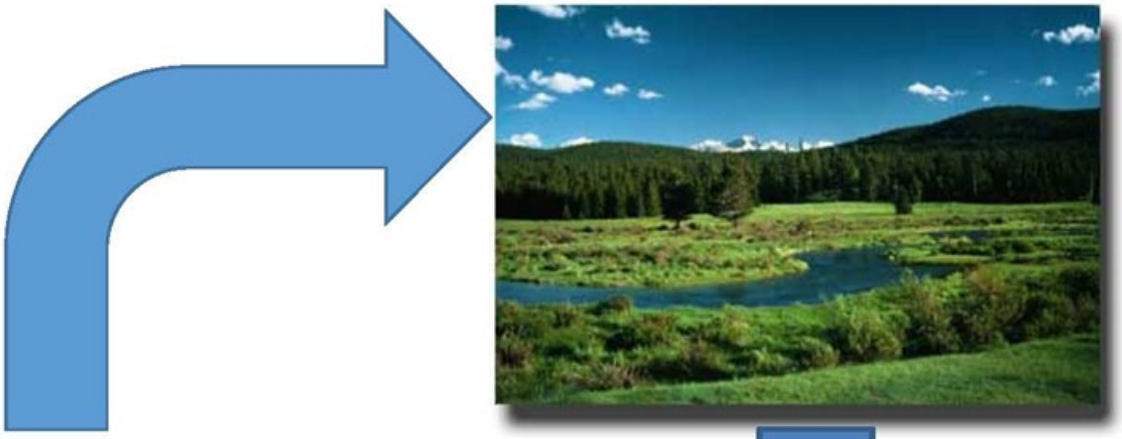
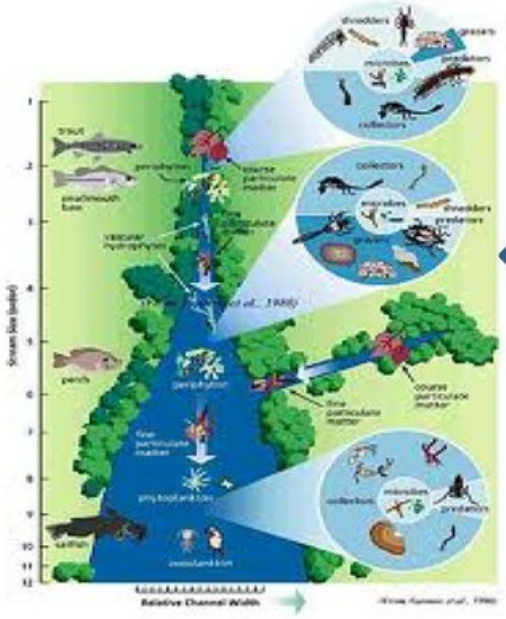
Appendix 1 to Assessments 1 and 3: Aquatic and Semi-aquatic Ecosystems

For The Rio Grande National Forest
Land Management Plan Revision Rocky Mountain Region





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Introduction

The purpose of this document is to provide an understanding of the type and extent of management influences that are considered for this ecological assessment on the Rio Grande National Forest. Consistency is important for this effort because we are addressing influences that can be quantified and compared throughout the study area. Historically, individual administrative units (e.g., National Forests and Districts) have conducted analysis, often in deference to adjacent units. This independent analysis can be cost prohibitive and "inconsistent" within the range of a particular taxa. We chose not to include uncommon activities that should be addressed only at a fine or project scale or an individual basis. The activities we chose are a subset of potential activities that are common and important for ecological form and function (Figure 1). However, the scales we are addressing should help prioritize reach/site level analysis as well as provide valuable information for management decisions at other scales. This document is a companion to the Conceptual Framework and Protocols for Conducting Multiple Scale Aquatic, Riparian and Wetland, Ecological Assessments (Winters et al. 2004) and part of the Species Conservation Project for the Rocky Mountain Region (Region 2).

We believe that the management activities, defined in various use categories, encompass the majority of activities located on the Rio Grande NF. These activities will be addressed individually and in aggregate. The history, positive and negative influences, and measurement criteria will also be documented. The different use categories were identified to start a process of "linking" activities with similar influences on aquatic, riparian, and wetland resources. This is the first step in addressing the additive influences of multiple activities on a particular resource. If other activities are identified at a specific location, they certainly should be evaluated in the context of the multiple-scale assessment process. Therefore this process is a living document and will be modified to include future observations. It is with this understanding that we see this assessment as a dynamic process as part of the Forest Plan Revision process.

The effects of anthropogenic activities on aquatic, riparian, and wetland ecosystems have been identified for several categories of important attributes, including water use, transportation, vegetation management, recreation, mining, biological (e.g. beaver suitability), and land ownership. One example of a specific influence is how railroads modify riparian and wetland function. Development of railroad prisms within the valley bottom could have a pronounced effect on soil movement, subsurface water flow, habitat and vegetation. For each category of effects, the potential influence of that particular anthropogenic activity will be explained. The effects analysis in each chapter discusses effects whether they are arguably direct or indirect.

USE CATEGORY	ACTIVITY
Water Use	Stream Diversions
Water Use	Transmission Ditches
Water Use	Transbasin Diversions
Water Use	Reservoirs
Water Use	Spring Development
Transportation	Roads
Transportation	Trails
Transportation	Off-Road Vehicles
Transportation	Railroads
Recreation	Developed Recreation
Recreation	Dispersed Recreation
Recreation	Ski Area Development

USE CATEGORY	ACTIVITY
Biological	Invasive Species
Biological	Beaver Removal
Biological	Pesticides
Mineral Extraction	Hardrock & Placer Mining
Mineral Extraction	Energy Development
Vegetation Management	Livestock Grazing
Vegetation Management	Large Wild Ungulates
Vegetation Management	Commercial Timber Harvest
Vegetation Management	Natural & Prescribed Fire
Vegetation Management	Tie Drives
Urbanization	Transmission Corridors
Urbanization	Urbanization

Figure 1. Anthropogenic uses identified for Analysis in Region 2. Similar influence groups are color coded. A subset of the most abundant inflences were analyzed.

In order to focus our efforts on the most likely areas for influences on aquatic ecosystems, we concentrated most of our evaluation within the valley bottoms. The geomorphic valley bottom can be described as “that area influenced by lateral and vertical stream migration over time”. Most streams in mountainous areas are located within the confines of steeper uplands (Figure 2). Activities that occur in this area have higher potential for direct and indirect influences on stream and riparian ecosystems. Because the valley bottoms tend to be lower in slope than the surrounding landscape. Historically, there has been a tendency for many management activities to be located in these areas. In particular, wider valley bottoms have a relatively flat, homogenous relief that is economically conducive to development of infrastructure. In addition, in an arid environment, vegetation productivity is increase by the abundance of water near the surface and nutrient deposition from upstream. The substrate in these areas tends to be alluvium deposited by the adjacent stream, which has larger “spaces” between gravels and other substrate to store water. In functioning valley bottoms these areas are often saturated and absorb contaminants from transportation spills and other sources. Directly, the presence of “infrastructure” in the valley bottom can restrict the movement and processes associated with the stream channel as well as maintain a boundary for riparian vegetation to grow and reduce habitat for riparian dependent plants and animals.

While anthropogenic activities in upland habitats can definitely have influences on aquatic systems, we felt that quantifying the anthropogenic influences within the valley bottom should be a higher priority and help prioritize restoration more efficiently than “potential” upland activities.

Figure 2. A mountain stream with limited valley bottom area. The valley bottom is being confined by the adjacent steep topography and large substrate.

Water resources

Stream Diversions

Introduction

Diversions on Forest Service lands in the Rocky Mountains are typically located in small headwater streams, where gravity can easily transport water through gravity downhill. Suitable habitat for aquatic species are often limited in these streams, and are further restricted during the late fall, winter, and early spring months when flows are generally at their lowest and ice cover is present .

Stream diversions can seriously reduce instream habitat and migration for aquatic biota, nutrient transport, sediment movement and water quality (including temperature) (Poff et al. 1997, Wohl, 2001). Water diversions during natural low flow periods can completely dewater streams that directly influence the distribution and abundance of aquatic macroinvertebrates and fishes (Auerbach, et al, 2012).

Figure 3. Small stream diversion in a headwater stream

Indirectly, stream diversions can influence channel geometry downstream. Peak flows during the annual snowmelt runoff maintain stream channel, by moving sediment and scouring the streambed (Wohl, 2000). Reduction of peak flows in low gradient, sinuous stream channels can cause channel narrowing, reduced channel capacity, and less overall instream habitat. A classic example of flow modification and altered stream channel capacity is the Platte River in Nebraska. Once a wide, braided river with numerous sandbars shaped by high snowmelt runoff from the mountain areas to the west, the Platte has narrowed considerably since Euro-American settlement so that it now has many single channel areas and abundant riparian vegetation (Wohl 2001). Physical changes resulting from diversion of high flows also affect the organisms that evolved under the historical conditions.

The degree of influence on aquatic and semi-aquatic ecosystems is dependent on the ecological “change” it produces. Planning for water diversion construction and placement may have had limited ecological technology in the past, but today we have the ability to incorporate ecological sustainability needs while including other demands with modern designs. New designs for diversion structures that allow migration of aquatic biota, and address seasonal and Life-history instream flow needs of aquatic resources, and site location all can lead to a balance between human and resource water needs (Poff, 2007). Modification of existing structures (some in place for decades) can result in benefits to aquatic resources while having minimal influences on existing human uses. While the size of a diversion structure may be relatively small on the landscape, the influence to aquatic, riparian, and wetland resources may be very large if the appropriate issues are not addressed.

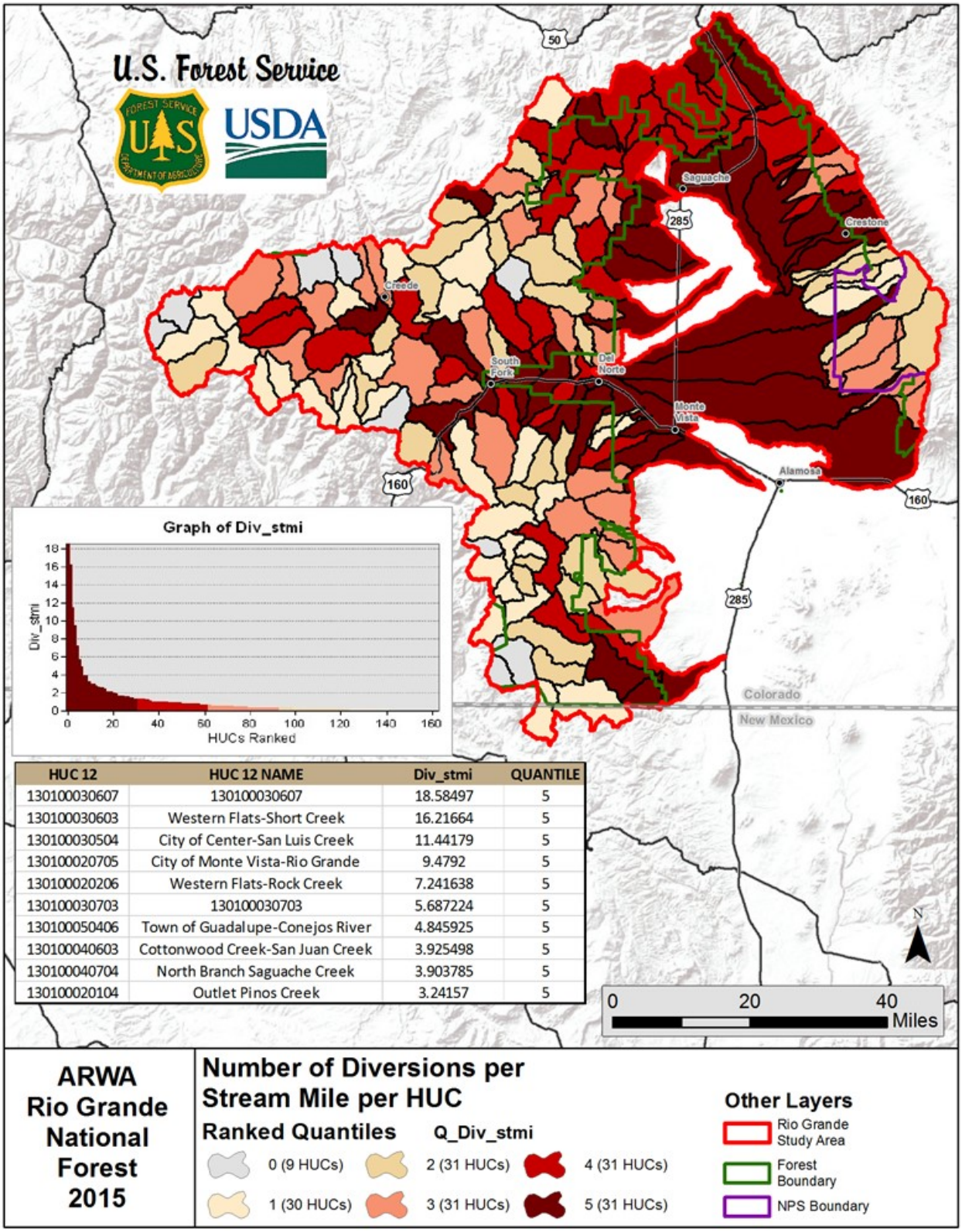
It is our intent to identify the locations and density of diversion structures within each subwatershed as a percentage of stream length. This analysis should help provide information that could prioritize future discussions and analysis at a smaller scale, in terms of fragmentation, water quality and quantity and overall stream health. In addition, it should help define areas where reintroduction of native species as well as manage recreational fisheries would be limited without significant and/or unrealistic change. In concert with the ecological driver analysis, it is an important step in quantifying the relationships between rare/common ecosystems and the influence of physical structures and understanding changes in water quantity. Identification of extremely rare ecosystem types should provide thought on the implications of future development.

Results

The results of the diversion density analysis are presented in Figure 4. Only 7 (4%) of the subwatersheds located totally within the Rio Grande National Forest or the Great Sand Dunes National Park are without diversions, and only 9 within the total study area (including HUC's bisecting the National Forest and National Parks) are without diversions. The diversion densities ranged from 19 to 0 diversions per permanent stream mile, with most of the quantile 5 (highest density) being on both public and private lands (32 total). Most of the subwatersheds with the highest densities were also adjacent to the San Luis Valley floor, where considerable agriculture and subsequent water management occurs. These results indicate that a higher percentage of diversions at this scale are either on private land and/or relatively close to the National Forest boundary.

The lowest density of diversions is associated with the South San Juan, Weminuche and La Garita Wilderness areas. Diversions associated with these wilderness areas most likely predate the Wilderness Act (1964), and/or are on private land outside the National Forest boundary. The 2 subwatersheds in quantile 5 located in the southern portion of the study area are associated are associated with the Conejos River, and agricultural land nearby.

There are 3 subwatersheds that are in quantile 5 that are also located entirely within the National Forest boundary. The Conejos River travels through one in the southern portion of the study area where most of the adjacent land is either private or administered by the Bureau of Land Management. Another of these subwatersheds is located just south west of the town of Creed, and contains a large flat area called Seven Parks. There is also considerable private land adjacent to the Rio Grande River where diversions for hay meadow watering in particular are occurring. There are most likely miscellaneous diversions for livestock, recreation and some human use within this area as well. The last subwatershed in quantile 5 is located in the northern portion of the National Forest. There is little private land in this area, with only small headwater streams present. The area does not appear to be used for agriculture, but numerous unpaved roads are located here. Further information is needed to understand why this area in particular falls into this group.



HUC 12	HUC 12 NAME	Div_stmi	QUANTILE
130100030607	130100030607	18.58497	5
130100030603	Western Flats-Short Creek	16.21664	5
130100030504	City of Center-San Luis Creek	11.44179	5
130100020705	City of Monte Vista-Rio Grande	9.4792	5
130100020206	Western Flats-Rock Creek	7.241638	5
130100030703	130100030703	5.687224	5
130100050406	Town of Guadalupe-Conejos River	4.845925	5
130100040603	Cottonwood Creek-San Juan Creek	3.925498	5
130100040704	North Branch Saguache Creek	3.903785	5
130100020104	Outlet Pinos Creek	3.24157	5

Figure 4. Results of the diversion density (#/stream mile/subwatershed) analysis. Names and values with the 10 highest values (quantile 5) are also presented.

Future Considerations:

Considerable diversion activity is present throughout the Rio Grande basin, most of it being associated with the San Luis Valley floor and current agriculture. Densities of diversions within Quantile 5 are generally quite high, with 4 subwatersheds containing more than 9 structures per mile of stream. The abundance of these structures would most likely limit movement and habitat of fish adapted to the lower elevation such as the Rio Grande Sucker and chub.

Quantile 4 subwatersheds average less than 2 diversions per stream mile, and are probably not evenly distributed; leaving connected habitat sufficient to support populations of fish and other aquatic organisms, if stream flows and associated water quality are adequate. Structures that allow organism passage at these structures would ensure ecological connectivity for relatively long distances, while areas with high densities would require considerably more reduction or combining of structures and addressing instream flow options.

While this assessment focuses on understanding the large scale factors that influence ecological conditions and influences that European settlers have had on the Rio Grande National Forest and surrounding landscape, we felt it was important to incorporate previous findings that have influenced the distribution and status of native aquatic species that are and will be of management concerns. Alves et al (2008) conducted an extensive assessment of Rio Grande cutthroat trout (Oncorhynchus clarki virginalis), a subspecies of cutthroat trout that is native to the study area. Their results concluded that historical populations inhabited mainstream habitats as low as 6000 feet in elevation. By 2008, the lowest elevation of inhabited streams was estimated to be approximately 7500 feet, and 11% of historic habitat was occupied in the upper Rio Grande River basin. There were several factors identified for the reduction in occupied habitat. The cumulative influences from numerous past and current actions will most likely limit the restoration of Rio Grande cutthroat trout to higher elevation, smaller streams and lakes. Working cooperatively with private and public water and private diversion owners could increase effective connected habitat by modifying existing structures to allow passage, design new structures to do the same, and negotiate stream releases to benefit identified important habitats rather than eliminating them from consideration. The success of the USDA Forest Service to modify road crossings of streams to improve connectivity has been highly successful, resulting in thousands of miles of streams allowing fish and other organisms to move to different habitats. The limited number of subwatersheds without artificial barriers could be used as examples of connected habitat where longitudinal aquatic processes continue and native species restored.

Impoundments

Introduction

Reservoirs have been constructed in the Rocky Mountains for recreation, power generation, snow making, agriculture and flood control. The predominant use for reservoirs has been for agriculture and municipal consumption (Wohl 2000). Reservoirs were constructed as early as the mid-1800s to help facilitate the timing of downstream flows to coordinate with the agricultural growing season in the Rio Grande Valley. While we consider impoundments to be within the overall “Water Use” category with diversions, they differ by storing water upstream of a dam. Water quality conditions can be considerably different downstream of a reservoir than diversions where no significant storage of water occurs.

Much of the surface water in the Rocky Mountains comes from annual snowmelt runoff from mountain areas. Consequently, large volumes of water are produced in the late spring and summer months, whereas flows are minimal (e.g., baseflow) during the remainder of the year (Wohl 2000). There is a relatively short period of time that ‘excess’ water is available in the stream system, while demand for this water

extends throughout different times of the year. The construction of reservoirs and subsequent water storage allows for a more “controlled environment”, where water can be stored and released to meet the demands of downstream users. Reservoir construction is being considered one of many alternatives to current and future water needs as populations in Colorado increase and more water is needed for municipal use. Reservoirs were constructed west of the Continental Divide to meet local municipal and agricultural needs, but many reservoirs have been built to store water that is subsequently transferred east of the Divide via transbasin diversion structures. This has not been the case in the Rio Grande Valley, where agreements and policies have maintained water within the Upper Basin.

Figure 5. A reservoir in the Colorado Rockies. Note the level of water compared to the high water line

Reservoirs can have both beneficial and detrimental effects on aquatic, riparian, and wetland resources. Dams clearly have an immediate influence on local conditions, and can influence resources many miles in either direction. The most noticeable influence of dams is the water that is accumulated behind it for release at appropriate times as well as for recreational purposes. These artificial lakes inundate historic riparian or wetland areas and create a new and different environment. Animal diversity can be increased or decreased, depending on the system. For example, stream aquatic invertebrate and algae communities are replaced with Lake Benthos, zooplankton, and phytoplankton. While many salmonids can exist in reservoirs, some fish species cannot tolerate the conditions found in standing water (Baxter and Stone 1995).

While some native species of plants and animals may not be able to tolerate the conditions created by reservoirs, some non-native species may thrive under those conditions, resulting in competition and/or replacement of native species. However, they are typically replaced with popular non-native recreationally valuable species, as well as other recreational activities. Many reservoirs in the Rocky Mountains are now dominated by non-native species of fish, while the dam forms a barrier for upstream migration, and is often used as the downstream extent of native fish recovery efforts. While many non-native species were planted to increase recreational opportunities, several, including the common carp (Cyprinus carpio) are undesirable in many areas (Baxter and Stone 1995). The influence of other non-native species, such as crayfish (Decapoda), mollusks (Mollusca), and bullfrogs (Rana catesbeiana) may also be significant.

Dams create barriers to migration of aquatic organisms (Ward and Stanford 1982). Populations of fish and other aquatic biota can be isolated upstream of reservoirs, limiting gene flow and potentially affecting population viability. In addition, the inability of fish to migrate upstream of a dam can limit their ability to

reach critical spawning habitat. Overall, dams can severely fragment populations of mobile aquatic organisms, effectively creating a series of isolated communities.

The negative effects of reservoirs on downstream water quality are well documented (Wohl 2001; Allen 1995; Ward and Stanford 1982; Hynes 1970). In addition, the disruption of the nutrient, sediment, and woody debris transport can influence conditions downstream. For example, reservoirs act as nutrient and sediment 'sinks', limiting the downstream transport of these materials (Ward and Stanford 1982). When sediment is sequestered in reservoirs, downstream stream reaches may begin to erode their banks and scour their channels. Reservoirs also trap large woody debris, which keeps them from reaching downstream stream segments where they would normally influence channel and riparian form and function (Maser and Sedell 1994).

Dam structure and operating practices also affect downstream processes. The temperature and nutrient content of water exiting reservoirs may depend on whether water is released from the bottom or top of the dam. These effects can be dramatic, and algae, benthic macroinvertebrate, and fish communities can be altered significantly (Maser and Sedell 1994). Bottom release reservoirs can increase trout production in reaches downstream from reservoir dams because temperature fluctuations are stabilized and food supply increases. However, erratic flows, gas supersaturation, and reduced spawning success due to low water temperatures can sometimes counteract the positive influences.

Management Implications

Reservoirs have been a valuable tool for managing the quantity of water needed for domestic and agricultural purposes downstream use. As the population increases along the Front Range of the Rocky Mountains, more interest is going to be shown for developing water within the National Forest boundaries.

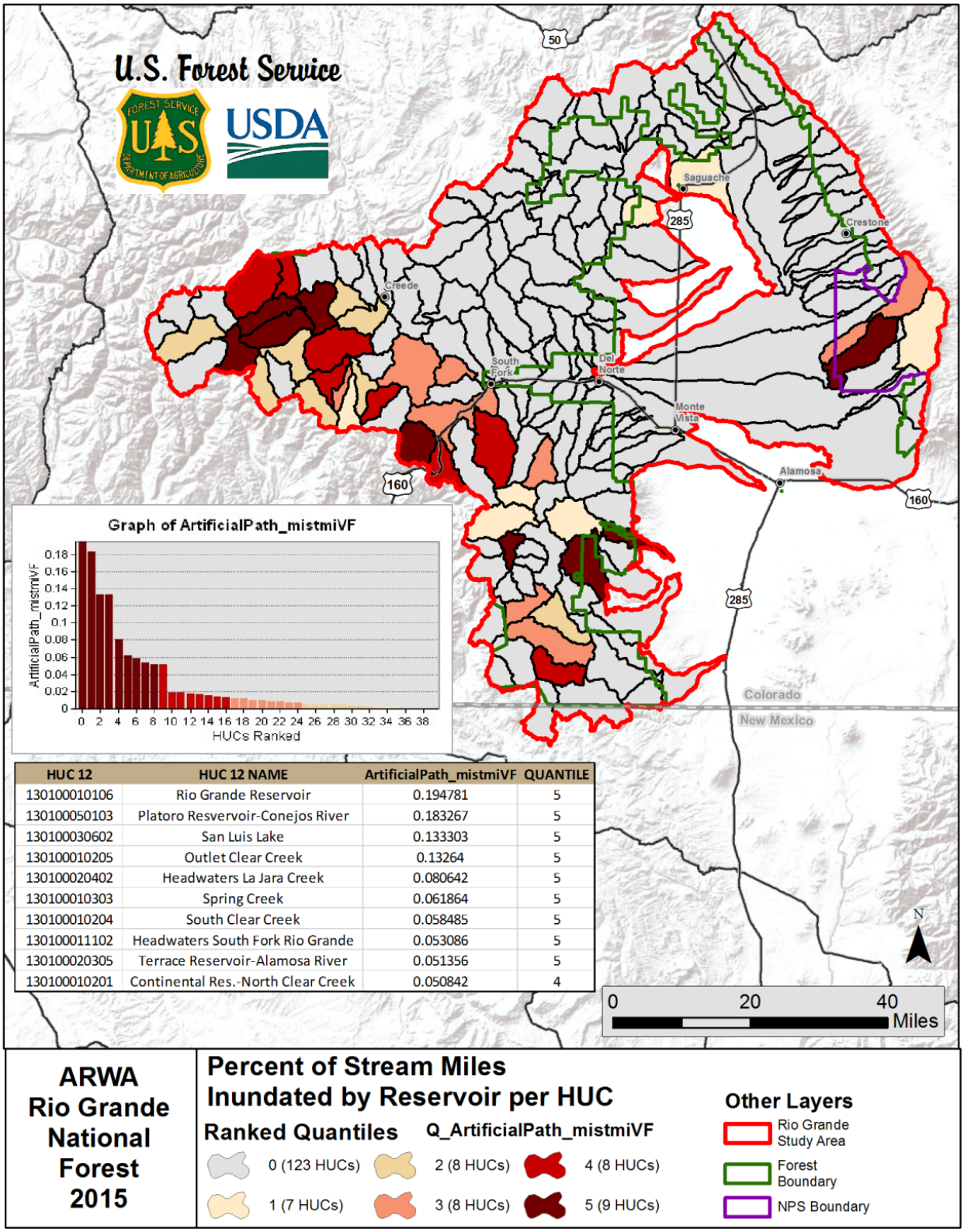
Because reservoirs can influence a wide variety of aquatic, riparian, and wetland resources, both at the reservoir site and upstream and downstream, special attention is made when addressing future reservoir construction. While building new reservoirs is expensive, there is some interest in increasing the size of existing structures, in order to facilitate flow modifications throughout the year. In order to assess the effects of new or modified reservoir construction, a full knowledge of the implications to aquatic, riparian, and wetland resources in and outside of the project area should be conducted. Adjusting reservoir releases can maintain or potentially improve ecological conditions downstream by maintaining/improving temperatures, "mimicking" the natural hydrograph and increasing nutrient releases. However, severe fluctuations within the reservoir can limit primary productivity and ultimately fish populations.

Results

The inundated stream length ratio for reservoirs is presented in Figure 6. The results indicate that throughout the upper Rio Grande basin reservoirs, inundate relatively little of the total permanent stream length within the identified subwatersheds, and are heavily influenced by the few large reservoirs in the study area. The range of densities was 0 to 0.2 miles of stream inundated for the total stream miles within each subwatershed. Small impoundments were not calculated for this analysis (such as stock ponds), mainly because they are located on intermittent streams.

The map presented is deceiving because of the scale used. It would appear that there are abundant reservoirs within wilderness areas, as well as other high elevation areas of the National Forest. However, reservoirs such as Rio Grande, Platoro and San Luis Reservoir are not associated with wilderness areas. It would appear that past reservoir construction in the study area was conducted at mid-elevations or higher, following a relatively consistent elevation across the western portion of the Rio Grande National Forest.

Several reservoirs such as Big Meadows Reservoir and several smaller reservoirs are within the National Forest boundary. The distance downstream of the reservoirs that are influenced by modified water quality and quantity were not quantified as considerable site/reach information would be necessary.



HUC 12	HUC 12 NAME	ArtificialPath_mistmiVF	QUANTILE
130100010106	Rio Grande Reservoir	0.194781	5
130100050103	Platoro Resvervoir-Conejos River	0.183267	5
130100030602	San Luis Lake	0.133303	5
130100010205	Outlet Clear Creek	0.13264	5
130100020402	Headwaters La Jara Creek	0.080642	5
130100010303	Spring Creek	0.061864	5
130100010204	South Clear Creek	0.058485	5
130100011102	Headwaters South Fork Rio Grande	0.053086	5
130100020305	Terrace Reservoir-Alamosa River	0.051356	5
130100010201	Continental Res.-North Clear Creek	0.050842	4

Figure 6. Results of the reservoir analysis for the Rio Grande national Forest and surrounding ecosystem

Management Considerations

Current reservoir locations and abundance do not appear to be "widespread" influences across the Rio Grande National Forest. While individual smaller reservoirs can be impactive in a localized area, they can also serve as barriers for recovering native fish upstream. The presence of a dam acts as a barrier for non-native fish movement upstream, and the reservoir pool can maintain a "stabile" environment for native fish.

In the future, there may be proposals to increase the size of existing reservoirs on National Forest managed lands. While surface area of modified reservoirs could become larger and inundate more public land, the potential to modify discharge rates to include ecological needs could improve riparian and aquatic form and function. In addition, recreational fishing opportunities at lower elevations could be increased if release flows were identified to maintain appropriate temperature and seasonal flows.

Trans Basin Diversions

Introduction

Transbasin diversions can have impacts similar to other diversion structures. In addition, they add 'new water' to the receiving basin and remove water from a different basin. Transbasin diversions can facilitate the invasion of non-native fish and other non-desirable species of plants and animals can enter a system where they can replace native species. Behnke (1979) found that several sub-species of cutthroat trout have been transported into other river basins where they would not normally occur. These introduced cutthroat trout subsequently hybridized with the native sub-species of cutthroat trout, leading to a loss of genetic diversity in native populations.

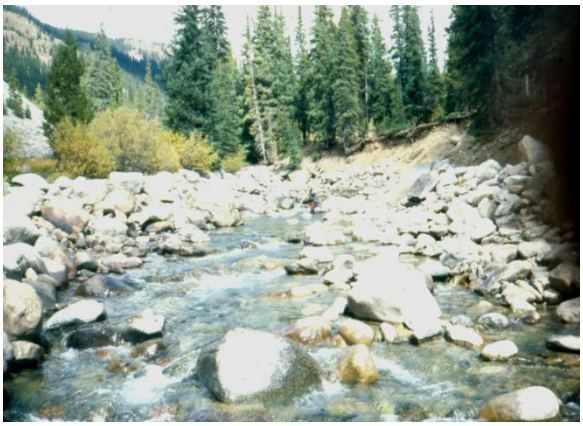


Figure 7. stream section upstream of a transbasin diversion. Bank stability is high and stream channel is stable.

Figure 8. Directly downstream of transbasin diversion associated with picture 4. Note the poor and unstable stream banks, and over wide channel

The diversion and transport of water from one watershed to another can result in physical, chemical, and biological changes to the receiving water body. For example, these activities can cause channel erosion, increased sediment transport, and deposition in reservoirs and channels. When the natural flow pattern of the receiving stream is altered, the ability to move stream channel material also changes (Wohl 2000). Relatively steep, step-pool streams with large substrate may not be significantly affected by increased discharge, but serious channel changes can occur if the volume of water released into the new system

regardless of stream type (picture 5) (Wohl 2001). Affected streams often exhibit elevated bank erosion, increased width-depth ratios, downcutting, and a habitat for aquatic organisms. Since these low gradient stream reaches tend to be the most productive reaches for aquatic organisms in Rocky Mountain streams, water augmentation from transbasin diversions can have a dramatic effect on stream biota. Moreover, chemical and microbiological contamination can result from transbasin water transport. Other elements of transbasin diversions effects are specifically addressed in the Water Use section under Stream Diversions.

Management Implications

Transbasin diversion projects are used to transport water for human use to areas with inadequate supplies in other parts of the landscape. While tunnels are sometimes used that avoids impacts to receiving streams, they are expensive and ditches are commonly used to move water from one stream to another. This last method is a cost effective way of transporting water, with gravity doing most of the work. However, ecological impacts can degrade large distances of the receiving stream.

While removing water from one subwatershed can have impacts of stream flows and associated habitat, tributaries downstream can help improve conditions at lower elevations. However, the receiving streams often exhibit multiple major influences much farther downstream. In order to adjust to the significant changes in water augmentation major stream channel modification downstream of the import source is necessary so massive erosion does not occur and instream channel integrity is not compromised.

Results

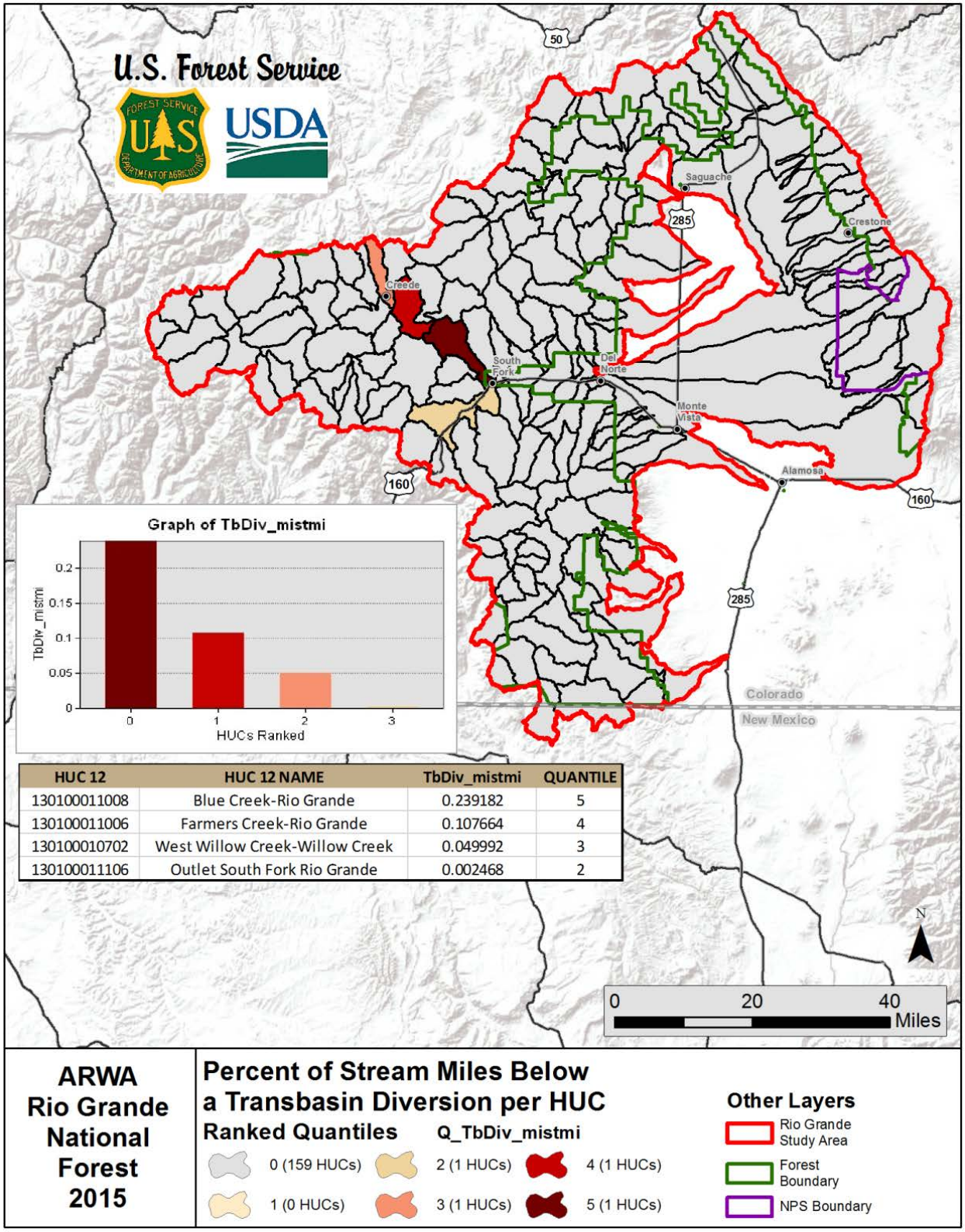
There are very few tranbasin (based on subwatersheds) within the Rio Grande study area (Figure 9). All of the diversions are within the upper Rio Grande River basin. As a result, species that have evolved in other basins could have been inadvertently transferred. The upper most subwatershed, West Willow Creek is diverted into the Farmers Creek sub basin. While Willow Creek exhibits modified stream flows, the receiving portion of Farmers Creek would be expected to be influenced from increased stream flows, as well as reduced flows at diversions into the Blue Creek subwatershed. The Blue Creek subwatershed also receives and diverts flows into the outlet of the South Fork of the Rio Grande River.

The Blue Creek and Farmers Creek subwatersheds would be expected to have the most influences from these series of diversions as they have the highest ratio of transbasin activity, plus water is received as well as diverted within their boundaries.

Future Considerations

The Rio Grande study area has only one system of transbasin diversions. These diversion systems comprise a relatively small percentage of the permanent stream systems within their boundaries (the largest being 23% of the total permanent stream length). However, as these systems can produce significant amounts of sediment downstream as a result of erosion, they could have considerably more sediment depositing downstream.

Fortunately there are no transbasin diversions from other river basins that could transfer unwanted species (including pathogens) and very different water chemistry and discharge into the Rio Grande system. In the future, trans basin projects identified within as well as outside the Rio Grande River system should consider the major biological and physical changes that can occur when they are implemented. Mitigation for these types of projects is extremely expensive to mitigate the effects of especially changes within receiving streams.



HUC 12	HUC 12 NAME	TbDiv_mistmi	QUANTILE
130100011008	Blue Creek-Rio Grande	0.239182	5
130100011006	Farmers Creek-Rio Grande	0.107664	4
130100010702	West Willow Creek-Willow Creek	0.049992	3
130100011106	Outlet South Fork Rio Grande	0.002468	2

Figure 9. Only 4 subwatersheds are influenced by tranbasin diversions.

Spring Developments

Introduction

Across the Rocky Mountain landscape (both in the plains and mountains) ground-water fed springs and associated wetlands are scattered in isolated locations (Winter et al. 1998). The Rocky Mountains and associated grasslands are located in an arid to semi-arid landscape, with low total annual rainfall and high annual rainfall variability (Wohl 2001), resulting in few conditions conducive to spring development. As the number of settlers and domestic cattle increased in the 1800s and 1900s, the capturing of water associated with springs became common, especially since many of these water sources were a considerable distance from streams. The water coming from springs often was and still is concentrated through pipes to watering tanks, or ponded for watering sources for livestock. Early settlers also capitalized on this relatively constant water source for drinking water.

Springs and associated wetlands provide unique and dramatic habitats on a relatively arid landscape in the Rocky Mountain region. The biodiversity in these specialized habitats is very high, as a result of the hydrologic, soil, and microclimatic conditions associated with them (Cooper 1986). The vegetation of springs may be dominated by mosses, herbaceous plants, woody plants, combinations of all of these groups, and likely the variability from site to site is extremely high. Most plants that occur at springs are highly sensitive to water chemistry changes, and stabile discharge. Many rare forms of invertebrates and amphibians also inhabit these environments because of the constant water temperatures, abundant food supplies and general lack of predators (Hammerson 1986).

The direct impacts to springs and associated wetlands from development are primarily due to altering the hydrologic regime that formed the spring discharge, and also the habitat affected by the flowing water. Once the springs are developed, they lose their unique characteristics, and may revert to upland conditions, and associated taxa are lost. Even when ponded, the hydrology and nutrient cycling capabilities of the system are altered dramatically, resulting in habitat no longer supportive of the communities that evolved there. Indirectly, the concentration of domestic livestock at these watering places can alter the biological communities there by intensive grazing activity, soil compaction, and the addition of nutrients.

Management Implications

Historically springs have commonly been used for watering of domestic livestock and human consumption. However, the consequences to biodiversity and species viability are only now being realized. Although opportunities in the past have been limited to procure water from other sources, we now have the ability to weigh the consequences and balance the need for development and maintain the viability of these rare ecosystems. Alternative water sources such as wells or slightly changing grazing strategies can restore spring and wetland function. However, in wetlands that have taken thousands of years to develop, such as fens, irreparable damage may have already been realized. Identification of new water sources and protecting existing spring environments are imperative if rare species of flora and fauna are to be protected.

Results

There was not a thorough source of data to analyze the location of springs across the study area and/or the percentage that have been modified by management. Springs in the arid west have historically been developed for various human and agricultural purposes. While these ground water driven ecosystems are uncommon and often contain rare and unique flora and fauna, there has been little study of these systems to understand their importance from a biodiversity and water quality standpoint. In addition, if climate change predictions of less water and stability in aquatic systems, spring discharge are a very important

source of water with high water quality (in most cases) and consistent temperatures. The area associated with the Sangre de Cristo range could be a valuable source of springs as relatively high amounts of calcareous bedrock is located here. The limestone found here and adjacent valley bottoms are dissolved by water, allowing water that percolated through the substratum to reach the ground surface. Several of the stabile populations of native fish in the upper Rio Grande Basin are found in streams and large springs in this area, indicating a link between their persistence and the characteristics of spring influence.

Additive results for the Water Category:

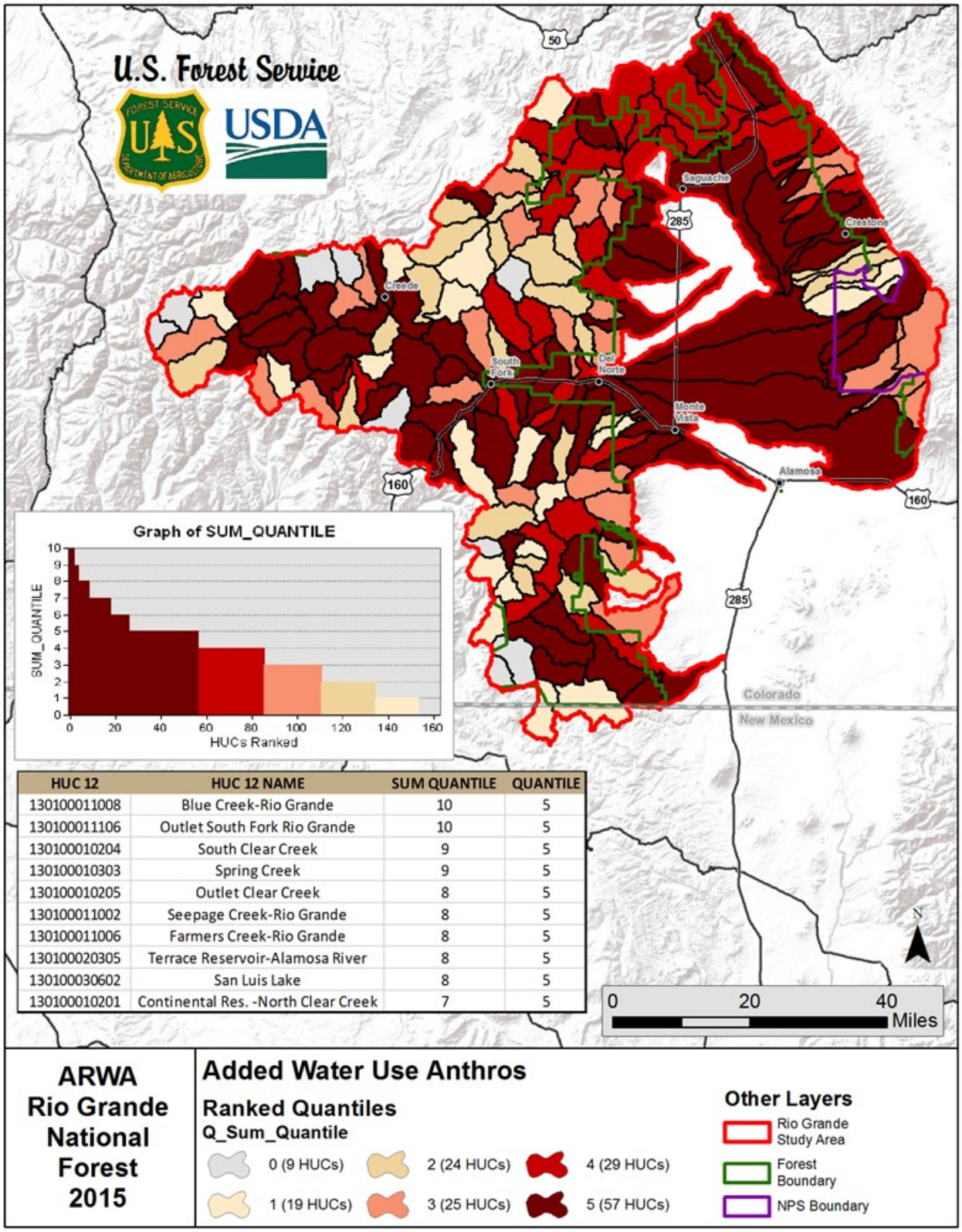
Ranks for each water use category were added to provide an overall additive rank of the water uses in the study area. While this could be considered to be a "cumulative" approach to water uses within the upper Rio Grande basin, we chose to use the additive term as a more accurate measure of abundance. While the finer scale influences on aquatic, riparian and wetland ecosystems have been well documented from past activities (See in part Wohl, 2001), our results should aid in identifying areas that could be focused on to understand the fine scale additive influences of water management in the study area.

Management Implications

The additive category represents the subwatersheds with various relative values of rank for water related management activities. These values can be used to identify priority subwatersheds for restoration, and or protection. With relatively few subwatersheds manage med for water related resources, the few that do not contain these activities could be used for native fish and other aquatic animal management, controls for monitoring ecosystem function within previously identified clusters of similar ecological function as well as other values.

Results

The results for the additive analysis for water resources are presented in Figure 10. There were a total of 28 subwatersheds with little to no water management (0 and quantile 1) that we quantified. These subwatersheds are relatively uncommon as 86 subwatersheds were within the 2 highest quantiles (4 and 5). In the 2 quantiles with intermediate values (quantiles 2 and 3), there were 49 subwatersheds. These results indicate that there are considerably more additive water management activity influences within the upper Rio Grande basin than moderate activities and between 3 and 4 times as many subwatersheds with little to no identified water activities when looked at in an additive analysis. While it would be intuitive to think that subwatersheds with no water management would be in wilderness areas, that is not the case. Three of the 4 subwatersheds Identified in the far western portion of the National Forest are not within wilderness areas. One subwatershed is isolated north of the town of South Fork. The highest ranks were mostly associated with the Rio Grande and South Fork pf the Rio Grande Rivers, San Luis Creek in the northern part of the Forest, the Conejos River in the far southern portion of the National Forest and especially near the town of Alamosa.



HUC 12	HUC 12 NAME	SUM QUANTILE	QUANTILE
130100011008	Blue Creek-Rio Grande	10	5
130100011106	Outlet South Fork Rio Grande	10	5
130100010204	South Clear Creek	9	5
130100010303	Spring Creek	9	5
130100010205	Outlet Clear Creek	8	5
130100011002	Seepage Creek-Rio Grande	8	5
130100011006	Farmers Creek-Rio Grande	8	5
130100020305	Terrace Reservoir-Alamosa River	8	5
130100030602	San Luis Lake	8	5
130100010201	Continental Res. -North Clear Creek	7	5

Figure 10. Additive ranks for the water management activities. Distribution of the ranked quantiles was considerably more than subwatersheds with few or no activities.

Management Considerations

The Rio Grande National Forest includes subwatersheds with limited areas of water management related activities. These results would indicate that the public lands, especially at higher elevations contain less fragmented stream reaches and more intact conditions for a variety of ecological purposes. Alves et al (2008) identified most of these areas as priorities for conservation populations of Rio Grande cutthroat trout as well as future recovery areas. Unfortunately, fish at lower elevations, including the Rio Grande sucker and chub face much more fragmented and water restricted habitats. Portions of subwatersheds at lower elevations on public lands, especially north of Del Norte and South Fork could be areas to evaluate if water and habitat are adequate and other anthropogenic activities are not severely limiting.

Understanding the distribution and additive amount of water management activities could help managers and stake holders identify where future projects may be located without impacting relatively unimpeached systems. The subwatersheds with high concentrations of development would most likely not witness severe ecological impacts as they are already highly modified.

Transportation

Roads

Introduction

Interstate and intrastate road networks (state and federal ownership, etc.) throughout the United States are a fairly recent phenomenon because motorized vehicles (cars and trucks) are a relatively new technology compared to horse-drawn wagons, trains, etc. In 1919, Lt. Colonel Dwight D. Eisenhower (later to become President Eisenhower) volunteered to join the U.S. Army's first transcontinental motor convoy from coast to coast (Weingroff 1996). The convoy originated in Washington, D.C., and after 62 days in transit, arrived in San Francisco on 5 September 1919. Many of the unrelenting and hazardous trials of the journey (mud, dust mechanical failures, etc.) can be directly attributed to the poor road conditions (extant wagon roads or pioneered roads) that were encountered during what must have been, two exhausting months of travel.

Statistics published by the Federal Highway Administration (Highway Statistics 2000; Public Road Length 1999) indicate that the nation's transportation network has expanded dramatically since the initial mass production of the Model T. In 1919, there was no national transportation network, with the exception of the railways. Eighty years later, the nation had constructed more than three million miles of rural road (this number does not include urban road miles). For example, by 1999, the state of Colorado had constructed 70,948 miles of rural roads, 51,875 miles of which were county roads. By comparison, the miles of rural roads under federal jurisdiction in Colorado in 1999 totaled 7,299. Now, the nation's road networks, both rural and urban, serve as conduits to transport a vast number of people, goods, and services. Clearly, expansion of the nation's road networks has had profound impacts on ecosystems and biotic communities.

Beneficial and detrimental effects of roads on environmental conditions (aquatic and wetland) have been debated among the public, natural resource scientists, natural resource land managers, and civil engineers. On one hand, the presence of roads has provided direct access to once remote locations so that natural resource managers are able to collect data and to implement restorative projects to protect, maintain, and enhance populations and habitats of aquatic and wetland biota. On the other hand, roads can profoundly contribute to the diminution and degradation of native aquatic and wetland ecosystems by altering natural drainage area (photo 6). In addition, roads have facilitated the consumptive use and in some cases,

extirpation, of indigenous plants and animals by human beings. The degree to which a road or road system will negatively affect environmental conditions is strongly associated with several critical factors such as road design, road placement, road-construction practices, road use, and road maintenance. Ironically, it is often difficult to reconcile the necessities of roads with their potential and actual negative impacts on aquatic and wetland ecosystems.

Figure 11. The Poudre River in northern Colorado is a good example of a paved road that limits the rivers ability to migrate laterally, move sediment onto its flood plain and absorb energy from floods.

Figure 12. An unpaved road crossing with limited ability to pass high flows.

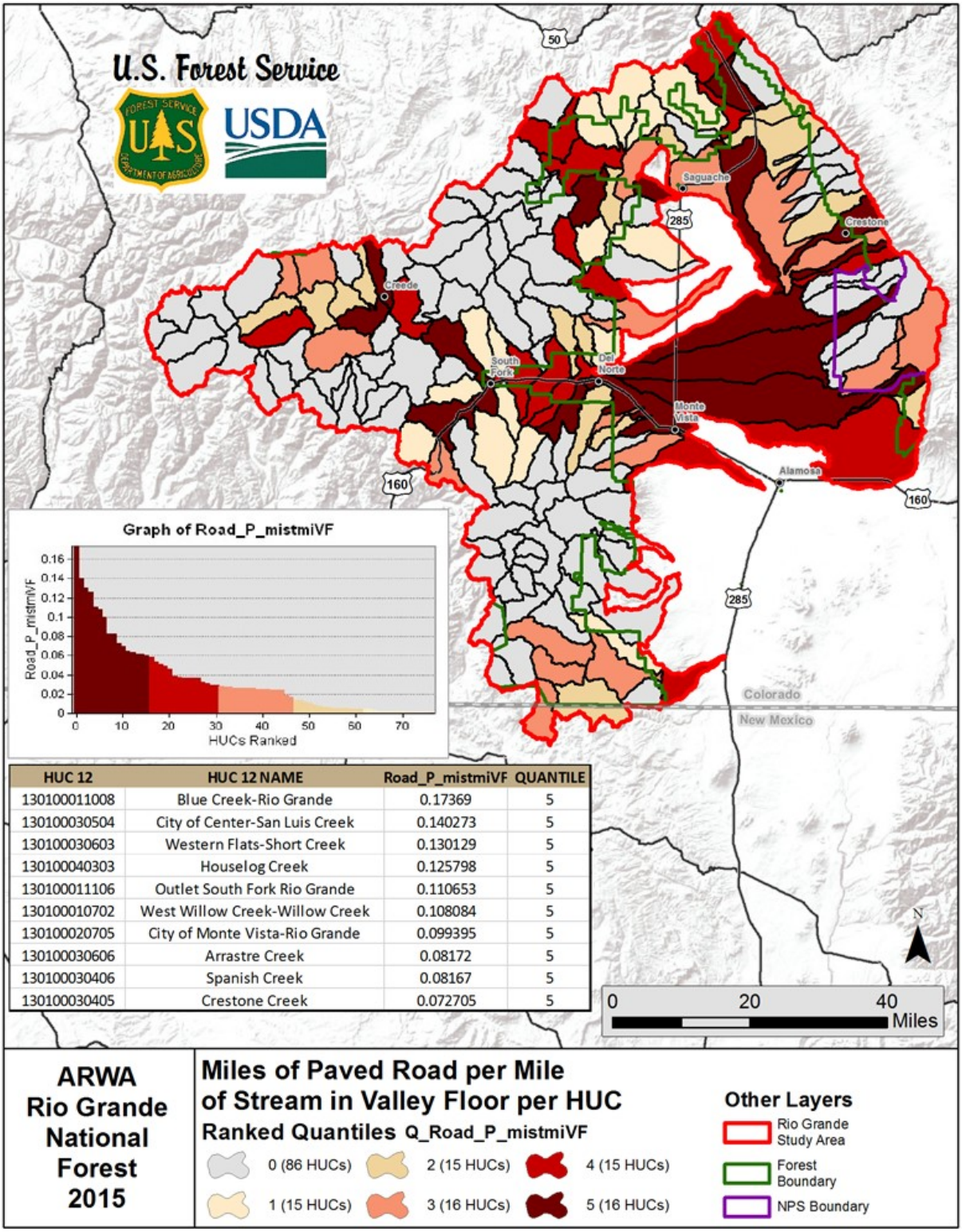
Management Implications

Roads are widespread and permanent features of National Forest lands. Roads and road networks under Forest Service jurisdiction can be managed to reduce or eliminate (in some cases) negative impacts to aquatic, riparian, and wetland ecosystems. The benefits that accrue to aquatic and wetland ecosystems by correctly designing, constructing, and maintaining roads in the National Forests are many. Properly designed, constructed, and maintained roads offer the following benefits to streams, riparian areas, and wetlands: reduction in soil erosion and sedimentation; reduction in soil compaction; reduction in chemical contaminations of soil and water; maintain water quality conditions conducive to supporting aquatic life; maintain nutrient cycling in lotic and lentic environments; support the abundance of riparian and wetland plant communities; and promoting many additional benefits to stream, riparian, and wetland environments. As the population in the United States ages and increases, there will be an increased demand by some Forest users for additional roads to access the National Forests. In addition, there will always be unwanted, illegal, user-created roads that must be managed or removed. Considering the likely future increase in demand for roads and the finite amount of the National Forest land, the probability of incurring additional resource damage and destruction to aquatic, riparian, and wetland ecosystems is relatively high. Appropriate road and travel management will be necessary, and include restricting the growth in motorized use and removing any class of unwanted road.

Paved Roads Density Results

The results of the paved road density analysis within the valley bottoms are presented in Figure 13. There are far more subwatersheds were identified with no paved roads identified in valley bottoms (86) than all the other quantile values combined (77). Paved roads are restricted to highways bisecting the Rio Grande Valley, both north to south and east to west. Along these routes are the main towns in the valley. Other paved state and county roads are located on the San Luis Valley floor, there are relatively few on the Rio

Grande National Forest. The highest density of paved roads in this exercise was 0.17 miles per stream miles within the Blue Creek subwatershed.



HUC 12	HUC 12 NAME	Road_P_mistmiVF	QUANTILE
130100011008	Blue Creek-Rio Grande	0.17369	5
130100030504	City of Center-San Luis Creek	0.140273	5
130100030603	Western Flats-Short Creek	0.130129	5
130100040303	Houselog Creek	0.125798	5
130100011106	Outlet South Fork Rio Grande	0.110653	5
130100010702	West Willow Creek-Willow Creek	0.108084	5
130100020705	City of Monte Vista-Rio Grande	0.099395	5
130100030606	Arrastre Creek	0.08172	5
130100030406	Spanish Creek	0.08167	5
130100030405	Crestone Creek	0.072705	5

Figure 13. Paved road density for the upper Rio Grande River basin. Relatively few paved roads exist here as compared to more populated parts of the Colorado front range (Winters, et al., unpublished assessment results.

Management Considerations:

Paved roads are designed primarily to withstand more traffic than unpaved roads. As populations in the country increase and more vehicle traffic occurs, there will be most likely more demand for paved roads. When future proposals are made to pave roads as well as build new ones on the Rio Grande National forest, there could be consideration to build roads outside of the valley bottoms. By doing so, the risk of flooding, spills into stream systems, and interactions would be dramatically reduced. While there are obviously short-term cost savings in constructions, longer-term costs with rebuilding and maintenance could be lessened. If paved roads are built in valley bottoms, they could be located as far from riparian areas as is feasible, and also in a way to drain riparian areas, absorb and pass floods without damage, limit contaminants and allow riparian habitat to function with streams.

Paved Road Crossings:

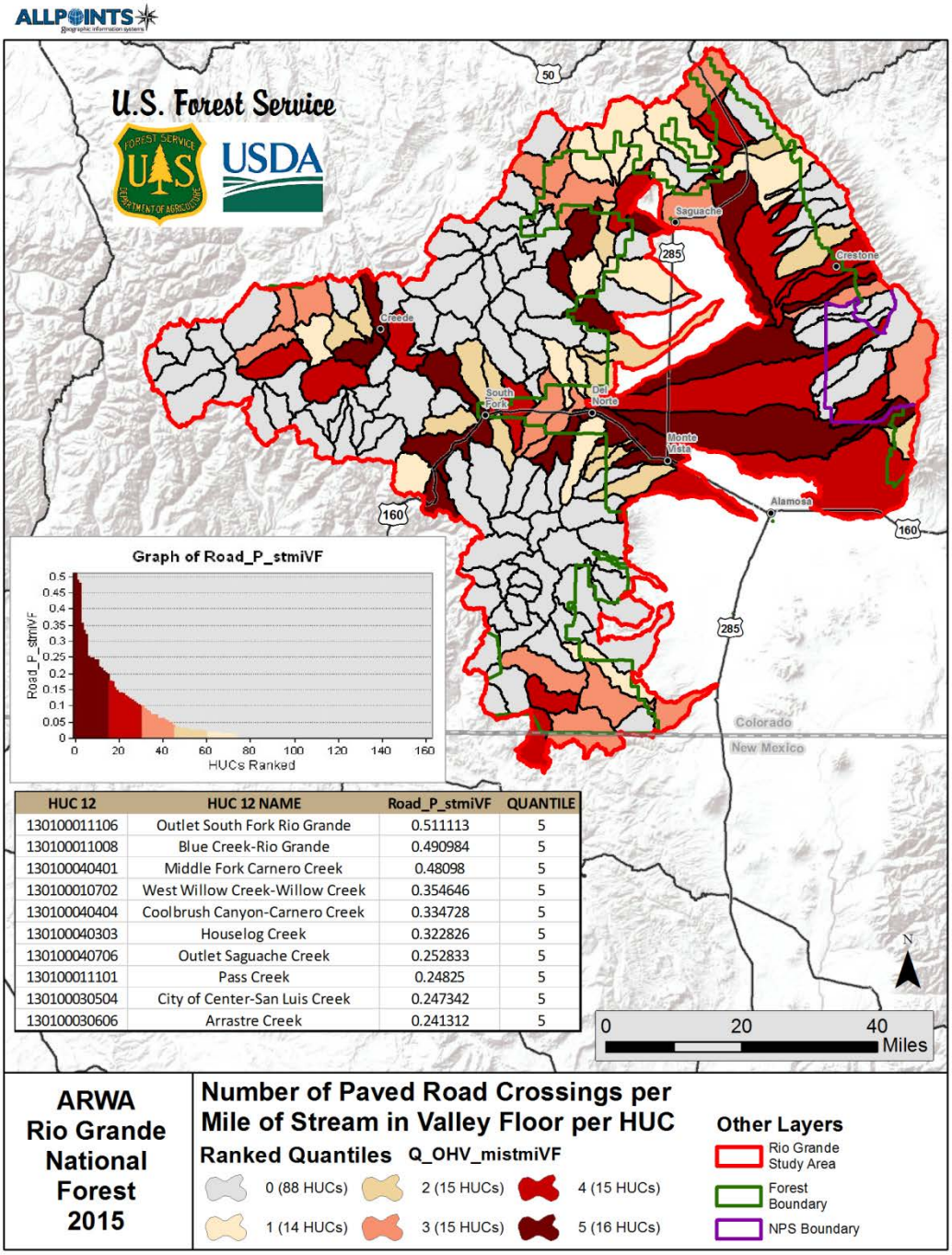
Road crossings can fragment water and riparian ecosystems and isolate populations of plants and animals. The result can be population loss if other impacts such as fire or contaminants. In addition, if too few individuals are isolated inbreeding can occur, resulting in low reproduction success and ultimate elimination. Many different fish and wildlife species will not pass through a poorly designed crossing. Terrestrial animals and some amphibians would rather climb the road banks and risk being hit by traffic. Properly designed crossings minimize the fear to through them, as well as unwanted contacts with vehicles. Fish, aquatic macroinvertebrates and some amphibians need stream crossings designed so they can swim upstream or downstream through them. Stream velocity, depth, habitat, etc., all need to be considered for proper movement.

Results:

Results of the paved road crossings are located in Figure 14. As would be expected, these crossings are associated with the main travel corridors in the basin. The higher values on the east side of the basin are mostly to the west of the Sangre De Cristo Mountains, accept the Cuchara Pass road. Subwatersheds on the western side of the drainage are mostly associated with highway 160, over Wolf Creek Pass and highway 149 thru Creede.

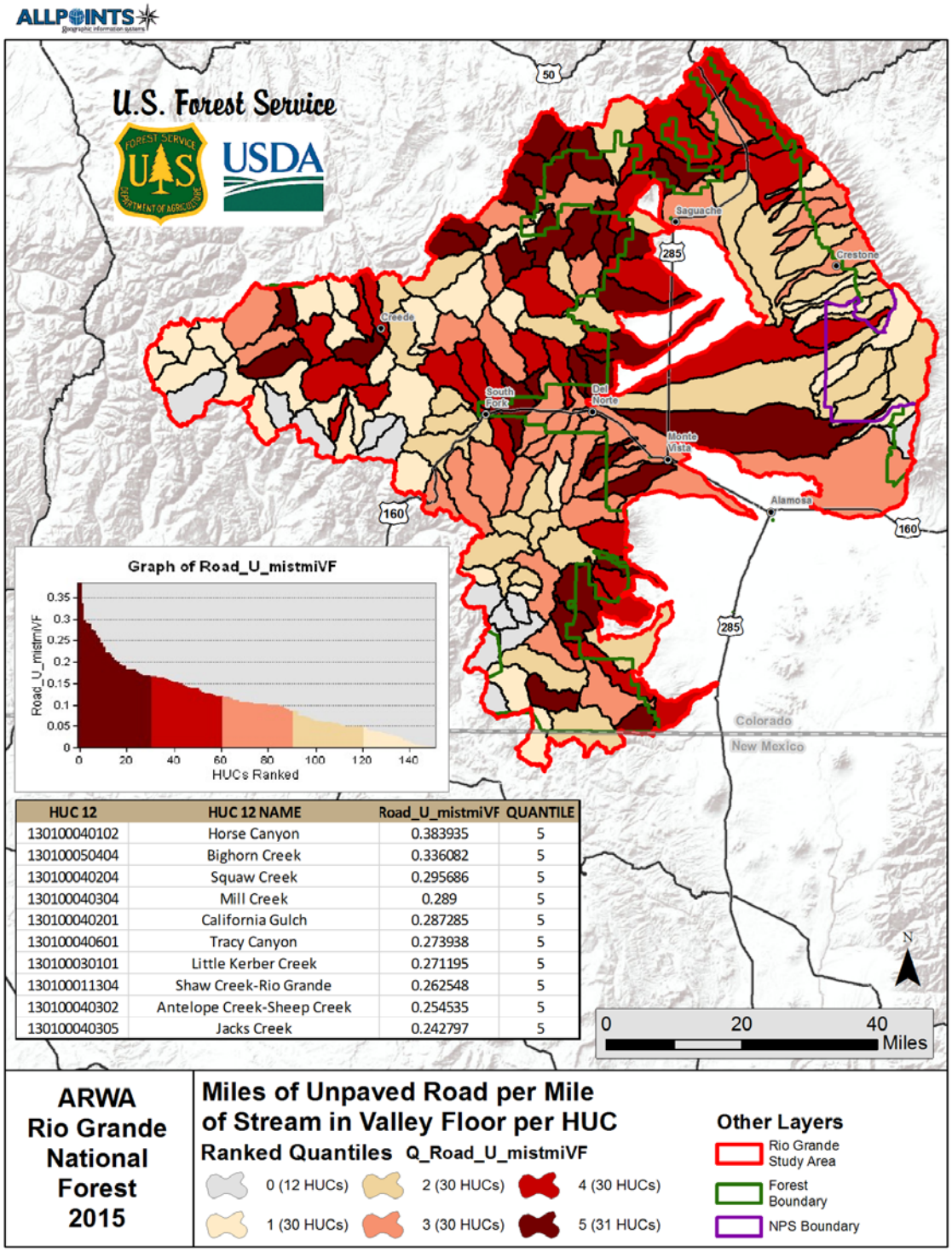
Future Considerations:

Paved highways and smaller roads associated with the Rio Grande National Forest are primarily under the jurisdiction of the local counties, and state of Colorado. Forests have an opportunity to provide input into designs and locations on Forests lands. Providing early input into designs and management of these roads can have important benefits to aquatic and wetland resources, including stream crossings and locations away from riparian and wetland ecosystems. The Forest Service is considered to be an expert agency in designing stream crossings in order withstand flooding while maintaining conditions for maintaining ecological function, including the passage of terrestrial and aquatic animals to pass.



HUC 12	HUC 12 NAME	Road_P_stmiVF	QUANTILE
130100011106	Outlet South Fork Rio Grande	0.511113	5
130100011008	Blue Creek-Rio Grande	0.490984	5
130100040401	Middle Fork Carnero Creek	0.48098	5
130100010702	West Willow Creek-Willow Creek	0.354646	5
130100040404	Coolbrush Canyon-Carnero Creek	0.334728	5
130100040303	Houselog Creek	0.322826	5
130100040706	Outlet Saguache Creek	0.252833	5
130100011101	Pass Creek	0.24825	5
130100030504	City of Center-San Luis Creek	0.247342	5
130100030606	Arrastre Creek	0.241312	5

Figure 14. Paved stream crossing density in the upper Rio Grande River basin.



HUC 12	HUC 12 NAME	Road_U_mistmiVF	QUANTILE
130100040102	Horse Canyon	0.383935	5
130100050404	Bighorn Creek	0.336082	5
130100040204	Squaw Creek	0.295686	5
130100040304	Mill Creek	0.289	5
130100040201	California Gulch	0.287285	5
130100040601	Tracy Canyon	0.273938	5
130100030101	Little Kerber Creek	0.271195	5
130100011304	Shaw Creek-Rio Grande	0.262548	5
130100040302	Antelope Creek-Sheep Creek	0.254535	5
130100040305	Jacks Creek	0.242797	5

Figure 15. Results of the unpaved road density analysis for the Rio Grande National Forest and surrounding ecosystem.

Unpaved Road Density:

Results:

Results for the unpaved road density are presented in Figure 15. These results show considerably more unpaved roads in the valley bottoms on National Forest lands as opposed to paved roads. While 31 subwatersheds were found to be in the highest quantile for density in the valley bottoms (app. 0.4 miles per stream miles within the valley bottom), only 12 were without any unpaved roads. The lowest densities were associated with the wilderness areas in the western part of the National Forest Service and the steep Sangre de Cristo mountains on the eastern side. The highest values were in the northern portion of the basin, although unpaved roads appear to be common throughout the National Forest associated with the valley bottoms. While the highest density of unpaved roads may appear relatively limited (0.4 miles per stream mile in the subwatershed), it is important to note that the valley bottom represents a limited amount of a subwatershed and the overall total density is most likely considerably higher if the uplands are included. The density of unpaved roads is definitely skewed towards more roads within the basin than less. As mentioned previously, the presence of unpaved roads in these areas can have significant direct and indirect influences on riparian ecosystems due to their position, removal of trees that fall naturally into the stream channel and riparian, and restriction of stream movement laterally. Instream habitat is compromised over time as a result of all of these factors.

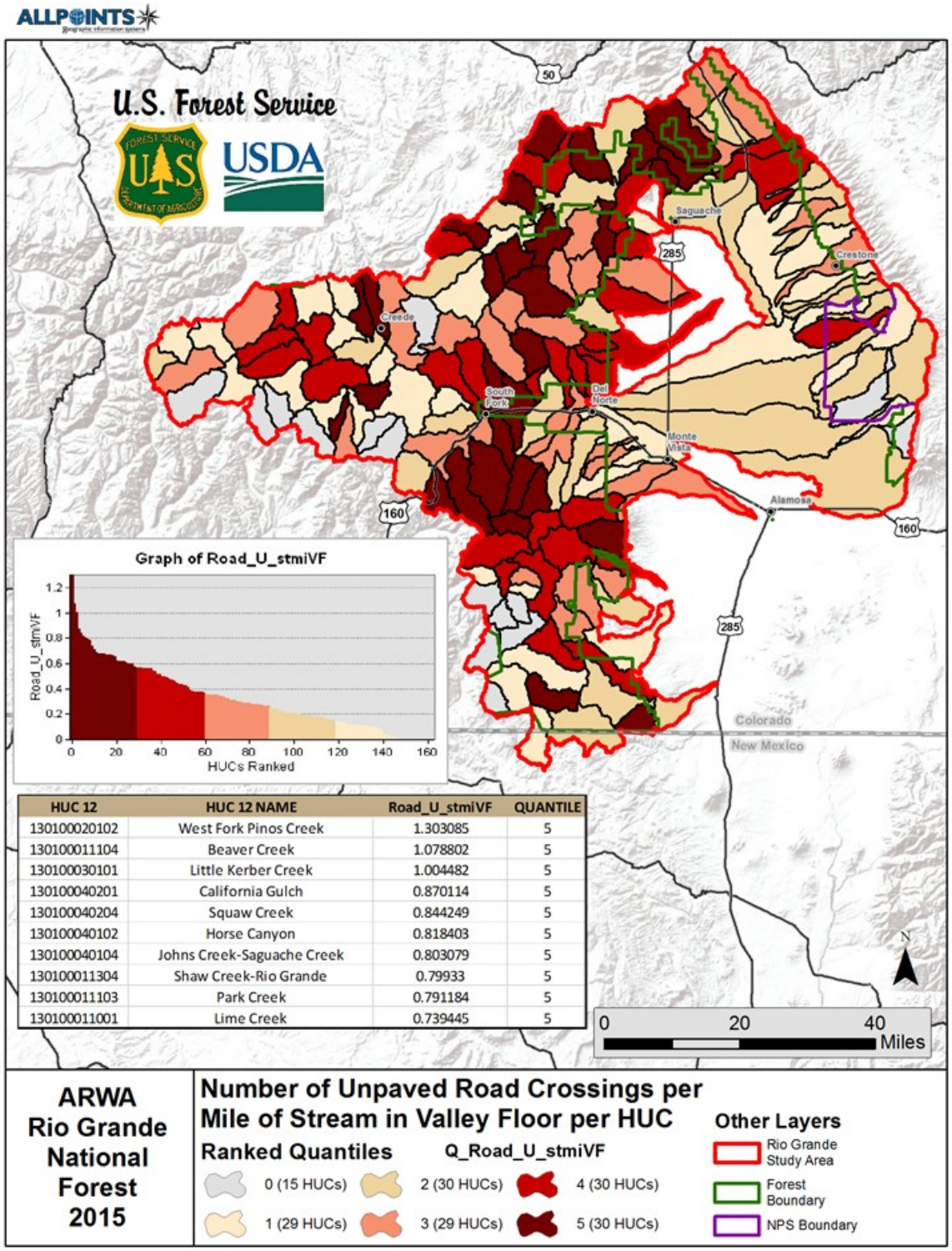
Future Considerations:

Understanding the influence, both directly and indirectly on aquatic and semiaquatic systems by unpaved roads is paramount to healthy ecosystems. Those subwatersheds that are located in quantiles 4 and 5 could be considered priorities for evaluation and subsequent treatment if high value aquatic resources are identified. Low gradient reaches that were previously identified as ecological drivers could be considered the highest priority due to their relatively large riparian areas, sensitivity to temperature changes, natural water storage in the alluvium and abundant instream habitat. By focusing on low gradient reaches as a high priority, more than 50% of the stream reaches could be considered lower priorities until low gradient areas are more resilient.

Unpaved Stream Crossings

Results:

Stream crossings are associated with most unpaved roads in the valley bottoms are. Historically these crossings were fairly primitive, being constructed of corrugated culverts, stream fords or small bridges. The results of this analysis are presented in Figure 16. Values ranged from 0 (15 subwatersheds, <10%) to 1.3 crossings per stream mile in the West Fork of Pinos Creek subwatershed. A total of 20 of the 30 subwatershed within quantile 5 were located totally within the Rio Grande National Forest. These results are considerable different than the paved road results and indicate a relatively high number of unpaved roads that are associated with valley bottoms and associated streams and riparian areas. While not equally distributed, there are likely areas that are considerably more concentrated than others.



HUC 12	HUC 12 NAME	Road_U_stmiVF	QUANTILE
130100020102	West Fork Pinos Creek	1.303085	5
130100011104	Beaver Creek	1.078802	5
130100030101	Little Kerber Creek	1.004482	5
130100040201	California Gulch	0.870114	5
130100040204	Squaw Creek	0.844249	5
130100040102	Horse Canyon	0.818403	5
130100040104	Johns Creek-Saguache Creek	0.803079	5
130100011304	Shaw Creek-Rio Grande	0.79933	5
130100011103	Park Creek	0.791184	5
130100011001	Lime Creek	0.739445	5

Figure 16. Results of the stream crossing density analysis conducted on the Rio Grande National forest and surrounding ecosystem.

Future Considerations:

Road systems have been developed on National Forest administered lands for a number of management related activities. As a “multi-purpose management” agency, it would be expected that densities could be higher than on adjacent lands where management is not as diverse. Historic and current vegetation management, grazing, water development and access for recreation all require transportation routes to access specific areas. Often these roads are maintained, with other roads eventually built to access new sources of interest. As a result of limited funding and technology just recently developed to understand the importance of connectivity within riparian and aquatic ecosystems, past maintenance and building of stream crossings did not consider their ecological importance.

Due to many limitations, prioritization of important subwatersheds could be conducted using the results of the ecological driver analysis, proposed fish and other animal reintroduction areas for aquatic and riparian areas to conduct inventories for passage issues. In addition, many areas have relocated road systems where crossings are not needed. Due to very limited funds within the agency, prioritization and direction is extremely important for focusing on the most important areas. In addition, the funds needed to rebuild damaged crossings would be reduced over time as maintenance costs would be reduced significantly. There could be new areas for reintroduction of native fish that would benefit greatly by the removal of movement blocking streams that benefit restored populations.

Proposed new roads could incorporate the values related to erosion, fragmentation and restoration to identify high priority areas for construction that could be more sensitive to valley floor ecology and species needs as well. There are currently building specifications that include sensitivity to important values on public lands. The incorporation of new design criteria to ensure proper stream function and biological processes are now available one that could be considered in these designs.

Trails

Introduction:

The history of recreational trails (non-motorized) in America is about 110 years old. Prior to 1891, essentially all of the known trails throughout the United States comprised Indian trails, old hunting trails, stock driveways, and game trails. However, with the creation of the United States Forest Service, the miles of trails constructed for recreational use would substantially expand the nation’s trails network.

In 1905, the U.S. Forest Service was created to manage Forest Reserves and since then the number of miles of trails in National Forests exceeds 133,000 miles (Williams 2000). Ironically, the total miles of trails in the National Forest system is less now than it was several decades ago (Williams 2000). Although the total trail miles in National Forests now is less than in the past, the popularity of backpacking, camping, hiking, horseback riding, and mountain biking strongly suggests that trail use is greater now than it has ever been. Because recreational trails can have a multiplicity of impacts on the land and on ecosystems, several organizations have been formed to promote “light on the land” techniques to minimize the impacts of trail use.

Trails can be considered as miniature roads, though clearly, there are obvious dissimilarities, impacting aquatic habitats and riparian areas in similar ways, though generally of lesser magnitude. Leung and Marion and Cole (1996) found that the rates of soil erosion for trails used by cyclists, hikers, backpackers, and horse riders were similar to those for roads. Elliot (2000) suggests, however, that the total amount of sediment originating from trails is generally less than that originating from roads because of the differences in the total surface disturbed between the two designs.

Changes to water quality can be directly attributable to road use, road construction, and road maintenance. Sedimentation due to road-surface erosion and mass wasting, chemical contamination, and compacted soils are the primary causes of water quality degradation due to road construction, road use, and road maintenance (Morrison et al. 1995; Waters 1995; Elliot and Hall 1997; Elliot 2000; Elliot et al. 1996).

According to many investigators road construction, road use, and road maintenance can directly affect watershed hydrology (Furniss et al. 1991; Waters 1995). Also, roads can affect watershed hydrology in indirect ways (Elliot et al. 1999).

Most of the harmful impacts to aquatic biota due to road use, road construction, and road maintenance are indirect impacts, excepting direct mortality to aquatic plants and animals during road use (stream crossings) and road construction. The effects of roads on aquatic biota can affect many of the life-history stages of aquatic animals by degrading or eliminating their associated habitats (Furniss et al. 1991; Waters 1995).

Road use, road construction, and road maintenance can negatively impact channel form and channel integrity, particularly at stream crossings (Waters 1995; Hagans et al. 1986; Heede 1980).

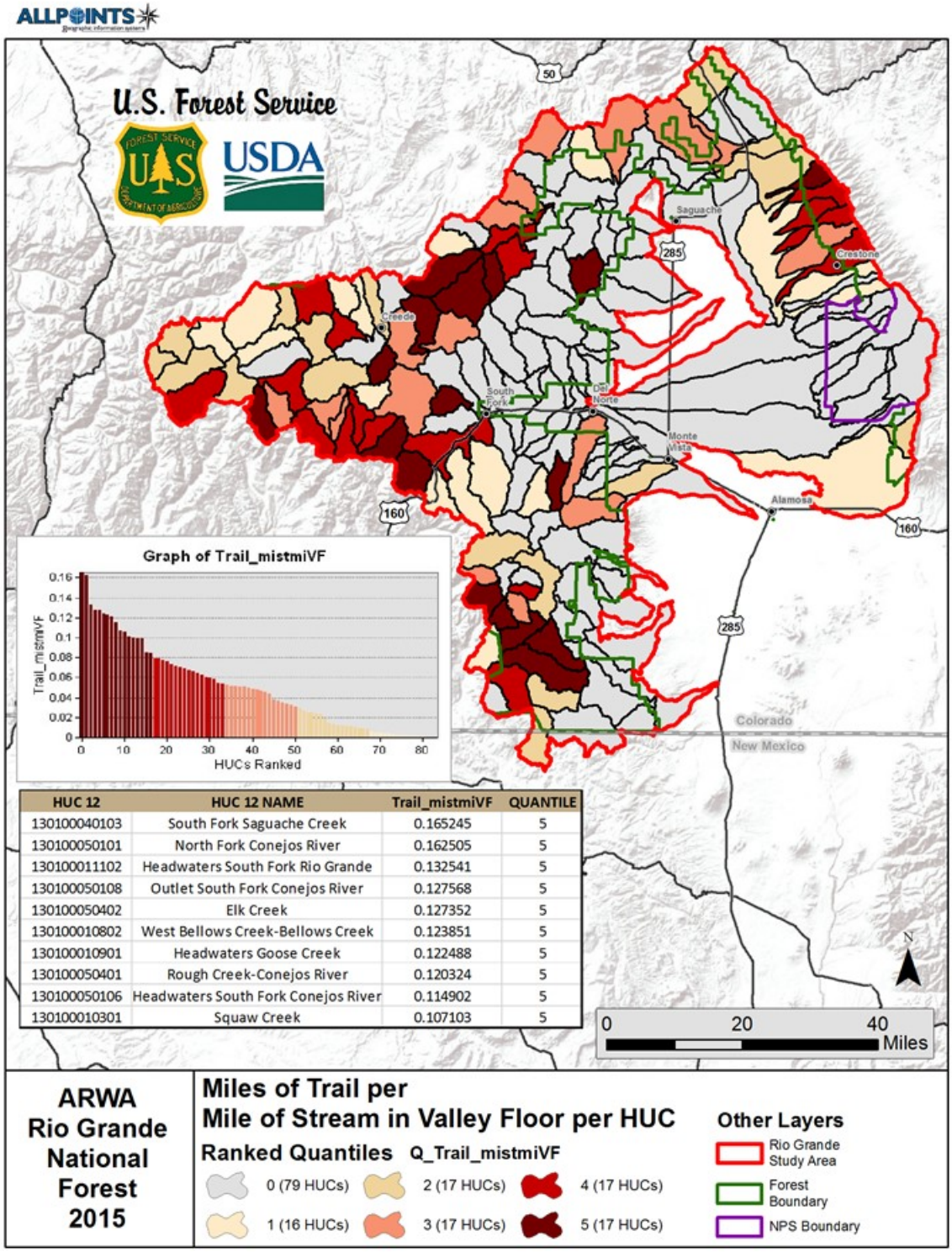
Results:

Results of the trail analysis on the Rio Grande National Forest and surrounding ecosystems are presented in Figure 17. It is apparent that most identified trails are located with designated wilderness areas with the highest density being located in the South Fork Saquache Creek and North Fork Conejos River. There are 79 subwatersheds without trails, which is by far the highest number of any quantile (0.16 miles per stream mile in the valley bottom per subwatershed. These results would indicate that there are few trails in the valley bottom. However, evaluations of maps indicate that there are a large percentage of existing trails located adjacent to streams, just very few trails. An example would be the Ute Creek system of trails in the Weminuche Wilderness (USDA Forest Service Recreation Map). Trail systems exist along all major tributaries and mainstem from its confluence with Rio Grande Reservoir to the Continental Divide and high elevation lakes almost 9 miles to the west. The large number of tributaries is reflected in the low density value. The area around the community of Crestone, and the popular “Crestone Needles” located on the Pike San Isabel National Forest also contains subwatersheds in the highest 2 quantiles, due to the steep topography and lack of roads. This is a popular area for recreationists during the summer months.

Management Implications:

There are benefits that accrue to aquatic, riparian, and wetland ecosystems if land managers properly design and maintain (e.g., best management practices) trail systems. The primary benefit to aquatic ecosystems is: reduced local degradation to these ecosystems due to trail construction, trail use, and trail maintenance and due to the increased difficulty of introducing invasive species. Riparian and wetland vegetation is effective in reducing erosion and sedimentation in streams and in retaining soil moisture. Plant-root networks provide soil stability and soil cohesion.

Appropriate trail management can also benefit native biota. Because trail networks can be used as conduits to disseminate non-native plants and animals into aquatic, riparian, and wetland ecosystems, improved trail management can reduce the probability that non-native species introductions will occur. Often, the “bucket brigade” seeks surreptitious avenues to ply their trade of introducing exotic species into new environments. By eliminating unwanted, user-created trails, exotic species introductions may be prevented, or at least, made more difficult to accomplish. Public education is also an important part of restricting the spread of invasive species.



HUC 12	HUC 12 NAME	Trail_mistmiVF	QUANTILE
130100040103	South Fork Saguache Creek	0.165245	5
130100050101	North Fork Conejos River	0.162505	5
130100011102	Headwaters South Fork Rio Grande	0.132541	5
130100050108	Outlet South Fork Conejos River	0.127568	5
130100050402	Elk Creek	0.127352	5
130100010802	West Bellows Creek-Bellows Creek	0.123851	5
130100010901	Headwaters Goose Creek	0.122488	5
130100050401	Rough Creek-Conejos River	0.120324	5
130100050106	Headwaters South Fork Conejos River	0.114902	5
130100010301	Squaw Creek	0.107103	5

Figure 17. Results of the trail analysis conducted on the Rio Grande National Forest and surrounding ecosystem.

Future Considerations:

Trails are necessary to guide travelers into areas that are not roaded, as well as enjoy a more primitive experience. This is especially true of designated Wilderness areas. However, when located in the wrong locations, such as wetlands and within riparian areas, they can by their location disrupt water flow, cause erosion and replace native vegetation. One of the more recent problems existing with trails located to these areas is the introduction of non-native invasive species, such as plants and potential aquatic pathogens such as whirling disease (Myxobolis sp.). Trails in sensitive alpine ecosystems have been found to initiate extensive erosion.

While trails are relatively benign compared to roads, the location of new trails and potentially relocation of damaging trails could be very important in the future for proper functioning of aquatic ecosystems. New trails built out of valley bottoms and far enough away from wetlands so not to influence hydrology would also ensure that some invasive species would not get established in aquatic ecosystems, wetlands and riparian areas. Erosion and subsequent sediment delivery to streams would also be minimized.

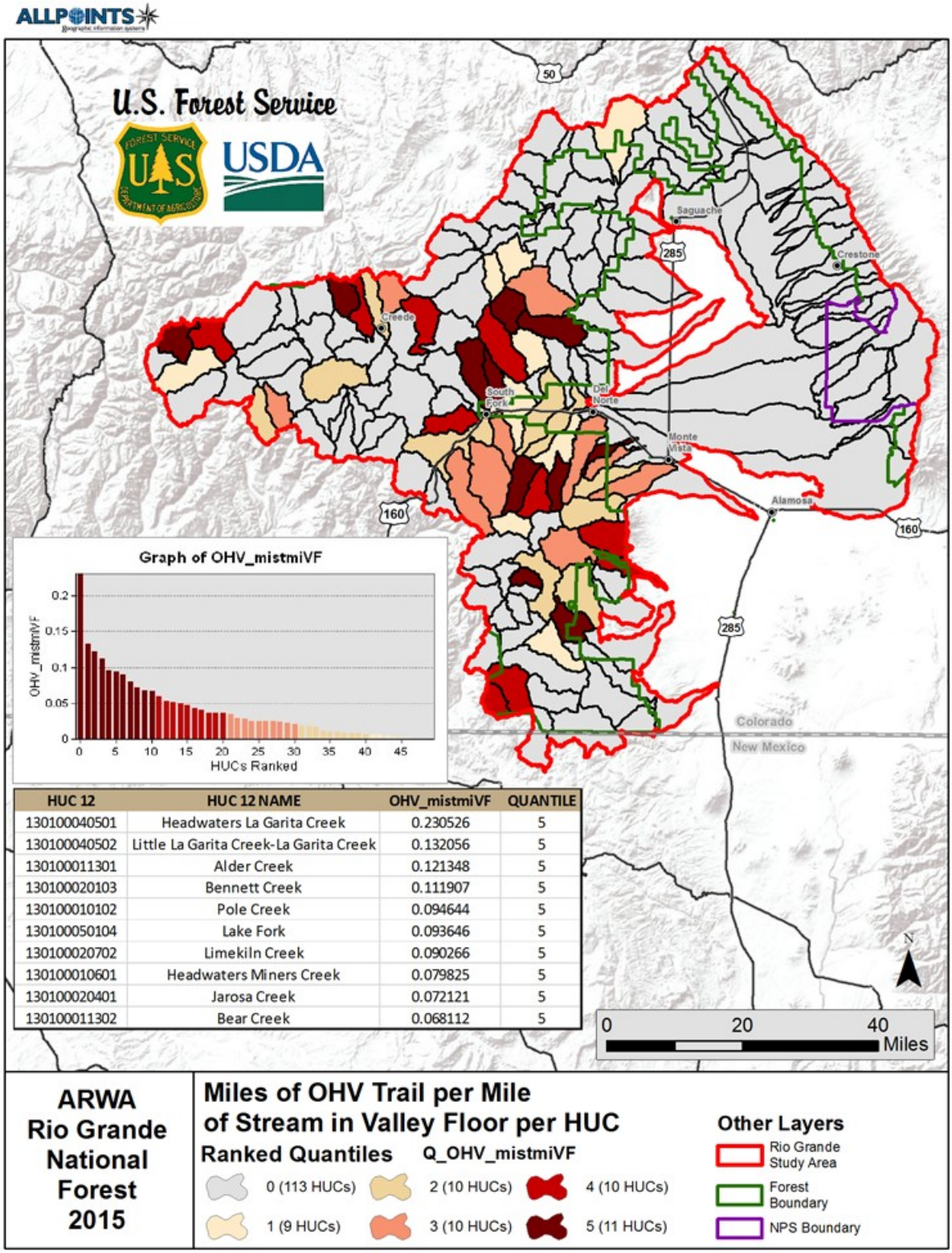
OHV Use

Results:

Results of the OHV trail locations are presented in Figure 18. OHV trail use appears to be fairly limited in the study areas. Of the 163 subwatersheds, 113 (app. 70%) do not have trails in the valley bottoms, and most are at lower elevations. There are 11 (app. 7%) in the highest quantile, with one, the headwaters of La Garita Creek in the south west portion of the National Forest. All the other trails have relatively few miles of trail in the valley bottoms. These results are based on identified trails identified by the Rio Grande National Forest and do not include user developed trails that could be present. As in all of the transportation, user created roads and trails are typically present, and enforcement is limited. However, the limited amount of trails in the valley bottom indicates that this use is probably limited and isolated.

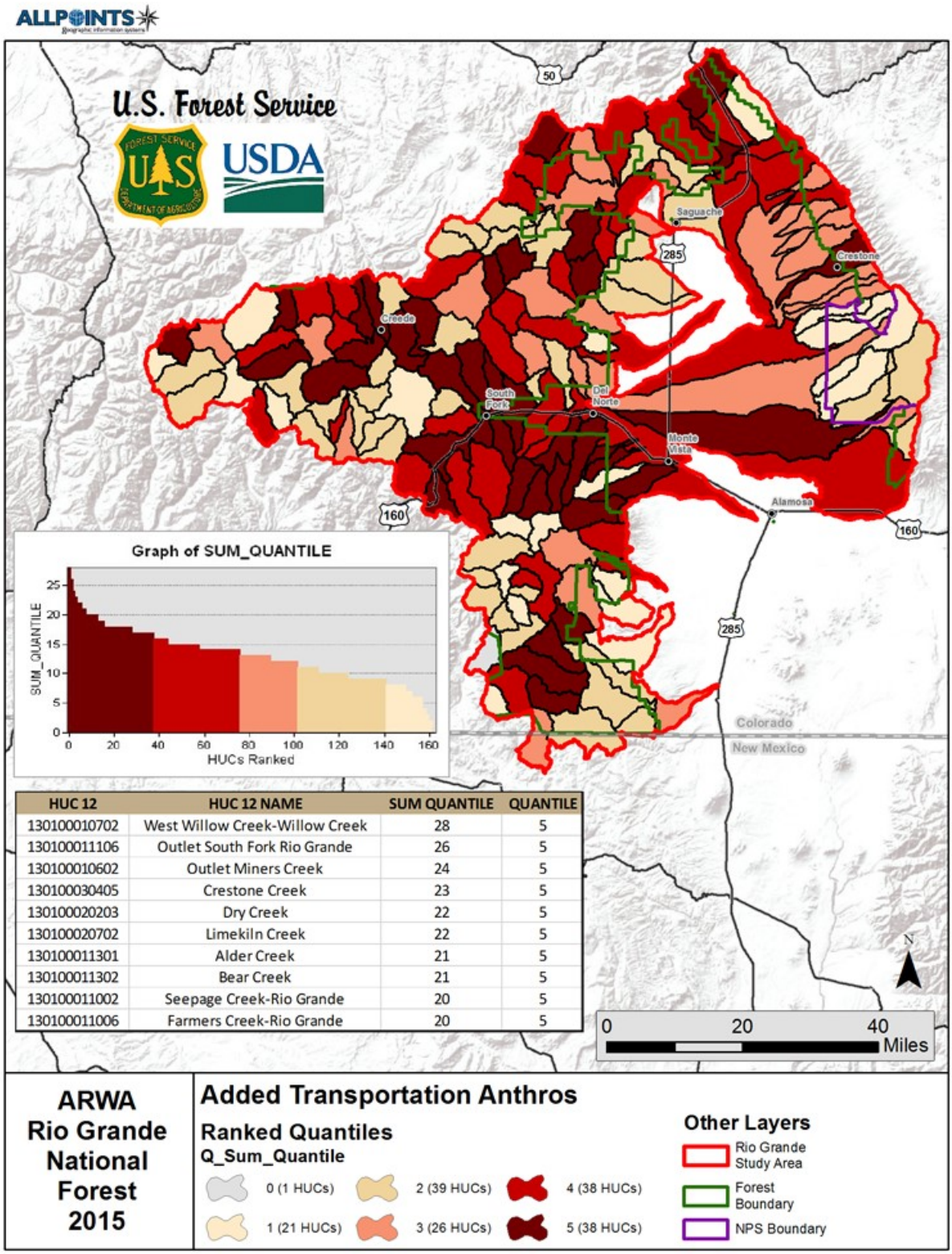
Future Considerations:

Based on our assessment results there appears to be very limited identified trails in the valley bottoms. That does not mean that there are not isolated areas where OHV use could be causing resource damage. OHV’s have the potential to cause resource damage if individuals do not follow regulations. As with all Forest visitors, OHV use should be monitored to ensure streams and wetlands are not compromised. Discussions of opening new trails to OHV use should consider the monitoring, maintenance and fragile ecosystems in these areas. With the increased size and horsepower and speed of today’s OHV’s, as well as aggressive tread design potential damage can occur. However, these statements should not be construed as all OHV use is damaging. OHV groups maintain many areas where they enjoy riding and like many other activities that can potentially impact aquatic resources are limited to a few unethical users.



HUC 12	HUC 12 NAME	OHV_mistmiVF	QUANTILE
130100040501	Headwaters La Garita Creek	0.230526	5
130100040502	Little La Garita Creek-La Garita Creek	0.132056	5
130100011301	Alder Creek	0.121348	5
130100020103	Bennett Creek	0.111907	5
130100010102	Pole Creek	0.094644	5
130100050104	Lake Fork	0.093646	5
130100020702	Limekiln Creek	0.090266	5
130100010601	Headwaters Miners Creek	0.079825	5
130100020401	Jarosa Creek	0.072121	5
130100011302	Bear Creek	0.068112	5

Figure 18. OHV trail locations



HUC 12	HUC 12 NAME	SUM QUANTILE	QUANTILE
130100010702	West Willow Creek-Willow Creek	28	5
130100011106	Outlet South Fork Rio Grande	26	5
130100010602	Outlet Miners Creek	24	5
130100030405	Crestone Creek	23	5
130100020203	Dry Creek	22	5
130100020702	Limekiln Creek	22	5
130100011301	Alder Creek	21	5
130100011302	Bear Creek	21	5
130100011002	Seepage Creek-Rio Grande	20	5
130100011006	Farmers Creek-Rio Grande	20	5

Figure 19. Results of the transportation additive rankings for the Rio Grande National Forest and surrounding ecosystem.

Additive Influences of the Transportation Group

Results:

The results of the additive influences of transportation activities are presented in Figure 19. One subwatershed had no transportation activities identified within its boundaries, while there is a trend toward less activities associated with wilderness areas in the western and a portion of the northern part of the Forest, most of the highest additive levels (quantiles 4 and 5) are found associated with areas of higher populations such as Creede, South Fork and Del Norte. These results could be the result of early development that needed natural resources to maintain infrastructure, expanding further into the surrounding areas, and in the case of Creede, proximity to mining areas.

Future Considerations:

The results of the transportation category show that human transportation is located throughout the valley bottoms of the Rio Grande National Forest. These activities have occurred throughout the last 200 plus years, beginning with primitive trails to wagon trails, to a wide range of transportation routes. Our results indicate that the cumulative ranks of transportation is highly skewed towards more than less activities, showing that the conditions within valley bottoms are conducive to transportation development. Future considerations could be given to limiting routes in these sensitive areas, as well as ensuring that the processes for maintaining healthy riparian areas and streams, natural storage in low gradient reaches are maintained. In addition, as discharge levels are expected to be reduced more variable, maintaining the quality of water related habitats, and reducing the effects of flooding on infrastructure is going to be important.

Recreation

Introduction

Recreational use is a key management activity for the National Forest Service. Many forests are located in close proximity to urban areas, facilitating the use of these public lands by visitors for a variety of uses. However, it is becoming increasingly difficult to balance the needs of increasing public demand for relatively natural settings of National Forests and Grasslands, while maintaining the resource values they are intended to provide. By understanding the extent and trends of recreational use and the influence it has on aquatic, riparian, and wetland resources, we can better balance public recreational needs with needs of the resources.

Recreational uses vary seasonally, but their influences on and wetland resources can persist year round. The influences of increased vehicular traffic and concentrated water recreation may be more apparent on surface water quality, whereas the influences of concentrated winter recreation (covered separately under Ski Areas and OHVs) may be more apparent in groundwater. Two general types of recreational patterns; developed recreation and dispersed recreation, are identified in this assessment based on the degree of associated infrastructure and user concentration or density. Developed recreation tends to concentrate human activities in localized areas and generally requires infrastructure such as parking lots, restrooms, and shower facilities. Examples of developed recreation include camping or picnicking in established campgrounds, downhill ski areas or resorts, or interpretive centers. In contrast, dispersed recreation requires little or no infrastructure and tends to decentralize or spread the activity across the landscape. Backcountry hiking and camping, cross-country skiing, and hunting are examples of dispersed recreation.

Recreational activities can have a direct effect on aquatic biota. For example, the abundance of the larval caddisfly *Dicosmoecus gilvipes* was reduced by extensive recreational activity, but effects were spatially and temporally localized (Wright and Li 1998). In contrast, the biomass of epilithic algae was not correlated with such activity. This study demonstrates the potential for multiple recreational activities to affect stream food webs and the need for further detailed studies. In addition, indirect effects may be produced from upland disturbance that affects hydrology and sediment yield. For example, disturbed soils associated with campsites can have insufficient nitrogen for rapid plant regeneration (Zabinski et al. 2002). Overall, research has shown that the greatest amount of damage to riparian vegetation occurs from initial periods of use even if uses seem relatively light (Clark and Gibbons 1991). Subsequent disturbance may add little additional effects to riparian vegetation (Cole 1979, 1987; Marion and Cole 1996). Other influences of recreational use on riparian and wetlands appear to be similar in type, but with less magnitude, to the effects of livestock grazing (Clark and Gibbons 1991). Any recreational use of upland and riparian areas will have some effects, but they are likely to be minor compared to the influence of roads, logging, livestock grazing, and mining (Clark and Gibbons 1991).

Influences also vary depending on whether the recreation is developed or dispersed. The lack of infrastructure may reduce the localized effects of dispersed recreation, because pollution or potential pollution sources are not as concentrated. Although dispersed recreation may not disturb significant portions of a particular watershed, site impacts can be considerable. For example, it has been found that <0.5% of a heavily used portion of the Eagle Cap Wilderness in Oregon was directly affected by trails and camping (Cole 1989, 2000). Most of the disturbed area was located far enough from streams so that the effect was negligible. Resistance and resilience of vegetation to recreational trampling varies by plant species and trampling intensity (Cole and Trull 1992; Marion and Cole 1996). Pronounced changes to soil and vegetation can occur at even low recreational intensity (Marion and Cole 1996). Forbs in closed canopy forested areas were most sensitive to camping effects (Marion and Cole 1996). Results suggested that total campsite impact would be less on a small number of high-use campgrounds, than on a greater number of dispersed, but lesser used, campgrounds (Marion and Cole 1996; Marion and Farrell 2002).

Recreational activities can exert strong influences on fishery resources. Although the types of recreational activities encompassed in this report are numerous, for example ranging from hiking to skiing to rafting, any type of human activity that potentially alters habitat conditions can indirectly affect fish populations. Although the magnitude of the effects may vary, recreational activities may have influences similar to those of forest and rangeland management practices such as timber harvest, grazing, mining, or road construction, (Meehan 1991). For example, activities that degrade stream banks, whether it is cattle frequenting streamside areas or heavily used hiking trails and stream crossings, may change channel morphology and influence thermal regime and have consequences for resident fish populations (Clark and Gibbons 1991; Meehan 1991).

Recreational angling may exert a direct influence on fish populations and communities, particular in freshwater systems, and may produce unfavorable outcomes where the goal is management and preservation of native fishes. Hooking mortality is variable among species targeted for sport fishing, but can be significant in some cases (Muoneke and Childress 1994). For salmonids, recreational angling can affect resident freshwater populations (Clark and Gibbons 1991; McDonald and Hershey 1989), and even migratory, sea-run populations (Palmisano 1993). Where native and nonnative sport-fish coexist, differences in angling susceptibility may complicate management. For example, native cutthroat trout (Oncorhynchus clarki) inhabit only a small fraction of their historic ranges, and interaction with nonnative salmonids (e.g., brook trout and rainbow trout) is cited as a key factor producing this pattern and affecting the persistence of existing populations (Fausch 1988; Behnke 1992). Unfortunately, cutthroat trout tend to be more vulnerable to angling than brook trout (MacPhee 1966; Paul et al. 2003), so recreational fishing may disproportionately affect native trout where they coexist with popular nonnative salmonids.

Subsequently, management strategies that aim to suppress nonnative salmonids through increased angler pressure have the potential to actually prevent recovery or induce further declines in native trout (Paul et al. 2003). Thus, recreational fishing policies must be carefully considered, even in catch-and-release fisheries, where sensitive, threatened, or endangered native fish species are present.

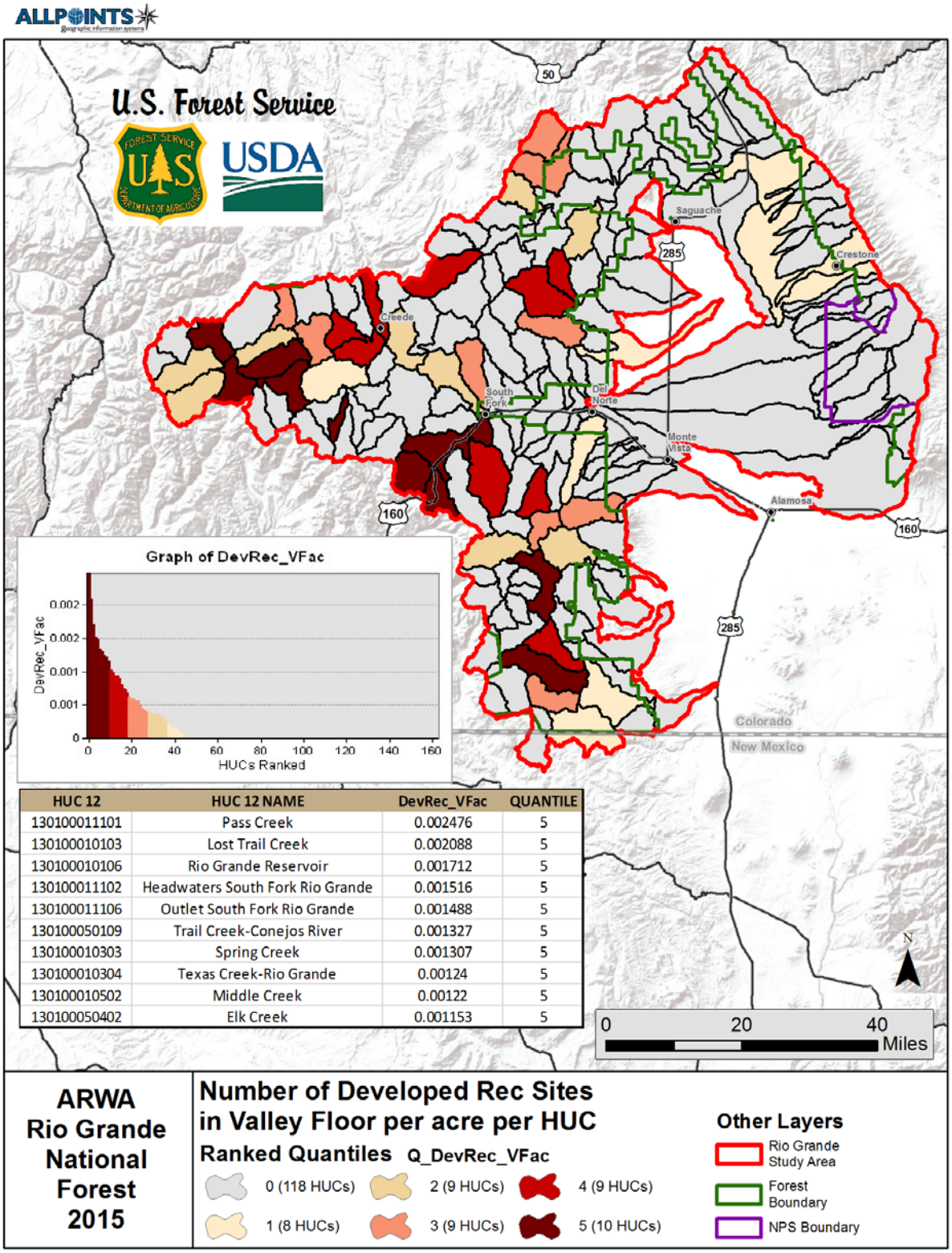
Developed Recreation Sites

Results:

Developed recreation site results are presented in Figure 20. Recreation camp sites are often located in valley bottoms to afford visitors direct access to water related activities as well as the aesthetic value of streams. Often however these sites impinge on riparian areas, can cause erosion from use and damage from stream function. Many of the influences stated are relative to the amount of use that they receive and the location of the sites. Out of a total of 163 subwatersheds evaluated, 118 or 73% of the subwatersheds evaluated did not have developed recreation sites in the valley bottoms. .Most of the higher densities (albeit very few) were located in subwatersheds that included the Rio Grande and South Fork of the Rio Grande Rivers, mainly due to the high recreation use such as fishing.

Future Considerations:

The relatively “flat” natures of valley bottoms as well as close proximity to water have made building developed recreation a high priority. However, sites are increasingly being located away from direct contact to riparian areas and streams. One of the problems is that valley bottoms are often relatively small, and roads bisect the area. Having to cross roads to enjoy the activities associated with the streams leads to unsafe conditions that are often difficult to mitigate. Enclosed toilets that do not seep into streams and associated water tables are a major advancement in design. Locations away from active riparian areas still within the valley bottom allow streams to migrate laterally and discourage trailing. While flooding can still be an issue with large events, more thought and planning is given to location. The closer developed recreation sites within valley bottoms are too active riparian and streams the more likely that unplanned consequences could occur. Areas identified outside of valley bottoms would be easier to maintain, and have less risk to aquatic ecosystems and from flooding.



HUC 12	HUC 12 NAME	DevRec_VFac	QUANTILE
130100011101	Pass Creek	0.002476	5
130100010103	Lost Trail Creek	0.002088	5
130100010106	Rio Grande Reservoir	0.001712	5
130100011102	Headwaters South Fork Rio Grande	0.001516	5
130100011106	Outlet South Fork Rio Grande	0.001488	5
130100050109	Trail Creek-Conejos River	0.001327	5
130100010303	Spring Creek	0.001307	5
130100010304	Texas Creek-Rio Grande	0.00124	5
130100010502	Middle Creek	0.00122	5
130100050402	Elk Creek	0.001153	5

Figure 20. Density of developed recreation sites on the Rio Grande National Forest within the valley bottoms.

Ski Areas

Introduction

Increasing demand for winter sporting opportunities has led to the creation and rapid expansion of ski resorts in forested watersheds (Brooke 1999). Today, almost 60 percent of all downhill skiing in the United States occurs on National Forests. In cooperation with over 100 ski area operators, the USDA Forest Service provided downhill skiing opportunities to approximately 31 million people in fiscal year 1997 (Ibarra and Zipperer 2001). Approximately 178,000 acres of National Forest Systems lands are currently under permit to ski areas. The ski industry hopes to extend the ski season or even have ski resorts open year-round (Hoffman 1998). Ski resorts continue to develop facilities for summer outdoor recreation activities such as golf, swimming, and tennis. With ski resort expansion, real estate development also expands. To maintain predictable revenues in spite of unpredictable weather, ski resorts increasingly rely on artificial snow to cover the slopes. Scientists warn that large ski resorts alter natural hydrological cycles, increase traffic congestion, and are magnets for urban sprawl, all of which may impair water quality (Ibarra and Zipperer 2001).

The construction and operation of ski facilities can influence water quality and alter natural hydrologic processes. Clearing of vegetation for ski runs increases the chances of soil erosion (Ries 1996), leading to higher turbidity and sedimentation in streams (Hoffman 1998). Pollutants from car emissions are deposited on the soil with precipitation. Runoff from roads, parking lots, or lawns may be contaminated with salt, heavy metals, petroleum residues, or landscaping chemicals. Expansion of impervious surfaces leads to increased peak runoff and shorter resident time of water in the watershed.

Newly developed ski resorts may cause shortages or dramatic fluctuations in water availability (Ibarra and Zipperer 2001). For example, consumptive water use can be moderately high, as much as 10 gallons per day- per skier (Ibarra and Zipperer 2001), and snowmaking operations can require large volumes of stream water. To meet water needs, ski resort operators may relocate stream channels, excavate wells, construct ponds, or pump water surface flow from adjacent watersheds. In addition to relocating water, a portion of the water used for snowmaking is lost via evaporation and sublimation, and fossil-fuel powered generators associated with snowmaking equipment can degrade air quality (Hoffman 1998).

Ski resorts are often located in high elevation environmentally sensitive sites. These areas are often glaciated with relatively high precipitation, and contain abundant riparian and wetland ecosystems. In mountainous regions, slopes are often steep, soils are thin, the subsurface is predominantly gravel and cobble, and aquifers are fractured bedrock. This type of aquifer is very sensitive to pollution because rapid groundwater flow can carry microbes and other pollutants for long distances (US EPA 1999). Ski resorts have a unique problem with wastewater treatment. Their peak need is in the winter, when conventional sewage treatment methods function at slower rates and microbial pathogens survive longer in water and soil.

Aquatic biota are clearly influenced by changes in hydrology, water quality, sediment yield, and channel morphology, which are all probable events associated with development and operation of ski areas. However, relatively few studies have directly examined the link between ski areas and changes in aquatic organisms. Ski area development clearly results in changes to the surrounding landscape, including loss of vegetation and topsoil, resulting in increased erosion (Ries 1996). Runoff from salt applied to ski area roads was shown to degrade water quality at a New Mexico ski area (Gosz 1977). In a study that did attempt to examine impacts on aquatic animals, abundance and biomass of stream invertebrates below a ski area were reduced, a result attributed to increased sediment load (Molles and Gosz 1980). In addition, downstream nutrient concentrations were elevated and dilution by downstream tributaries was necessary to dilute nutrients to acceptable concentrations.

Ski areas may also impinge upon particularly important aquatic resources. For example, ski areas in the Intermountain West are often located in higher elevation watersheds that contain sensitive and threatened species of native cutthroat trout. Historically, these trout were also found in lower elevation streams, but habitat loss and competition with nonnative fishes has generally restricted their present distribution to headwater streams, where they often exist as isolated populations (Behnke 1992). Thus, ski area activities that influence these small streams, such as erosion from ski runs or dewatering for snowmaking, can have profound influences on the population viability of these trout.

Management Implications

Ski areas provide outdoor recreation for millions of people every year. Because of the sensitive location of these activities and the extensiveness of the land alterations, great care must be taken to minimize impacts to aquatic resources. Parking areas, roads, buildings, wastewater treatment facilities and other permanent structures should be carefully sited. Increased peak flows can be expected if artificial snowmaking is extensive and channel changes are expected in unarmored streams. By understanding the sensitivity and risk associated with the location of ski areas, and managing accordingly, impacts could be limited.

Results:

Only one active ski area is currently located within the Rio Grande National Forest, Wolf Creek Ski Area at the top of the South Fork of the Rio Grande River. For this purpose it was not included in this analysis.

Future Considerations:

Ski areas are generally considered a culmination of anthropogenic activities. Sediment from large parking lots often enter stream channels, snow making requires water at times when very limited water is available in streams, nutrients and chemicals enter streams from deicing practices, treated sewage and other sources, etc. While recreational skiing is one of the highest use activities in the state of Colorado, careful consideration should be taken to ensure that impacts to high elevation wetlands and other aquatic ecosystems are not encouraged. Glaciated valleys, identified in the ecological driver section as having high densities of wetlands are a major concern as they are often targeted for development. Sediment runoff can also be routed to settling ponds before they reach stream channels where they settle and can considerable ecological damage.

Dispersed Recreation

Management Implications:

Dispersed camping is difficult to quantify although it is very popular. Direction is typically developed to ensure that camping is not done within a reasonable distance from water bodies. An evaluation of over 2000 dispersed recreation sites on the Bighorn National Forest revealed that proximity to roads and streams as well as landscape slope accounted for over 90% of the variability in choosing sites (Winters et al, 2003). In wilderness areas, dispersed sites were often located within close proximity to lakes. These results indicate that education may be the best deterrent to dispersed camping and its side effects near streams and riparian areas. Human waste associated with high density dispersed sites is visually unacceptable as well as entering stream channels, altering chemical composition.

Biological Influences

Invasive Species

Introduction:

Invasive plants are commonly considered to be today's greatest threat to natural biodiversity and ecosystem health. States and other governmental entities have long designated plant species, which are non-native and invasive, as "noxious weeds." In general, invasive plants are those species, not native to a given area, that have the potential following introduction to spread and to cause significant detrimental impacts to native communities and human resources (Shelley and Petroff, 1999). Invasive plants generally exhibit one or more characteristics which enable them to aggressively out-compete native plant species

Invasive plants are potentially a side effect of many human related activities addressed as a 'measurement' item under many of the specific anthropogenic factors discussed elsewhere in this document. However, they are also covered under their own separate factor category because of the potential environmental impacts associated with the invasive species themselves, as well as the potential effects associated with their management.

Within the Rocky Mountains and western Great Plains, noxious weeds are the most common and widespread invasive plant. Treatment of noxious weed acres on National Forest System lands in the west has expanded greatly over the past decade (USDA Forest Service 2080 files). There are an estimated twenty species of invasive noxious weeds currently present in this region that have received substantial management emphasis over the past several decades. Noxious weeds are found in all habitat types, at all elevations and settings. Some species are particularly invasive in wetland or riparian ecosystems (such as purple loosestrife or leafy spurge) while others are capable of invading the drier portions of these ecosystems (e.g., several of the knapweeds, two species of toadflax, and yellow star thistle). Some species are best adapted to invade into disturbed sites while many are capable of invasion into essentially pristine conditions. All are highly competitive and are frequently able to dominate and suppress native ecosystems.

Invasions by exotic, aquatic animals (e.g., fish, amphibians, crustaceans, mollusks, and insects) are a pervasive impediment to maintaining intact natural aquatic ecosystems in the United States and this is a recurrent theme across the nation (Rahel 2000). Additionally, intentional distributions of native species beyond their historical ranges have provided high recreational value, often at the detriment to native species. In the American west, it is likely, that the first humans to translocate native fish from their natal streams, rivers, and lakes into previously fishless waters were Euro-Americans: sheep herders, settlers, and miners (Knapp et al. 2001). In the mid-nineteenth century, translocations of fish were undertaken to provide food for local immigrant communities and other settlers who commonly used fish where available as a common food source. Native Americans were not known to translocate fish in the Rocky Mountains, as they were relatively plentiful and other sources of food were generally available to them.

After the transcontinental railway was completed in 1869, this new national infrastructure provided an effective conduit by which to translocate species from coast to coast. Interestingly, many non-native trout (e.g., brook trout, brown trout, and rainbow trout) were introduced into the western United States by railway in the mid- to late 1800s (Fuller et al. 1999). In the eastern United States, non-native species such as brown trout were introduced into native ecosystems much sooner than in other parts of the country (e.g., mid to late 1800s).

Non-native fish species such as rainbow trout have hybridized with native salmonids such as golden trout and cutthroat trout, while brook trout and brown trout tend to have a competitive edge over native trout where they occur in sympatry (Behnke 2002). Luckily, there are some limitations associated with the pervasiveness of non-native trout in the Rocky Mountains. Vincent and Miller (1969) found an elevation limit for brown trout between 2,590 m and 2,750 m in the Poudre River drainage in Colorado. While they found brook trout at higher elevations, their conclusion was that water temperature limited the expansion of brown trout (and probably rainbow trout) into upper elevation streams. Warmwater fish (e.g., sand shiner; *Notropis stramineus*) are also limited to elevations related to habitat conditions and water temperature. The highest diversity of fish species found in the upper Missouri River Basin are restricted to habitats within the Great Plains, unable to withstand the environmental conditions found in the more mountainous areas (Baxter and Stone 1995). These temperature "barriers" no doubt restrict the movement of eastern plains fish, and some fish such as the common carp (Cyprinus carpio) from moving into streams within the Bighorn Mountains. In addition, thermal barriers no doubt limit the downstream distribution of non-native and native salmonids.

While the introduction of non-native fish has changed the distribution and arguably taxa "fitness" of many native species, they have also provided an important recreational source for an increasing population in the Rocky Mountains. In 1996, there were approximately 4,833,715 fishing days in the Rocky Mountain Region of the USDA Forest Service, resulting in an estimated $183,535,664 in economic output (TRCA 2000). Obviously, maintaining this important recreational activity is valuable to the public, and must be balanced with native species management. Many of the native subspecies of cutthroat trout are relatively sensitive to angling pressure, and anthropogenic influences brought about by Euro-American settlement. Indeed, the yellow fin trout (Oncorhunchus clarki mcdonaldi) became extinct in only 17 years following its discovery by anglers in Twin Lakes, Colorado (Behnke 2002). One account documents that in 1876, General George Cook and his soldiers caught several thousand Yellowstone cutthroat trout in a couple of weeks while camping on the Tongue River west of Sheridan, Wyoming. Other accounts of early Euro-American inhabitants describe extremely large catches of native trout in relatively short time periods. While the social values and legal constraints no longer allow such unregulated harvest, it appears that fishing pressure alone may have reduced the range of native trout by itself.

Non-native trout such as brook and brown trout seem to be well adapted to the changes brought about by Euro-American settlement. Anthropogenic activities, such as those described in this assessment, have in large part resulted in habitat conditions that are quite dissimilar to those that were probably here prior to Euro-American settlement (Wohl 2001). Trout species such as the brown and brook trout appear to be more resilient to the cumulative influences of these activities, in some cases filling a void that may have been left by the elimination of native sub species of cutthroat trout in the Rocky Mountains. While rainbow trout do not appear to be as resilient in the Rocky Mountains (in large part because of their spring spawning behavior) they are successfully reared in hatcheries and can be planted in marginal habitats where they are quickly removed by anglers. This "put and take" management provides angling in some areas where habitat conditions are no longer suitable for self-sustaining populations of native salmonids.

While elevation and temperature limits may limit the invasion of certain species, one invasive species in particular is a realized threat to native and non-native salmonids in the Rocky Mountains, the whirling disease parasite (Myxobolis cerabalis). This microscopic parasite was first introduced into the United States 1950s (Behnke 2002). However, more recent findings of Myxobilis cerabilis in Rocky Mountain States such as Colorado and Montana have shown that they can have dramatic effects on salmonid populations (other than brown trout) often in valuable fisheries. Stream habitat degradation and increased sedimentation may increase populations of this invasive parasite by creating more habitats for its intermediate host, the tubifix worm (Tubifex tubifex). In more pristine, high elevation stream systems, the

whirling disease parasite does not appear to be becoming well established. This observation may be due to the habitat and temperature limitations of the tubifix worm itself. Increased sedimentation and stream temperatures from management activities could increase the habitat occupied by tubifix worms and ultimately the whirling disease parasite.

Water quality can be both positively and negatively affected by the introductions of invasive animal species. Invasive mollusks and other filter feeders can negatively alter or even improve water quality by filtering dissolved and suspended pollutants from waters. Also, filter-feeding invaders can reduce primary productivity by reducing phytoplankton populations. In the Bighorn Mountains, as with most Rocky Mountain streams, productivity is limited and effects from filtering of nutrients are doubtful.

The most profound impacts of invasive, aquatic animals are their biological influences on native aquatic biota. Invasive fish, crustaceans, mollusks, and amphibians can deplete native aquatic biota, by out-competing them for essential resources (Knapp and Matthews 2000; Pilliod and Peterson 2001). Also, invasive species can diminish native populations of aquatic biota (invertebrate and vertebrate) by predation (Knapp and Matthews 2000). Altered predator-prey relationships can also disrupt food chains and nutrient cycling by displacing or eliminating vulnerable trophic levels (e.g., large zooplankton).

A variety of benefits may accrue to aquatic, riparian, and wetland ecosystems if proper management strategies to control invasive, aquatic animals are implemented. Many non-endemic species of plants and animals have been and will continue to be managed for public utilization. Several species of fish are managed as recreational species in the Rocky Mountain Region. Trout, such as rainbow trout (*Oncorhynchus gairdneri*) are in high demand by the public. Other species that were thought to be important as a recreational or food source like the common carp (*Cyprinus carpio*) are now out of favor with the public and have become competitors with native species.

When native aquatic fauna and their associated ecosystems remain intact, they provide rare opportunities to investigate how these ecosystems evolved and how their structures and functions are related to their evolution. Collecting and expanding available data that can assist our understanding of the complex interactions among ecosystems and associated fauna helps to preserve ecosystems and their faunal communities.

Management Considerations:

Invasive plant and animals can have irreversible impacts on wetland, Riparian and Aquatic Ecosystems. Species such as the whirling disease parasite (*Myxobolus cerebrals*) and cheat grass (*Bromus tectorum*) are typically thought of as organisms that are here permanently, although measures to reduce whirling disease has already began. Unfortunately, wetlands and riparian areas provide excellent conditions for invasive plants, with relatively abundant water and good soil conditions. Many invasive plants outcompete native species, provide poor habitat for native animals and disrupt other ecological functions.

Invasive aquatic species are becoming more abundant even with considerable effort to stop them. Didymo (*Didymosphenia geminate*) is actually a native diatom that in recent years has been found to have massive “blooms” that outcompete other native benthic plants and animals. Other invasive aquatic species that have recently become established in Colorado and New Mexico waters include foreign species of mussels (*Dreissenidae*), New Zealand mud snails (*potamopyrgus antipodarum*), and most recently spiny water fleas (*Cecopagidae*) have become established in the state. Once any of these invasives become established they are almost impossible to remove. As a result, education and not allowing them to enter our waters are the only way to keep them from being established.

Future Considerations:

Weed free hay is one technique that has been used to minimize invasive plants from entering Wilderness areas. Using a similar idea for stocking trout in Wilderness areas and other water bodies within Forest boundaries is also an important topic to be discussed with partners. However, new pathogens associated with stocking must also be considered, especially in Wilderness Areas.

Because aquatic invasives are typically transferred by recreational equipment such as boats, wading boats, stocking and other vectors that carry water from one body of water to another, education on decontamination and inspections at high volume reservoirs are crucial. Other equipment that has the potential to transfer water from one infected water body to another, such as firefighting equipment are important subjects that need to be identified and techniques used to ensure invasives are not transferred.

Influence of Beaver Removal

Introduction

Beaver (*Castor canadensis*) are habitat-modifying keystone species in lotic, riparian, and wetland habitats (Butler 1995; McKinstry et al. 2001; Collen and Gibson 2001), and their dam-building activities can influence a large proportion of a given watershed and landscape (Naiman et al. 1988). Beaver are an integral part of most headwater stream ecosystems in the Intermountain region (Wohl 2001), where their activities can alter stream channels and riparian zones and affect basic processes such as nutrient cycling (Naiman et al. 1988; Naiman et al. 1994). Beaver impoundments generally have a positive effect on aquatic, riparian, and wetland habitats because they elevate water tables and enhance riparian vegetation (Olson and Hubert 1994), create deeper water habitats with velocity and thermal refugia (Hagglund and Sjoberg 1999), decrease water velocities and promote sediment retention (Naiman et al. 1988), improve water quality by facilitating riparian habitats that intercept nutrient and chemical contaminants (Olson and Hubert 1994), and increase upstream water storage to buffer against floods and summer droughts (Olson and Hubert 1994). These beaver-induced hydrological and biogeochemical changes also affect aquatic, riparian, and wetland biota. For example, beaver ponds exert strong influences on aquatic invertebrates (McDowell and Naiman 1986; Clifford et al. 1993; Margolis et al. 2001), fishes (Snodgrass and Meffe 1998; Hagglund and Sjoberg 1999), herpetofauna (e.g., amphibians and reptiles: Russell et al. 1999; Metts et al. 2001), and birds (Brown et al. 1996; McKinstry et al. 2001).

Figure 21. An active beaver dam in the Rocky Mountains. These ponded sites provide numerous benefits for aquatic ecosystems as well as storing water for downstream use.

Unfortunately, Euro-American settlers were concerned with the economic exploitation of beaver, rather than their benefits as ecosystem engineers, and nearly extirpated them from the North America. European beaver (Castor fiber) were nearly extirpated by 1600, and early immigrants found a rich source of beaver pelts in America. At the time of European arrival in North America there may have been up to 400 million beaver living on the continent (Naiman et al. 1988), but by 1850 this number probably dropped below nine million. Nonetheless, trapping continued and the pattern of beaver extermination observed earlier in Europe was essentially repeated in North America (McNamee 1994). The removal of beaver brought about major and long-lasting changes in the western landscape, because it signified the loss of a dynamic structuring element. Beaver removal has, in part, contributed to increase down cutting of stream channels (Wohl 2001), and a reduction in the complexity and extent of aquatic and wetland habitats. For example, wetland habitats in the western U.S. are rare, but provide habitat for a large proportion of waterfowl species in the area (McKinstry et al. 2001). Beaver create these types of regionally rare habitats, so their local extirpation likely reduced these habitats and affected wildlife populations.

Loss of beaver would affect sediment delivery and flow regime. Beaver impoundments often facilitate sediment deposition and storage (Wohl 2001), but in their absence, sediment might be transported further downstream and be deposited in crucial fish spawning habitats. Rocky Mountain region hydrographs are likely affected by loss of beaver impoundments because water storage capacity in first through fourth order streams is reduced. Thus, water is delivered more quickly in the absence of beaver dams, rather than being slowly released to buffer against periods of low flow.

Results:

Researchers at the University of Wyoming identified habitat suitability characteristics necessary for the colonizing of beavers in mountain streams

Suitable beaver habitat was modeled using GIS (Olson and Hubert,1994).

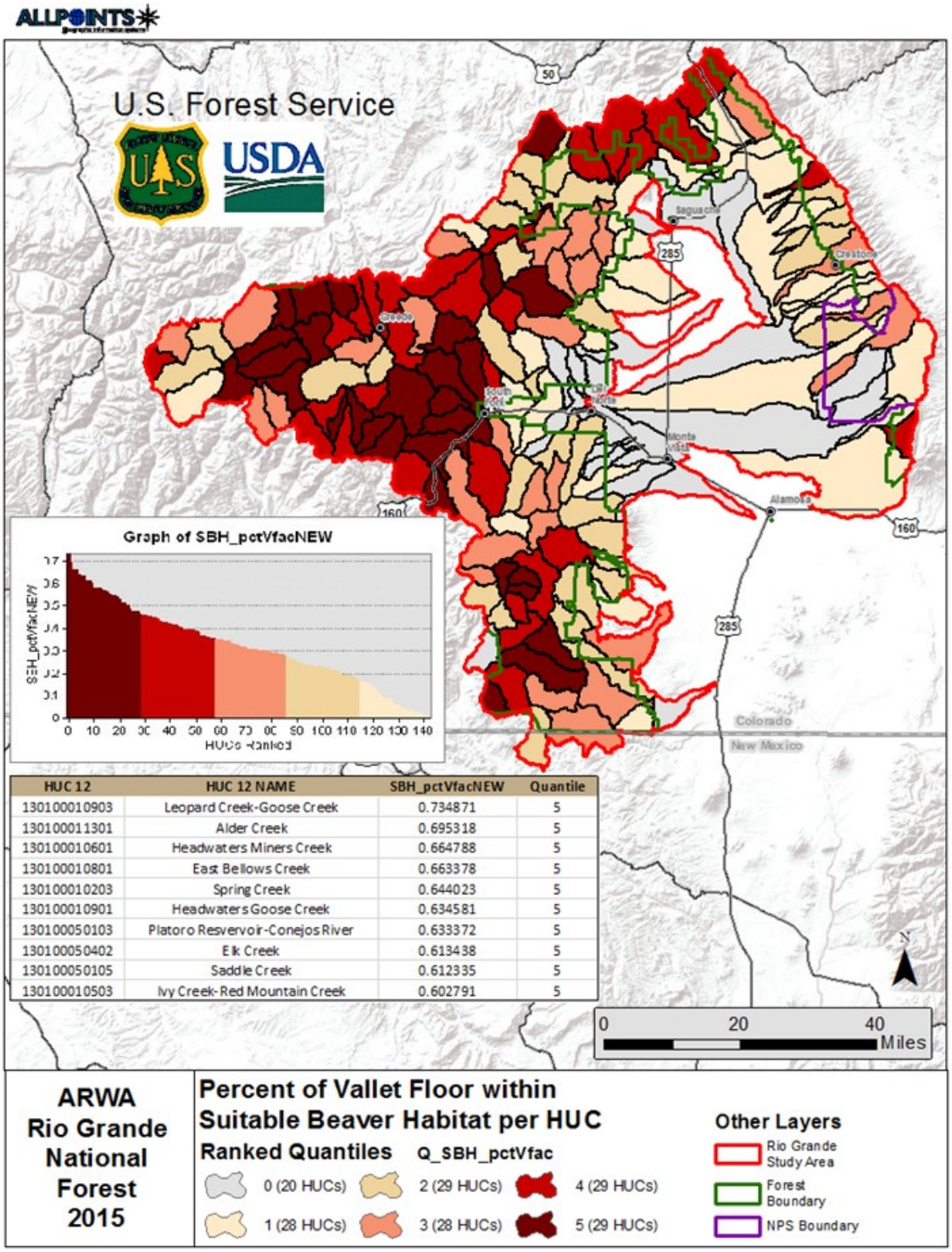
Model parameters for evaluation using existing vegetation information, and NHD stream layers included:

a. Gradient <= 4%

b. Within 200m of Aspen or Willow vegetation type

c. Permanent Streams

Stream reaches that had high correlation with these variables were mapped on a 1:24,000 scale and densities were calculated on a total stream mile bases for each subwatershed. Measures of suitable beaver habitat were based on stream length with high suitability per acre of valley bottom per subwatershed. The results are presented in Figure 22. Beavers have been trapped in irrigation systems on the valley floor by the Colorado Parks and Wildlife and periodically transplanted in Rio Grande National Forest streams (Randy Ghormly, Forest Fish and Wildlife Program Manager, pers. Comm.). Approximately 25 high suitability subwatersheds with more than 4 miles are located within the National Forest and National Park boundaries, several relatively far from private lands and/or the Rio Grande valley floor. Further evaluation at the site/reach level would need to be evaluated to ensure survival, low migration and reduced conflicts if the beavers migrated from the area. There are a considerable amount of habitat for beaver colonization on the western half of the valley, especially north of the Town of South Fork. By relocating beaver into high suitability areas, not only would low gradient stream reaches benefit, but beavers would be less likely to migrate into unwanted areas and conflict with water irrigators and crop lands in the valley bottom.



HUC 12	HUC 12 NAME	SBH_pctVfacNEW	Quantile
130100010903	Leopard Creek-Goose Creek	0.734871	5
130100011301	Alder Creek	0.695318	5
130100010601	Headwaters Miners Creek	0.664788	5
130100010801	East Bellows Creek	0.663378	5
130100010203	Spring Creek	0.644023	5
130100010901	Headwaters Goose Creek	0.634581	5
130100050103	Platoro Resvervoir-Conejos River	0.633372	5
130100050402	Elk Creek	0.613438	5
130100050105	Saddle Creek	0.612335	5
130100010503	Ivy Creek-Red Mountain Creek	0.602791	5

Figure 22. Beaver suitability results for the Rio Grande National Forest and surrounding landscape. Results were based on high suitable stream miles per acre of valley bottom per subwatershed.

Future Considerations:

The public's view of beavers has changed dramatically in the last few decades. Once considered (and is still to a limited extent) as a "pest", many municipalities and the public are considering beavers as having a key role in maintaining water on the landscape, providing buffers for fire fighting, and reducing flooding downstream. The general public is also favoring restoring beaver colonies as a places to fish, hunt and generally view natural sytems.

As water becomes more valuable, and its role for maintaining ecological diversity as well as reducing dramatic flooding events and storing water within floodplains and low gradient stream corridors beavers are being utilized throughout the country.

Due to their transient behavior when populations exceed habitat potential, they will always be a threat to some landowners. However, the benefit of their activities in appropriate habitats is well understood. Management activities within narrow valley bottoms are often in conflict with the natural water storage ability of beavers. However, it is questionable whether these activities and location of infrastructure are not the problem in these areas. Transportation corridors are often the infrastructure that is in direct competition for "space" for beaver activity, and flooding has compromised road prisms and crossings. However, it can be argued that the location and/or design of the transportation footprint is in a marginal location, and/or the design of crossings could not be modified to accommodate beaver activity. In the future, education will most likely continue to argue the benefits of beaver on the National Forest landscape, challenging us to continue developing strategies to accommodate their activities that benefit humans and the environment. Only 1 subwatershed does not contain the conditions for adequate beaver habitat, and is located in a steep portion of the very southern edge of the National Forest and beyond.

Recreational and Native Fisheries

Recreational Fishing has continued to grow although hunter use has gone down over the past few years in Colorado (Congressional Sportsman's Foundation {www.www.sportsmenslink.com}). In 2011 alone, the total anglers in the state were estimated at 767,000 anglers, spending 8.4 million days (almost 4 times that of hunters) and accounting for over 10,000 jobs. While these numbers represent the entire state, there are currently over 100 areas identified on the Rio Grande National Forest for fish as well as parking and camping for fishing on the Forest. With over 1700 miles of perennial streams and 4800 acres of lakes, the Rio Grande National Forest represents a significant source of angling recreation for visitors. Emphasis on maintaining and improving and/or protecting high quality fish habitat and access could be a future consideration given increases is visitors and populations throughout the state.

Rio Grande Cutthroat trout, suckers and chubs are the only native fish to the upper Rio Grande basin that are considered rare and in any threat of extirpation. While these species will be addressed under the "Species of Conservation Concern" as part of the Forest Planning process, a couple important habitat considerations are pertinent here.

In part, the purpose of this assessment and assessment 3 are to identify unique, important less/more influenced by management, we think that this information can be valuable in helping prioritize future establishment of rare taxa, as well as protect ecological conditions that are important for their survival. For instance, it has been identified that the strongest populations of chubs and suckers MAY be along the Sangre de Cristo mountain range where the influence of springs are found. The conditions produced from the groundwater surfacing here may be "key" to their survival in the upper basin. Other spring environments are found on private land in the area as well as on BLM and FS lands near Saguache. Are these spring large enough? Are they already developed for agricultural and or municipal purposes? They may be valuable sources for future restoration efforts. The Rio Grande cutthroat trout restoration efforts

have been active for several years. Possibly some of the information presented can assist biologists identify areas with little impacts, higher stream densities and other characteristics that can make prioritization less complicated.

Mineral Extraction

Hardrock and Placer Mining

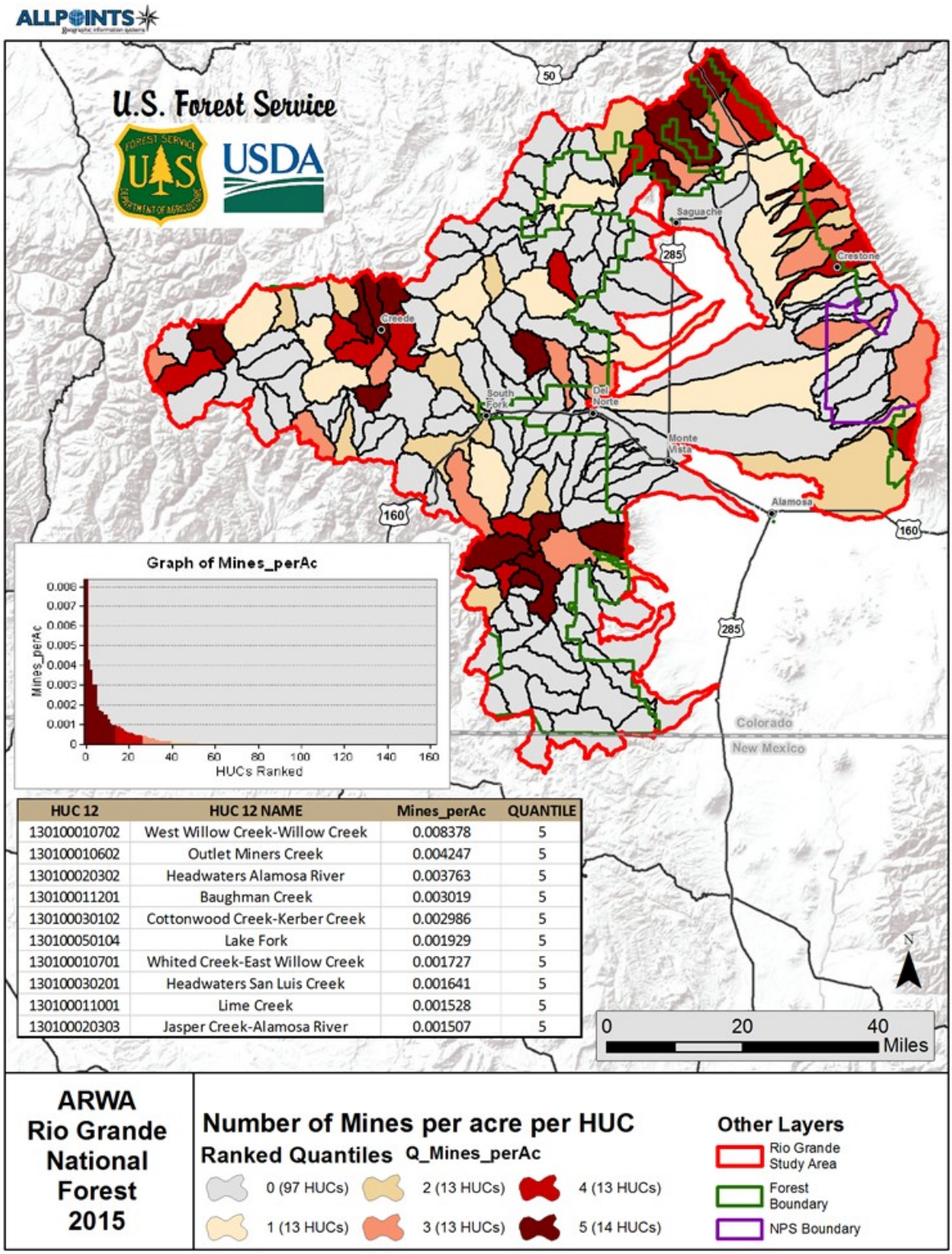
In the United States, extensive hardrock mining started in the 1880s remained a major industry in many states during the following 70 to 80 years (Wireman 2000). Mining has had a high legislative priority for over a century. The 1872 U.S. Mining Laws Act granted top land-use priority to mineral extraction on all public lands not specifically withdrawn (Nelson et al. 1991). The legacy of historic hardrock mining includes more than 200,000 abandoned or inactive mines. As of 1992, there were more than 500 operating mines in the United States, of which, more than 200 are gold mines. As of 1997, there were approximately 60 mine sites in 26 states on the Federal Superfund National Priorities List because of serious pollution problems (Wireman 2000).

Metals sought during past and present mining activities in the Southern Rocky Mountains include copper, gold, lead, molybdenum, nickel, silver, vanadium, and zinc (Deacon et al. 2001). Mineral extraction can significantly influence water quality and aquatic, riparian, and wetland resources if done in an incorrect manner. These influences can be brief or long lasting, and they differ with the type of ore, the mining and processing methods, and after mining ceases, the overall nature of how the mine is properly closed. The impacts from mining include transport and deposition of sediment, acid runoff, and release and transport of dissolved metals and other associated mine contaminants (Wireman 2000).

Results:

The results of the mining analysis are presented in Figure 23. Mining is or has been concentrated in 5 areas, Creede (a historic mining center in the valley), the town of Bonanza area in the northern part of the National Forest, Galena Mountain and Bear town in the southern San Juan mountains, and the Summitville area east along the Alamosa River (Figure 23). The West Willow Creek-Willow Creek near Creede exhibits the highest number of active/inactive mines in the Rio Grande National Forest and surrounding ecosystem, and has almost twice as many mines as the next subwatershed (Outlet Miners Creek). Both of these subwatersheds are near Creede in Mineral County. There are also past and some current activity north of the area between the towns of Del Norte and South Fork.

It is apparent that at least historic hardrock mining and exploration has occurred in many areas of the Rio Grande National Forest and surrounding landscape. We attempted to identify the distribution of active and historic mine sites, as they are the most reliable indicator we could identify that would compare actual ground disturbance. In addition, all streams and wetlands have not been adequately evaluated for the level of potentially natural or anthropogenically contributions of especially metal contamination from existing mine audits and tailings. While there is very good information the largest and most impactive areas, more subtle influences that could impact species or populations of aquatic and semi-aquatic taxa life-history or restoration into native habitats may need to be quantified at a site or reach level.



HUC 12	HUC 12 NAME	Mines_perAc	QUANTILE
130100010702	West Willow Creek-Willow Creek	0.008378	5
130100010602	Outlet Miners Creek	0.004247	5
130100020302	Headwaters Alamosa River	0.003763	5
130100011201	Baughman Creek	0.003019	5
130100030102	Cottonwood Creek-Kerber Creek	0.002986	5
130100050104	Lake Fork	0.001929	5
130100010701	Whited Creek-East Willow Creek	0.001727	5
130100030201	Headwaters San Luis Creek	0.001641	5
130100011001	Lime Creek	0.001528	5
130100020303	Jasper Creek-Alamosa River	0.001507	5

Figure 23. Results of the mines analysis for the Rio Grande National Forest and surrounding ecosystem, Results generally follow known mining districts, with the exception of the Sangre de Cristo Mountains, where historic exploration and limited sites occurred.

Management Considerations:

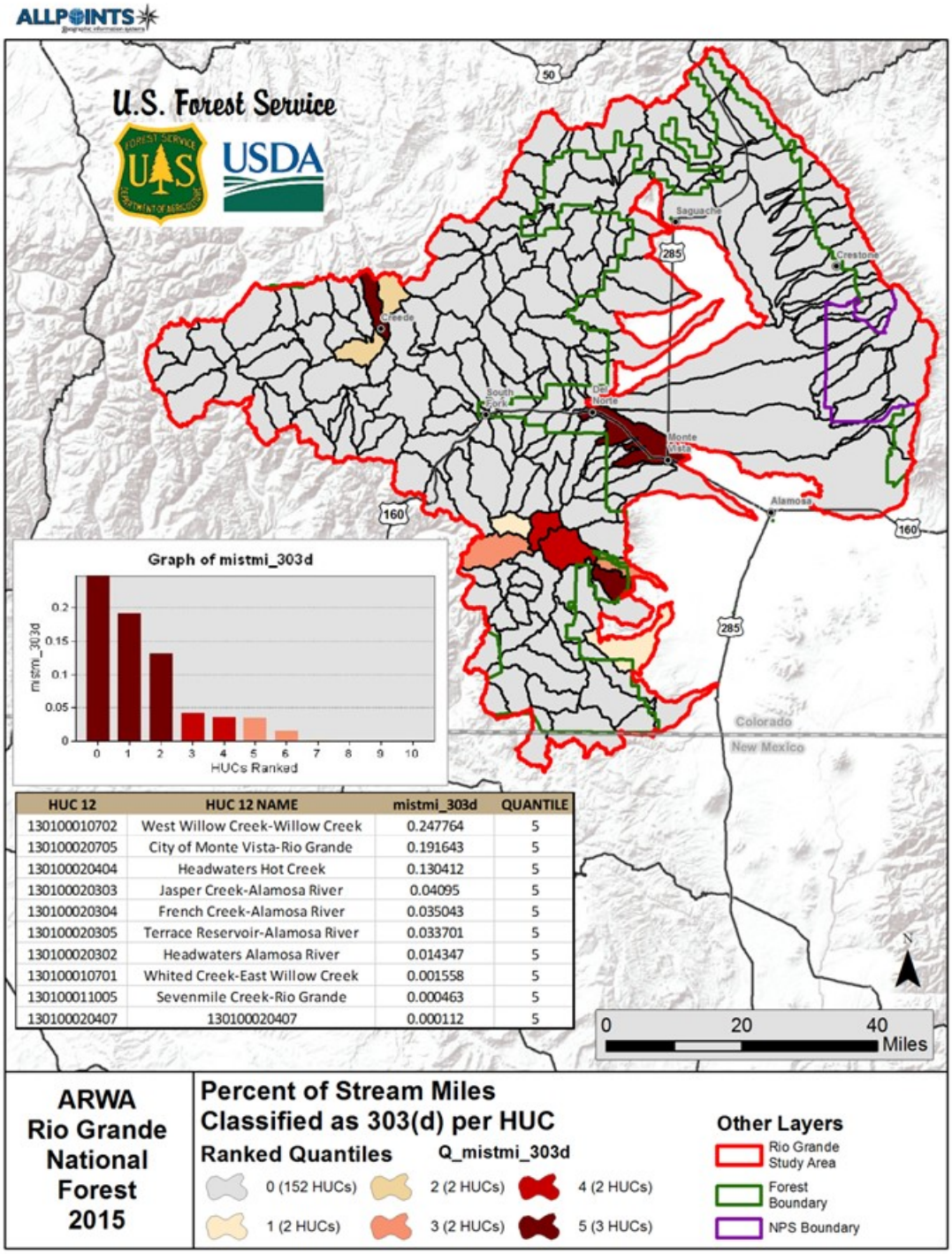
Subwatersheds with historic and/or current mining activity may be identified as having residual toxic levels of metal ions released from audits, tailings or stored in soils and stream substrates. Common metals found in effluents and are toxic to aquatic life include (but not limited to) cadmium, zinc, copper, and lead. Efforts to eliminate contaminants is extremely costly, as reflected in the case of the Summitville Superfund site. While metal bearing geology also releases contaminants through groundwater discharge and close proximity to the surface, it would appear that most of the identified areas of mine concentrations are located in known human mining concentration areas. However, the density of mine audits are limited, the highest being 0.008 per acre of subwatershed.

There are several management related options for addressing mining impacted aquatic ecosystems. Audits, tailings and accumulation in metals substrates require large cooperative efforts are needed to remove toxic materials and restore ecosystems. The Leadville Superfund site is an example of a major effort that has shown significant reduction in toxins and improvement in aquatic life in the Arkansas River. The subwatersheds associated with the mining near Creede and Summitville contain streams that have been identified as being impaired by the state of Colorado (Figure 24) under section 303D of the Clean Water Act.

While the Rio Grande National Forest has extremely limited funding for these large projects, The USDA Forest Service has responsibility for various aspects of the management of the area, which do not result in additional impacts to the area involved. As being at least partially on USDA Forest Service managed lands, support is possible from an administrative, monitoring and other supportive activities would be valuable, as well as ensuring that management help improve the current compromised situation.

Other streams and wetlands in the study area have elevated levels of metal contaminants that are not identified under the Clean Water Act process, based on the results found in Figure 23. While not all mine audits or tailings pile release these contaminants, some at least release levels that may be toxic to certain organisms or various life-history stages at different times of the year. In addition, concentrated sediments within valley bottoms, toxic levels of metals can be released into streams and wetlands if disturbed and reintroduced into the aquatic environment.

By identifying important habitats such as low gradient valley bottoms and other sediments where toxic metal sources could be concentrated, appropriate management or protection can be identified. Maintaining stream channel and riparian integrity also help to ensure that metals are not released back into the system and compromise aquatic life. This is very important when considering restoring native aquatic species. While streams and wetlands may appear to be below acute toxic levels, the systems that are in historic mining areas or associated with exposed mineralization, may be at levels low enough to only be detected seasonally or at low levels that can impeded reproduction or other life history stages. Appropriate sampling and analysis for these contaminants is necessary to ensure restoration efforts will be successful



HUC 12	HUC 12 NAME	mistmi_303d	QUANTILE
130100010702	West Willow Creek-Willow Creek	0.247764	5
130100020705	City of Monte Vista-Rio Grande	0.191643	5
130100020404	Headwaters Hot Creek	0.130412	5
130100020303	Jasper Creek-Alamosa River	0.04095	5
130100020304	French Creek-Alamosa River	0.035043	5
130100020305	Terrace Reservoir-Alamosa River	0.033701	5
130100020302	Headwaters Alamosa River	0.014347	5
130100010701	Whited Creek-East Willow Creek	0.001558	5
130100011005	Sevenmile Creek-Rio Grande	0.000463	5
130100020407	130100020407	0.000112	5

Figure 24. Subwatersheds with streams identified under the Clean Water Act as being impaired under section 303D by the State of Colorado. It is important to note that not all streams within each subwatershed have elevated levels, but should be suspect as having some level of elevated metals.

Cattle Grazing

Introduction

Grazing by domestic livestock has been an important use of the lands that now constitute the National Forests and Grasslands since the 1500s when the Native Americans began to acquire horses and other domestic animals from the early European explorers and settlers moving north from Mexico (Young 1994; Galbraith and Anderson 1971). From this time on, Native Americans traditionally maintained horse herds as both their preferred means of transportation and as a symbol of status. These herds typically traveled with the tribes as they moved between seasonal territories. At various times in the year, the tribes made use of lands that are now National Forests and Grasslands, and the tribal livestock went with them. For the most part, the horses were maintained in relatively small and localized ranges simply so that they could be found and moved when needed.

Figure 25. Cattle (left) and sheep (right) grazing

In the mid to later part of the 1800s Euro-Americans began to move into the Rocky Mountains and the western grasslands of the Great Plains, frequently bringing livestock with them (Lauenroth 1994; Pieper 1994). As the demand for beef, wool, and lamb increased during, and in the decades following the civil war, large herds of livestock were moved into and through the region. As the early settlers discovered the value in grazing livestock in the mountains and grasslands, large numbers of animals were brought into the area. At this time, there was neither any systematic applied management nor any authority to regulate the grazing activity. Basically, the livestock owner who got to the feed first got it and those who came too late got little to nothing. Within a very short few years, the serious overstocking of the rangelands, coupled with the initiation of an extended drought period, serious impacts to rangelands are still noticeable in some areas today (Pieper 1994; Oliphant 1947). While this drought plus lack of forage had the unintended effect of significantly reducing stocking levels, the reduction in stocking was by no means adequate to provide for recovery of the vegetative, soil and aquatic, riparian, and wetland resources (Young 1994; Pieper 1994).

Following the formation of what is now the Forest Service, and continuing for decades, there was a concentrated effort to gain control over the livestock use on the National Forests and Grasslands (Rowley, 1985). At first this was focused on simply requiring permits and eliminating trespass. But over time, this moved into making very significant reductions in the permitted and actual use, and in moving management toward implementing the best available science. Today, livestock numbers are significantly reduced compared with historic levels (Elmore and Kauffman, 1994; USDA Forest Service files) and are generally judged to be within grazing capacities on the National Forest System (NFS) lands. For the most part, management has intensified as well. However, the focus is on managing livestock use in a manner

that will ensure compatibility with the other uses and values of the National Forests and Grasslands. While problems still remain in places, they are generally localized.

Livestock grazing has the potential to have a significant detrimental impact on aquatic, riparian, and wetland resources if it is not managed properly (Binkley and Brown 1993). This very important resources comprise only about 2% of the landscape in Colorado, and losses are estimated to be more than 50% (U.S.G.S.1999). It should be pointed out that there are a number of reasons for this loss, many that occurred prior to current laws and policies (Wohl, 2001). There are numerous references to document these potential impacts although most references discuss impacts from improperly managed livestock grazing rather than from proper management (Platts and Raleigh 1981; Kauffman and Krueger 1984; Buckhouse 1981; Meehan and Platts 1978; Binkley and Brown 1993; Larson et al. 1998).

Livestock grazing may also be used to positive effect when managed properly and when focused on meeting well defined objectives. Grazing can: stimulate new growth of both herbaceous and woody species; increase total production of vegetation; provide increased palatability and nutrient quality to other animal grazers; increase herbaceous plant density, and alter habitat structure and composition to meet specific species objectives (such as managing for specific threatened or endangered wildlife species habitats or alteration of habitat relationships to favor certain plant species) (Krueger and Anderson 1985).

Livestock grazing tends to affect some habitats and plant communities to a greater degree than others, and therefore are at greater risk. In general, cattle tend to prefer relatively open, low gradient habitats with ready access to water and temperature moderating tall vegetation, with abundant palatable forage and/or browse resources. These needs are met to a large degree within riparian and wetland habitats. The habitats most commonly preferred by cattle are generally low gradient, willow/cottonwood (or associated hardwood species) with palatable grass and grass-like species (Rinne, 1999). These areas most frequently occur in association with fine textured soils. Cattle use of habitats declines markedly as slopes increase, as tree canopy cover increases, and as distance to water increases. This is true both for uplands and for riparian habitats. In addition, use of uplands declines as upland forage resources mature and decline in palatability and nutrition (Roath and Kreuger 1982). Sheep on the other hand prefer uplands and normally only utilize riparian/wetlands when moved to those areas to acquire water, or congregated there (Glimp and Swanson 1994). Bison tend to prefer upland open grasslands and windswept ridges. Risks to aquatic, riparian, and wetland resources then depend directly on the species of livestock and the type of habitat present (Marlow et al. 1985; 1989). Riparian vegetation tends to be quite resilient and when managed properly has a relatively rapid recovery while stream channel conditions frequently take longer to recover (Binkley and Brown 1993).

In order to validate the modeling of the effects of livestock management, it will be necessary over time to analyze new and existing field data with a focus on determination of resource conditions and trends as they relate to livestock management. Significant amounts of historic data currently exist for terrestrial habitats although little of this is currently in an electronic format. Areas of high livestock preference and/or area with low resiliency would likely be priority areas for data collection.

Results and management Considerations

The purpose of this analysis was to identify the amount of subwatersheds intersecting or within the Rio Grande national Forest that are currently available to cattle grazing. This by no means is meant to identify current use, influences, preference or timing. Instead we are evaluating the availability of the landscape that we have identified by ecological drivers to be available, and identify areas for future consideration for monitoring and evaluation.

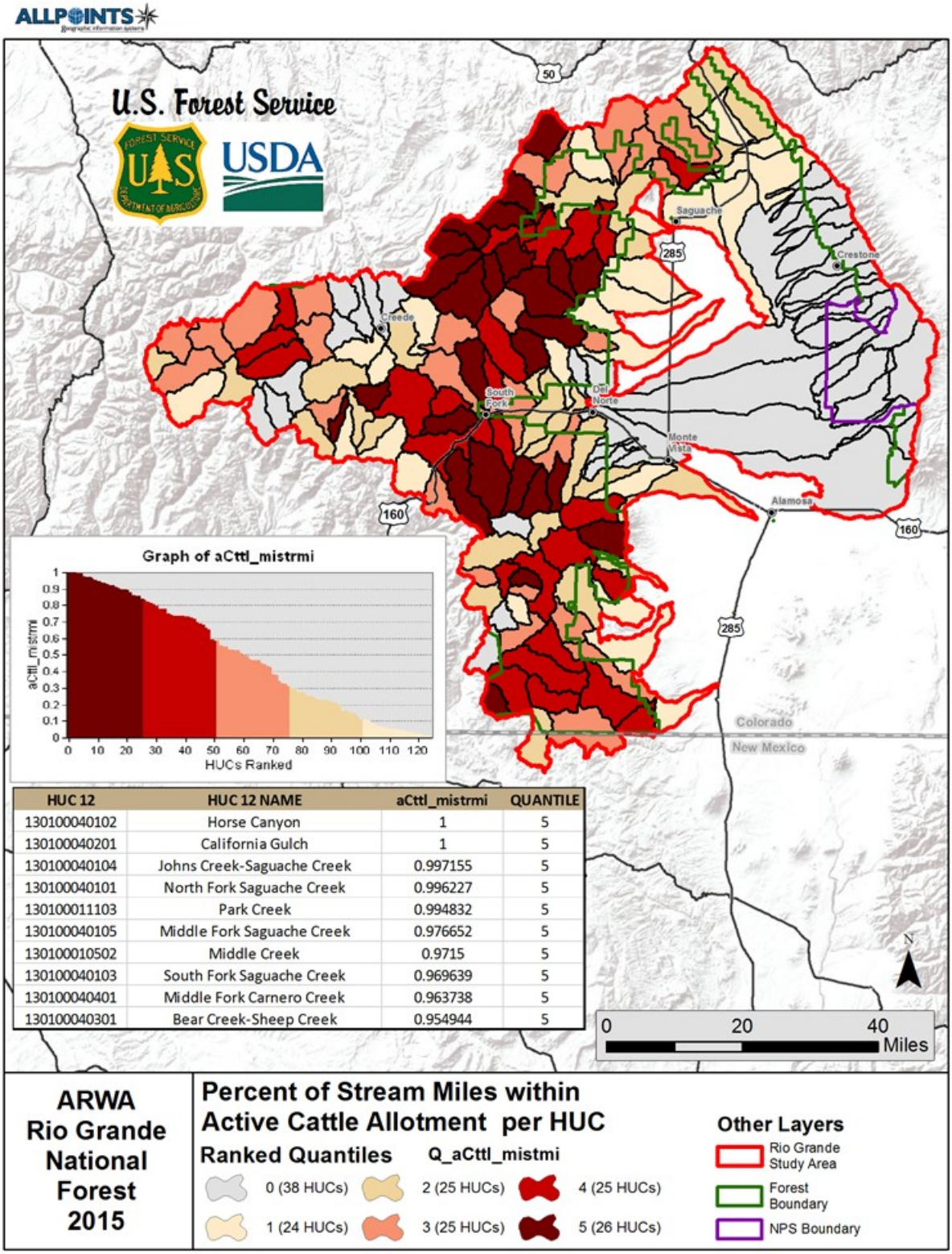
A considerable amount of the project scale is currently available for cattle management (Figure 26). Percentages of stream miles within active allotments for the 2 highest quantiles include 50 subwatersheds, and range from approximately 60-100 % of permanent streams within these active allotments. Approximately 125 subwatersheds out of a total of 163 (77%) have active allotments with permanent streams in them. Most of the subwatersheds without active allotments are located on the steep Sangre de Cristo Mountains on the eastern portion of the National Forest. There a total of 10 subwatersheds on the west side of the National Forest without active allotments, half of these are located just north-east of the town of Creede, associated with the La Garita Wilderness area. Five of the subwatersheds with inactive allotments are associated with the South San Juan Wilderness Area.

From an elevation standpoint, active allotments are found from the valley floor to the continental divide, with negligible "pattern" between landscapes. Platts (1991) identified several grazing strategies that had variable influences on streams and riparian areas, and concluded that no single strategy met all grazing or resource needs over a complex landscape. Monitoring and strategies for alpine areas are different from glaciated valleys that are different from low gradient, willow dominated stream reaches. Indeed, the calculated cattle grazing preference is variable on a landscape this large. Platts along with many others identified various techniques for minimizing impacts to sensitive aquatic and semi-aquatic ecosystems in mountainous areas.

Presented below are conditions that could be considered for further investigation given the findings of the Aquatic Ecological Driver Assessment, management activities in the study area related to aquatic and semi-aquatic resources and the broad availability of cattle grazing opportunities in the upper Rio Grande Valley on National Forest lands.

High elevation Glaciated Valleys – These valleys were formed by glacial scour and typically contain high concentration of wetlands and wetland related plants and animals that may be quite rare. Our analysis in Assessment 3 illustrated that while these valleys contain approximately 50% of the wetlands in the Rio Grande National Forest, they comprise approximately 30% of the Forest landscape. Based on these results, there appears to be several subwatersheds associated with relatively high concentrations of wetlands as well as high proportion of active cattle allotments. It should be noted however, that there are also subwatersheds in wilderness areas that exhibit glaciated landscapes that have no active allotments. Consideration for glaciated areas with extensive wetlands could be examined further if not already for their relationship to cattle grazing and potential influences on the wetland communities as a "whole" and not individually. It is questionable as to whether standards or general guidelines in these valleys that are at high elevations would be effective is grazing as well as the growing season is during a short period of the year. Interdisciplinary evaluation of these glaciated valleys could be done to ensure the form and function of high concentrations of wetlands and riparian areas.

Influence of Climate Change through stream channel maintenance - The analysis we prepared in Assessment 3 identified that predicted variables over time that may have a dramatic change in mean annual discharge in the future across the Rio Grande valley. These data indicate that mean annual discharge may decrease up to 20% in the next 25 years and 30% by 2080 in the study area. These data are not inconsistent with other models developed for the southern Rocky Mountains and reflect changes in precipitation solar penetration and snowmelt. The impacts on stream and wetland morphology, riparian and wetland vegetation and stream biota could be magnified if proper conditions are not maintained to promote resilient ecosystems. Stream discharge in the study are influenced considerably by snowmelt, precipitation at lower elevations, natural storage in alluvium, channel and wetland structure and shading, and anthropogenic influences in the valley bottoms.



HUC 12	HUC 12 NAME	aCttl_mistrmi	QUANTILE
130100040102	Horse Canyon	1	5
130100040201	California Gulch	1	5
130100040104	Johns Creek-Saguache Creek	0.997155	5
130100040101	North Fork Saguache Creek	0.996227	5
130100011103	Park Creek	0.994832	5
130100040105	Middle Fork Saguache Creek	0.976652	5
130100010502	Middle Creek	0.9715	5
130100040103	South Fork Saguache Creek	0.969639	5
130100040401	Middle Fork Carnero Creek	0.963738	5
130100040301	Bear Creek-Sheep Creek	0.954944	5

Figure 26. Results of the active allotment density for cattle within valley bottoms For the Rio Grande National Forest and surrounding landscape

Future Considerations

Influencing snow accumulation and melting and precipitation are not factors we cannot influence at this scale. However, channel and wetland structure, shading and anthropogenic influences are. We chose to use the valley bottom area for analysis of anthropogenic influences because it is the area that influences riparian and stream systems the most. Even within valley bottoms, steep, narrow valleys are typically lined with larger substrate and are more stable than wide low gradient valleys with fine sediment and meandering channels Rosgen (1996). While our analysis in Assessment 3 illustrated that approximately 63% of the permanent stream channels are within the confines of steep, stabile stream channels with limited sunlight penetration and forage for livestock, only about 20% are in highly sensitive low or moderate gradient stream reaches. These limited areas can store considerable amounts of water in the associated valley bottom. They are extremely important for providing aquatic and riparian habitat as well as absorb excess water to be released slowly downstream. Shading from woody riparian vegetation can also have major influences on stream temperature, bank stability, aquatic habitat and stream morphology, more so than stabile channels.

Cluster 4 from Assessment 3 has the highest number of subwatersheds with low gradient stream channels comprising more 14% of its total stream length (53 subwatersheds). Clusters 5, 6 and 7 have higher percentages of low gradient channels, but are highly influenced by extending into the relatively low gradient valley bottom.

While there does not appear to be a relationship between the percentage of active cattle allotments and the abundance of low gradient stream channels in cluster 4, we should ensure that the conditions in the relatively small amount of low gradient stream channels are maintained at a high level of function for the future. Even in clusters 1-3, where low gradient channels represent less than 10% of the total stream length, ensuring shade, stability and habitat could ensure the function of stream and riparian areas for the future. The maintenance of the highest vertical elevation of native woody vegetation (e.g. willows, Spruce and cottonwoods) ensures that we are not influencing long-term climate change trends upward and eliminating important ecosystems and taxa.

Geology, springs and productivity – In assessment 3 we identified the calcareous geology along the Sangre de Cristo mountain range as being important for naturally occurring springs, influencing water temperature and increasing aquatic productivity for native plants, fish and other animals. Available active cattle allotments are very low or absent in this area. While spring development and extensive grazing could have a major influence on rare plants and animals, as well as unique characteristics, it is doubtful that there is significant influence from cattle grazing in this area.

Springs associated with rare and unique species of plants and animals as well as habitats (e.g. fens) are rare environments in the Rocky Mountains, especially where granitic geology is found. The form of glaciated valleys allows for snowmelt to percolate through the steep mountain peaks and emerge on the lower valley sides and bottoms, allowing a variety of different wetlands. Isolated springs at lower elevations are less common, and often developed and utilized early in European development and indeed by Native Americans and wildlife prior to settlement. While there is direction protecting the impact of wetlands (Executive order 1190 {1972} and the Clean Water Act {1972}, the Environmental Protection agency estimates that more than 50% of wetlands across the country are no longer present on the landscape (http://www.epa.gov/nscep). While comprising only 2% of the Colorado landscape, springs and associated wetlands are extremely important for terrestrial and aquatic ecological function and rare plants and animals (http://www.cnhp.colostate.edu/cwic/index.asp). The development of springs is a common and accepted means of watering livestock. The recent publications on inventory and monitoring of groundwater dependent ecosystems (http://www.fs.fed.us/geology/GDE_Level_II_FG_final_March2012_rev1_s.pdf) and assessment of

wetland systems by Cooper and Merritt (2012) should be extremely helpful in the future for weighing the various benefits of groundwater driven ecosystems.

Sheep Grazing

Introduction

Sheep prefer to graze and occupy upland areas rather than “wet” areas (Platts, 1991). As a result, they are normally not considered impactive to streams, riparian areas and wetlands, unless they are concentrated their through management practices. In both Platts and Rinne (1999) review of a large volume of studies, they suggested that adequate monitoring was not completed prior to several studies, and ecological conditions needed in riparian and wetland ecosystems had to be determined by instigating several important factors responsible for the systems to function adequately, and not develop a “goal” for a large landscape when there is a high variability in land form and function.

The lack of sheep/riparian interactions in most of the literature I reviewed indicates that solutions to maintaining healthy ecosystems and provide grazing for sheep may not be as difficult as cattle. Indeed, if not crowded in riparian areas they will tend to forage on uplands, and generally steeper slopes than cattle (Glimp, 1994). Reviewers that we cited all identified constant herding as a beneficial way to maintain sheep grazing in uplands along with alternate water supplies. The biggest concern was that herder’s camps were often located in valley bottoms, and sheep herds along with them were concentrated in these areas, often for several days. If concentrated in these valley bottoms during early spring and summer, major impacts to riparian plants and soils could be impacted.

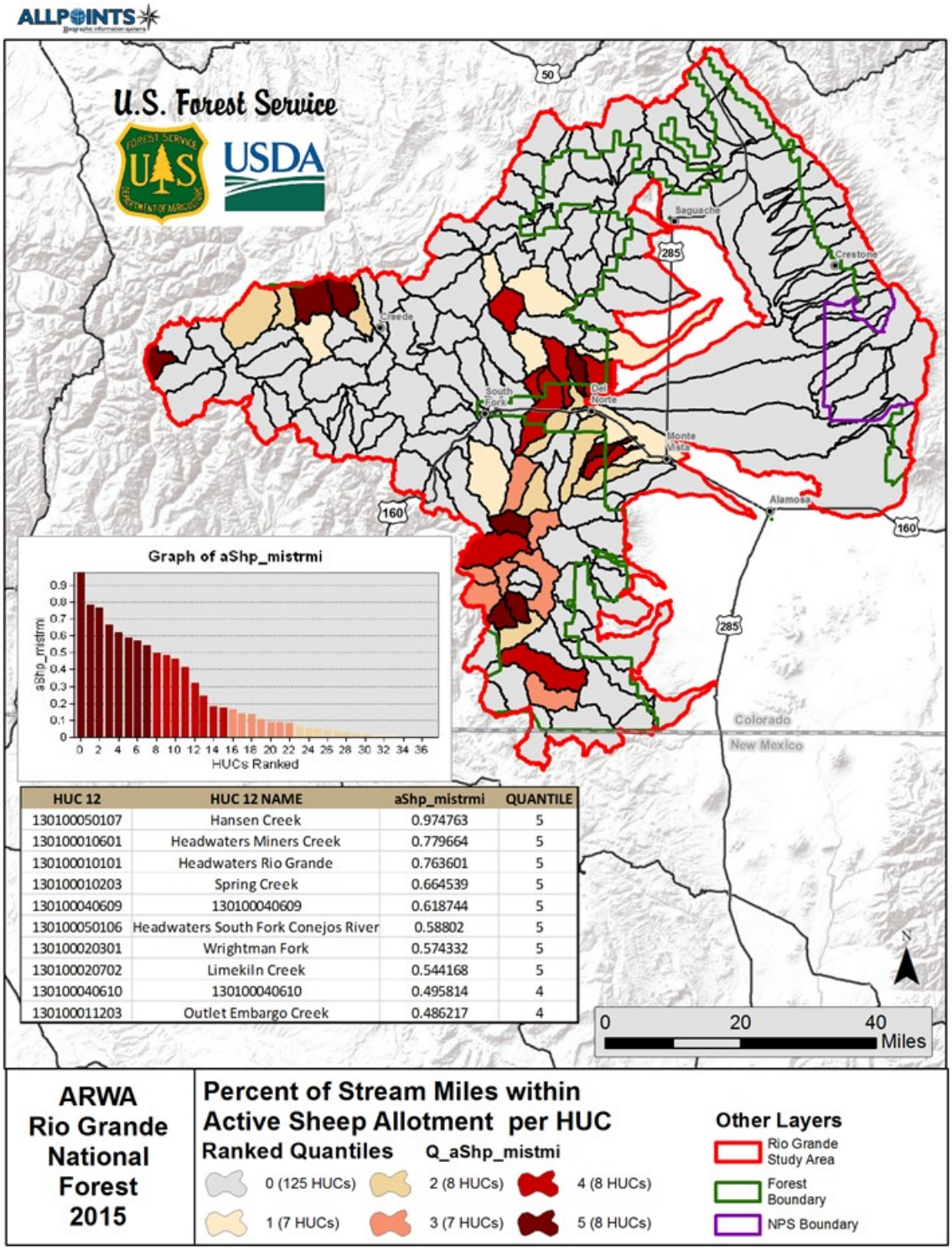
Results

Relative to cattle allotments, there are relatively few sheep allotments, based on our measure of permanent streams per active allotment. A total of 6 of the 8 subwatersheds are at relatively high elevations however, indicating that they could have a higher likelihood to be associated with riparian areas and, glaciated valleys and wetlands. On the western side of the study area, some of these areas are associated with the Weminuche and South San Juan Wilderness areas. While again we are not able to identify the intensity and duration of grazing in these areas, there location indicates concentrations of wetlands much higher than at lower elevations.

All of the identified subwatersheds on the western side of the study area with grazing allotments identified, including 4 in the highest quantile are associated with glaciated valleys.

Future Considerations

Spatially, there are far fewer active allotments for sheep grazing than cattle. In lower elevation subwatersheds, techniques to manage sheep outside of riparian areas are probably relatively easy give the avoidance of wet areas by them. Managing the herd locations and where they are “bedded”, along with the herders would maintain the herds and habitat. In the occasion that non-native invasive plants (e.g. Canadian thistle, Cirsium vulgare) become established, intensive grazing by sheep could be used. It appears that having constant and consistent herd movement would be necessary to avoid significant damage to riparian and stream ecosystems.



HUC 12	HUC 12 NAME	aShp_mistrmi	QUANTILE
130100050107	Hansen Creek	0.974763	5
130100010601	Headwaters Miners Creek	0.779664	5
130100010101	Headwaters Rio Grande	0.763601	5
130100010203	Spring Creek	0.664539	5
130100040609	130100040609	0.618744	5
130100050106	Headwaters South Fork Conejos River	0.58802	5
130100020301	Wrightman Fork	0.574332	5
130100020702	Limekiln Creek	0.544168	5
130100040610	130100040610	0.495814	4
130100011203	Outlet Embargo Creek	0.486217	4

Figure 27. Results of the relationship between permanent streams and active sheep allotments per subwatershed in the Rio Grande National Forest Ecosystem.

Commercial Timber Harvest

Introduction

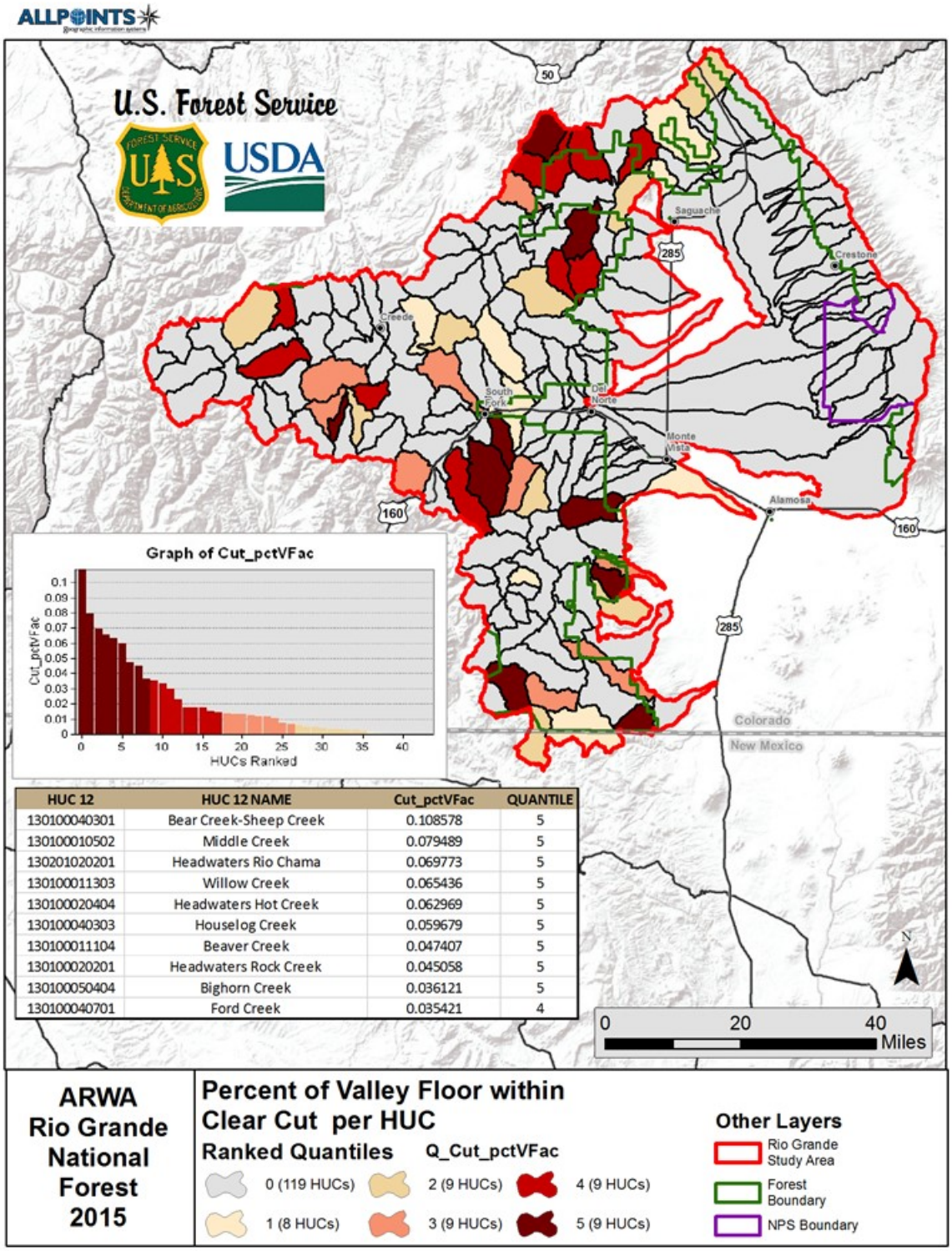
Commercial timber harvest in riparian areas and wetlands has been shown to have dramatic, long-term impacts to stream habitat and ecosystems, especially in the Northwest (Sidell, 1994). Instream and riparian habitats rely on the shading, food source, habitat, and stream bank stability from living and dead trees associated with these areas. In addition, sediment trapping, energy absorption from flooding and many terrestrial benefits are also important values of trees and shrubs in riparian areas, streams and wetlands. While many more recent improvements in timber harvest have helped to ensure trees and wood remain an important part of the riparian stream and wetland ecosystems in the Rocky Mountains, extensive ecological damage was done during the early European settlement, when the larger and easier to harvest trees were along stream channels (Wohl, 2001).

Results

The results of the clearcut timber harvest in valley bottoms are presented in Figure 28. It is very apparent that timber sales have been limited in the Rio Grande National Forest and surrounding landscape in the last few decades. The highest density of harvest in the valley bottom was 0.1 % of the total valley bottom within the Bear Creek-Sheep Creek subwatershed. These results indicate that timber harvest has not been a significant influence within valley bottoms in the recent past

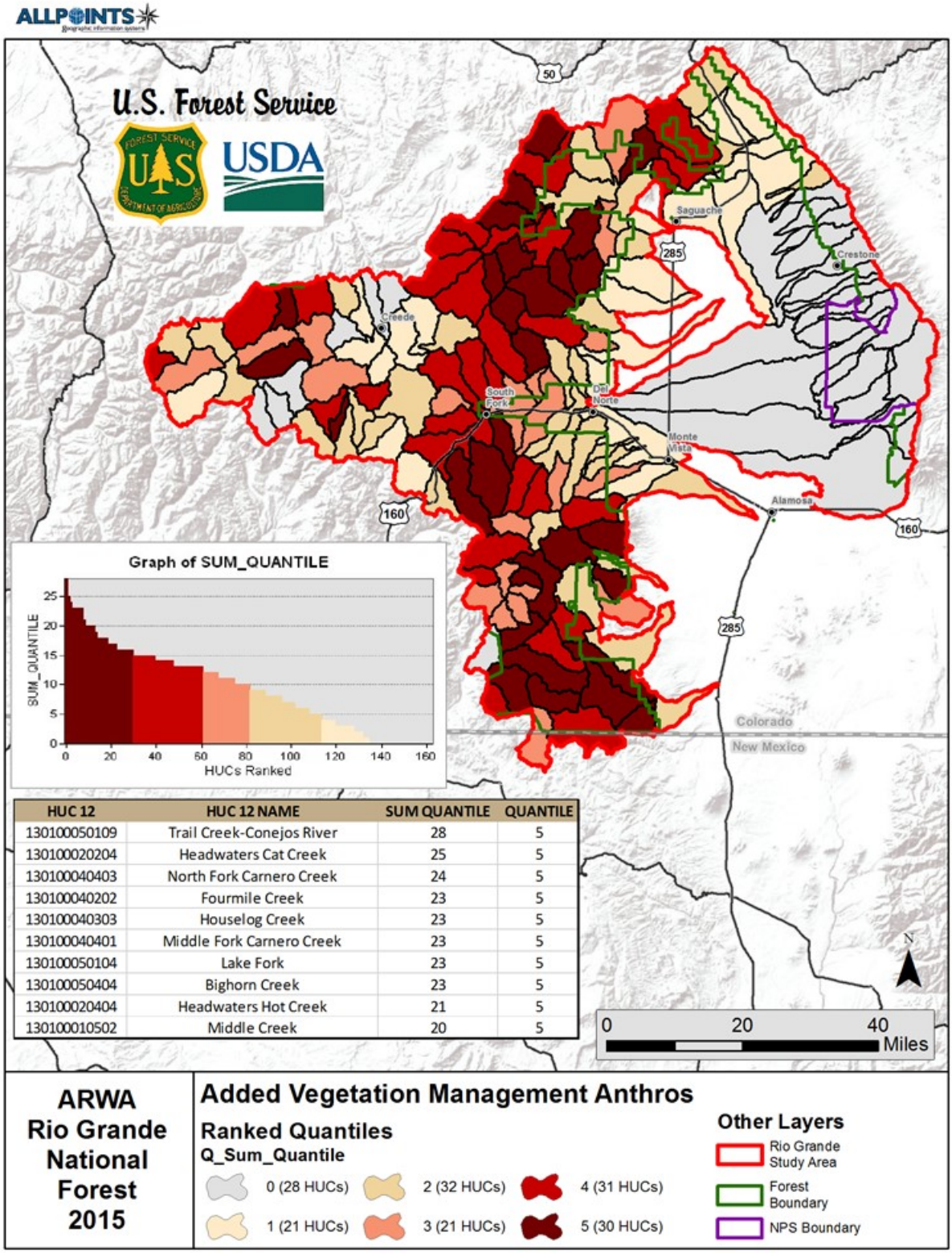
Future Considerations

As mentioned previously, timber harvest and the removal of wood from valley bottoms was probably most impactive during the mid to late 1800's and early 1900's. Today, other than removing wood from stream channels, timber harvest has not been an important influence. However, with the large fires that have occurred in the last few years in the western portion of the National Forest, care must be taken to ensure that trees are not removed from valley bottoms other than those pieces not considered for maintaining ecological form and function of stream, wetland and stream ecosystems. Even trees left lying on riparian valley floors are important for trapping sediment and debris during floods, providing habitat for terrestrial organisms and seedbeds for other herbaceous and woody plants. Stream crossings planned and constructed to represent natural stream channels will pass trees through them, much the same as natural stream channels. Since a large portion of this very important resource has been removed from the valley bottoms in the past, collaboration with Silviculturists and timber managers could result is replacing some of this wood in important valley bottom areas.



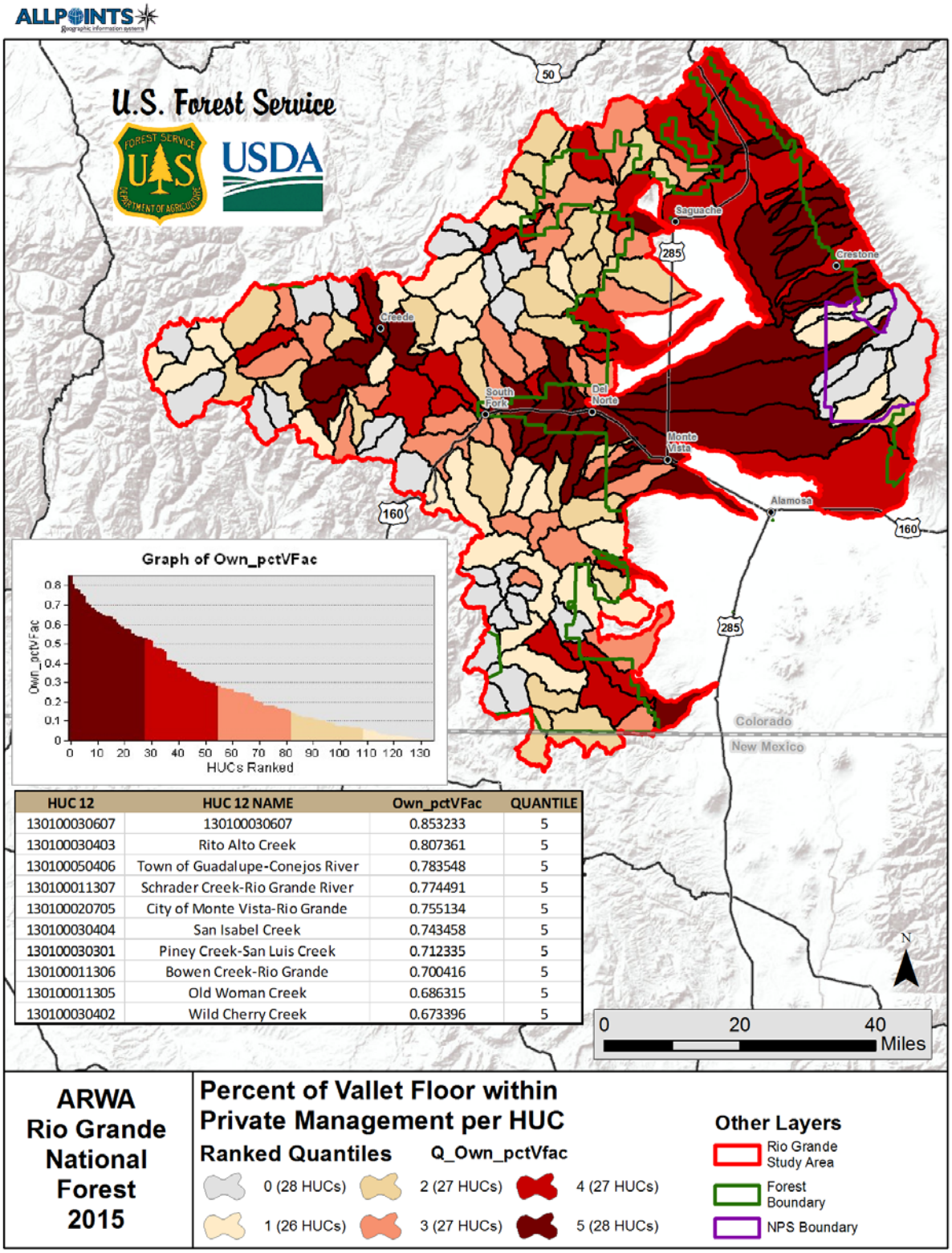
HUC 12	HUC 12 NAME	Cut_pctVFac	QUANTILE
130100040301	Bear Creek-Sheep Creek	0.108578	5
130100010502	Middle Creek	0.079489	5
130201020201	Headwaters Rio Chama	0.069773	5
130100011303	Willow Creek	0.065436	5
130100020404	Headwaters Hot Creek	0.062969	5
130100040303	Houselog Creek	0.059679	5
130100011104	Beaver Creek	0.047407	5
130100020201	Headwaters Rock Creek	0.045058	5
130100050404	Bighorn Creek	0.036121	5
130100040701	Ford Creek	0.035421	4

Figure 28. Percentage of valley bottoms with active clear cuts conducted in the last 2 decades. The percentage for these activities is very low, even in the highest levels.



HUC 12	HUC 12 NAME	SUM QUANTILE	QUANTILE
130100050109	Trail Creek-Conejos River	28	5
130100020204	Headwaters Cat Creek	25	5
130100040403	North Fork Carnero Creek	24	5
130100040202	Fourmile Creek	23	5
130100040303	Houselog Creek	23	5
130100040401	Middle Fork Carnero Creek	23	5
130100050104	Lake Fork	23	5
130100050404	Bighorn Creek	23	5
130100020404	Headwaters Hot Creek	21	5
130100010502	Middle Creek	20	5

Figure 29.



HUC 12	HUC 12 NAME	Own_pctVFac	QUANTILE
130100030607	130100030607	0.853233	5
130100030403	Rito Alto Creek	0.807361	5
130100050406	Town of Guadalupe-Conejos River	0.783548	5
130100011307	Schrader Creek-Rio Grande River	0.774491	5
130100020705	City of Monte Vista-Rio Grande	0.755134	5
130100030404	San Isabel Creek	0.743458	5
130100030301	Piney Creek-San Luis Creek	0.712335	5
130100011306	Bowen Creek-Rio Grande	0.700416	5
130100011305	Old Woman Creek	0.686315	5
130100030402	Wild Cherry Creek	0.673396	5

Figure 30.

Need for Change

This section identifies information that has been identified or understood to be important to Stream, Riparian and Wetland Ecosystem form and function since the Forest Plan developed in 1996. In addition, this information is important to maintain ecological sustainability of these systems and the plants and animals in them. It is not meant to be complete, but focuses on the priorities we felt could be accomplished in a relatively short period of time.

Ecological Drivers

The Rio Grande is located in a relatively high elevation landscape, with 3 major geologic types, predominately high gradient landscapes

- The calcareous geologic formation and groundwater systems along the Sangre de Cristo mountain range is extremely limited spatially and should be considered an important feature for potentially rare plants and animals, including fish downstream
- The volcanic subwatersheds on the western portion of the National Forest could be more productive for aquatic, wetland and riparian species due to calcium and other inorganic nutrients
- Glaciated valleys are very important for wetland development, containing higher densities than the rest of the Forest
- Low gradient stream channels are the most sensitive and important stream types and associated riparian areas to stream health and have limited management direction.
    - Cluster 3 contains subwatersheds with the highest percentage of low gradient channels that are not influenced considerably by the valley floor.
- Beaver colony development can have a major influence on stream recovery and riparian development and could be identified as a management tool.
- Climate change Analysis shows potential change in discharge and expected changes in stream and wetland temperature dynamics and health.
- Stream density in subwatersheds is variable between subwatersheds and could be important for future species and riparian management.

Anthropogenic resources

Valley bottoms provide a morphological basis for managing riparian and stream monitoring and restoration efforts, while riparian areas are based on “existing” characteristics and locations.

- Transportation
    - Designs are available for determining fragmentation from inadequate stream crossings and improvements to meet stream function
    - Transportation corridors in valley bottoms restrict stream channels and riparian areas, increasing impacts from flooding and reducing habitat. New road construction and relocation of existing roads in valley bottoms would improve conditions
- Grazing
    - Low gradient response reaches are paramount for management of grazing and riparian and stream ecosystems and will be more important in the future

        - Results of the climate change analysis indicate that proper grazing management could reduce the influence of future grazing management
    - Glaciated valleys could be considered sensitive to grazing impacts, due to the abundance of wetlands and could be managed differently than other landscapes
    - Maintaining riparian woody species at late seral stages in low gradient reaches would increase stream shading and reduce stream and riparian temperatures in lieu of climate change.
    - Restoring riparian trees and woody shrubs would be an effecting water temperature control
    - Fencing denuded low gradient riparian areas and reestablishing woody shrubs and trees is needed where chemicals and or grazing over time has eliminated vegetation.
- Invasive Species
    - Numerous non-native plants, pathogens and animals have been introduced to streams, riparian areas and wetlands. Direction to reduce the introduction of invasives such as whirling disease and chitrid fungus could be a priority to protect ecosystems in the future.
- Rare wetlands such as springs and fens require additional protection where rare taxa and downstream temperature influences are paramount
- Managing subwatersheds for ecological resiliency would aid in the restoration and stability of mining impaired subwatersheds.
- The resiliency of streams, riparian areas and wetlands must be high in order to be able to ensure the impacts of future climate change and human influences associated with drought, fire and insect and diseases
- Trees and woody material in streams and riparian has been limited from past management practices, resulting in reduced resiliency and habitat quality and quantity.
- Recreational fishing demand has increased as opportunities related to decreased access and habitat conditions. There is a need to increase the fishing opportunities on public lands and quality of fish habitat while ensuring impacts from visitors does not increase.

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Note: In addition to citations directly from this document we included other's that were identified as being important sources of information that may help in understanding information further.

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