for these species in the Assessment Area?

C-5. What limiting factors, such as streamflows, reservoirs and areas of sediment deposition, control levels of sediment transport within the streams?

Step 4. Reference condition questions for water quality, quantity and aquatic habitat

C-6. How would pre-European sediment yield, transport and deposition be characterized?

C-7. How would pre-European aquatic habitat and fish populations be characterized?

Step 5. Synthesis questions for water quality, quantity and aquatic habitat

C-8. What watersheds are currently characterized by hydrologic patterns and processes that are farthest from the historic patterns?

C-9. How do current fisheries differ from pre-European populations, composition and distribution?

Step 3. Current Condition

Introduction

In the Upper South Platte Watershed Assessment Area, there are a number of different factors that combine to determine the relative sensitivity of its watersheds to water quality and aquatic habitat problems. Sediment is the dominating concern in this system because it is effected by disturbances and can affect aquatic habitat. There are some water quality problems in the Assessment Area other than sediment, but they are relatively well defined and are currently being addressed by other projects (see Water Quality discussion below).

Four factors are examined in this section to determine the relative susceptibility of the watersheds to sediment related problems. These include; 1) erodibility and availability of soils in each watersheds source zones, 2) area of each watershed in an elevational zone where surface erosion is more prominent, 3) limitations to the transport of sediments and likelihood of deposition due to the physical stream structure, and 4) existing water quality data that identifies watersheds with sediment problems. These factors are combined to determine which watersheds are at the most risk overall. For each factor, the watersheds are grouped into categories. Then all four categories were combined to form a composite score. This allows the watersheds to be ranked in terms of priority for restoration management activities.

Channel Dynamic Equilibrium

The concept of channel dynamic equilibrium is used in the following analysis. Peak flows are the primary channel forming device and can cause changes in the stream structure when changed. The condition of a stream in terms of its channel integrity can be described by observing the reaction of the channel to changes in flow or sediment. If peak flows and sediment increases are sufficiently high, the way a stream reacts to these changes may be altered. This discussion provides an “equilibrium” measure to evaluate how a stream channel responds to increased peak flows and increased sediment yield.

A channel that is in dynamic equilibrium responds to changes in stream flow or inputs of sediment, but does not lose physical integrity. Equilibrium does not imply a static condition in the stream channel; a stream in equilibrium will exhibit physical changes. However, the basic structure, i.e., pool frequency, pool depth, and pool:riffle ratio, will remain basically the same over time, even given average storm events and naturally fluctuating flow conditions.

Disequilibrium is a state in which the bed armoring has been destroyed by a high flow event and bedload movement is significant enough to alter channel structure (pools, riffles, etc.). As compared to a stream in equilibrium, a stream out of equilibrium will often have fewer pools, longer riffles and the pools will often be filled with migrating sediments. A large percentage of what normally forms the stream bed would be loose and frequently transported.

> Question C-1: What are the physical structures (channel morphology) of the streams and how do those structures affect the movement (sediment transport and deposition) and quantity of sediment in the streams?

The movement of sediment in the stream system is controlled by channel morphology. When sediment is introduced into the stream system it is moved (transported) as long as the sediment transport capacity of the stream exceeds the supply of sediment. Streams are classified by certain characteristics (morphology) that define their sediment transport capacity in general terms. There are three main types of reaches that are defined by their ability to move sediments; source, transport and response reaches

Source reaches are generally located in steeper areas where there is a supply of sediment available for movement downstream (sediment source areas). Although these reaches are high gradient and fast moving, the amount of sediment available for transport usually exceeds the ability of the stream to move the sediments. These reaches are generally smaller tributaries or headwater areas where the streamflow is lower. Sediments are moved intermittently from the source reaches during peakflow or a disturbance event. Because of the high gradient and high velocities in these streams, peakflow events can result in the movement of large amounts of sediment.

Stream reaches may have a greater capacity to transport sediments than the surrounding watershed and upper reaches can supply. These reaches are considered "supply limited" and are higher streamflow than source reaches and higher velocity than response reaches. Most sediment that is delivered to the reach is transported downstream. These stream reaches are called transport reaches, a reflection of their ability to move sediment downstream.

Lower gradient stream reaches are generally not able to transport all the sediment that is delivered to them from upper stream reaches, tributaries or the surrounding watershed. These reaches are "transport limited" because their ability to transport sediment is exceeded by the amount of sediment supplied to them. Increased sediment delivery to these reaches is deposited in the reach rather than transported further downstream. Therefore, these stream reaches are called response reaches. Response reaches are typically pool-riffles or braided channels and although tend to have the highest streamflow in the system, are the slowest moving. Transport of sediments deposited in response reaches usually occurs during peak flows events (snowmelt runoff or summer rainstorms).

The relationship of the different reaches determines where in the watershed potential problems with sediment deposition would occur. The most sensitive stream segments are response reaches that have transport reaches entering them. These reaches have the highest potential for sediment deposition because the sediment transport capacity (in comparison to supply) of the upper reach is so much greater than the ability of the response reach to move the sediments.

Sediment deposition in response reaches is a natural process. The sediment will form bars or be stored in banks, etc. and the reach will retain its function. However when sediment yield is increased or a catastrophic event occurs higher in the watershed, the amount of sediment delivered by a transport reach can overwhelm the response reach with sediment deposition. The reach may move outside of dynamic equilibrium and not function properly until peak flow events possibly restore the channel to a functioning condition (dynamic equilibrium) by transporting the excess sediment downstream.

In this assessment, stream channels were classified using a classification system called the "Level 1 Rosgen Stream Classification Method", which characterizes streams based upon the landform and fluvial features of the reach's valley and channel pattern, shape, dimension and relief (see Appendix E for more details). The transportation capacity of a reach can be estimated by coupling the reach's Rosgen classification with its gradient. In this way, the Assessment Area stream reaches were classified as source, transport or response reaches (Map W-2).

The spatial distribution of source, transport, and response reaches governs the distribution of potential impacts and recovery times for the system. Transitions between source and transport reaches and transport and response reaches define locations in the channel network where impacts

Map W-2. Sediment Transport Potential and Areas Susceptible to Summer Storms. This map displays the source, transport and response reaches. It also shows the watershed areas under the 7,500-foot elevation line where peakflows from summer storms are dominant.

from increased sediment supply may be pronounced and persistent. Upstream transport reaches may rapidly deliver increased sediment loads to the downstream response reach that may have insufficient transport capacity to accommodate the additional sediment load. Consequently, locations in the channel network where transport reaches flow into response reaches are very susceptible to impacts from increased sediment supply. This is evident in the sediment fans deposited at the confluence of Buffalo and Spring Creeks following the storm events subsequent to the Buffalo Creek fire. The areas of greatest susceptibility to pulses of sediment are transitions from the highest gradient reaches into a low gradient reach. For example, a high gradient transport reach could have high velocity and high streamflow resulting in a large carrying capacity for sediments. If it suddenly changes to a slow moving response reach the sediments will rapidly fall out of suspension and deposit in the channel or along the banks.

Map W-1. Rosgen Stream Classifications. Rosgen stream types are displayed. The majority of the mainstem channels are C with some E types. The majority of the smaller tributaries are A and B types.

Map W-1 shows the Rosgen classifications for the watershed and Map W-2 shows the source, transport and response reaches. Most of the main channels in the 13 watersheds are response reaches.

Critical Sediment Sources and Water Quality

Sediment Source Zones and Erosion Hazard

Question C-2. Where are the most sensitive and highly erodible soils and how do they relate to the watershed's streams? Where are the critical sources of sediment and how do they relate to the watershed's streams?

Map W-3. Relationship between Sensitive and Highly Erodible Soils, Sediment Source Zones and Drainage Network. This maps identifies the sediment sources zones, which are defined as 50 feet on either side of a stream plus 3 times the percent slope. Therefore, steeper areas have greater sediment source zones than less steep areas. The erosion rating for soils is also shown on this map. Where highly erodible soils are within the sediment source zone there is the greatest potential for erosion reaching the stream.

The most sensitive and highly erodible soils are defined in the soils assessment (Issue B). Nearly the entire Assessment Area has highly erodible soils and erosion rankings are relative to the other soils in the Assessment Area. The lower erosion ratings are still associated with soils that are highly erodible.

Each stream has a sediment source zone that includes areas adjacent to the stream that are most likely to contribute sediments. Steeper areas have proportionately larger sediment source zones because the steep gradients make it more likely that eroding soils will be delivered to the stream. Sensitive and highly erodible soils located in the sediment source zone would have a higher potential to contribute sediment to the stream compared to sensitive and highly erodible soils outside of the sediment source areas. Therefore, the critical information is identifying areas with erodible and sensitive soils that are located in the stream source zones. Map W-3 shows the locations of the streams and source zones. Exhibit 15 shows the percentage of source zone area for each watershed and the percentage breakdown into erosion classifications. The table also shows the overall erosion rating. This overall rating is a composite score that gives increasing weight to higher erosion hazard ratings (i.e., low, moderate, high, very high and extreme). It also incorporates the source zone as a percentage of the watershed area.

Exhibit 15. Erosion Rating Breakdown by Watershed

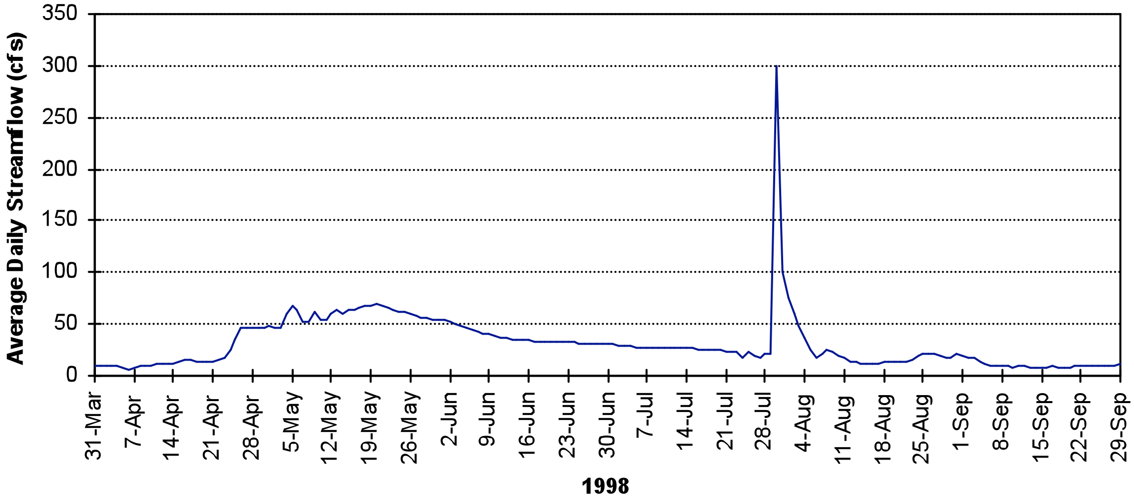
Watershed	Source Zone	Area of Low	Area of Moderate to	Area of Very High to	Overall

	(% of watershed)	Erosion Rating (% of watershed)	High Erosion Rating (% of watershed)	Extreme Erosion Rating (% of watershed)	Erosion Rating
Craig Creek	9	17	30	54	327
Deer Creek	10	5	58	37	308
Elk Creek	13	10	54	36	306
Lower N. Fork Comp	14	23	38	39	294
Geneva Creek	11	26	27	47	290
Lost/Goose Creek	13	28	27	46	288
Buffalo Creek	13	30	35	35	270
Trout Creek	15	21	54	25	269
Waterton/Deckers	14	35	28	37	265
North Fork Headwaters	12	34	31	36	262
Horse Creek	14	46	25	29	237
Cheesman Composite	15	45	30	25	230
West Creek	14	55	32	13	195
Average	13	29	37	34	

The 7,500 Feet Zone and Sediment Sources

The flow regime of the Upper South Platte watershed has been extensively studied to understand mountain stream hydrology. It has been found that above an elevation line of 7,500 feet, peakflows are more dominated by snowmelt and that channel formation at higher elevations is primarily determined by long-term snowmelt patterns. In Colorado, there is no paleoflood field evidence that shows water flows much higher than bankfull discharge above 7,500 feet in Colorado. A similar pattern was found by Jarrett (1990) who concluded that flood frequency (out of channel flow) frequency in the Rocky Mountains is based somewhat upon elevation of the drainage area. He also proposed a 7,500 flash flood elevation limit. This study was reinforced by a study by Grimm et al. (1995) on Bear Creek, a tributary to the South Platte River just north of the Assessment Area, which indicated a trend of increased grain size (coarsening) downstream of the 7,500 foot flash flood elevation limit proposed by Jarrett. This study showed that the energy for moving sediments was much greater below this elevation limit. It appears that for similar stream types, the elevational limit for flooding plays a significant role in the distribution of sediment. Stream discharge records of Buffalo Creek displayed the dramatic differences between snowmelt and summer storm runoff in 1998 (Exhibit 16). Buffalo Creek has only 20 percent of its watershed area below 7500 feet.

Exhibit 16. Sediment/Water Trends–Station Name: Buffalo Creek at Mouth at Buffalo Creek



This elevational effect is important because rainfall events have a greater potential to transport sediment into stream channels by overland flow-sheet wash processes, than peak flows that are snowmelt dominated. Snowmelt peak flows are less likely to be flood events (out of bank) with greater potential of erosion and transport. However, it should be noted that although higher elevation peakflows are primarily caused by snowmelt, the largest peakflows include some rainfall events. The sediment source zones below an elevation of 7,500 feet are the critical sources of sediment because they are more easily accessed by the higher peak rainfall events than snowmelt runoff events.

Peak flows at lower elevations are also larger than higher in the watershed. Larger peakflows mean more energy potential to transport greater volumes of sediment. The size of rainfall generated floods increases dramatically as elevation decreases. Therefore, peakflows at lower elevations are both more likely to be events that result in significant erosion, and to have the carrying capacity to carry eroded sediments downstream or into areas of deposition.

Map W-4 displays that the Waterton/Deckers Composite and Lower North Fork Composite watersheds are where the majority of the sediment source zones coincide with areas below 7,500 feet. To estimate the vulnerability of each watershed to rainfall dominated peak flows, the percentage of area below 7,500 was calculated. The watersheds were then grouped into categories and ranked by this percentage (Appendix E). Horse Creek and Waterton-Deckers had the greatest percentages; 80 percent of Horse Creek and nearly 50 percent of Waterton-Deckers is located below 7,500 feet. These two watersheds would be vulnerable to rainfall peak flows and the types of erosive processes that go with those events. Four of the watersheds do not have any area in this elevation zone including Deer Creek, Craig Creek, Geneva Creek, and North Fork Headwaters. Their ranking was zero and is not indicated on the figure.

Sediment Transport Limiting Areas

As discussed above in Channel Dynamic Equilibrium, locations in the channel network where transport reaches flow into response reaches are very susceptible to impacts from increased sediment supply. Areas downstream of the junction between a higher gradient reach and a lower gradient reach are susceptible to sediment deposition. These junctions are termed sediment transport limiting points. Map W-5 shows the distribution and ranking of these points. Those ranked "high" (red dots) have a greater likelihood of sediment deposition. The "low" (green dots) ranking reflects changes in channel type where the change in gradient is not great enough to result in significant deposition. The "moderate" ranking (yellow dots) are changes in channel type that have a moderate risk of sediment deposition.

The "high" ranking (red dots) are the areas of most concern for deposition of excess sediments that may get into a stream system. The density of high transportation limiting points (red dots) were examined for each watershed to determine which watersheds had the physical features that would put the streams at the most risk for deposition from excess sediments. The watersheds were then grouped into rankings of low to very high density for these junctions. Density was the greatest in Horse Creek Watershed. There is a big drop to the next highest, Elk Creek and Cheesman composite. Deer Creek did not have any of these high ranking junctions.

Map W-5. Sediment Transportation Limiting Factors. The "high" transport limiting areas are response reaches where the sediment supply from steeper channels has a greater likelihood of exceeding the transport capacity of a lower gradient reach. These are areas in which A and Aa+ channels meet C and E channel types. The "moderate" transport limiting factors areas exist where sediment transport capacity of the stream is greater than the "high" areas, but the sediment supply to the reach is not as great as the "high" areas; "moderate" areas occur downstream of where B and G type channels meet A and E type channels. The "low" transport limiting ranking reflects changes in channel type where the change in gradient is the lowest to limit sediment deposition. These include areas where A and Aa+ channels meet B and G type channels. In these areas, the gradient is usually high enough to supply the energy to move or transport sediment through these reaches. Transport capacity is greater than or equal to sediment supply. It also shows the watershed areas under the 7500 foot elevation line where peakflows from summer storms are dominant.

Existing Water Quality

Question C-3: What are the sources and causes of water quality impairments as they relate to the state water quality rules and regulations and the Clean Water Act?

The State of Colorado's Department of Health has identified stream reaches within the Assessment Area that have impaired water quality. Some of these reaches have water quality problems severe enough to only partially support their beneficial uses. The federal Clean Water Act requires states to compile a list (303(d) list) of streams that are impaired (do not fully or partially support their beneficial uses). In the Assessment Area, four stream segments have been placed on the State of Colorado's 303(d) list including Headwaters of North Fork South Platte River, Geneva Creek, Trout creek and South Platte River above Cheesman Reservoir (see Appendix E). Two of the segments, Headwaters of North Fork South Platte River and Geneva Creek, are listed for mining related impacts (see Map W-6). Projects are underway to address the water quality problems in these segments. The other two segments (Trout Creek and South Platte River above Cheesman) are listed

Map W-6. Water Quality Impairment. This map displays the stream segments on the State of Colorado's 303(d) and Evaluation and Monitoring list. The segments are further divided into mining related and sediment related.

for sediment. The sediment problems impairing the South Platte River above Cheesman come from outside the Assessment Area and will not be discussed further. A project in Trout Creek has defined the water quality problems as being primarily associated with excessive nutrient loading from human development in the upper watershed (Personal communication 1999). A joint project between the US Forest Service and the State of Colorado's Department of Health is working on identifying sources of water quality impairment in Trout Creek.

If there is a concern for a stream and the documentation is not adequate for listing on the 303(d) list then it may be placed on the Monitoring and Evaluation list. Sixteen stream segments in the Assessment Area are on the Monitoring and Evaluation list (see Appendix E). Two of the 16 stream segments that are listed on the Monitoring and Evaluation List are listed for possible mining related water quality impairment in Geneva Creek. The remaining stream segments are listed for sediment related problems. Half (7) of the segments are in the Waterton/Deckers Composite watershed. Three segments (Buffalo Creek, Lower North Fork South Platte, and Lower South Platte) have been impacted by the floods following the Buffalo Creek fire. The remaining segments are likely all associated with road impacts. The segments on the Monitoring and Evaluation List for sediment will be used as the targets for restoration and protection projects.

Water quality data for the streams in the Assessment Area were examined and the watersheds ranked for water quality related problems. Two of the watersheds, Waterton/Deckers Composite and Lost/Goose Creek are ranked very high and high for water quality related problems. These problems are related to sediment loads.

Human disturbance was evaluated by determining the number of road and trail crossings of streams and the road density within each watershed. Map W-4 shows the results of this analysis.

Map W-4. Human Disturbance of the Drainage System. This map displays watershed ratings by road density, and road and trail crossings.

Aquatic Habitat

Question C-4: Where are the known populations of aquatic species of special interest located in the Assessment Area? Where is potential habitat for these species in the Assessment Area?

Current fish communities in the Assessment Area consist primarily of seven species of fish. These include: rainbow trout (*Oncorhynchus mykiss*), brown trout (*Salmo trutta*), cutthroat trout (*Oncorhynchus clarki*), brook trout (*Salvelinus fontinalis*), longnose sucker (*Catostomus catostomus*), white sucker (*Catostomus commersoni*), and longnose dace (*Rhinichthys cataractae*). None of the four trout species found in the Assessment Area are native to the area, however, the three non-game fish species are native. The only species of trout that is native to the Assessment Area is the greenback cutthroat trout (*Oncorhynchus clarki stomias*). This subspecies does not currently exist in any of the Assessment Area's streams. However, a section of Craig Creek had recently been considered for re-introduction of this native species. The non-game native fish species are still present in the Assessment Area at certain locations (mostly at lower elevations). Map W-8 shows the distribution of fish populations in the Assessment Area.

Map W-8. Need for Stream Restoration and Distributions of Important Aquatic Habitat. This map displays the habitat for trout species and locations of population sampling. Trout habitat covers all of the streams except for the smallest streams. The map also identifies restoration need for fisheries.

Brook trout have become well established and maintain self-sustaining populations in most of the smaller tributaries and high elevation streams within the Assessment Area. The brook trout is well adapted for surviving at high elevations (relatively cold water temperatures) and in small streams. In many of the high elevation streams in the Assessment Area the brook trout is the only fish species that is present. In the Assessment Area it appears that brook trout become replaced by other trout species in larger streams and at elevations that are less than about 7,600 feet. As with other species of trout the brook trout is sensitive to a variety of environmental disturbances (Chevalier et al. 1984; Lloyd 1985; Marcus et al. 1990). Brook trout are the Management Indicator Species (MIS) for the Pike/San Isabel (PSI) National Forest. Map W-9 shows the distribution of brook trout in the Assessment Area.

Brown trout are the most widely distributed species of fish within the Assessment Area. Naturally reproducing populations of brown trout occur in most major tributaries and mainstem streams throughout the Assessment Area. Only the higher elevation streams and some of the smaller streams do not hold populations of this species. Some areas where brown trout were not found in fish samples include; the upper reaches of Craig Creek, upper Elk Creek, Turkey Creek, the North Fork of Lost Creek, and the North Fork of the South Platte River upstream from its confluence with Lake Fork. At most locations where brown trout were present they were the dominant fish species.

Map W-9. Distribution of Target Aquatic Species and Their Habitat (Brook Trout). This map displays the habitat distribution of brook trout, which are the management indicator species for the Pike-San Isabel National Forest.

Rainbow trout are naturally reproducing and supplemented by stocking at various locations within the Assessment Area. Populations of this species are highest in medium to large streams within the Assessment Area. Areas where rainbow trout have been well represented in fish collections include; Horse Creek, Goose Creek, the North Fork of the South Platte River downstream from Geneva Creek, and the mainstem South Platte River. Although complete information regarding distribution is not available, it is likely that rainbow trout inhabit the lower reaches of most major tributaries to the North Fork and mainstem of the South Platte River.

Limiting Factors for Sediment Transport

> Question C-5. What limiting factors, such as streamflows, reservoirs and areas of sediment deposition, control levels of sediment transport within the streams?

Cheesman Lake is the only major reservoir in the Assessment Area. It functions as a sediment deposition area for the headwaters of the South Platte River. The Reservoir has altered the flow regime below the reservoir by reducing peak flows and increasing lowflows. This moderating effect has resulted in a more stable channel downstream of the reservoir in terms of sediment yield, transport and deposition.

The Roberts Tunnel has also altered flows in the North Fork South Platte River. The Roberts Tunnel brings water from the Blue River (Lake Dillon) through the continental divide and discharges it into the North Fork South Platte River just below the confluence with Geneva Creek. This discharge likely does not effect sediment yield and transport significantly because it primarily increases lower flow levels in the summer and fall. However, it may increase a rainfall induced peakflow in the summer by increasing the base flow in the channel at that time of the year.

The areas above an elevation of 7,500 feet in the Assessment Area are generally limited by sediment transport. In these areas the dominant peakflow events are from snowmelt runoff, which usually do not exceed bankfull capacity. Streams in areas below 7,500 feet may also be limited by sediment transport but only until the next large rainfall/flood event when sediment transport exceeds that available during snowmelt runoff.

Field observations noted that large amounts of sediment are stored in response reaches. In general, those observations and the preceding analyses support the concept that transport of the stored sediment occurs during peak flow events, usually generated by summer rainstorms. Therefore, sediment supply appears to exceed transport capacity in many of the response reaches.

Step 4. Reference Conditions

The runoff regime under the reference condition was somewhat different than the current condition. A lower density of trees would result in lower evapotranspiration rates and more water available for streamflow. The snow in the forest mosaic would melt and contribute to runoff over a longer time in the spring because some snow would melt sooner in openings and later from shaded areas. More runoff would likely result in larger riparian areas. The riparian areas likely extended higher into the drainages than they do today as a result of more water available for runoff, and snowmelt occurring over a longer time.

Pre-European Sediment Yield, Transport and Deposition

> Question C-6. How would pre-European sediment yield, transport and deposition be characterized?

More frequent fires (reference condition) likely resulted in more frequent erosion, sediment transport and deposition events than under the current condition. These more frequent events would appear as pulses of sediment to the system and the majority would not cause streams to move out of dynamic equilibrium.

Large disturbance events such as fires and subsequent flash flooding cause disruption in the flux of sediment that enters the drainage network. Geomorphic investigations in the Buffalo Creek area (Jarrett, 1999) in the burned and unburned areas indicate at least 10 fire/flood sequences in the past 2,500 years have occurred prior to the 1996 Buffalo Creek fire. Maximum peak discharges were estimated to be 1.5 times higher in burned areas than unburned areas in Colorado. At least one paleoflood was larger than the July 12, 1996 flood, and runoff evidenced by much thicker alluvial deposits produced by several of the prehistoric fires than following the 1996 wildfire. Hillslope erosion following wildfire and high rainfall events appears to be a major source of sediment to the drainage network. In the Buffalo Creek area, it was estimated approximately 10 mm of erosion from the hillslopes occurred based upon a hundred hillslope erosion measurements in the affected area (Jarrett, 1999). The rainfall events in the burned areas moved sediments ranging from silt size to cobble sized, up to some 2.5 meter diameter boulders that were transported in some channels (Jarrett, 1999). The large events tend to degrade many channels by overwhelming them with deposition of sediment and causing them to move out of dynamic equilibrium.

The paleoflood records indicate that events of the magnitude of the erosion and sediment deposition associated with the Buffalo Creek fire and floods have occurred approximately every 250 years. While that data suggests that Buffalo Creek is within the historical context, the Assessment Area appears to be in a condition where many more and possibly larger “Buffalo Creeks” could occur within the next 250 years.

Pre-European Aquatic Habitat and Fish Populations

> Question C-7. How would pre-European aquatic habitat and fish populations be characterized?

The current fish communities in most Colorado streams differ greatly from the communities that existed prior to European settlement. Historically, longnose sucker, white sucker, longnose dace, and greenback cutthroat trout were known to inhabit the Upper South Platte River and North Fork South Platte River (Appendix F). Of these four fish species the greenback cutthroat trout is the only species that has disappeared completely from the Assessment Area. The exact historic distribution of greenback cutthroat trout in the Assessment Area is unknown. However, Behnke (1992) suggests that this species was a common inhabitant of mountain and foothill tributaries of the South Platte River. It is likely that the historical range of greenback cutthroat in the Assessment Area was similar to the area that is occupied by other trout species today (Map W-8).

The greenback cutthroat trout is easily displaced by other species of trout, and rapidly disappeared from areas that were stocked with nonnative trout species (Behnke 1992). Brook trout were probably the first nonnative species to be introduced into the South Platte system. The exact date that brook trout were introduced is unknown, however, specimens were collected during 1872 from the South Platte near Denver, Colorado (Wiltzius 1985). Rainbow trout were stocked in some Colorado locations as early as 1882. A stable population of rainbow trout was reported in Cheesman Lake by 1907 (Wiltzius 1985). Brown trout were stocked in the Denver area in the late 1800s and nonnative subspecies of cutthroat trout were probably introduced during the early 1900s. The native greenback cutthroat trout were lost through hybridization or displacement probably within a few years after nonnative trout were introduced.

The greenback cutthroat trout is listed as threatened under the Federal Endangered Species Act and the U.S. Fish and Wildlife Service in cooperation with other agencies have initiated a reintroduction plan (USFWS 1995). The other native species of fish still exist in the Assessment Area are not considered managed species or species that are especially sensitive to disturbance.

Step 5. Synthesis Questions for Water Quality, Quantity and Aquatic Habitat

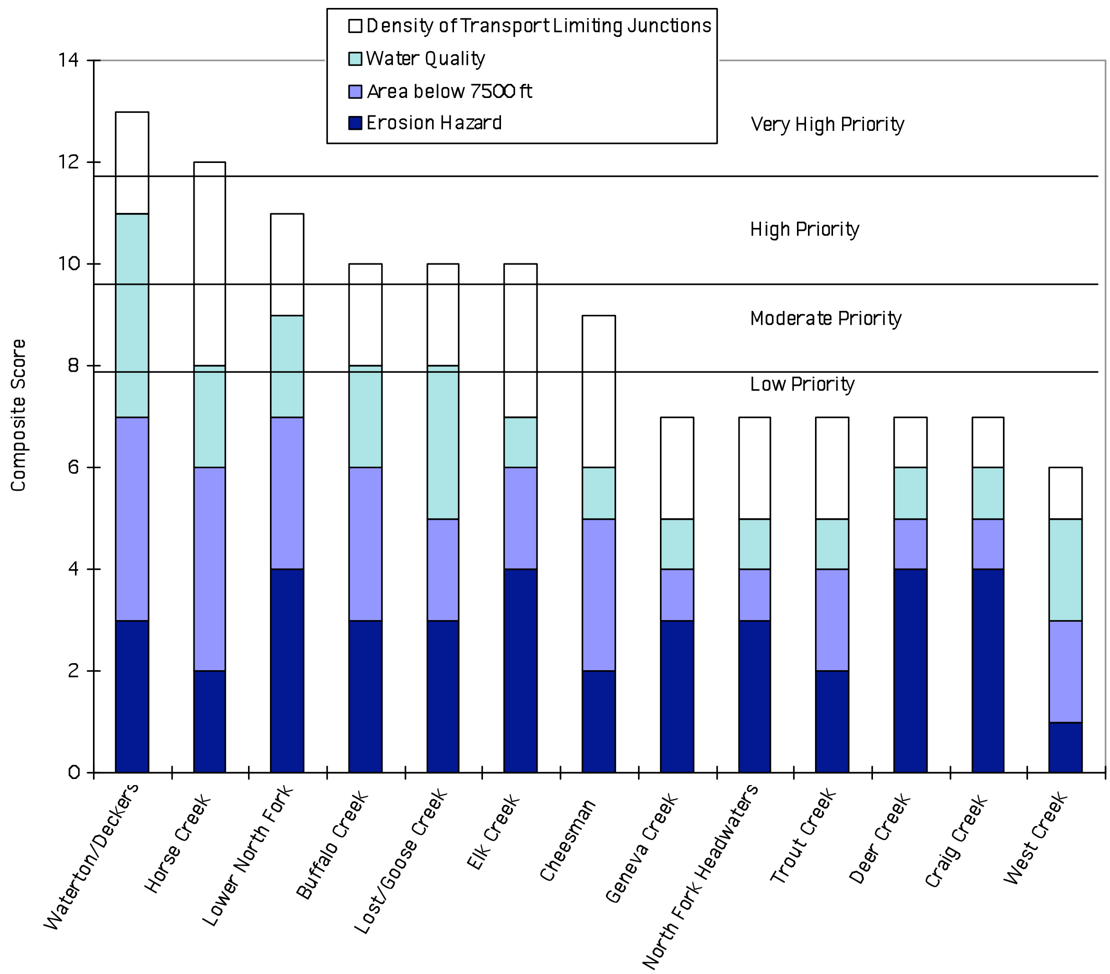
> Questions C-8. What watersheds are currently characterized by hydrologic patterns and processes that are farthest from the natural patterns?

Map W-10. Watershed/Vegetation Management Restoration Priorities by Watershed. This map combines Maps W-2, W-3, W-5 and W-6. Horse Creek and Waterton/Deckers are the highest rated watersheds for restoration priority.

Four factors are examined in this section to determine the relative susceptibility of the watersheds to sediment related problems. These include; 1) erodibility and availability of soils in each watersheds source zones, 2) area of each watershed in an elevational zone where surface erosion is more prominent, 3) limitations to the transport of sediments and likelihood of deposition due to the physical stream structure, and 4) existing water quality data that identifies watersheds with sediment problems. These factors are combined to determine which watersheds are at the most risk overall. For each factor, the watersheds are grouped into categories. Then all four categories were combined to form a composite score. This allows the watersheds to be ranked in terms of priority for restoration management activities (Map W-10).

The top three watersheds ranked in terms of restoration priority are Waterton/Deckers, Horse Creek and Lower North Fork (Exhibit 17). The next group of watersheds, Buffalo Creek, Lost/Goose Creek, Elk Creek and Cheesman, are ranked nearly the same although they have different scores that comprise those rankings. The remaining watersheds are all ranked basically the same and are not identified as priorities in this analysis.

Exhibit 17.Watershed Restoration Priority



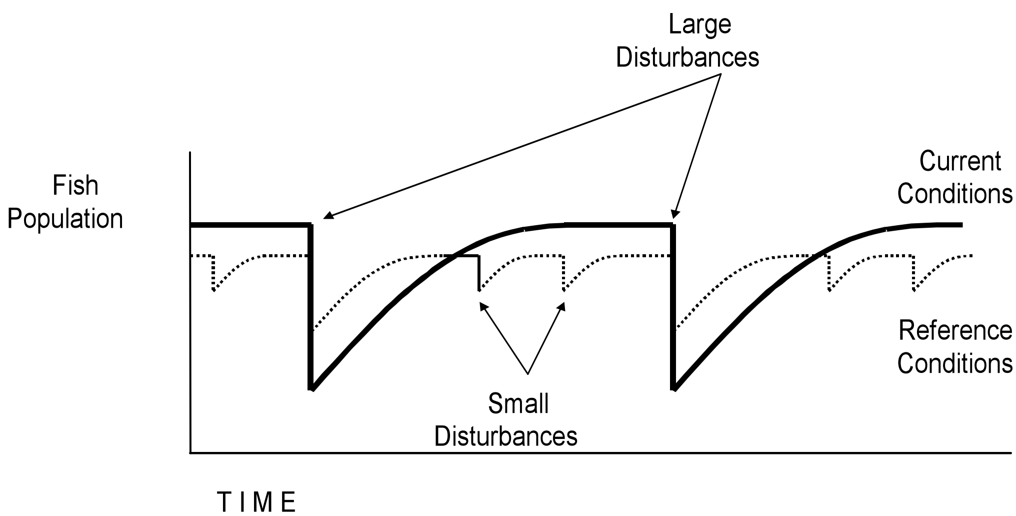
The top three priority watersheds have some major differences. Waterton/Deckers and Lower North Fork are the two largest watersheds in the Assessment Area (>100,000 acres). Waterton/Deckers appears to be rated appropriately over the majority of the watershed, except for Wigwam Creek. Removing Wigwam Creek from the Waterton/Deckers watershed would likely increase its rating. The Lower North Fork watershed is composed of two distinct sections, the upper and lower sections. The lower section, downstream of the Craig Creek confluence, is the area below 7500 feet and contains the sediment related water impacts. The lower section of Lower North Fork watershed would likely rate higher than the entire watershed. Horse Creek is the smallest watershed in the Assessment Area (<5,000 acres) which increases in importance of the one water quality reach and the two red dots located in this watershed.

Question C-9. How do current fisheries differ from pre-European populations, composition and distribution?

The reference condition disturbance regime would likely have resulted in more frequent, less catastrophic sediment inputs than the current condition. The sediment inputs would have consisted of mostly sand and gravels and would be easily transported through transport reaches and deposited in response reaches.

There would be minimal differences in sensitivity to the reference disturbance regime between greenbacks and current trout species. The current disturbance regime could result in larger variations in trout populations than the reference disturbance regime. Larger, more catastrophic disturbances would reduce the quality of larger portions of fish habitat than smaller more frequent disturbances. The reference condition would therefore result in more sustainable trout populations in the Assessment Area (Exhibit 18).

Exhibit 18.Conceptual Fish Population Sensitivity to Disturbances



It is likely that the historical range of greenback cutthroat trout in the Assessment Area was similar to the area that is occupied by other trout species today. The current trout populations are not considered more or less sensitive to disturbances than the historical populations.

Cheesman Dam, which was completed in 1905, has moderated the streamflow in the South Platte River below Cheesman Lake. The peakflows have been reduced, although Cheesman is a water supply reservoir, and more importantly for the fishery, the lowflows have increased. The flow modifications have resulting in the South Platte River below Cheesman becoming a gold medal trout fishery. This section of river likely supported a smaller population of trout before Cheesman Dam was constructed.

LANDSCAPE SYNTHESIS

The landscape synthesis focuses on identifying significant differences, similarities or trends of key ecosystem processes or components. The components of this step are listed below.

- Capability of ecosystem to achieve existing management plan objectives or to be restored to sustainable watershed conditions
- Cumulative effects of catastrophic disturbance on target species
- Prioritization of watersheds in need of restoration management

A synthesis was conducted for each of the three issues. The synthesis is documented in the following series of tables resulting in recommendations (Exhibits 20, 21 and 22). This format tracks the issue from findings to recommendations. This section of the assessment will focus on combining the three issues into a landscape synthesis resulting in prioritization of watersheds for restoration management.

Synthesis of Issue A

The synthesis of Issue A (forest vegetation and wildlife) resulted in the identification of Cheesman, Trout Creek and Waterton/Deckers watersheds as high ranking for restoration. The ponderosa pine/Douglas-fir montane forest appears to be relatively dense and even-aged. The density of the ponderosa pine/Douglas-fir forest (as evidenced by crown closure) is generally dense enough to sustain a substantial crown fire. The evidence is that the crown closure that existed before the Buffalo Creek Fire was nearly identical to that existing in the majority of the ponderosa pine/Douglas-fir forest. The result is a high fire risk throughout the ponderosa pine/Douglas-fir forest.

Synthesis of Issue B

The synthesis step for soils (Issue B) resulted in identification of Horse Creek as extreme and, Buffalo Creek, Cheesman, Deer Creek, Elk Creek, Lower North Fork and Waterton/Deckers as high risk in the composite soils synthesis. The soils are rated as highly erodible throughout the Assessment Area, especially compared to other finer textured soil types. There are serious concerns for catastrophic erosion and sediment deposition as evidenced by the experience of the Buffalo Creek Fire in 1996.

Synthesis of Issue C

The synthesis of Issue C (water and fish) resulted in identification of Horse Creek and Waterton/Deckers as very high in the composite watershed restoration synthesis. Maintaining or restoring watershed health is the overall goal. Although the effects of the Buffalo Creek Fire have dramatically changed Buffalo and Spring Creeks the changes are temporary. Those streams are recovering quickly and fish habitat is being restored. Watershed conditions that adversely impact watersheds constantly are the main concern for watershed health. Watershed health concerns include the roads, changes in the hydrologic regime due to reservoirs, and changes in the species composition of fish populations. Of those concerns, problem roads were targeted in the identification of restoration project areas. However the main watershed health concern is that the forest condition is setup for a series of catastrophic fires, such as Buffalo Creek or larger, now and that with fire suppression as the key management strategy, the forests will regrow to the same condition with the same catastrophic result in the future.

Rankings for the three issues were combined on one table (Exhibit 19). The table shows clearly that two watersheds rank highest - Waterton/Deckers and Horse Creek. These two watersheds consistently rank higher than the other watersheds. This table presents the overall restoration ranking by watershed for this Landscape Assessment.

Exhibit 19.Overall Watershed Restoration Ranking

Watershed	Fire Hazard	Vegetation long-term sustainability	Target Terrestrial Species	Composite Vegetation and Wildlife	Composite Soils Risk	Sediment source zone	Sediment transport limiting	Area less than 7500 feet	Water Quality Impairment	Watershed Restoration
Waterton/ Deckers	High	High	High	High	High	High	Moderate	High	Very High	Very High
Horse Creek	High	High	Medium	Medium High	Extreme	Moderate	Very High	Very High	Moderate	Very High
Lower North Fork	Medium High	Medium High	High	Medium High	High	Very High	Moderate	Moderate	Moderate	High
Cheesman	High	High	High	High	High	Moderate	High	Moderate	Low	Moderate
Elk Creek	Medium High	Medium High	Medium	Medium	High	Very High	High	Low	Low	High
Trout Creek	High	High	High	High	Moderate	High	Moderate	Low	Low	Low
Buffalo Creek	Medium	Medium	High	Medium High	High	High	Moderate	Moderate	Moderate	High
Deer Creek	Medium High	Medium High	Medium	Medium	High	Very High	Low	Low	Low	Moderate
West Creek	High	High	Medium	Medium High	Moderate	Low	Low	Low	Moderate	Low
Lost/Goose Creek	Low	Medium	Medium	Medium	Low	High	Moderate	Low	High	High
North Fork Headwaters	Low	Medium High	Low	Medium	Low	High	Moderate	Low	Low	Low
Geneva Creek	Medium	Medium	Low	Low	Low	High	Moderate	Low	Low	Low
Craig Creek	Low	Low	Low	Low	Low	Very High	Low	Low	Low	Low

Exhibit 20. Issue A Synthesis

Issue/ Key Question	Finding	Cause	Future Trend	Outcome/ Resources Affected	Recommendations
A1	Ponderosa pine and Douglas-fir types occupy the montane forest zone and the majority of the Assessment Area. Spruce/fir and lodgepole pine occupy the subalpine zone. Late seral stages dominate the Assessment Area.	Extensive grazing, logging between 1870-1900, and fire suppression from 1900 to present.	Continued dominance of PP/DF type.	NA	NA
A2	Lack of disturbances in PP/DF since extensive logging of area. Two key processes in the S/F and LP forests: insects create small-scale disturbance, insects and fire create large-scale disturbance, fire may occur on a 300- to 400 year cycle while insect mortality is an on-going process with periodic epidemics	Extensive grazing, logging between 1870-1900, and fire suppression from 1900 to present changed stand structure and density. Most of the area has not had a fire in 148 years. It is likely that much of the area would have burned about 1906 and again in from multiple fire starts in 1963 had these fires not been suppressed. Insect outbreaks in the S/F and LP forests often follow windthrow, events, which leads to insect population increases. Insect-caused mortality in LP and S/F forests increases fuel loads and sometimes lead to stand-replacement fires.	Fires in PP/DF forests may follow fuel build-up which occurs during wet periods. Continued natural processes in S/F and LP where fires do not threaten structures.	Large-scale stand-replacement fires like Buffalo Creek followed by erosion and flooding that threaten life and property.	N/A
A3 & A4	The lack of openings that act as fire breaks and the presence of dense stands covering most of the PP/DF area encourage crown fires that can kill trees over thousands of acres and lead to soil erosion on a massive scale. Watersheds with large amounts of PP/DF are the most “at risk” (Waterton/Deckers, Horse, Chees-man, West, and Trout).	Fire suppression (compounded by logging in the late 19th century which removed the larger trees).	Continued fire suppression often unsuccessful in preventing large, stand-replacement fires.	Additional catastrophic fires followed by erosion and flooding in the PP/DF forests.	N/A
A5	Leafy spurge, kocia, salt cedar, defuse knapweed, Canada thistle, musk thistle, yellow toad flax, Russan thistle have become common invasive plants in burned areas (Buffalo Creek Fire),	Introduced by people and domestic animals.	Continued spread to new areas	Further loss of forage values and native plants	Follow Pike-San Isabel Noxious Weed Management Plan. Consider noxious weeds when planning thinning, creating openings, or building trails or roads into uninfested areas or

Issue/ Key Question	Finding	Cause	Future Trend	Outcome/ Resources Affected	Recommendations
	out-competing native plants and reducing forage value, requiring extensive efforts to combat				crossing infested areas with equipment and vehicles.
A6	Habitats within the area support 30 target species. The large habitat blocks are the montane forest characterized by PP/DF forest. Snags and cavities are generally lacking.	Current conditions	High risk of large-scale fires. Gradual increase in snags and cavities as forests age.	More snags and cavities would increase habitat for some species. Large scale forest fires would reduce habitat quality and quantity dramatically.	Maintain/create snags & trees w/cavities.
A7 & A8	The natural range of variation in vegetation in the PP/DF forests included openings (that may have covered 10 to 20% of the area) and a mosaic of age classes (ranging from seedlings to trees over 400 years). PP predominated except on north slopes. DF predominated on north slopes. The natural range of variation in vegetation in the S/F and LP forests was probably similar to current conditions.	Frequent large-scale fires that burned at different intensities throughout the PP/DF forests.	N/A	A mosaic of openings and patches of different age classes and densities in the PP/DF forests which tended result in fires that skipped around rather than killing all trees over several thousand acres. Insect damage and/or windthrow in the S/F and LP forests resulted in uneven-aged stands of shade tolerant species (S and F). Fires in the S/F and LP forests resulted in even-aged stands of LP, aspen, and/or S.	N/A
A9 & A10	Key process in the PP/DF forests was large-scale fire on an average 60 year cycle. These were often a mixture of surface and crown fires that created a mosaic of openings and patches with different age classes and tree densities. Two key processes in the S/F and LP forests: insects create small-scale disturbance, insects and fire create large-scale disturbance, fire may occur on a 300- to 400 year cycle while insect mortality is an on-going process with periodic epidemics.	Fires in PP/DF forests may follow fuel build-up which occurs during wet periods. Insect outbreaks in the S/F and LP forests often follow windthrow, events, which leads to insect population increases. Insect-caused mortality in LP and S/F forests increases fuel loads and sometimes lead to stand-replacement fires.	N/A	Effects on resources remained within the natural range of variation.	Recreate pre-European forest conditions-in PP/DF forests. Create 5-10 acre openings (10 to 20% of the landscape). Thin remaining stands to the appropriate species mix and tree densities. Leave large PP trees and some large DF trees. Favor DF on north slopes. Use prescribed fire to maintain some openings, generally on south slopes. Consider removing blowndown in S/F forests to reduce insects population explosions. Maintain aspen stands for sapsuckers and other resource values. Consider leaving a buffer around aspen stands. Regenerate LP stands, log and burn stand-sized patches, allow some to regenerate to aspen.

Issue/ Key Question	Finding	Cause	Future Trend	Outcome/ Resources Affected	Recommendations
					Plan for a low-density road system. Treat stands that are near to existing roads to avoid new roads where that strategy will meet resource objectives. Decommission roads not needed for future management. Stormproof existing roads and new roads not planned for decommission-ing. Consider erosion potential of soils when planning treatments. Closely monitor results and implement an adaptive management approach to restoration activities.
A11	Many species would benefit from increased numbers of snags, large trees with cavities, openings, and age class diversity in PP/DF forests Sub alpine zone have high levels of snags and cavities	Loss of these components over time due to fire suppression and logging	Gradual increase in snags and cavities as forests age. High risk of large-scale fires.	Adverse impacts to many species, including TES species, reduced species diversity and abundance if large-scale fires happen.	Thin, create openings, create snags and cavities, increase age class diversity in PP/DF areas Consult recovery plans for TES species

Exhibit 21. Issue B Synthesis

Issue/ Key Question	Finding	Cause	Future Trend	Outcome/ Resources Affected	Recommendations
B1	Road and trail networks, rural and suburban development locally cause detrimental soil compaction, which reduces or eliminates infiltration of surface water into the soil column. The result of decreased infiltration is the increase of sheet erosion that can lead to rill and gully erosion during periods of precipitation or snow melt.	Insufficient design and maintenance	Increased erosion due to expansion of road and trail networks as a result of development.	N/A	Reduction of local erosion by correction of design, improve maintenance and local closure and reclamation of roads & trails
B2	Map S-2 displays the current high erosion hazards. There is an area in the northern central portion of the Assessment Area that is rated as extreme erosion hazard. Severe erosion hazard areas are prevalent in the Assessment Area.	Inherent soil erodibility and human soil compaction.	Increased erosion hazard due to expansion of road networks as a result of development.	N/A	N/A
B3	The faults and fractures that are present are such that, while influencing local topography and stream locations, their density, type, and orientation do not create significant weaknesses that lead to large zones of mass movement and instability.	N/A	N/A	N/A	N/A
B4	Horse Creek rated extreme in potential for soil movement following wildfire. Watersheds rated as high are Buffalo Creek, Cheesman, Deer Creek, Elk Creek, Lower North Fork, and Waterton/Deckers.	Those watersheds displayed high soil erosion hazard, hydrophobicity potential and fire risk.	Potential for catastrophic wildfire followed by erosion.	Substantial soil erosion similar to Buffalo Creek.	Reduce risk of wildfire in priority watersheds.
B5	Hydrophobic soils are not well understood. They can result in a higher rate of sheetwash instead of infiltration.	Inherent soil characteristics	N/A	N/A	N/A
B6	Reference conditions are hard to establish, but using. photographic and survey records and ecologic reconstructions by fire ecologists we commonly get a picture of more open forests. Pre-European influences were both natural such as lightning		Wildlife will never return to Pre-European levels. Wildfires will increase in scale and frequency if the current management plan is followed.		Reduce tree densities, create openings and increase the frequency of ground fires to clear out the understory and reduce build up of fuel

Issue/ Key Question	Finding	Cause	Future Trend	Outcome/ Resources Affected	Recommendations
	started fires and possibly wide spread fire application by Native Americans. Both of these events disturbed soil and increased erosion. Also, Pre-European conditions had abundant wildlife similar Alaska and Arctic Canada. Some of these large herds were very destructive to soil.				
B7	Historic soil losses in the Assessment Area probably were similar to present rates, however, the potential for soil loss has steadily increased under fire suppression. Because of the granular characteristic of weathered granite the resulting soil will always have tendency towards being highly erosive.	Assessment Area has natural tendency towards erosive soils but can be exacerbated by severe fires	Under continued fire suppression the threat of massive soil losses following wildfire over extended periods increases.	Additional catastrophic fires followed by extensive erosion and flooding in the PP/DF forests.	Reduce tree density, fuel build up and understory height and create openings to act as fire breaks in the PP/DF forests as described in Issue A.
B8	Erosional events such as Buffalo Creek occurred in prehistory. The evidence is in the large expanses of even aged PP stands that the European settlers harvested and some are still to be seen. For these to have occurred a devastating fire had to come through the area resulting in massive erosion until revegetation stabilized the area.	Natural or Aboriginal.	N/A	N/A	Reduce tree density, fuel build up and understory height and create openings to act as fire breaks in the PP/DF forests as described in Issue A.
B9	The role of micrphytic crusts is unclear, but it is probable that their soil stabilizing role is lost during an intense fire.	N/A	N/A	N/A	Further research on the function of microbiotic crusts, especially following fire. Document responses to disturbances associated with restoration projects.
B10	The watersheds were ranked for both the pre- and post-European periods for soil disturbance patterns (Map S-1). The change in rankings were given a direction and magnitude. The watersheds with the greatest change from reference conditions are Deer, Elk and Trout Creeks, which contain some of the highest human populations.	Human caused changes resulted in a change in rankings for soil disturbances.	Increased human disturbances due to increased development.	Some increased detrimental impacts to soils in areas of construction of roads, etc.	Use management direction to minimize extent of new roads.

Issue/ Key Question	Finding	Cause	Future Trend	Outcome/ Resources Affected	Recommendations
B11	Map S4 shows the ranking for watersheds that are at risk for soils, have areas of high erosion hazards, and are susceptible to potential soil loss following fire (combination of Maps S1 through S3). Horse Creek is the only watershed that is identified as extreme risk. Buffalo Creek, Deer Creek, Elk Creek, Lower North Fork, and Waterton/Deckers watersheds are all identified as high risk.	The watersheds ranked as high or extreme risk have a combination of factors that lead to their ranking.	Increasing soil impacts in areas of human development. Catastrophic erosion events associated with large fires such as Buffalo Creek Fire.	Extensive soil erosion as evidenced following the Buffalo Creek Fire.	Reduce fire risk, minimize new road construction and other human development related impacts. Review Buffalo Creek fire area for erosion mitigation and soil stabilization efforts that worked. Formulate an action plan for future fires in the area.

Exhibit 22. Issue C Synthesis

Issue/ Key Question	Finding	Cause	Future Trend	Outcome/ Resources Affected	Recommendations
C1	There are 899 miles of stream in the watershed. 48 percent are A and Aa+ types channels (high gradient (greater than 4 percent)), 23 percent are B and G types channels (moderate gradient (2 to 4 percent)), 25 percent are C and E type channels (low gradient < 2 percent), and 4 percent are lakes and reservoirs.	Geomorphic influences	N/A	N/A	N/A
C2	Transport potential is dependent upon the hydrometeorological characteristics of the watersheds and stream channel morphology.	Areas below 7500 feet are more susceptible to greater transport potential because of the increased influence of rainfall dominated peak flows; response reaches , especially those areas in which channel gradient and characteristics change from a sediment transport areas to one where sediment supply exceeds transport capacity of the stream (places where Rosgen A channels meet to Rosgen C and E channels) are more susceptible to limiting transport of sediment prior to large storm events; in addition, reservoirs and impoundments on streams will be sources of storage for sediment	Historic flash floods are evident in the recent (Holocene) geologic record and will continue to occur into the future		
C3	The are four stream segments listed on the State 303(d) list. They are: Trout Creek, South Platte River above Cheesman portions of Geneva Creek and the Hall Valley area. 17 other reaches are listed on the State's monitoring and evaluation list for sediment. These reaches are the targets for water quality.	Trout Creek is listed for sediment but the actual impacts are from nutrient enrichment. The South Platte River above Cheesman is listed for problems outside the watershed. Geneva Creek and Hall Valley were listed for water quality impacts from historic mines. Most of the reaches on the Monitoring and Evaluation list are sediment impacted from roads.	Continued road and mine impacts for listed segments. The State and EPA are assessing Geneva Creek and Hall Valley area for possible remediation projects, that should improve water quality there. Large-scale fires like Buffalo Creek could seriously impact more streams.	Road derived sediments may be transported downstream where deposition could cause pools to fill and fish spawning habitat to be adversely affected. Agencies are becoming more aware of possible problems with sediment yield from roads in the assessment area.	Inventory roads in watersheds where sediment problems have been identified. Recommend treatments to problem road segments where necessary. Use caution in designing new roads to minimize any sediment yield increases. Where new roads are proposed, design the roads to minimize amount of new roads. Use temporary roads where possible and decommission them following use.
C4 & C7	Brook trout are the management indicator species for the PSI Forest.	Greenback cutthroat trout were eliminated from the assessment area	Distribution will remain until habitat is altered, potentially by large cata-	Large-scale fires will adversely effect habitat but natural or human recovery	Reduce fire risk and potential sediment increases from brook trout

Issue/ Key Question	Finding	Cause	Future Trend	Outcome/ Resources Affected	Recommendations
	They are located above 7500 feet in elevation in all 6th level watersheds and have good populations in those areas.	through introduction of non-native trout species. Brook trout do not compete well with rainbow trout in warmer waters below 7500 feet in elevation.	strophic wildfires.	will occur and allow recolonization of habitat. If large areas of a watershed above 7500 feet burned brook trout could potentially be eliminated from that watershed.	habitat areas.
C5	Cheesman Dam and Roberts Tunnel have changed the natural flow regimes.	Cheesman Dam reduces peak flows and increases low flows.	Effects will continue	Fish below Cheesman and Roberts Tunnel experience higher low flows than under reference conditions	N/A
C6	Pre-European sediment yield and transport were characterized by more frequent, smaller sediment events.	Smaller more frequent fires.	N/A	N/A	N/A
C8	Waterton/Deckers, Horse Creek and Lower North Fork watersheds are rated the highest for restoration projects.	They have the highest overall combination of water quality problems, sediment source zone, elevation below 7500 feet and sediment limited junctions.	Continued water quality problems related to roads.	Fish habitat and channel dynamic equilibrium adversely affected.	Target watersheds listed and loacte in areas were road rehabilitation projects can be done with the vegetation restoration project.

LANDSCAPE RECOMMENDATIONS

The landscape recommendations for the Upper South Platte Watershed have two goals;

- reduce the probability of fire the magnitude of Buffalo Creek or larger,
- and create/restore forest conditions that are sustainable.

The Buffalo Creek Fire was examined in this assessment and it was generally determined that fires of that magnitude occurred in the reference condition. Restoration of the reference condition is not acceptable in portions of the Assessment Area that have higher human populations or critical areas for water supply. In general, a reference fire regime that included Buffalo Creek magnitude fires would not be acceptable because of the high potential for property damage, water supply impacts and most seriously loss of human life. Therefore the goals that guide the recommendations use sustainable conditions and reduction of fire magnitude as targets.

Watershed Targets

The restoration project should be targeted in the watersheds listed in order in Exhibit 22. Wigwam Creek watershed should be dropped from the Waterton/Deckers project area because it is quite different than the rest of the watershed. However, if it makes sense include Horse Creek in the project area. Horse Creek is quite small and has the same ranking as Waterton/Deckers. The slopes on the eastern side the South Platte River appear to be a good location. There are three creeks (Russell Gulch and Pine and Sugar Creeks) that are on the State's Monitoring and Evaluation List in that area. Pine Creek was observed to be overwhelmed with fine sediment near its mouth (Exhibit 23). Stream restoration projects could be completed in one or all of the streams listed to restore fish habitat and reduce sediment yield to the South Platte River where the fish habitat is very important. There are also existing roads in this area that could be used during the restoration project.

The Elk Creek, Deer Creek and Lower North Fork area also appears to be a good target for restoration. There are however, several problems with restoration projects in these watersheds. The largest concentration of human development is located in these watersheds and they contain large sections of private land. Because they have houses and commercial buildings, a reference fire pattern would not be allowed. Fires within the developed portions of these watersheds would be suppressed. Even if a reference condition could be achieved, some wildlife would not use the improved habitat because they tend to stay away from human interaction. These three watersheds do have some contiguous areas of high fire risk but they also have some existing fire breaks (roads) and have easy access for firefighters.

Landscape Considerations

Locate restoration areas where tree density will be reduced in areas such that topographic features provide additional fire protection. Where practical, leave higher density "burn areas" around the treated areas and close to natural fire breaks. These "burn areas" will be allowed or encouraged to burn but will be small enough to not endanger the treated stand. Initially introduce fire only where the risk of escaping is small. Fire will be a useful tool in restoring the landscape but caution should be used in its application during the early stages of the restoration project.

Consider a revised "let it burn" policy. Create a plan for each area, considering fire risk, etc., to guide any fire suppression efforts. Identify "no-burn" and "let it burn" areas. Consider allowing fire suppression in some areas until several restoration projects have been completed.

Exhibit 23.Pine Creek just above confluence with the South Platte River

Carefully consider and research restoration/protection measures that should be implemented following fire. In particular, summarize efforts at Buffalo Creek and rate their effectiveness. Identify areas and situations where they should be applied. Discourage structural approaches and encourage approaches that work with the natural processes. In particular, avoid structures in streams below 7500 feet, as they tend to be temporary sediment storage features and can be quite expensive. Consider instead riparian rehabilitation.

Restoration Activities

There are two basic approaches to changing the forests to a sustainable condition, large-scale thinning or an attempt to restore forest mosaic conditions. There may be an approach that falls between these two but they will be used here to examine the differences in the approaches. For both approaches the results should be closely monitored and an adaptive management approach implemented for restoration activities The two approaches are briefly described and evaluated (Exhibit 24) below.

Thinning This approach would use thinning to reduce tree density throughout the restoration area. The approach may be more of a selection harvest in some stands. Large ponderosa pine trees and some large Douglas-fir trees would be favored. Douglas-fir would be selected over ponderosa pine on north slopes.

Mosaic This approach would also reduce tree density throughout the restoration area. Openings of 5-10 acres would be created on 10-20 percent of the landscape. Thinning or selection harvest described above would be used on approximately 50 percent of the treatment area. The burn area approach suggested above would be integral. Prescribed fire would be used to maintain openings, generally on south slopes. Fire could also be used to reduce fuel loading and create mosaic conditions.

Exhibit 24.Comparison of Restoration Approaches

Thinning Approach		Mosaic Approach	
Advantage	Disadvantage	Advantage	Disadvantage
All of treated areas have reduced fire risk			Leaves some areas unchanged – "burn areas"
	Requires more treatment per restoration area	Allows restoration over a larger area because some restored areas are "undis-turbed"	
Fits into current Pike/San Isabel NF Management Area direction			Some larger openings and maintaining them may not fit into current Pike/San Isabel NF Management Area direction
	No distinct fire breaks	Openings create fire breaks for crown fires	
Greater reduction in fuel loading in restoration area			Some areas in restoration area will have no reduction in fuel loading
	Require more frequent treatments to maintain conditions. Thinned forest will grow and become more dense.	Less frequent treatment required to maintain conditions. Openings can be designed to be relatively self maintaining.	
	Creates more uniform wildlife habitat conditions	Creates more diverse wildlife habitat conditions	
More treatment for insect and disease concerns			Some areas would not be treated, those areas would remain susceptible to insects and disease
	Some soil disturbance throughout restoration area	Some areas would have no soil disturbance. Openings, that would have the highest soil disturbance could be placed in areas with lower erodibility	
	More difficult to use prescribed fire as treatment technique because of lack of fire breaks	Burn areas will be designed to burn. Openings are also good areas to be main-tained by fire. Openings would be fire breaks for crown fires.	

Hydrology and Soils Recommendations

- Investigate innovative restoration techniques that would result in minimal soil disturbance and low-density road systems. Use Forest Plan management direction to minimize extent of new roads.
- Treat stands that are near to existing roads to avoid new roads where that strategy will meet resource objectives.
- Avoid instream structures when considering restoration. The stream systems repair themselves quickly with some help. Consider riparian plantings to accelerate natural restoration processes.
- For decommissioned roads, recontour the first ¼ mile of road to minimize unauthorized use.
- Consider erosion potential of soils when planning treatments.
- Inventory roads in watersheds where sediment problems have been identified. Recommend treatments to problem road segments where necessary.
- Use caution in designing new roads to minimize any sediment yield increases. Use temporary roads where possible and decommission them following use.
- Stormproof existing roads and new roads not planned for decommissioning.
- Reduce fire risk and potential sediment increases from brook trout habitat areas.
- Reduce local erosion by correction of design, improve maintenance and local closure and reclamation of roads and trails
- Increase the frequency of ground fires to clear out the understory and reduce build up of fuel
- Further research on the function of microbiotic crusts, especially following fire. Document responses to disturbances associated with restoration projects.
- Review Buffalo Creek fire area for erosion mitigation and soil stabilization efforts that worked. Formulate an action plan for future fires in the area.
- Consider riparian planting of willows and other native species in Buffalo and Spring Creeks.
- Carefully investigate sediment yield, transport and deposition patterns to ensure restoration project will minimize erosion and sediment yield.

Wildlife Recommendations

- Consult recovery plans for TES species
- Research specific habitats required for TES species and try to incorporate into restoration plan.
- Maintain aspen stands for sapsuckers and other resource values. Consider leaving a buffer around aspen stands.
- Create snags and trees with cavities

Plants

Follow Pike-San Isabel Noxious Weed Management Plan. Consider noxious weeds when planning thinning, creating openings, or building trails or roads into uninfested areas or crossing infested areas with equipment and vehicles.

Secondary Considerations

- Regenerate lodgepole pine stands, log and burn stand-sized patches, allow some to regenerate to aspen.
- Consider removing blowdown in spruce/firs forests to reduce insects population explosions.

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