AQUATIC AND RIPARIAN RESOURCES

Abstract: Waters originating on the Forest provide for many, and often conflicting uses. Many people depend on the Forest to supply water for municipal use and irrigation. Streams and riparian areas provide favored recreation sites for anglers, campers, rafters, and other recreationists. The same streams and riparian areas also provide habitat for a variety of aquatic and terrestrial plants and animals.

There are 1,937 miles of perennial streams and 476 lakes on the Forest. These vary from nearly pristine water bodies in wilderness areas to streams that have been heavily impacted by human activities including timber harvest, grazing, road construction, and mining. Native fish populations have been affected by habitat modification and by the introduction of nonnative fish. Seven species of fish have been identified as management indicators for the Forests and Grassland.

A revised watershed condition assessment conducted for the *FEIS* assessment indicates that of the 177 watersheds on the Forest, 41 were rated as functional, 87 were rated at risk, and 19 were rated nonfunctional. Thirty watersheds with less than 10 percent NFS lands were not rated. In addition, 12 stream segments are listed by the State of Colorado as having impairment of designated uses.

Watershed conservation practices and *Forest Plan* standards and guidelines prescribe extensive measures to protect aquatic and riparian resources. If all applicable measures are implemented and if they are effective, adverse effects from any of the alternatives should be minimized. However, as levels of activity increase, the risk that conservation practices will not be properly implemented or will not be entirely effective increases. Therefore, alternatives which propose higher levels of activity for various resources pose greater inherent risks to aquatic and riparian resources.

INTRODUCTION

Riparian areas combine a unique blend of physical and biological processes, and play a role as a critical interface between terrestrial and aquatic ecosystems. Because of this, understanding of the complex interactions between upland and water resources should be enhanced by combining the discussions of water, riparian, and aquatic resources in this *FEIS*. The organization of this section is explained below.

Aquatic and riparian resources are specifically linked to many of the revision topics explained in Chapter One of this *FEIS*.

Revision Topic: Biological Diversity: As described above, riparian ecosystems play important roles in linking ecosystem processes in aquatic and terrestrial systems.

> Managing for appropriate composition, structure, and function in ecosystems must take aquatic and riparian ecosystems into account.
>
> *Revision Topic: Instream Flows and Water Yield:* Providing for adequate flows for maintenance of viable stream systems and populations of aquatic management indicator species is a key need of future forest management, and the needs of humans for additional flows must be balanced with the requirements of aquatic ecosystems.

In addition, successful management of water resources is linked to stewardship of other resources of concern in the Revision Topics for Intermix, Recreation, Timber, and Travel Management.

The legal framework governing management of the complex interactions between aquatic and riparian resources is overlapping and complementary, as described below.

The existing resources affected by National Forest management are discussed for each topic, but environmental consequences of management activities are combined to clarify direct, indirect, and cumulative effects in the conclusion of this chapter.

L FRAMEWORK

ariety of laws and other policies govern the management of aquatic and riparian resources.

The *Organic Administration Act of 1897* recognized watersheds as systems that have to be managed with care to sustain their hydrologic function. One of the primary reasons for establishing the National Forests was to provide for "favorable conditions of water flow."

The intent of the *Clean Water Act*, a series of Acts from 1948 to 1987, is to restore and maintain the chemical, physical, and biological integrity of the nation's waters. The Act requires (1) compliance with state and other federal pollution control rules, (2) no degradation of instream water quality needed to support designated uses, (3) control of nonpoint source water pollution by using conservation or "best management practices," (4) federal agency leadership in controlling nonpoint pollution from managed lands, and (5) rigorous criteria for controlling discharge of pollutants into the waters of the United States.

One of the purposes of the *National Forest Management Act of 1976* is to prevent watershed condition from being irreversibly damaged, and to protect streams and wetlands from detrimental impacts. Land productivity must be preserved. Habitat for aquatic indicator species must support at least a minimum number of reproductive individuals and be well distributed to allow interaction between populations.

The *Endangered Species Act* requires federal agencies to conserve threatened and endangered species and the ecosystems they depend on, including riparian and aquatic ecosystems.

The *Safe Drinking Water Act* requires federal agencies having jurisdiction over any federally owned or maintained public water system to comply with all authorities respecting the provision of safe drinking water. The State of Colorado has primary enforcement responsibility through drinking water regulations.

Executive Orders 11988 and 11990 direct federal agencies to avoid to the extent possible the impacts associated with the destruction or modification of floodplains and wetlands. Agencies are directed to avoid construction and development in floodplains and wetlands whenever there are any feasible alternatives.

Other laws pertaining to watershed management can be found in *FSM 2500*, while laws, objectives, and policies related to fisheries management can be found in *FSM 2600* (described in the Terrestrial Habitat and Wildlife Section of this *FEIS*). Regulations have been passed in support of these laws that specifically require (1) protecting surface resources and productivity from all natural resource management activities - *CFR 219*, (2) watershed analysis as part of all planning activities - *CFR 219* and *FSM 2500*, and (3) limiting resource use when necessary to protect watershed condition - *FSM 2500.*

Finally, the Rocky Mountain Region has developed a *Watershed Conservation Practices Handbook* which became final between release of the *DEIS* and this *FEIS* (*FSH 2509.25*). To learn how we intend to ensure that soil, water, and aquatic life will be protected on the ground, readers can obtain copies of the *Watershed Conservation Practices Handbook* from the Forest or from the Regional Office. Effects analysis in this section assumes that the design criteria will be effectively implemented.

AFFECTED ENVIRONMENT

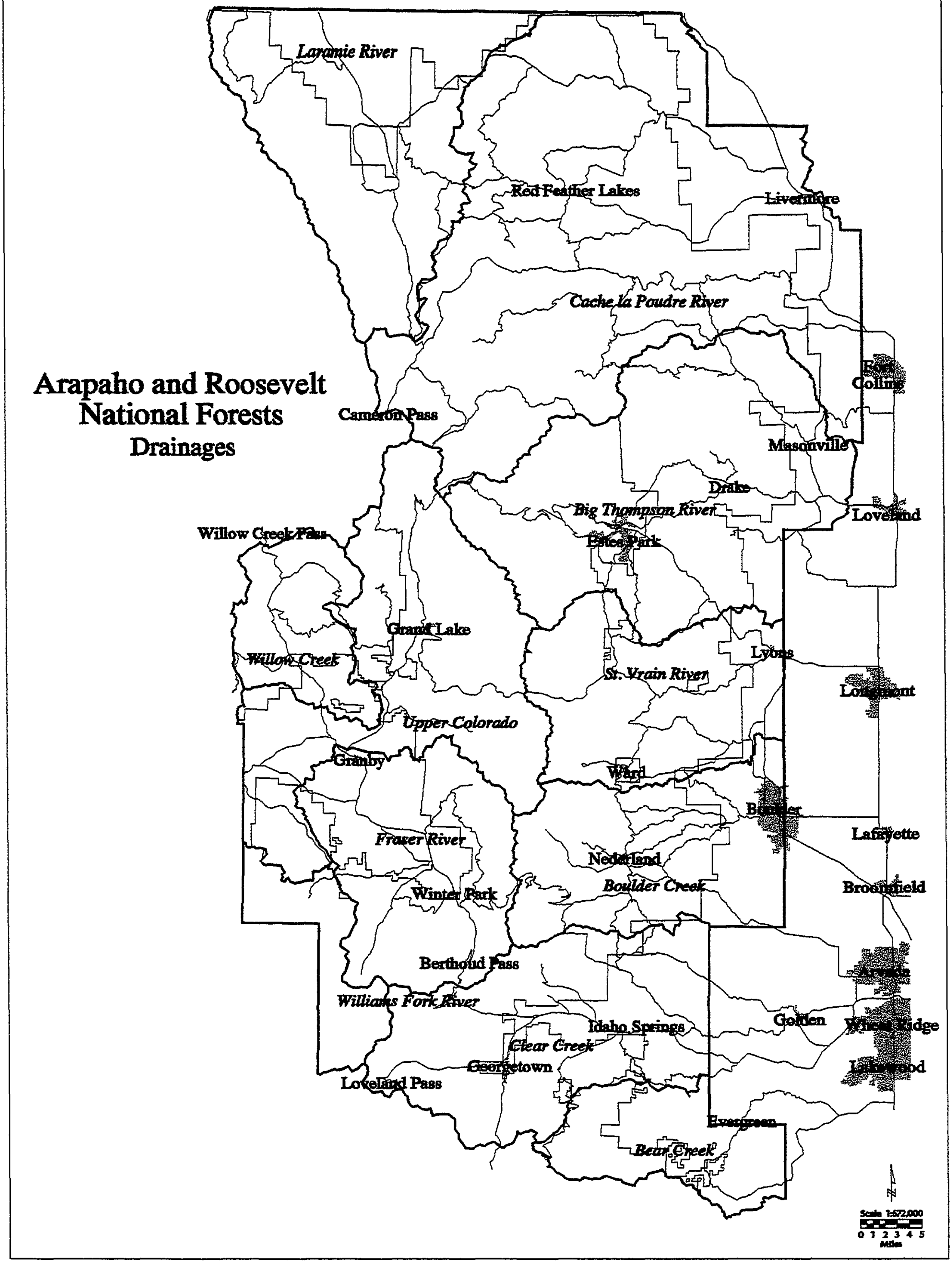
The Continental Divide runs through the spine of the Arapaho and Roosevelt National Forests and divides water flowing from the Forest into two river basins. Water originating on the Sulphur Ranger District flows into the Colorado River and water from the Pawnee National Grassland and Redfeather, Estes-Poudre, Boulder, and Clear Creek Districts flows into the Platte River. Streams that feed these two river basins traverse a wide range of elevations, habitats, and climates across the Forests and Grassland. Elevations range from over 14,000 feet along the Divide to 5,000-7,000 feet where the streams leave the Forest. There is a steep precipitation gradient that follows elevation on the Forest. High-elevation areas near the divide receive more than 40 inches of precipitation while low-elevation areas near the Forest boundary receive less than 16 inches annually. Areas of the Grassland receive between 10 to 14 inches of precipitation annually.

Because of the wide array of conditions encountered, streams and other aquatic habitats range in character, each with unique habitat assemblages and aquatic species. Existing aquatic ecosystems, habitats, species composition, abundance, and distribution have been influenced by both natural and human disturbances. Following is a description of the aquatic and riparian resource within the Forests and Grassland.

Two major river basins have portions of their headwaters on the Arapaho and Roosevelt National Forests: the Platte River and the Colorado River. On the north end of the Forest, the Laramie River is a tributary to the North Platte River. The Cache la Poudre, the Big Thompson River, St. Vrain Creek, Boulder Creek, Clear Creek and Bear Creek are tributaries to the South Platte River on the east side of the Forest. On the Grassland, Pawnee Creek, Crow Creek, Cedar Creek, Sydney Draw, and Owl Creek are all are ephemeral tributaries to the South Platte River. Only a few potholes and springs on the Grassland provide perennial water sources.

Headwaters of the Colorado River flow from the west side of the continental divide on the Forest. The Fraser River, Upper Colorado, Willow Creek, and the Williams Fork River are tributaries to the Colorado River. Drainages on the ARNF are shown in Figure 3.2.

Figure 3.2


Arapaho and Roosevelt
National Forests
Drainages
Laramie River
Red Feather Lakes
Livermore
Cache la Poudre River
Cameron Pass
Fort Collins
Masonville
Drake
Big Thompson River
Loveland
Estes Park
Willow Creek Pass
Grand Lake
Willow Creek
Lyons
St. Vrain River
Longmont
Upper Colorado
Granby
Ward
Boulder
Lafayette
Fraser River
Nederland
Boulder Creek
Broomfield
Winter Park
Berthoud Pass
Arvada
Williams Fork River
Golden
Wheat Ridge
Idaho Springs
Clear Creek
Georgetown
Lakewood
Loveland Pass
Evergreen
Bear Creek
Scale 1:672,000
0 1 2 3 4 5
Miles

SURFACE WATER

Arapaho and Roosevelt National Forests

Aquatic and riparian resources are widespread and common on the Forest.

There are approximately 1,937 miles of perennial stream on the Forest, with an additional 1,896 miles of intermittent streams flowing at some time during most years. There are also 476 lakes (greater than one acre in size) totaling 13,401 acres on the Forest. These values have been updated from the *DEIS* with new information based on improved GIS coverages.

Topographic maps issued by the U.S. Geological Survey (USGS) typically do not show the entire stream network. Many of the small, intermittent or ephemeral streams are not mapped. A technique called contour crenulation can be used to extend the mapped streams and gain a truer picture of the stream network. Contour crenulation has been completed for the Forests and Grassland and the results have now been digitized into a geographic information system (GIS). Contour crenulation recognized an additional 3,420 miles of ephemeral drainages on the Forest not including the Williams Fork drainage or any on the Pawnee National Grassland.

The flow regime for streams on the Forest is typical of streams in the Rocky Mountains that derive most of their runoff from snowmelt. Flows peak in May or June, gradually recede during the summer and fall to a relatively constant baseflow, which is maintained throughout the winter until flow begins to increase in the spring. Peak flow is typically one to two orders of magnitude greater than baseflow. Annual water yield from the Forest is approximately two million acre feet. (An acre foot of water will cover an area approximately the size of a football field to a depth of one foot.)

The Forest plays an important role in supplying water for agricultural and municipal use. The Forest serves as both the primary source of water and as a site for water development. Because storage and transport of water plays such a critical role in human existence in the arid West, water development is and will continue to be a vital use of the Forest. However, water development can cause adverse environmental effects. Most of the streams which originate on the Forest are over-appropriated, meaning that there is a greater demand for the diversion and storage of water than can be met by the available supply.

Recent human activities have had considerable impacts upon aquatic ecosystems on the Forest. Disturbances caused by Euro-Americans began in the last century with gold mining and continue through today. Water development and other activities such as road construction and maintenance, timber harvest, grazing, fire and fire suppression, mineral extraction, recreational and ski area development, and residential development can affect water resources. Effects of continuing resource management programs for each of these uses are addressed in the environmental consequences section.

The existing condition of affected watershed resources is a product of the effects to date of these combined resource activities. These uses were considered cumulatively in a watershed assessment of existing impacts. Sixth-level watersheds on the Forests were assessed as described below to identify areas where high levels of use may be impacting stream health. Grassland watersheds were not assessed.

Watersheds form a nested group of land areas. The U.S. Geological Survey (USGS) developed a system, which the Rocky Mountain Region adopted, to delineate watersheds at different scales by using watershed levels (Seaber, et al. 1987). The following table shows how watersheds can be delineated at different levels.

Table 3.10 Levels of Watersheds

Watershed	Level	Watershed Identification Number
Missouri River	1st Level	10
South Platte River	2nd Level	1019
Upper South Platte Rivers	3rd Level	101900
Cache la Poudre River	4th Level	10190007
Cache la Poudre River about South Fork	5th Level	1019000702
Joe Wright Creek	6th Level	101900070208

Thus, all sixth-level watersheds fit within a fifth-level watershed, all fifths within a fourth, and so forth. Different levels of watersheds can be selected for different analysis needs by aggregating or disaggregating them. The most useful levels to use as accounting units for analyzing the effects of management activities on the Forests and Grassland are typically the sixth or seventh levels, although effects and protection need to be considered for each stream reach. Sixth-level watersheds vary in size but generally range from 5,000 to 20,000 acres and seventh-level watersheds generally range in size from 500 to 2,500 acres.

There are 177 sixth-level watersheds that contain at least some NFS lands administered by the ARNF. However, landownership is highly mixed across the Forest. Of these 177 watersheds, only one is made up entirely of NFS lands, and even this watershed is burdened by easements with outstanding rights that remove some management control from the Forest Service. The ARNF manages less than 50 percent of the land base in 88 of the 177 watersheds influenced by the Forest.

These ownership conditions indicate the opportunity for and benefit of collaborative stewardship across most of the Forest where NFS lands make up only a fraction of the watershed. In this assessment, only watersheds with 10 percent or more in NFS lands were analyzed, which resulted in 147 of the 177 watersheds being rated.

The watershed condition assessment is significantly revised from the assessment in the *DEIS*. The previous assessment identified only watersheds of concern for both deteriorated condition or high-value threatened, endangered or sensitive species (TES) habitat. The revised sixth-level watershed assessment gauges impacts from road development, flow disruptions, recreation, mining, grazing, and non-USFS land uses against the inherent erosion sensitivity of each watershed. Both quantitative and qualitative assessments of stream and riparian health were used. A detailed explanation of the analysis method can be found in Appendix B.

The factors above were selected because they represent characteristic impacts in watersheds across the Forest. Roads are pervasive and have a high potential for impacting streams because they are relatively permanent, highly disturbed sources of chronic sedimentation. Timber harvest and burns increase water yield and are potential sources of erosion. Flow disruptions can significantly fragment and reduce aquatic habitat. Recreation, mining, grazing, and non-USFS land uses can affect erosion and sedimentation, water quality, stream stability, and riparian condition.

Watersheds were rated in the following categories:

> *Class I (functional)*: The watershed is fully functioning and is in good condition. Only major events cause longterm changes. Human disturbances are not compromising watershed function or stream segment integrity.
>
> *Class II (at risk)*: The watershed is functional, but condition is fair. Watershed condition may be in a downword trend, or at risk of degradation, or not yet fully recovered from past damage. Recovery is feasible naturally with added protection or over time, or with minimal capital investments.
>
> *Class III (non-functional)*: The watershed is in poor condition and dysfunctional. Recovery requires substantial capital investments and revised management. Land-disturbing actions are not precluded, but must complement recovery.

Watershed condition classes are listed in Table 3.11. Forty-one watersheds were rated as functional, 87 were rated at risk, and 19 were rated non-functional. In addition, Table 3.11 indicates where threatened, endangered, or sensitive (TES) fish species would warrant additional protection to reduce the risk of extinction.

It is important to note that the watershed assessment does not establish thresholds which prohibit future management activities. Insufficient details about how activities have impacted stream health are known to warrant such an approach. Watersheds vary in their resistance to change. Equal amounts and types of disturbance may seriously degrade conditions in a watershed, but may not be noticeable in a more resistant watershed. Furthermore, watersheds also vary in resilience, with some areas able to recover more rapidly than others. Thus, instead of prescribing specific treatments for watersheds of concern, the watershed condition assessment allows us to identify watersheds whose health may be impaired, schedule more detailed analysis, and prioritize watershed improvement needs. It also identifies watersheds that may require additional protection measures when management activities are proposed. Some watersheds identified in the assessment still show the effects of activities that occurred up to a century or more ago. For instance, degraded conditions in portions of the Clear Creek watersheds can be attributed to mining activities from the late 1800s, as well as the effects of urbanization in the late 1900s. Similarly, Nunn Creek watershed has been affected by livestock grazing by thousands of animals, and while grazing continues, it is at rates that are orders of magnitude smaller. These watersheds, and others with degraded conditions, may just require additional time for recovery, or may need care not to create increments of additional effects that would inhibit further recovery.

Table 3.11 Watershed Condition Assessment for the ARNF[a]

Watershed Name	Final Watershed Condition Class	Contains TES Fish
West Branch Laramie River	1	
Upper Laramie River	2	
Rawah Creek	1	
Laramie Comp1	3	
Nunn Creek	2	
Laramie Comp2	2	
McIntyre Creek	1	
Jimmy Creek	2	
Laramie Comp3	2	
Lagarde Creek	1	
Forrester Creek	1	
Grace Creek	2	
Stuck Creek	2	
Johnson Creek	2	
Laramie Comp4	N/R	
Boswell Creek	2	
Upper Sand Creek	3	
Shell Creek	2	
Antelope Creek	1	

Watershed Name	Final Watershed Condition Class	Contains TES Fish
Lone Tree Creek	1	
Vance Creek	1	
Bear Creek	1	GBN
Bear Creek Upper Comp	2	
Cub Creek	2	
Turkey Creek	N/R	
West Fork Clear Creek	3	
Bard Creek	2	GBN
Clear Creek	3	
South Clear Creek	3	
Clear Creek Comp	2	
West Chicago Creek	1	
Chicago Creek	1	GBN
Chicago Creek Comp	3	
Mill Creek	1	
Fall River	2	
Clear Creek Comp	2	
Trail Creek	N/R	
Barbour Fork Creek	2	
Clear Creek Lower Comp	N/R	
North Clear Creek	2	
Chase Gulch	3	
Eureka Gulch	3	
Russell Gulch	N/R	
Beaver Brook	N/R	
Ralston Creek	N/R	
Ralson Creek Comp	N/R	

Watershed Name	Final Watershed Condition Class	Contains TES Fish
Deer Creek	2	
North St. Vrain	N/R	
Rock Creek	2	
Cabin Creek	2	
Dry St. Vrain	2	
North St. Vrain Comp	1	
Middle St. Vrain	2	
South St. Vrain	3	
St. Vrain	2	
Left Hand Creek	2	
James Creek	3	
Left Hand Comp	2	
North Boulder Creek	2	GBN
Middle Boulder Creek	3	
Fourmile Creek	3	
Upper Boulder Comp	2	
South Boulder Creek	2	GBN
Jenny Creek	2	
Upper South Boulder Comp	3	GBN
Lump Gulch	2	
Beaver Creek	2	
South Beaver Creek	2	
South Boulder Middle Comp	2	
Beaver Creek - Coal Creek Trib.	N/R	
Wind River	N/R	
Fish Creek	2	
Dry Gulch	N/R	

Watershed Name	Final Watershed Condition Class	Contains TES Fish
Big Thompson Composite	2	
West Creek	1	
Fox Creek	1	
N. Fork Big Thompson	1	
Miller Fork	1	
N. Fork Big Thompson Comp	2	
Buckhorn Creek	2	
Stove Prairie	N/R	
Sheep Creek	1	
Fish Creek	1	
Stringtown Gulch	1	
Bear Gulch	1	
Buckhorn Creek Form Stove Prairie to Bear Gulch	N/R	
Lower Buckhorn Comp	2	
Cedar Creek	2	
Big Thompson Comp	2	
Dry Creek	1	
Muggins Gulch	2	
West Fork Little Thompson	2	
North Fork Little Thompson	2	
Little Thompson Comp	1	
La Poudre Pass Creek	3	
Hague Creek	N/R	
Joe Wright Creek	2	GBN
Upper Poudre Composite	1	GBN
Sheep Creek	1	GBN
Williams Gulch	2	GBN

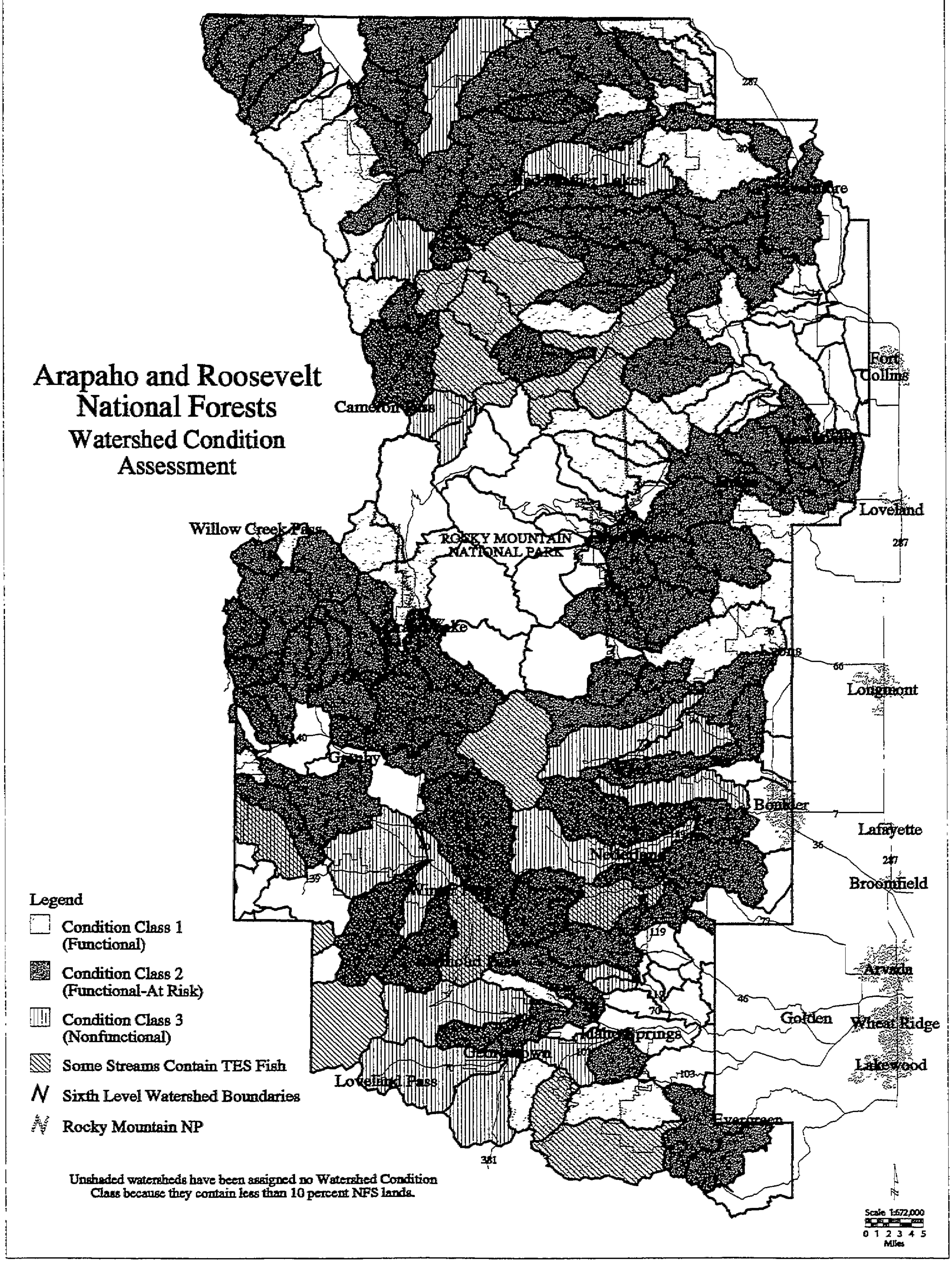
Watershed Name	Final Watershed Condition Class	Contains TES Fish
Roaring Creek	2	GBN
Sevenmile Creek	2	
Middle Poudre Comp	1	GBN
Bennett Creek	2	
Lower Poudre Comp	2	
Beaver Creek	2	GBN
Upper S. Fork Poudre	1	GBN
Pennock Creek	1	GBN
Little Beaver Creek	1	
S. Fork Poudre Comp	1	GBN
North Lone Pine Creek	3	
South Lone Pine Creek	2	
Lone Pine Creek	2	
Sheep Creek	2	
George Creek	2	GBN
North Fork Cache La Poudre	2	
Bull Creek	2	
North Fork Poudre Comp1	1	
Trail Creek	2	
Mill Creek	2	
Bull Creek	1	
North Fork Poudre Comp2	1	
Fish Creek	1	
Georges Gulch	N/R	
Meadow Creek	2	
Rabbit Creek	1	
North Fork Poudre Comp	2	

Watershed Name	Final Watershed Condition Class	Contains TES Fish
Elkhorn Creek	2	
Youngs Gulch	1	
Upper Poudre Comp	2	
Hewlett Gulch	2	
Lower Poudre Comp1	2	
Upper Lewstone Creek	N/R	
Lower Lewstone Creek	N/R	
Poudre River	N/R	
Rist Canyon	N/R	
Opposition Creek	N/R	
Baker Gulch	1	
Colorado Comp	1	
Supply Creek	2	
East Inlet Creek	N/R	
Stillwater Creek	2	
Arapaho Creek	1	CRC
Lake Granby Comp	2	CRC
Willow Creek	2	
Trout Creek	1	
Pass Creek	2	
Willow Creek Upper Comp	2	
Buffalo Creek	2	CRC
Cabin Creek	2	
Gold Run	2	
Trail Creek	2	CRC
Willow Creek Comp	2	
Willow Creek Lower Comp	2	

Watershed Name	Final Watershed Condition Class	Contains TES Fish
Fraser River	3	CRC
Vasquez Creek	2	CRC
St. Louis Creek	2	CRC
Ranch Creek	2	CRC
Fraser Upper Comp	3	
Crooked Creek	3	
Strawberry Creek	2	
Tenmile Creek	2	
Fraser Lower Comp	N/R	
Drowsey Water Creek	2	
McQuery Creek	2	CRC
Sheriff Creek	2	
Ute Bill Creek	2	
Gardener Creek	2	
Colorado Lower Comp	1	
Beaver Creek	2	
Muddy Creek	3	CRC
Bobtail Creek	N/R	CRC
Darling Creek	N/R	
Kinney Creek	N/R	CRC
Keyser Creek	N/R	
Williams Fork Lower Comp	N/R	
Williams Fork Res. Comp	N/R	

[a] Abbreviations used in the table are: *Left column:* "Comp" following a name indicates composite watersheds; these are watersheds that are part of larger watersheds but are not true watersheds because water enters from outside the watershed boundary. They are the portions of the larger watershed remaining after the true watersheds are defined. *Middle column:* Numbers for the final watershed condition indicate: Class 1 - functional; Class 2 - at risk; Class 3 - nonfunctional. N/R stands for "not rated" because less than 10 percent of the watershed is in NFS lands. *Right column:* GBN indicates presence of greenback cutthroat trout, a federal threatened species; CRC indicates presence of Colorado River Cutthroat trout, a Forest Service designated sensitive species.

Figure 3.3


Arapaho and Roosevelt National Forests
Watershed Condition Assessment
Cameron Pass
Willow Creek Pass
ROCKY MOUNTAIN NATIONAL PARK
Fort Collins
Loveland
Longmont
Granby
Boulder
Lafayette
Broomfield
Nederland
Arvada
Golden
Wheat Ridge
Lakewood
Georgetown
Loveland Pass
Evergreen
287
66
7
36
119
72
46
70
103
40
381
Legend
Condition Class 1 (Functional)
Condition Class 2 (Functional-At Risk)
Condition Class 3 (Nonfunctional)
Some Streams Contain TES Fish
Sixth Level Watershed Boundaries
Rocky Mountain NP
Unshaded watersheds have been assigned no Watershed Condition Class because they contain less than 10 percent NFS lands.
Scale 1:672,000
0 1 2 3 4 5
Miles

In addition to the watershed condition assessment above, overall stream health can be assessed using information available from other agencies. The State of Colorado produces a biennial report on the status of water quality in the state (State of Colorado, 1994). The report is prepared to fulfill section 305(b) of the Clean Water Act. The report lists stream segments which have impaired designated uses because of water-quality problems. Designated beneficial uses include such things as aquatic life, recreational use, and municipal and agricultural water supplies. Each of the segments has been given a status indicating the severity of the water-quality problem. An explanation of the status applicable to these segments has been condensed from the 305(b) report and is given below:

> *Water Quality Limited, Allocated (WQLA)*: The designated uses of the water body are not impaired, but data indicators indicate a probable downward trend that may impair aquatic life. The assimilative capacity of the segment has been allocated. Water-quality based effluent limits are in effect on the segment.
>
> *Water Quality Limited (WQL)*: The designated uses of the water body are not impaired, but data indicators indicate a probable downward trend that may impair aquatic life. Assessment information indicates the potential for impairment of the designated uses in the near future.
>
> *Partial Support (PS)*: The designated uses of the water body are present, but it is uncertain whether these are at attainable levels, or some impact to the uses has been noted.
>
> *Not Supporting (NS)*: Designated uses are measurably impaired because of water pollution. Use may be present but at significantly reduced levels from full support in all or some portion of the segment. There is some certainty that the water body cannot be fully used as designated because the survival, propagation, production dispersion, community structure, or species diversity of aquatic life is impaired.

The report lists 12 impaired stream segments which are partially or entirely on the Forest. Nine of the segments occur in the Platte River Basin and three occur in the Colorado Basin. Impaired stream segments are shown in Table 3.12.

Table 3.12 Stream Segments with Designated Use Impairment

Stream Segment	Status	Pollutant
Platte River		
Bear Creek, from source to Harriman Ditch	WQLA	Un-ionized ammonia
Clear Creek, from Silver Plume to Argo Tunnel, Idaho Springs	PS	Metals
Leavenworth Creek	PS	Metals

Stream Segment	Status	Pollutant
West Clear Creek, from Woods Creek to confluence with Clear Creek	NS	Metals
Woods Creek	NS	Metals
Lion Creek, above West Clear Creek	NS	Metals
Fall River and tributaries	NS	Metals
North Fork Clear Creek	NS	Metals
Left Hand Creek	NS	Metals
Colorado River		
Colorado River tributaries from Lake Granby to the Roaring Fork River	NS WQL	Sediment Salinity
Williams Fork River	WQL	Metals
Fraser River	PS WQL	Sediment Un-ionized ammonia

Some of the conditions contributing to impairment of beneficial uses in these segments are likely to arise from activities on the Forest and some are likely to be caused by other activities, as explained below. Even where impairment occurs on other lands, management on the Forest must be sensitive to the potential for cumulative effects.

Only the headwaters of Bear Creek are located on the Forest. Un-ionized ammonia is a pollutant that is associated with waste water treatment. It is likely that this pollutant is confined to the stream reach below the town of Evergreen and below the Forest boundary.

Clear Creek and its tributaries, Leavenworth Creek, West Clear Creek, Woods Creek, Lion Creek, the Fall River, and North Clear Creek intersect the Colorado mineral belt and have been degraded by past mining activities and natural causes due to contact with minerals (State of Colorado, 1994). Much of the mining occurred below the Forest boundary, but some of the impacted stream reaches, for example Leavenworth Creek, West Clear Creek, Woods Creek, and Lion Creek are on the National Forest. Left Hand Creek, in the St. Vrain drainage, also crosses the mineral belt and has been heavily impacted by past mining.

Colorado River tributaries below Lake Granby are impacted from sediment from both natural and anthropogenic sources. For example, Willow Creek has elevated sediment levels from natural landslides as well as from road construction and silvicultural activities. However, it should be noted that not all tributaries suffer equally from sediment impacts. Several tributaries of Willow Creek have neither roads nor timber harvest in their watersheds; any human caused sedimentation is minor, but broadscale designation loses accuracy at finer scales.

The Williams Fork River is the site of the processing plant for ore from the Henderson Mine. Only a short reach of the river (about 1.5 miles) crosses the Forest below the processing plant. However, upper tributaries to the Williams Fork are impacted by water diversions by the city of Denver.

The primary source of sediment in the Fraser River is Highway 40 over Berthoud Pass. The Forest is cooperating with the State Highway Department, Winter Park Ski Area, and the towns of Fraser and Winter Park to reduce sedimentation. As noted above, un-ionized ammonia is a pollutant that is associated with waste water treatment, which occurs below the Forest boundary.

All other stream segments on the Forest have water quality that is as good or better than state standards. The Forest has been sampling lake water quality for sensitive lakes in wilderness areas since the summer of 1995. The objective is to detect any changes in lake chemistry that could result from airborne pollution. This is described in more detail in the Air Resources Section.

Pawnee National Grassland

There are no identified streams within the Pawnee National Grassland which flow year long. Intermittent drainages within the Grassland include Crow Creek, Owl Creek, Willow Creek, and Pawnee Creek. These stream channels contain approximately 20 perennial ponds totaling between 15 and 35 acres in area. These groundwater-fed ponds are located in low spots within the intermittent stream courses. A few of these ponds were excavated to provide stock water. The number of playas has not been estimated, but they are common and widespread.

The perennial potholes on the Grassland, and their inhabitants, are exposed to a broad range of environmental conditions. Primary environmental conditions to which these aquatic communities are presently exposed on an annual basis include fluctuating water levels and variations in temperature and water chemistry. Severe spring and summer thunderstorms which result in significant precipitation can cause flood events which may link ponds along an intermittent stream course for a few hours to a few days. The intensity of storm and precipitation amounts needed to connect ponds reoccurs approximately every three to five years. Storm events that connect isolated ponds are important to maintaining genetic diversity of aquatic life within the pond ecosystems over time. It is believed that aquatic organisms redistribute during these flood events, but the majority of the drift is downstream with little upstream migration occurring.

Annual and daily water temperatures and water chemistry fluctuations have not been investigated within the Pawnee National Grassland aquatic ecosystems. However, it is reasonable to assume that both characteristics have a wide range of natural variation, based upon annual range in air temperature. Air temperatures range from over 100°F in the summer to freezing during the winter months. Assuming water temperatures of ponds also vary in relation to air temperature, then plants and animals would respond to these changes, with corresponding changes in water chemistry as a result of photosynthesis, respiration, decomposition, and other processes.

GROUNDWATER

Forest snowmelt recharges groundwater aquifers. Recharge to deep, confined aquifers occurs almost exclusively near or at mountain fronts, below the Forest boundary. Streams originating on the Forest also recharge smaller, unconfined aquifers within and outside the Forest.

Groundwater use on the Forest is limited. Domestic livestock and wildlife use springs. Campgrounds, administrative sites, and some residential developments within the Forest use wells. However, most groundwater use occurs outside the Forest boundary.

Groundwater is an important source of water for livestock on the Grassland, where there is little surface water. Early management strategies on the Grassland strove for water developments to be closely enough spaced that cattle need only walk a mile to water from anywhere on the plains. While this goal was not achieved, water developments (windmills, stockponds) are now distributed at approximately 2 to 3 mile intervals across the Grassland.

In general, groundwater quality in Colorado is excellent in mountain areas where snowfall is heavy (State of Colorado, 1994). Typical forest management activities have limited impact on groundwater. Groundwater quality can be affected by oil and gas development, mining, and herbicide and pesticide application. Less than 100 acres of noxious weeds are treated annually by hand spraying. Areas on the Forest that do contribute to groundwater pollution are the same areas with significant surface water problems. These are the areas impacted by past mining, as listed above. The ARNF, and others, are working to clean up these areas. However, reclamation of abandoned mines is costly, and can only be carried out as budgets allow.

RIPARIAN AREAS, FLOODPLAINS, AND WETLANDS

Riparian areas are interdependent with adjacent terrestrial and aquatic ecosystems. Aquatic ecosystems provide the moist soil conditions that riparian vegetation requires, and riparian vegetation provides bank stability, a source of nutrients, shade and overhead cover for fisheries; it also acts to trap sediment before it reachs the stream channel.

Riparian vegetation provides vertically diverse habitats, and the number of species present is usually high for plants and animals. Cover, food and water are provided to resident or migrating terrestrial animals. Riparian zones along rivers and streams are key migration routes for wildlife and connectors between different ecosystems, habitats and elevations (Thomas et al. 1979).

Certain terrestrial wildlife species are directly dependent on or closely associated with aquatic environments. These include amphibians, waterfowl, bald eagle, osprey, dipper, belted kingfisher, spotted sandpiper, river otter, water shrew, muskrat and beaver. Numerous other terrestrial animals are associated with riparian zones that are adjacent to water bodies. Comparing terrestrial vertebrates known or likely to occur within the Arapaho and Roosevelt National Forests (Table 3.65) to riparian habitat within the Forests (Table 3.66), over 90 percent of terrestrial species are estimated to use riparian habitat to some degree (see Terrestrial Habitat and Wildlife section). More wildlife species use riparian vegetation than any single type of Forest vegetation (Table 3.65). Similar relationships occur on Pawnee National Grassland.

Wilson's warbler, northern leopard frog, and boreal toad were selected as management indicators for montane riparian areas and wetlands. Northern leopard frog was also selected as the management indicator for prairie riparian areas and wetlands (see *FEIS*, Appendix G).

Thus, although riparian areas only make up a small fraction of the Forests and Grassland, they are of critical importance in producing and maintaining biotic diversity. They also serve as a focal point for many recreational activities, particularly where roads parallel to streams make access to riparian areas convenient.

Types and extent of riparian vegetation are influenced by channel types. Channels with steep side slopes and undeveloped floodplains generally lack riparian areas or only support a narrow ribbon of riparian vegetation directly adjacent to the stream channel. More moderately sloping channels often support wider bands of riparian vegetation, and gently sloping, meandering meadow channels, with wide floodplains, support large riparian areas.

Floodplains occupied by healthy vegetation communities reduce the severity of floods by allowing flood waters to spread out over the floodplain. Vegetation slows the speed of the water and allows sediment to settle out and water to infiltrate. Water is slowly released from alluvial aquifers back to the channel during drier periods of the year.

Wetlands are those areas that are inundated by surface or groundwater that normally support vegetation or aquatic life requiring saturated or seasonally saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas such as sloughs, potholes, wet meadows, river overflows, mud flats, and natural ponds. On a national level, wetlands are a shrinking resource. On the Forest, wetlands provide unique habitat for species that may not be found elsewhere. Federal policy dictates that there will be no net loss of wetlands on federal lands.

The Forest has an inventory that shows the location and extent of riparian areas across most of the Forest, except for portions of the Estes-Poudre District, where the inventory is incomplete. Based on projections made from the inventory, there are an estimated 87,000 acres of riparian area on the ARNF-PNG. In addition to the mapped areas, many streams have narrow ribbons of riparian vegetation running along the stream edges which are not visible from aerial photographs because they are located under a canopy of trees, or are simply too narrow to map. Nearly all perennial streams and some intermittent streams have some riparian area associated with them. However, no riparian classification has been established, and the only assessment of riparian condition is the subjective analysis completed by Forest and District personnel for use in the watershed condition assessment. During that subjective riparian assessment, streams within 30 watersheds were identified as having degraded riparian conditions. These results were largely verified by the revised watershed condition assessment.

Primary activities that have affected the quality of riparian conditions in the past are recreation use and development, road construction, and grazing within riparian or wetland areas.

Although more detailed data would allow for wiser management of the Forest's riparian resources, the lack of it does not prevent routine application of measures for riparian protection. Conservation practices to protect riparian areas, wetlands, and floodplains can be incorporated into range-use permits, road construction stipulations, and plans for timber harvest, mining, and recreation use. The Rocky Mountain Region's *Watershed Conservation Practices Handbook* contains practices that will be routinely applied to activities across the Forest, regardless of the management prescription in which they occur.

FISHERIES AND AQUATIC HABITATS

Aquatic habitats considered within the Forests and Grassland include streams, lakes, and their associated wetland and riparian habitats. Both permanent (perennial) and seasonal (intermittent) water sources can create significant aquatic and riparian habitats. These areas make up key habitat for native and nonnative fishes, amphibians, and aquatic invertebrates. Seven species of fish and two amphibians were selected as management indicators for aquatic and riparian habitats (see Table 3.14).

Stream Habitat Conditions

Primary stream characteristics which can be used to describe the health of the aquatic ecosystems in forested mountain streams include the amount of woody debris within the stream channel, pool and riffle frequency, water quality, and quantity. Primary characteristics which describe the quality of aquatic ecosystems on the Grassland include the amount and types of vegetation surrounding the water source, water quality, water depth and quantity. Interrelationships between physical characteristics and biological response are complex and not easily described. Land management activities which cause change in one or more physical feature can indirectly cause change in the other stream features. Variability of each of these characteristics is quite high under natural conditions, even without human intervention. However, extensive and intensive land management activities can cause habitat loss or alteration outside the range of natural variation (except variation associated with catastrophies). These activities include timber harvest, domestic livestock grazing, road construction, recreation development, water diversions and flow augmentation. Adverse channel modifications can occur, including sedimentation of pool and riffles, removal of large trees from the stream channel, lowered water tables, changes in the riparian and wetland plant communities, and direct modification of channel morphology. These changes can adversely affect the quality of habitats for aquatic management indicator species.

Stream surveys quantifying these characteristics have been completed for a small cross section of streams on the Forest. Results for ten forested streams of varying size are presented below.

Table 3.13 Habitat Characteristics of Ten Steams Located Within the ARNF

Stream Name	Average Width (feet)	Frequency Wood/Mile	Frequency Pools/Mile	Width-to-Depth Ratio
Colorado River	68	125	4	52
Hamilton Creek	7	596	18	11
Vasquez Creek	12	159	62	11
Clear Creek #1	23	84	33	15
Chicago Creek	13	254	9	N/D
Middle St. Vrain R.	25	284	16	19
N. Lone Pine Creek	8	485	19	15
S .Fk. Poudre River	36	139	13	21
Sheep Creek	15	236	23	N/D
Nunn Creek	6	22	51	8

Following is a brief summary of these primary stream characteristics within the Forests and Grassland, with interpretation of the habitat characteristics displayed above.

Woody Debris

Natural woody debris plays many complex physical and biological roles which are important to the health of the forested aquatic stream ecosystem. Wood plays an important physical role in shaping channel morphology by creating small reservoirs which store inorganic and organic sediment, and by directing and concentrating stream flow to cause scour. This directed scour is a channel-forming process which creates pools, and stabilizes or destabilizes streambanks. Important biological functions include providing substrate for aquatic invertebrates, contributing to organic enrichment, and providing escape and resting cover for fish and other aquatic-dependent species.

Management activities which influence the abundance and distribution of woody debris into stream channels include timber harvest, streamside facilities development, flow modifications, and channelization. Valley bottom timber harvest reduces the amount of woody debris available for recruitment. Historic railroad tie logging in the North and South Platte River drainages reduced stream woody debris with resulting changes in stream complexity; most of these streams are overwidened with a concomitant loss of in-channel habitat diversity (Wroten 1957). Streamside facilities development (roads, trails, campgrounds, etc.) also directly remove sources of woody debris along stream channels. Flow modifications affect the distribution and movement of woody debris within stream channels. Periodic flood flows which redistribute woody debris within channel reaches must occur to provide for channel forming and maintenance processes.

Woody debris counts are highest in densely forested, relatively unimpacted streams such as Hamilton Creek. However, woody debris recruitment to most streams within the Arapaho and Roosevelt National Forests has been modified as a result of the management activities listed above. Stream survey data from a limited number of streams tends to indicate that woody debris abundance (pieces per mile) is reduced where management activities have occurred in streamside riparian zones (Table 3.13). The best example of this is Clear Creek #1, where streamside cleaning for mine props, construction, and road location has occurred.

In contrast, Nunn Creek is a meadow system where lower counts of woody debris would be expected. Woody debris also contributes to habitat characteristics in meadow reaches of forested streams where it occurs, but the frequency of occurrence depends on distance from sources of woody material and the relative size of wood compared to the stream. Transport of wood within meadow systems probably only occurs during extreme flow events, when many other channel-forming processes also take place.

The role of woody debris in Grassland streams is likely to be reduced due to the limited quantity of wood available for recruitment and the rarity of perennial flows for redistribution. When present, wood from cottonwoods probably provides rare and unique habitat diversity and structure for aquatic and riparian species.

Pool Habitat

The physical and biological significance of pools within stream ecosystems has been well documented. Pools function as areas where organic and fine inorganic sediments are deposited, in comparison to faster flowing riffle areas where sediment and bedload materials are transported. Pools also provide the physical fish habitat required for feeding, resting, overwintering, and escaping from predators. Slow water in pools is critical for fish both in summer and winter, particularly at low-flow periods. In Grassland aquatic ecosystems, it is perennial pools (potholes) that provide the bulk of aquatic habitats.

Management actions can influence natural processes and pool riffle ratios in forested streams. Measured pool frequency in streams on the Forest indicate that past management activities may have dramatically changed aquatic habitat capability. Road construction, water development, and streamside vegetation management through timber harvest and grazing are the primary activities reducing pool frequency within streams on the Forest.

The Richmond and Fausch (1994) study of eleven undisturbed forested streams on the Forest found pool frequency averaging 69 pools per mile in streams with channel widths averaging about 16 feet (range 9 to 30 feet). However, other measured pool frequencies observed on the Arapaho and Roosevelt National Forests show highly reduced pool frequencies, presumably a result of human influences and streamside activities (see Table 3.13). The best example of this is Chicago Creek, where placer mining and streamside road construction have simplified and channelized the stream, increased stream gradient, and eliminated most pools. Instream fish habitat projects have attempted to remedy this by adding instream dam or wire structures to create pools.

Width-to-depth ratios also provide clues to the quality of pools in a stream. Generally, the smaller the ratio, the more likely that high quality pools will be present. Relatively good examples of this are Hamilton Creek and Vasquez Creek, where streamside activities have been limited, and pool quality is relatively high.

Water Quality

General water quality conditions on the Forest were described earlier in this section. Water quality parameters of particular interest in management of aquatic ecosystems are changes in temperature and input of chemical pollutants or sediment. Aquatic organisms can be directly and indirectly impacted by changes in water quality, with the potential for longterm and cumulative impacts to habitat and population viability.

Chemical pollutants include substances from mining activities in or near streams, and airborne acid precursors. Mining activity impacts to aquatic environments are most apparent within the Boulder and Clear Creek drainages, where acid mine drainage into many mountain streams has caused significant reduction in aquatic diversity and productivity. Current water quality degradation as a result of airborne pollutants is not known, but monitoring of water quality impacts from air pollution is addressed in the Air Quality section of the revised *Forest Plan* and *FEIS*.

Temperature fluctuations influence distribution patterns, life cycle phenomena, trophic relationships, and behavioral responses of aquatic organisms (Ward and Stanford 1982; Staso and Rahel 1994). Interactive and complex relationships may exist with other physical and environmental variables (light, dissolved oxygen, pollution, etc.) which mask the effect of temperature variation. Optimum temperatures for aquatic organisms in mountain streams are below 20°C (68°F). Arapaho and Roosevelt National Forest biologists and hydrologists work under the assumption that temperature regimes are maintained within the range of natural variation, and are not a limiting factor under current management, but a thermograph monitoring program was started in 1996 to validate this assumption. Ward's (1986) observations on St. Vrain Creek tend to support the assumption, because summer temperature averages were maintained below 15°C. However, observations in Willow Creek in 1996 recorded temperatures above 20°C and monitoring will continue.

Natural watershed disturbances such as forest fires, landslides, and storm events can cause pulses of suspended sediment. These pulses are generally of short duration, lasting an hour or two, which aquatic organisms can tolerate or avoid. Jim Nankervis (pers. comm.) measured one pulse of suspended sediment of 457 milligrams per liter in Left Hand Creek the summer following a forest fire. Values within this range were repeated, but duration was less than one day, and were believed to be a few hours.

Fishes and stream invertebrates have evolved or adapted to the variation in suspended sediment within the relatively clear streams on the Forest. Therefore, it is likely that the aquatic organisms within these streams are intolerant to highly elevated suspended sediment episodes lasting longer than a few hours. Management activities which will cause unavoidable shortterm input of suspended sediment should be designed to not exceed the expected intensity and duration of natural sediment pulses. However, chronic suspended sediment sources on the Forest have degraded aquatic resources by filling pools, reducing mean depths, covering spawning gravels, and reducing macroinvertebrate habitat by filling interstices. Primary chronic sources are roads and trails at stream crossings and parallel to stream courses. Localized effects of livestock grazing and recreation uses also can affect the integrity of aquatic ecosystems by damaging soil structure within riparian areas or causing bank sloughing into stream habitat.

Although aquatic organisms have evolved with these processes, two key factors have changed. First, the rates of sedimentation can be greatly accelerated relative to natural rates by management activities. More importantly, aquatic ecosystems have now been fragmented, often by water diversion, which prohibits movement to refugia or recolonization of disturbed habitats. These changes make maintenance of existing habitats, including reducing human-caused sediment production wherever possible more important than it may have been prior to settlement of watersheds on the Forest.

Water Quantity

A key feature for maintaining any aquatic ecosystem is an adequate quantity of water. Water quantity must be adequate to maintain viable populations of fish, maintain channel processes, and provide the key habitat features necessary to support aquatic species through all stages of their life history.

As described earlier, all streams that originate on the Forest are over-appropriated, meaning that more water has been allocated to users than exists in the system. This gives rise to situations where water is depleted from stream channels or supplemented with water from inter- and transbasin diversions. Both water depletion and augmentation are common on streams on the Forests and Grassland. Complex water collection and transmission systems move water from most areas of the Forest to other parts of the Front Range for agricultural, municipal, and hydroelectric uses. Tributaries of the South Platte are the sites of both local water diversions, and the recipients of augmented flows from other drainages. Water collected from tributaries to the North Platte and the Colorado Rivers (primarily the Laramie, Fraser, and upper Colorado Rivers) is moved across watershed and basin boundaries into headwaters of the South Platte, chiefly the Cache la Poudre River, Big Thompson River, and Boulder Creek. When water is diverted from natural channels or artificially augmented from other sources, channel processes and habitat characteristics can be changed.

Streams from which water is diverted contain reduced aquatic habitat, both in terms of quantity and quality. Lowest flows below dams often occur during the winter, when supplies of deeper, flowing water are critical to fish survival under snow and ice. Streams into which augmented flows are directed experience above normal flows, which change habitat attributes of cover, velocity, and available spawning areas for fish. Perhaps the most significant impact of water development on aquatic ecosystems is the change in watershed connectedness that occurs when flow regimes are changed. Transbasin diversions through ditches and pipelines have potential to allow movement of previously isolated fauna into new watersheds. Diversion of stream flows into pipelines or ditches can completely dewater downstream reaches. Organisms that may have evolved to use larger mainstem streams during some parts of the year are now confined to isolated headwater areas, because extensive water diversion systems intercept flows from all major canyon systems along the Front Range and most streams tributary to the Colorado River. Fragmentation through dewatering and creation of fish barriers has substantially reduced access to a diversity of aquatic habitats on the Forest. These effects are not described site-specifically in this document but are widespread on streams that have diversion, storage, or augmentation.

Limited stream survey data does not allow a comprehensive overview of stream features across the Forest; however from available data and observations, where human activities have occurred in or near streams, declines in aquatic habitat quantity and quality are often observed.

FISHERIES POPULATIONS

Human-induced habitat alterations and introductions of exotic fish species have altered fish communities in most watersheds to the extent that there are few natural, native fisheries remaining on the Forest. Because fishing is and has been an important recreational use of the Forest, stocking of nonnative trout has occurred in virtually every lake or stream within the Forest. Present populations and species distributions reflect stocking efforts over the last 100 years (see Table 3.14.). The most widely stocked nonnative trout species include brook trout, brown trout, and rainbow trout, and the introduction of these species has had significant ramifications for native trout populations. Greenback cutthroat trout, Colorado River cutthroat trout, brook trout, brown trout, and rainbow trout were selected as management indicator speceis for montane aquatic ecosystems. Plains topminnow and plains killifish were selected as indicators for prairie aquatic ecosystems. See *FEIS*, Appendix G for descriptions and analyses related to management indicator species.

Table 3.14 Current Distribution of Fish Species Within the Arapaho and Roosevelt National Forests and Pawnee National Grassland, Indicating Native and Nonnative Occurrences and Management Indicator Status (MIS)

Fish Species	Colorado River Drainage	North Platte River Drainage	South Platte River Drainage	Pawnee National Grassland	Lakes and Reservoirs Forestwide
Colorado River cutthroat trout (Onchorychus clarki pleuriticus)	Y (native,MIS)				
Greenback cutthroat trout (Onchorynchus clarki stomias)			Y (native,MIS)		Y
Yellowstone cutthroat trout (Onchorynchus clarki bouvieri)			Y		Y
Snake River cutthroat trout (Onchorynchus clarki spp.)			Y		Y
Colorado speckled dace (Rhinichthys nubilus yarrowi)	Y (native)				
Mottled sculpin (Cottus bairdi punctulatus)	Y (native)				
Longnose dace (Rhinichthys cataractae)		Y (native)	Y (native)		
Mountain sucker (Catostomus platyrhychus)	Y (native)				
Mountain whitefish (Prosopium williamsoni)	Y (native)				
Rainbow trout (Onchorynchus mykiss)	Y (MIS)	Y (MIS)	Y MIS)		Y (MIS)
Brown trout (Salmo trutta)	Y (MIS)	Y (MIS)	Y MIS)		
Brook trout (Salvelinus fontinalis)	Y (MIS)	Y (MIS)	Y MIS)		Y (MIS)
Lake trout (Salvelinus namaycush)					Y
Kokanee salmon (Onchorynchus nerka kennerlyi)					Y

Fish Species	Colorado River Drainage	North Platte River Drainage	South Platte River Drainage	Pawnee National Grassland	Lakes and Reservoirs Forestwide
Arctic grayling (Thymallus articus)					Y
Brook stickleback (Culaea inconstans)				Y (native)	
Stoneroller (Campostoma anomalum)				Y (native)	
Creek chub (Semotilus atromaculatus)				Y	
Fathead minnow (Pimephales promelas)		Y (native)		Y (native)	
Bigmouth shiner (Notropis dorsalis)				Y	
Blacknose shiner (Notropis heterolepis)				Y	
Western golden shiner (Notemigonus crysoleucas auratus)					Y
Red shiner (Notropis lutrensis)				Y	
Sand shiner (Notropis stramineus)				Y	
Gizzard Shad (Dorosoma cepedianum)				Y	
Western longnose sucker (Catostomas catostomus griseus)	Y (native)	Y (native)	Y (native)		Y (native)
White sucker (Catostomas commersoni)			Y (native)	Y	
Plains killifish (Fundulus zebrinus)				Y (native,MIS)	
Plains topminnow (Fundulus sciadicus)				Y (native,MIS)	
Iowa darter (Etheostoma exile)				Y (native)	
Black bullhead (Ictalurus melas)				Y	
Green sunfish (Lepomis cyanellus)				Y	

Johnny darter (Etheostoma nigrum nigrum)				Y	
Largemouth bass (Micropterus salmoides)				Y	

Native fisheries have not been impacted on the Grassland to the same extent as on the Forests, because surface water is extremely limited and opportunities to create fisheries are more limited. However, some perennial potholes have been stocked with piscivorous game fish on the Grassland as well, to the detriment of small native minnows.

Populations and habitat for native and nonnative fishes in the major drainages flowing through the Forest and Grassland are described below.

Key Colorado River Basin Populations

Colorado River basin headwater tributaries contain habitat for a number of native and nonnative fish species, as shown in Table 3.14.

The native Colorado River cutthroat trout was listed as a Region 2 sensitive species because of concern for its population decline. Until elimination of federal category 2, the species was also recognized by the U.S. Fish and Wildlife Service (USFWS) as at risk. One of the factors considered key to shrinking Colorado River cutthroat trout distribution is the introduction of nonnative trout species. Rainbow trout and other subspecies of cutthroat trout hybridize readily with Colorado River cutthroat trout, while brook and brown trout outcompete the native cutthroat for habitat. However, several pure populations of Colorado River cutthroat trout persisted in relatively isolated headwater tributaries throughout its historic range.

Presently, small Colorado River cutthroat trout populations occur on the Forest in tributaries of the Fraser River, Willow Creek, Williams Fork, and the Upper and Lower Colorado River drainages. Reintroduction efforts have expanded Colorado River cutthroat trout populations to their current distribution. Colorado Division of Wildlife records indicate Colorado River cutthroat trout occupy 21 streams (91 miles) and 21 lakes (500 acres) within Arapaho and Roosevelt National Forests. However, fish survey data indicate that very few pure populations exist, and these fish are isolated within small headwater drainages.

The primary threat to the continued existence of viable populations of native Colorado River cutthroat trout on the Forest is genetic isolation and decline as a result of competition with nonnative trout. Colorado River cutthroat trout currently occupy only about 10 percent of habitat capable of supporting populations within the Forest. A biological barrier prevents recolonization of most of its former range, because the other trout species now occupy nearly all watersheds. This suppresses the expansion of native populations because brook and brown trout can outcompete native cutthroat, and rainbow trout interbreed with native fish. As a result, the remaining genetically pure populations are physically isolated from each other and cannot contribute to a healthy gene pool, which increases risk of eventual extinction. Colorado River cutthroat trout are not protected under the Endangered Species Act. However, cooperative interagency efforts to develop a conservation plan for Colorado River cutthroat trout are underway.

Key Platte River Basin Populations

The Laramie River drains the northern end of the Arapaho Roosevelt National Forest into the North Platte River in Wyoming. The Laramie River also contains a unique assemblage of native and nonnative fish species (Table 3.14, North Platte River drainage column). Past fish surveys emphasized sport fishes, and as a result, it is likely that not all native, nongame fishes were recorded. However, it is known that no trout were native to the North Platte River, because of geologic isolation during cutthroat trout evolution, so all trout occurrences are a result of nonnative trout introductions.

The Cache la Poudre River, Big Thompson River, St. Vrain Creek, Boulder Creek, Clear Creek, and Bear Creek are tributaries of the South Platte River that originate on the Forest. The greenback cutthroat trout is native to the South Platte River drainage. The greenback cutthroat trout suffered a severe decline as a result of nonnative trout stocking and widespread habitat degradation (Benke 1992). The only five remaining stocks of pure subspecies occurred in small headwater streams above barrier falls, two of which are on the ARNF. In 1973 the greenback cutthroat trout was listed as endangered under the Endangered Species Act. Its status was downlisted to threatened in 1978 to allow more flexibility in recovery efforts. Since then, active recovery efforts have resulted in restoration of the subspecies to several lakes and streams within its historic range.

Presently, small populations occur on the Forest in tributaries of Cache la Poudre River, Boulder Creek, and St.Vrain River. Reintroduction efforts have expanded greenback cutthroat trout to their current distribution. Colorado Division of Wildlife records indicate that the greenback cutthroat trout occur in 17 streams (90 miles) and one lake (11.4 acres) within the Arapaho and Roosevelt National Forests, but few of these are considered stable populations. This is less than five percent of the habitat that was once capable of supporting these native cutthroat.

Risks to the viability of greenback cutthroat trout population are similar to those described above for Colorado River cutthroat trout. Fish survey data indicate that pure populations of these fish are isolated within small headwater streams. However, hatchery programs and wild broodstocks have been developed. This allows management of isolated stocks with some degree of safety and protection from catastrophic events affecting native populations, but longterm genetic effects of this management program are not known.

Lake and Reservoir Fisheries

There are 476 lakes and about 30 significant reservoirs within the Arapaho and Roosevelt National Forests. Almost all natural lakes are very small, generally less than 100 surface acres, and typically less than 30 acres. One hundred and sixty five of the lakes and most reservoirs provide a measurable sport fishery. The remaining lakes do not contain habitat sufficient to support a fishery. Sport and nongame fish species and relative distribution reported by Colorado Division Wildlife are shown in Table 3.15.

Table 3.15 Game Fish Species Present in 165 Lakes, 13,036 Surface Acres, ARNF

Fish Species	Number of Lakes Occupied	Acres Occupied
Rainbow trout	52	11,244
Brook trout	68	10,558
Colorado River cutthroat trout	21	500
Greenback cutthroat trout	1	11
Cutthroat trout (Onchorhynchus sp.)	70	8,664
Brown trout	24	10,614
Lake trout	11	8,434
Arctic grayling (Thymallus articus)	3	237
Trout hybrids (Onchorhynchus sp.)	3	149
Kokanee (O. Nerka kennerlyi)	4	9,994
Walleye (Stizostedion viterum	1	132
Yellow perch (Perca flavescens)	1	132

Historic fish occurrence within Arapaho and Roosevelt National Forests lakes is not known. The presettlement aquatic ecology of these lake systems was presumably much different than it is now. Prior to western expansion and settlement, many of the alpine lakes within the Rocky Mountain region above 11,000 feet elevation did not contain fish. Fish were stocked in these high mountain lakes from the late 1800s through the 1950s to create sport fishing opportunities, but effects on native invertebrates or amphibians are not known. Presently on the Arapaho and Roosevelt National Forests, a number of lakes contain native or reintroduced native populations of greenback and/or Colorado River cutthroat trout. Seventy alpine lakes (totaling approximately 700 acres) contain nonnative sport fish. There are also at least nine alpine lakes (29 acres) which do not contain sport fish. It is likely that all accessible lakes were stocked at one point in time and only those with capability to sustain populations or a sport fishery contain fish today.

Pawnee National Grassland Populations

Historic native fish distribution within the short grass prairie aquatic ecosystems is not known. However, historic fish distribution can be surmised based upon limited sampling records and personal conversations with aquatic ecologists and fisheries biologists. It is likely that most native fish species currently found in some ponds were well distributed throughout the river basins and most tributaries within their range of tolerance. Table 3.14 includes a list of fish which may have historically occurred within the Pawnee National Grassland boundary. This includes both public and private landownership.

Because of the lack of historical stream and pond sampling records, the list of aquatic species currently within the Pawnee National Grassland boundary remains as described above. Recent surveys have better described populations in major drainages on the Grassland, which largely confirm this list and document current distribution of management indicator species (CDOW 1997). The only nonnative game species present are largemouth bass and green sunfish. These species have been stocked in a few perennial ponds to provide a limited sport fishery. However, the economic value of this sport fishery is insignificant to the local area. In fact, largemouth bass stocking may be detrimental to native plains fisheries, because native fishes like the plains topminnow did not evolve with piscivorous predators, and so are likely highly susceptible to predation.

RESOURCE PROTECTION MEASURES

Healthy watersheds protect water quality and provide sustainable ecosystems within a dynamic equilibrium. Natural disturbances such as large, stand-replacing wildfires or landslides, can throw watersheds out of equilibrium and drastically affect both site productivity and water quality. Such events can reset the dynamic equilibrium, but over time the watersheds recover to a balance of vegetative cover, surface conditions, and resulting stream flow.

Watersheds and streams can retain a healthy balance with some resource use and disturbance. Watersheds will be protected by limiting disturbance in each watershed to levels that safeguard the integrity of the stream channels, streamflow, water quality, and aquatic and riparian habitat. Where watersheds are at risk, remedial projects will be implemented to restore watershed health.

The goal of limiting watershed disturbance is to allow management activities to occur, but at a level and in locations which will not impair watershed and stream health. Individual watersheds can withstand disturbance from management activities. Disturbance levels can vary from watershed to watershed, depending on existing conditions and watershed resistance or resilience. Some stream channel types are more resistant to disturbances than others, while some have higher resilience and recover more quickly than others.

Most streams on the Forest are steep to moderately steep, with narrow floodplains and beds composed primarily of cobbles and boulders. These streams are relatively resistant to watershed disturbance. While low-gradient channels make up a small proportion of the total stream miles on the Forest, they support the most productive aquatic habitat and extensive riparian areas that are of critical importance to aquatic and terrestrial life. They are also much more sensitive to watershed impacts.

Reference streams can be used to compare stream conditions in high quality watersheds to streams of similar stream type in disturbed watersheds. This comparison helps to assess the effects disturbance has had on the stream condition. Under ideal conditions, reference streams should be located in watersheds with very low levels or no existing disturbance. However, because of the extensive history of use on the Forest, "least disturbed" stream reaches may have to be used as references for some stream types.

A general watershed assessment was discussed earlier in this text. As new management activities are proposed, site-specific analysis will be performed which will consider the impacts of existing and proposed activities, and their effects on stream and riparian health. In watersheds where risks are high, watershed improvement or additional mitigation measures may be used to offset the effects of the proposed activities.

Watershed conservation practices will be used to safeguard activities which occur in watersheds on the Forest. The Rocky Mountain Region has developed a guide to watershed conservation practices, effective December 26, 1996 (*FSH 2509.25*). Copies of this handbook are available from the Forest or Regional Office. The handbook includes standards and design criteria which will be applied to all management activities to protect soil, aquatic resources, and riparian areas. These criteria describe in detail what will be done to protect stream channels and water quality. Conservation practices will also help protect watershed condition and indirectly protect aquatic habitat and biota. They limit direct impacts to stream health and help to maintain the chemical, physical and biological integrity of Forest waters. Their use complies with nonpoint source pollution control regulations and with the NFMA.

ENVIRONMENTAL CONSEQUENCES

Nearly all activities carried out on the Forests and Grassland and described in this *FEIS* have the potential to affect aquatic and riparian resources. Activities that disturb the soil surface have the greatest potential, and the risk of adverse effects increases the closer the disturbance is to streams or wetlands.

Environmental consequences of activities are expected to be proportional to the level of activities that occurs. In this *FEIS*, two budget levels are considered: experienced and full implementation. This aquatic and riparian resource analysis focuses on effects from the experienced budget levels. Any reference to specific numeric quantities for activity levels refers to recently experienced budget levels for aquatic resource management. Typically, effects from oil and gas leasing, mining, grazing, and water development are not tied to Forest Service budgets. Effects are more likely to increase with full implementation budgets for such activities as recreation, road and facility construction, and timber harvest. Under full implementation budgets, prescribed fire management would likely increase over experienced levels, which may lead to a longterm reduction in effects from wildfire. With the exception of fire, effects from full implementation budget levels are expected to be equal or greater than experienced levels.

EXISTING, DIRECT, AND INDIRECT EFFECTS

Surface water, groundwater, floodplains, riparian areas, and aquatic habitats for indicator species and other organisms are all closely related. Discussion of effects on these resources will be dealt with together since the pathways of effects that influence all of them are similar. When they are impacted differently, it will be specifically noted and described.

Watershed conservation practices, and *Forest Plan* standards and guidelines, prescribe extensive measures to protect soil, riparian, and aquatic resources. If all applicable measures are implemented and if they are effective, adverse effects to these resources from management activities should be minimized. However, as the levels of activity increase, the risk that conservation practices will not be implemented or will not be cumulatively effective increases. Consequently, alternatives which propose greater levels of activity for various resources generally pose greater risk to aquatic and riparian resources.

For each of the resource areas described below, the environmental consequences for aquatic resources are compared by alternative, based on relative indices of disturbance for each type of activity.

EFFECTS OF VEGETATION MANAGEMENT ON WATER YIELD

Water yield increases from vegetation management are of great interest to many of those who depend upon water originating from the Forest. As noted in the Affected Environment section, the demand for water is greater than the supply. The Forest provides water not only for municipal and agricultural use but also contributes flow for endangered species as far downstream as the Platte River in Nebraska.

Streamflow from forested watersheds is a function of total precipitation and losses due to evapotranspiration and groundwater storage. Trees in the watershed affect streamflow by transpiring water, intercepting snow or rain which may be evaporated or sublimated back into the atmosphere, and by modifying the understory's evapotranspiration (Kaufmann et al. 1987). Removal of trees can increase water available for streamflow by reducing evapotranspiration and increasing snowpack accumulation into the openings (Alexander et al. 1985). Consequently, the two major forest management activities which influence water yield are timber harvest and fire.

The increase in water yield caused by timber harvest or fire is largely determined by the amount of precipitation which occurs on a site. Thus, treatment in spruce-fir yields the greatest increases per unit area, because spruce-fir typically occupy the wetter sites. Increases are smaller for treatment of lodgepole pine and smallest for ponderosa pine. Increases in streamflow from vegetation management are not permanent. As an area is restocked and the trees grow, water that was available for streamflow is slowly redirected back to evapotranspiration. Research at the

Fraser Experimental Forest indicates that water yield increases from timber harvest persist at declining levels for approximately 80 years (Troendle and King, 1985).

Many experiments have measured changes in streamflow from timber harvest on small watersheds (typically 100 to 1000 acres). However, as watershed size increases, it becomes progressively more difficult to measure the same changes. It is not that the additional streamflow is not present at the larger scales, but rather that as the changes in streamflow become proportionately smaller in comparison to the total streamflow, they become increasingly difficult to detect and are eventually masked by the natural variance of the system. Since fish-bearing streams are generally larger and lower in the watershed, water yields that do not change channel stability are unlikely to affect habitat for aquatic indicator species.

Water yield increases caused by timber harvest were modeled for Alternative B and for the timber benchmark, using the methods outlined in WRENSS (EPA, 1980). The timber benchmark is the estimate of the maximum timber harvest that could be sustained for all forested lands except for those lands legally withdrawn or not physically operable. Modeling water yield for this benchmark offers an estimate of how much additional water could be produced if timber harvest was maximized on the Forest. For Alternative B, water yield from timber harvest is expected to increase by 2,962 acre feet (AF) at the end of five decades. (An acre foot will cover a football field to a depth of 1 foot. It is about the amount of water used in one year by the average household in Colorado.) For the timber benchmark, water yield from timber harvest would be expected to increase by 6,690 acre feet at the end of five decades. Existing water yield for the Forest is approximately 2 million acre feet, so increases will be on the order of 0.15 to 0.33 percent of existing yield.

Because the Forest is bisected by the Continental Divide, water from the western portion of the Forest drains into the Colorado River and water from the eastern portion drains into the Platte River. The table below shows the water yield increase from timber harvest for Alternative B and for the timber benchmark for each drainage.

Table 3.16 Water Yield Increase from Timber Harvest (Avg. AF/year)

Platte River Basin					
Alternative B	1st Decade	2nd Decade	3rd Decade	4th Decade	5th Decade
	484	913	1205	1418	1676
Timber Benchmark	2106	2510	3863	3911	4577
Colorado River Basin					
Alternative B	1st Decade	2nd Decade	3rd Decade	4th Decade	5th Decade
	270	546	876	1130	1286
Timber Benchmark	4	276	334	1929	2113

Water yield increases every decade even though harvest levels remain relatively constant at 6.5 to 6.9 million board feet per year for Alternative B. This is because water yield persists for about

80 years, as discussed above, so that water yield increases produced by harvest in the first decade add to increases from harvest in the second decade, and so on.

Modeling was not performed for the other alternatives, but because water yield increases are roughly proportional to the proposed harvest volume for each alternative, relative changes in water yield increase can be estimated by comparing harvest volume for Alternative B with the planned volume for other alternatives. The average water yield increase for Alternative B is 0.1165 AF feet per thousand board feet (MBF) harvested.

Fire, both prescribed and natural, will have a considerable effect on water yield. It is estimated that wildfire will burn approximately 1,100 acres per year for each alternative except Alternative H, where 3,700 burned acres are expected. An additional 6,000 acres of forested land will be treated for fuel management through a combination of prescribed fire and mechanical treatment. (For a detailed description, see the Fire section in this chapter.) For Alternatives B, E, and I, the water yield increase caused by fire will exceed that caused by timber harvest.

The values in Table 3.17 differ from those in the table above because they display the average annual water yield generated by vegetation treatment over five decades rather than decade by decade increases from treatments in previous decades. However, the table does allow the comparison of water yield increase by alternative.

Table 3.17 Estimated Water Yield Increase by Alternative (Average AF/yr over 5 decades)

Alternatives	A	B	C	E	H	I
Harvest Volume	17,576	6,668	19,369	2,036	1,017	14,855
Water Yield-Timber	2,048	777	2,256	237	118	1,731
Water Yield-Fire	1,614	1,614	1,614	1,614	2,190	1,614
Total Water Yield Increase (AF/yr.)	3,662	2,391	3,870	1,851	2,308	3,345

It should be noted that the present water yield of the Forest includes water yield increases from past and current vegetation management. While timber harvest declined under the 1984 *Forest Plan* to a low of 2,244 MBF in 1995, the average harvest volume for the period 1976 to 1994 was 14,647 MBF. This volume is greater than the projected volume for all alternatives except A, C, and I. As the water yield from past harvest diminishes, water yield increases from planned harvest for Alternatives B, E, and H will be insufficient to make up the difference, and total water yield from the Forest will decline slightly. However, water yield increases from vegetation management or fire make up only a small fraction of the total water yield for the Forest.

EFFECTS OF TIMBER HARVEST ON AQUATIC AND RIPARIAN RESOURCES

Timber harvest can affect aquatic resources by increasing water yield and by potentially increasing erosion and sedimentation. Harvest in riparian zones reduces streamside vegetation, which can increase annual and daily stream temperature fluctuations, reduce overhead cover, and decrease the supply of large woody material available for recruitment to streams. Conversely, logging slash and debris can choke streams and reduce dissolved oxygen levels as debris decays, creating anoxic conditions toxic to fish and other aquatic organisms. Major increases in erosion from harvested areas themselves are unusual, but the road and skid trail network associated with timber sales can increase the risk of erosion and sedimentation.

Changes in vegetative structure from timber harvest also lower the quality of riparian corridors used by terrestrial wildlife species by reducing cover and changing available food and forage sources.

Increases in flows, changes in riparian vegetation, and impacts to streambanks from logging operations all have the potential to alter fish habitat in streams on the Forest in watersheds where timber harvest occurs. Direct effects of vegetation removal are most likely to result in reductions in overhead cover that provides hiding and resting areas for fish. Indirect effects of timber harvest would include changes to thermal buffering that could increase summer or decrease winter temperatures to sub-optimal ranges, increasing stress on fish during these periods or changing reproductive potential due to delayed spawning or emergence. Other indirect effects would be reductions in spawning and hiding cover as a result of increased substrate embeddedness and pool filling from sedimentation. However, provided that timber harvest does not exceed the hydrologic threshold, and that watershed conservation practices to protect riparian areas are implemented, changes in fish habitat occurring as a result of vegetation management should be minimal. Care during project planning and implementation is needed to ensure that vegetation management does not impair attainment of desired conditions for aquatic and riparian habitats or affect viability of aquatic indicator species..

All alternatives are achievable, but risk of adverse consequences to watersheds and fisheries increases with increasing harvest levels. The potential for impacts to water resources is proportional to scheduled harvest acres, and is shown below. Average drainage densities for crenulated drainages, intermittent streams, and perennial (potentially fish-bearing) streams were calculated from GIS (geographic information system) stream data for all NFS lands on the ARNF, excluding the Williams Fork drainage and Pawnee National Grassland.

Table 3.18 Comparison of Potential for Impacts between Alternatives on Land Suitable and Available for Timber Harvest

Alternative	**A**	**B**	**C**	**E**	**H**	**I**
Suitable & Available Timber Lands (1,000 acres)	35.5	18.9	38.7	4.2	2.1	30.0
Potentially Affected Aquatic Ecosystems						
Crenulated Ephemeral Drainages (miles)	944	502	1092	111	56	798
Intermittent Streams (miles)	397	211	433	47	23	336
Perennial/Fish-Bearing Streams (miles)	490	261	534	58	29	414
Total Streams (miles)	1,831	974	2,059	216	108	1,548

This analysis assumes that average drainage densities can be applied accurately to suitable and available timber lands, and that there is equal risk and consequence of effects from timber harvest and related activities carried out in proximity to the three stream types. In reality, risk and consequence are probably not equal for crenulated, intermittent, and perennial streamcourses. Most timber harvest tends to occur in the upper portions of watersheds, so effects are more likely for intermittent and crenulated drainages. Conversely, direct effects are less likely but potentially more significant for perennial, fish-bearing streams.

Implementation of watershed conservation practices is key to avoiding or minimizing impacts to aquatic species and potentially affected streams under any alternative. Actual areas harvested in any given year would vary depending on alternative and budget levels, with site-specific effects on aquatic and riparian resources occurring in proportion to proposed harvest levels.

Table 3.19 Comparison of Potential for Impacts between Alternatives—Stream Miles with Potential for Adjacent Timber Harvest

Alternatives	A	B	C	D	H	I
Annual Acres Harvested	3,219	1,193	3,308	232	145	1,537
Crenulated	9	3	9	<1	<1	4
Intermittent	4	1	4	<1	<1	2
Perennial	4	2	5	<1	<1	2
Total	17	6	18	1	<1	8

EFFECTS OF TRAVELWAYS ON AQUATIC AND RIPARIAN RESOURCES

Roads are probably the single greatest source of increased sediment in streams on the Forest. Many streams have roads or trails directly adjacent to them, where nearly all erosion delivers sediment directly to the stream. Sediment fills pools, reducing habitat for fish, and fills the interstitial spaces of the streambed, reducing habitat for invertebrates and spawning fish. Unlike many other disturbances which increase erosion, sedimentation from travelways tends to be chronic and to last as long as the travelways exist, which can create long-term impacts on habitat for indicator species.

There are more than 4,050 miles of road within the boundaries of the Forest, and an additional 700 miles on the Grasslands. The roads include I-70 and other highways, paved and unpaved county roads, private roads, and an extensive network of mostly gravel and native surface roads maintained by the Forest. The Forest recognizes 1,974 miles of these as system roads. There are 573 miles of system roads on the Grassland. In addition there are more than 600 miles of "ways," roads and tracks created by use which are not managed as part of the road system. There are also approximately 900 miles of trails on the Forest, of which 722 are recognized as part of the trail system. These travelways provide a background level of disturbance that contributes to direct and indirect effects on aquatic and riparian resources. Trends in increased recreation on the Forest are likely to continue and to accelerate these effects.

Compliance with revised *Forest Plan* standards and guidelines and with watershed conservation practices should prevent problems with new or reconstructed roads. However, bringing existing roads into compliance with new protection measures is a major challenge. More than three-quarters of the sixth-level watersheds (140 of 177) have roads located adjacent to at least 20 percent of the stream miles in the watershed. Fifty two watersheds have roads adjacent to more than 50 percent of the stream miles. Even though many of these roads occur on private land or run across easements, they do contribute cumulatively with Forest roads to watershed conditions.

Future road management should consider relocation or obliteration of existing roads and ways to reduce associated impacts, because road and trail effects can be greatly reduced by proper location and design. Good location keeps travelways away from stream channels, riparian areas, steep slopes, high-erosion-hazard areas and areas of high mass movement. Good design provides stable cut-and-fill slopes and adequate drainage which allows water to filter through vegetated buffers or sediment traps before entering the stream channel. Realignment of roads and other travelways so that they traverse riparian areas and streams at perpendicular rather than parallel angles would improve the quality of riparian and aquatic habitats in presently impacted stream reaches by reducing chronic sediment sources. If relocation is not possible, aggressive seasonal restrictions would limit road damage and subsequent sedimentation.

There are both economic and ecological consequences from increased sediment derived from roads and other sources. Sediment does not dissipate and is carried through the stream system where it may affect diversion structures, reservoirs, and water supplies. It can shorten the usable life of structures or result in higher maintenance costs. Since channels are interconnected, sediment delivered to ephemeral channels moves on to perennial channels during spring runoff. High sediment loads impact stream health by reducing pool depths, filling interstitial spaces in the streambed used by macroinvertebrate life, adhering to gills of aquatic life, changing channel morphology, and damaging habitat.

Alteration of fish habitat by sedimentation includes reductions in spawning gravels and hiding cover as substrates become more embedded. Pool volume can be reduced as sedimentation increases. During critical low-flow or overwintering periods, reduced pool depth can result in insufficient protection for fish, and increase the risk of summer or winter kills. Sediment deposition in spawning gravels reduces both success in locating appropriate spawning areas and can reduce the survival of emerging juvenile fish.

Roads, trails and associated human travel cause reduction, disturbance and interruption of riparian habitat. Accordingly, numerous wildlife species associated with riparian areas are adversely affected. The potential for adverse effects by alternative is estimated to be directly related to the habitat effectiveness values in Tables 3.69, 3.70, and 3.76 and 3.77 (in the Terrestrial Habitat and Wildlife section), based on amount of open travelways. Higher habitat effectiveness values equate with lower risk to riparian habitat.

Each alternative proposes road construction, reconstruction, and obliteration of "ways" (unauthorized roads). Longterm risks to water resources increase with increased road construction and decrease with road obliteration. Reconstruction causes shortterm increases in erosion but provides the opportunity to stabilize roads and improve drainage.

Total estimated road miles for the first decade vary from 1,829 miles for Alternative H to 2,361 miles for Alternative C. Relative impacts of the alternatives are based on the net increase (road construction minus obliteration) for each alternative. The degree of trail impacts is negligible relative to roads, and does not change this comparison. Relative to the existing road network, the effects of construction or obliteration proposed under the various alternatives are minimal, because impacts are dominated by the existing condition. Very little new construction is proposed in the first decade under either experienced or full implementation budget levels. Most of the increase in system road miles comes from redesignation of existing "ways" as system roads. Some ways would be designated as trails as well. Remaining ways would be obliterated as funding is made available. Comparisons of shifts in travelway status for the combined Forests and Grassland are shown in Table 3.20 for all alternatives at experienced budget levels.

The smallest net increase in roading has the least adverse effect on retention and enhancement of diverse habitats provided by riparian and aquatic ecosystems. The following table includes roads and trails under Forest Service jurisdiction, although other roads are present within affected watersheds.

Table 3.20 Relative Impacts of Miles of Roads and Trails between Alternatives at Experienced Budget Levels

Alternative	A	B	C	E	H	I	Existing
Forest Developed Roads (FDR)	2,343	2,218	2,361	2,301	1,829	2,303	1,974
Forest Developed Trails (FDT)	748	778	723	759	740	723	722
User-Created Ways	596	30	591	508	418	608	690
Ways Converted to FDR	12	190	25	108	0	23	N/A[a]
Ways Converted to FDT	10	29	15	15	10	15	N/A[a]
Ways Obliterated	72	441	59	59	680	44	N/A[a]

[a] Not applicable

Only Alternative H, which would obliterate nearly all ways and close additional existing roads, represents a substantial reduction in road- and trail-produced sediment input to aquatic and riparian ecosytems. All other alternatives represent approximately equal levels of continued chronic sedimentation, with open, recognized road densities greater than existing. Converting ways to roads can be beneficial if drainage systems are improved through regular maintenance; however, the Forest has exceeded its fiscal capacity for travelway maintenance, so there is limited assurance that overall road conditions would actually be improved.

Effects of Fire on Aquatic and Riparian Resources

Wildfire and prescribed fires and their associated suppression activities have the potential to impact aquatic and riparian resources.

By burning vegetation and organic matter on the soil surface, wildfire can greatly increase erosion rates. Erosion and sedimentation following wildfires tends to be very heavy, overwhelming other erosional sources, including timber harvest and roads, until the land revegetates. Fire suppression efforts considerably increase erosion potential from fire lines constructed by heavy equipment. The removal of vegetation also increases the speed with which overland flow reaches the channel network and the amount of water added to the streamflow. The combination of these effects can greatly increase peak flows in burned watersheds and result in major channel cutting. When catastrophic fires burn through riparian areas, buffering vegetation is lost and effects on aquatic ecosystems can be even more severe. Adverse impacts can persist for many years.

The effects of prescribed fire can be considerably less severe. Because the location and intensity of the fire are controlled to a greater degree, more ground cover remains and erosion potential is reduced. For example, sediment-trapping buffers can be left around stream channels to reduce the amount of sediment delivered to the stream. Entire watersheds are rarely burned by prescribed fires, which reduces the effects of changes in water yield and peak flow. Furthermore, the judicious use of prescribed fire can help to reduce the risk of catastrophic fires that would otherwise burn through and severely damage riparian areas.

Wildfires burn about 1,100 acres annually on the Forest. While wildfire can have devastating consequences to aquatic ecosystems, the effects of wildfire are not expected to vary between alternatives, except for Alternative H, where the area burned annually is expected to increase to 3,700 acres. However, the area affected annually by fuel management (combination of prescribed fire and mechanical treatment) is expected to increase from the experienced budget of 4,000 acres to 7,000 acres for the fuel budget for all alternatives. Of the 7,000 acres, 6,000 are forested acres and 1,000 acres are grass and shrubs. Additional prescribed burning is intended primarily to improve wildlife habitat or reduce fuel loads.

The impact of the alternatives is compared below, based on the number of acres of prescribed fire proposed annually and the miles of streams potentially affected within that area. Potentially affected stream miles were developed from average drainage densities as described in the timber harvest discussion.

Table 3.21 Relative Impacts between Alternatives for Prescribed Fire and Wildfire

Alternative	A	B	C	E	H	I
Acres burned	5,100	5,100	5,100	5,100	6,200	5,100
Potentially Affected Stream Miles						
Crenulated	14	14	14	14	16	140
Intermittent	6	6	6	6	7	6
Perennial	7	7	7	7	9	7
TOTAL	27	27	27	27	32	27

All alternatives except H propose equal amounts of burning, so potentially affected aquatic ecosystems are expected to be similar, although site-specific project locations and effects will likely vary. Approximately three to four times more wildfire would occur under Alternative H than would occur under the other alternatives. While fuel management could result in the largest longterm reduction in effects from catastrophic wildfire, good interdisciplinary planning and implementation of watershed conservation practices at the project level are necessary to reduce risks of impacts to aquatic and riparian habitats and indicator species.

EFFECTS OF GRAZING ON AQUATIC AND RIPARIAN RESOURCES

Grazing can have detrimental effects to aquatic resources, particularly because in many areas of the Forest much of the usable forage is found only in riparian areas. Grazing in riparian areas directly affects vegetative condition and habitat quality in a number of ways.

Longterm use has changed the vegetation composition on some riparian sites. Loss of willows and deep-rooted grasses makes streambanks in these sites more susceptible to natural erosive forces. Grazing also reduces bank stability through vegetation removal and bank trampling; it can compact soil, increase sedimentation, cause stream widening or downcutting, and often changes riparian vegetation, resulting in insufficient overhead cover for fish. Stream widening and sedimentation can reduce instream cover and habitat quality for fish through mechanisms similar to those described for vegetation removal through timber harvest or fire, but grazing impacts are compounded by repeated yearly use of the same areas by livestock. Downcutting often leads to channel straightening and reduced stream sinuosity, which eliminates habitat for aquatic indicator species associated with stream bends, such as lateral scour pools and undercut banks.

Livestock grazing can also lower water quality by introducing bacteria and pathogens into water bodies along with fecal material. Although this impact has occurred, it has not changed designated uses of stream water, according to the State 305(b) report (State of Colorado 1994).

Watershed conservation practices designed to protect range and riparian areas should be included in range-use permits and allotment operating plans as they are revised and updated.

Under all alternatives, all 51 permitted allotments on the Forests and Grassland that are currently active are to be left open. Alternatives differ in how they treat closures of vacant allotments, areas outside existing allotments, and reduction of grazing levels in allotments. Alternatives vary from Alternative I, which would close 34 vacant allotments and consider opening additional allotments, to Alternative H, which would close all 75 vacant allotments, reduce grazing on all permitted allotments, and schedule analysis for closing allotments in recommended wilderness areas, core habitat areas, core restoration areas, and habitat corridors. Alternatives A, C and I would continue grazing at approximately present levels, and vacant allotments could not be closed. Alternative B would close the vacant allotments and grazing on active allotments would continue at present levels.

In the short term, decisions to close vacant allotments have little effect on aquatic resources because the allotments are not now being grazed. However, it is probable that if vacant allotments are not closed, they will be grazed sometime in the future. It should be possible to minimize harm to streams and riparian areas through the use of conservation practices, but they are often difficult to implement without the use of expensive techniques such as fencing. Thus, whenever grazing is carried out, it can potentially impair the desired conditions for riparian and aquatic ecosystems. The following comparison of risk to aquatic and riparian resources is based on the number of available allotments and the level at which they are grazed.

Table 3.22 Comparison of Impacts between Alternatives for Livestock Grazing

Alternatives	A	B	C	E	H	I
Active Allotments	51	51	51	51	51	51
Open Vacant Allotments	41	0	41	0	0	41
Closed Vacant Allotments	34	75	34	75	75	34
AUMs Grazed[a]	25,433	17,400	25,433	17,400	8,200	30,400
Suitable Rangeland Grazed	91,572	62,653	91,572	62,653	48,550	105,800

[a] Animal unit months

Livestock grazing under any of the alternatives is assumed to have high potential for direct impact on riparian and aquatic resources, because the vast majority of suitable acres are located in or adjacent to riparian areas.

EFFECTS OF MINING ON AQUATIC AND RIPARIAN RESOURCES

Mining has had considerable impact on the Boulder and Clear Creek Districts of the Forest through hardrock mining, and additional stream miles have been impacted by placer mining within the floodplains of affected streams.

One of the most pervasive environmental problems caused by mining is acid mine drainage. Acid mine drainage occurs when iron-containing sulfide minerals from adits, shafts or tailings piles are exposed to air and water (Ficklin and Smith 1993). Acid drainage typically carries increased concentrations of dissolved metals, which can be harmful to aquatic biota. Stream fisheries have been essentially eliminated in watersheds with acid mine drainage.

Placer mining conducted earlier in this century entirely disrupted some riparian and aquatic ecosystems as fluvial deposits were literally turned upside down as miners searched the gravels for gold. Lasting effects have totally changed channel structure and processes, reduced instream cover and habitat diversity for fish, and removed original riparian vegetation from the areas.

The Rocky Mountain Region of the Forest Service has contracted with the Colorado Geological Survey to inventory abandoned mines on Forest land. Twenty-four abandoned mines that have severe environmental impacts were identified on NFS lands. The Forest now has an assessment of past mining impacts, and environmental concerns will be identified by priority so that funding for clean-up can be sought.

Current mining operations are generally small and limited in number. Much of the mining on the Forest today is recreational in nature. Large increases in mining activity are not anticipated for the future, but cannot be ruled out. The 1866 mining law limits Forest Service authority over mining activities, but allows the setting of terms and conditions to minimize impacts to Forest lands.

As shown in Table 3.23 the same level of mining activity is anticipated for all alternatives, so potential impacts to aquatic habitats and populations would be equal.

Table 3.23 Comparison of Impacts between Alternatives for Locatable and Salable Minerals

Alternative	A	B	C	E	H	I
Acres of Surface Disturbance - Locatable[a]	40	40	40	40	40	40
Acres of Surface Disturbance - Salable[b]	10	10	10	10	10	10

[a] Locatable minerals are minerals such as gold, silver, and molybdenum.
[b] An example of a salable mineral is gravel.

EFFECTS OF UTILITY CORRIDORS ON AQUATIC AND RIPARIAN RESOURCES

Three general types of utility corridors have varying potential to affect aquatic and riparian resources. Above-ground power and telecommunications corridors require vegetation clearing, but ground disturbance is limited to pole or tower locations. Streams and wetlands can often be spanned with no need for disturbance.

Below-ground power and telecommunications corridors require ground disturbance along the entire length of the corridor, including crossings of aquatic or riparian ecosystems. However, these corridors require relatively narrow trenches and minimal vegetation clearing. These utility corridors can often be located along other existing corridors such as roadways.

Below-ground oil, gas, or water transmission lines are most likely to significantly affect aquatic and riparian resources. These corridors often contain far larger pipelines that require large, deep trenches. Potential for leaks or spills that could cause environmental damage exist with these corridors but not with power or telecommunications corridors. To allow for gravity feed, these corridors are located parallel to natural stream courses. Wide construction and access corridors are sometimes maintained to allow for repairs and cleaning.

Utility corridors of all three types currently exist on the Forests and Grassland, and they are unlikely to be eliminated in the future. In fact, increasing urbanization makes it likely that there will be an upward trend in utility corridors. There is not likely to be any difference in utility corridor proposals between the alternatives because corridors are instigated and developed by private utilities rather than by Forest management direction.

EFFECTS OF RECREATION ON AQUATIC AND RIPARIAN RESOURCES

People are drawn to water when recreating on the Forest. Many developed and dispersed recreation sites are located in riparian areas or near streams. Impacts include damage to vegetation, soil compaction and increased runoff, increased bank erosion, sedimentation, and the potential for the introduction of human waste into the waters. Most impacts tend to be localized, but in areas of high recreational use, the cumulative impacts can be considerable. Water quality on the Forest both affects and is affected by recreation. Recreationists are warned to drink only treated water, because although data are not available, streams across the Forest are assumed to contain Giardia. Recreational use of the Forests and Grassland is expected to nearly double before the year 2005. The increase is anticipated for all alternatives. Despite the use of watershed conservation practices to protect aquatic resources, impacts will invariably increase with use because stream and lakeside areas are favorite locations for recreation.

Dispersed motorized and nonmotorized winter recreation has little potential to affect aquatic and riparian resources. Nonmotorized uses on snow are crosscountry skiing and snowshoeing. These activities compact snow but usually have minimal effects on soils and streams. Compacted snows usually melt more slowly so that runoff is delayed, but the areas affected are too small and scattered to have detectable effects. Motorized uses on snow include snowmobiles and snow cats. Effects on soil and water are minimal, for the same reasons.

Developed winter recreation sites have potential to significantly affect aquatic and riparian resources. There are three ski areas which operate on the Forest: Winter Park, Loveland, and Eldora. The Winter Park ski area includes designated recovery waters for Colorado River cutthroat trout, a management indicator species. Operation of Loveland and Eldora ski areas have potential to affect non-resident indicator trout.

Ski area development can lead to increased water yield and erosion through timber clearing for lifts, runs and other facilities. Ski areas and snow resorts typically remove forest vegetation from much of the area. Snowmelt runoff is increased, especially if cleared areas are compacted or snowmaking has artificially increased the snow depth. Substantial amounts of such disturbances can increase the size and duration of spring high flows. Stream channel damage can result. Snowmaking that drains water from streams also reduces winter base flows which are limiting to populations of fish and other aquatic biota. Life cycles of such biota can be disrupted. Ski areas and snow resorts also typically disturb soils throughout cleared areas. Erosion and sediment can result, especially from soils that are near streams, unstable, or highly erodible. Aquatic habitat can be damaged as a result. In addition, these uses can also degrade wetlands and riparian areas by draining or filling them or by altering their vegetation. Often, ski lift terminals are constructed in valley bottoms, which can cause long stretches of stream to be culverted, with a resultant increase in barriers to fish passage and loss of riparian and wetland habitat. These impacts often have adverse effects on aquatic and wildlife habitat.

Ski area expansion or development would vary by alternative. Alternatives A and H reflect the range of potential effects. Alternative A would permit three existing and six potential ski areas. Alternative H would permit only existing ski areas and would reduce expansion potential at Loveland. Alternative B would allow for expansion at existing areas, redevelopment of ski facilities at Berthoud, and would permit development of a new ski area at St. Marys Glacier.

Fishing activities are often the primary reason for recreational visits to the Forest, and are associated with many other recreational visits as well. The ease of access to numerous streams, lakes and reservoirs within the Arapaho and Roosevelt National Forests provides a wealth of angling opportunities within a range of recreational settings from developed urban to pristine. The current economic value of recreational angling on streams in lakes within the ARNF ranges between $1.5 and $2.5 million annually, with trends in coldwater angling in the Rocky Mountain region showing a consistent increase of approximately 10 percent between 1965 and 1985 (Flather and Hoekstra 1989). Colorado license sales and angling surveys support these figures for regional trends and use (Nehring 1991). Assuming little change in the economy or catastrophic biological events, demand for and use of angling opportunities within the ARNF is expected to increase along these same trends (Table 3.24). Increases in user days shown in the table were based on a 1 percent average annual increase. Economic benefits were held constant at $20 per 8-hour angling day.

Table 3.24 Projected Use and Economic Value of Angling within the ARNF

Year	1995	2000	2005	2015	2025	2035	2045
User Days (X 1,000)	123.0	130.0	138.0	153.0	170.0	188.0	208.0
Economic Benefit (X 1,000)	$2,500	$1,600	$2,800	$3,100	$3,400	$3,800	$4,160

Fishing pressure on the Forest is expected to continue to increase under any of the alternatives. Fishing is already "supply limited," meaning that there is more pressure on easily accessible fisheries than populations can support. This effect is managed in cooperation with the State of Colorado Division of Wildlife, which stocks many streams across the Forest with catchable trout. These put-and-take fisheries satisfy some fishing demands, but do little to satisfy anglers in search of "quality" fishing experiences. The desire for quality fishing is managed by the State through special regulations restricting species limits, size limits, and tackle. Anglers willing to travel farther from developed roads and trails can be rewarded with less crowded fishing conditions and opportunities for wild or larger trout.

Heavy fishing is assumed to exert downward pressure on recovering populations of greenback and Colorado River cutthroat trout on the Forest, because with more recreationists fishing on more waters, there is a greater likelihood of harvesting these fishes. These effects are considered in *FEIS Appendix G* and in the viability assessment contained in the cumulative effects discussion that concludes this section.

Rehabilitation of degraded watersheds and improving habitat for fish can result in positive impacts for recreational angling. Over the past 15 years, approximately 28 stream-habitat improvement projects have been completed resulting in over 900 instream structures. Program direction has emphasized and will continue to emphasize maintenance of these structures over construction of new structures. Instead, improvement of watershed conditions will focus on controlling nonpoint sediment sources and improving overall watershed function. Generally, these habitat improvements do not result in increased angling opportunities, but can change the quality of the experience and improve an angler's catch.

Demand for recreational opportunities will continue to increase whether or not the Forest provides facilities. If insufficient facilities are available to meet the demand for developed recreation, use may simply be shifted to dispersed sites, with added and uncontrolled effects on soils, vegetation, and riparian values at those sites. The relative impacts for the six alternatives are shown in Table 3.25. Impacts on riparian and aquatic habitats from recreational travel have already been discussed in the Travelways section, earlier in this chapter. The direct impacts to fisheries and fishing experiences are expected to be proportional to use rather than variable by alternative. In addition to ski area effects already discussed, comparison of impacts on aquatic, riparian, and fisheries under the alternatives is based primarily on the amount of land disturbed to develop new or reconstruct existing recreation facilities, because many of these facilities are located within or adjacent to riparian areas. Potential impacts are increases in erosion, sedimentation, increased soil compaction, and loss of riparian vegetation. However, compared to the effects of ongoing dispersed recreation forestwide, the direct effects of recreation site development are temporary. The indirect effects of longterm conversion of riparian areas to hardened sites are more significant. Hardened sites change riparian thermal characteristics and vegetation structure. The water-absorbing and filtering functions of riparian areas can be substantially reduced by recreational development in the floodplain.

Table 3.25 Relative Impacts between Alternatives for Recreation Area Development

Alternative	A	B	C	E	H	I
Acres of Reconstruction Activities	180	476	100	498	114	101
Acres of New Construction Activities	20	62	18	75	15	18
Total	200	538	118	573	129	119
Acres Allocated for Developed Ski Areas	21,685	16,527	21,544	20,349	9,101	22,142

Effects of Oil and Gas Leasing on Aquatic and Riparian Resources

To date, oil and gas development has occurred only on the Grassland. Because of the near absence of surface water and fisheries, protecting aquatic resources has not been a primary concern. However, protection measures for riparian and aquatic resources are important precisely because these resources are rare and perennial water bodies on the Grassland hold rare native plains fishes (see *FEIS* Appendix G). Standard mitigation measures control surface erosion, protect groundwater, and ensure the safe use and storage of drilling fluids.

Risks from oil and gas well drilling include the potential for contamination by petroleum products, drilling mud, and other contaminants. Road and drill-pad construction also increases the risk of erosion and sedimentation.

Standard stipulations and procedures are used to protect riparian areas, stream channels, and water quality. The State of Colorado and the Bureau of Land Management drilling regulations require isolation of water-producing zones as wells are drilled and before wells are abandoned.

If exploration discovers economic quantities of oil or gas, a producing field can be developed. Effects from such a field would include more surface disturbance and potential contamination from water and oil brought to the surface.

Alternative H projects a reasonably foreseeable impact of 53.3 acres of disturbance, including 3.5 miles of road on the Grassland and 0 acres on the Forest. All other alternatives project a reasonably foreseeable impact of 73.5 acres of disturbance, including 5 miles of additional roads on the Grassland, and 137 acres, including 30 miles of road, on the Forest; totals are 210.5 acres and 35 miles, as shown in Table 3.26.

Table 3.26 Comparison of Impacts between Alternatives for Reasonably Foreseeable Oil and Gas Development

Alternatives	A	B	C	E	H	I
Acres disturbed	210.5	210.5	210.5	210.5	53.3	210.5
Road miles	35	35	35	35	3.5	35

Effects of Land Use Authorizations for Water Facilities on Aquatic and Riparian Resources

Various laws prior to the Federal Land Policy and Management Act of 1976 (FLPMA) provide for rights-of-way over public lands. The Forest Service has the responsibility for all existing grants and permits located on National Forest System lands, including their administration, amendment, and renewal when authorized and appropriate.

Water developments on the Forest include diversions, storage reservoirs, and augmentation through transbasin diversions from the west slope to the Front Range. Diversions reduce or eliminate downstream flows, which can affect channel size and limit habitat for aquatic and riparian management indicator species. Dams alter flow regimes by storing water during runoff to release later in the year. Both dams and diversions can impose significant barriers to migration and can dewater streams during certain time periods, which fragments aquatic ecosystems. In some cases, altered flow regimes prolong periods of runoff and can enhance riparian vegetation communities.

Dams affect stream channels in different ways depending on their operation. Reservoirs store sediment and release sediment-free water from the dam. As the released water seeks sediment to carry it can downcut or widen the channel below the dam. On the other hand, if water storage reduces peak flows, the result can be the stabilization or reduction of channel capacity.

Transbasin diversions can have spectacular effects on channels. When water is diverted from one basin and released into streams in another basin, waterflow in the receiving basin is greatly augmented. This can cause severe downcutting or widening as the channel adjusts to the increased flows. Failures of both dams and diversions also severely affect aquatic ecosystems.

When they occur, all of these impacts are both local (directly below the reservoir or diversion) and far reaching. Local impacts affect fish, plants, mammals and birds. When combined with the cumulative effects of the many other dams and diversions in the Platte or Colorado River basins, water facilities on the Forest contribute to dewatering downstream of National Forest system lands with adverse effects to threatened and endangered species in the Platte River and Colorado River mainstems.

The *Forest Plan* of 1984 contained provisions to protect aquatic habitats and stream channels. Since 1991, the Forest has been reviewing water-use permits to ensure that aquatic habitats and stream channels are protected and to assess whether the uses were meeting *Forest Plan* standards. Some users have agreed to the concept of resource-protection flows. This *Forest Plan* revision proposes new standards to maintain flow in perennial streams and to restore flow in some impacted streams (*Water Conservation Practices Handbook, FSH 2509.25*, effective 12/26/96). The final standard and design criteria for bypass flows are found at Standard 12.5 (7) of the *WCP*, and prescribe considerably less protection than originally described in the *DEIS*.

The Forest Supervisor has the authority and duty to assure that permits are consistent with the *Forest Plan* and the Endangered Species Act. As permits are amended, renewed, or issued, the Forest will analyze environmental effects and ascertain if mitigation or new terms and conditions are required to meet the proposed *Forest Plan* standards and guidelines and/or the Endangered Species Act. In some cases, analyses and terms will focus on single permits; in others, they will address all permits in the watershed. The degree of effects is currently unknown. While the effects of these projects can be significant, effects are not expected to vary between alternatives for two reasons. First, demand for water-use authorizations is driven by proponents of water development rather than by Forest programs or budgets. Second, many water facilities are operated under perpetual easements or other authorizations that are not subject to environmental mitigation.

CUMULATIVE IMPACTS

Precipitation falls on all parts of a watershed and water flows over and through the soil mantle throughout the watershed on its path to stream channels. Consequently, aquatic resources are influenced by all the activities in the watershed and are an excellent indicator of cumulative effects.

Nearly all activities proposed in the Forest Plan have the potential to affect water resources and indicator species that rely on aquatic and riparian habitats. Activities that disturb the soil surface have the greatest potential, and the risk of adverse effects increases as the disturbance is located nearer stream channels. Watersheds whose function is at risk have been discussed previously (Affected Environment, Surface Water). These watersheds may be near their capacity to assimilate further impacts, or may need positive action to reverse downward trends in watershed condition.

In some cases, events on the Forest can contribute to significant effects far downstream. An example is the effect of water depletions from water development on the Forest. Relatively small depletions (on a basin-wide scale), when combined with many other depletions in the Platte River system, have a substantial effect on the amount and timing of flow in the Platte River in Nebraska and have contributed to the jeopardy of several endangered species.

In other cases, activities off the Forest can contribute to significant effects within Forest boundaries. The urbanization of intermixed private lands within the Forest is one example. Continued development of these lands for residential purposes has the potential to affect aquatic and riparian resources. Increased runoff and sedimentation from roads, roofs, and driveways; increased use of surface and groundwater; increased use of herbicides, pesticides, and fertilizers; and increased recreation uses on adjacent National Forest System lands can all be attributed to urbanization. If activities on intermixed private lands approach tolerance limits for watershed disturbance, additional activities on the Forest may be limited to avoid adverse and cumulative watershed effects.

Cumulative effects to aquatic and riparian resources can be managed best by a three-pronged approach:

1. Applying appropriate watershed conservation practices to all activities and monitoring their effectiveness.

2. Limiting surface disturbance in watersheds and controlling the location of those disturbances so that the ability of the watershed to assimilate effects is not exceeded, riparian values are protected and enhanced, and the viability of aquatic populations is ensured.

3. Scheduling and implementing watershed and aquatic ecosystem rehabilitation measures in those watersheds that may be near or over tolerance levels.

Applying this approach should manage direct effects of existing and proposed management activities so that the overall physical integrity of aquatic and riparian ecosystems, and habitats they provide is not compromised in a cumulative way. The same approach will presumably also reduce the indirect effects of management activities on the biological integrity of these ecosystems. Therefore, biodiversity contributed by these valuable aquatic and riparian habitats should be retained under any of the *Forest Plan* revision alternatives. Alternative H provides for the greatest cumulative retention or enhancement of biodiversity, including the component contributed by aquatic and riparian ecosystems. The remaining alternatives would probably not have significant differences in terms of cumulative effects on biodiversity, because relative to conditions on the Forest as a whole, alternative effects do not vary greatly.

In addition, however, future management of National Forest and Grassland resources must be carried out in cooperation with other agencies. This is key because most Forests and Grassland management focuses on maintenance, protection, or enhancement of *habitats*, rather than the organisms that inhabit them, but the National Forest Management Act also requires maintenance of population viability. Management of *populations* is the role of state and other federal agencies that rely on Forest management of habitats to meet overall viability goals. The most specific example of this is the maintenance of viable native trout populations identified as management indicators. Cooperative recovery efforts, including state control of nonnative stocking and careful management of fishing in refuge streams to protect pure strains of native Colorado River and greenback cutthroat trout, are key to retaining this element of Forest ecosystems. Protection and improvement of habitat for indicator species should be focussed on species and locations judged to be significant by all involved agencies. Successful management of threats to species viability, such as whirling disease, will also rely on joint efforts. Thus, the longterm maintenance of biodiversity in aquatic and riparian ecosystems depends not only on National Forest management but also on other agency actions.