Regional-Scale Climate Change Vulnerability Assessment for Infrastructure in the National Forests and Grasslands of the Rocky Mountain Region

Including roads, trails, and recreational facilities

Michael J. Furniss

Pacific Northwest Research Station (retired)

Carol Howe

GMUG National Forests

September, 2016

Note: This is a low-resolution version of this report: A high-resolution version that allows zooming to GIS detail (230MB), the Appendixes, and the component GIS analyses are available at: http://bit.ly/R2_InfrastructureVA

Contents

Summary

Climatic conditions, particularly extreme rainfall, snowmelt, and flooding, pose substantial risks to the infrastructure on and near the National Forests and Grasslands of the Rocky Mountain Region. Essentially all infrastructure is vulnerable to some degree, but risks and vulnerability differ greatly from place to place. Useful distinctions can be made that can inform environmental assessments, land-use planning, and prioities for climate adaptation.

The region has a great deal of valuable infrastructure: 45,136 miles of roads, miles of trails, and many campgrounds.

This analysis evaluated the vulnerability of roads, trails and campgrounds by using the indicators for exposure to fluvial damage, including: proximity to streams, and road- and trail- stream crossings. These indicators were available at the regional scale. More detailed indicators are not available at the regional scale of this analysis and may be queried at National Forest/Grassland or watershed scales.

The analysis shows that about 7,289 miles are road are within 100 feet of a stream, and 13,339 miles of road are within 300 feet of a stream. There are approximately 71,181 stream crossings of roads and motor-trails. These indicate the most vulnerable roads and those subwatersheds that may be most affected by roads and trails.

A wide variety of tools and methods are available to reduce the vulnerability of infrastructure and increase its resilience. The most important of these at the regional scale are detailed here, including transportation analysis, performance monitoring and adaptation, storm-proofing, hydrologic disconnection, and a vartiety of other effective Best Management Practices.

Recommended citation: Furniss, M.J. and Carol Howe. 2016. Regional-Scale Climate Change Vulnerability Assessment for Infrastructure in the National Forests and Grasslands of the Rocky Mountain Region: Including roads, trails, and recreational facilities. For: Rocky Mountain Region, USDA-Forest Service, and Rocky Mountain Research Station, USDA-Forest Service. 117 pages.

Introduction and Background

Climatic conditions, particularly extreme rainfall, snowmelt, and flooding, pose substantial risks to the infrastructure on and near the National Forests and Grasslands of the Rocky Mountain Region. Floods happen frequently in the region, and large and very large floods happen occasionally. These events result in damage or destruction of infrastructure and impacts to environmental values and services.

This is not new – infrastructure has always been vulnerable to climatic stresses. Rapid climate change is very likely to increase the size and frequency of these climatic stressors, thereby increasing the hazards and risk to infrastructure, people, and ecosystems of the region. Anticipating changes in risk and consequences can enable managers to respond by setting priorities and executing projects for adding resilience to infrastructure.

Rapid population growth and demands for water and other forest products has resulted in cumulative effects to forest resources, particularly close to populated areas. Climate change adds to these effects, and multiplies the risks. The type of risks remain as always (e.g., washouts, landslides, culvert failure, streamside road avulsion, and so on), but place importance and likelihood of risks may change. We can anticipate the myriad changes that will be wrought by a rapidly warming climate and prepare, with known practices, to make national forest and grassland infrastructure more resilient, safe, and with less impact to public water resources and ecosystems.

The report is a broad-scale review of specific vulnerable infrastructure -- primarily roads, trails, and recreation facilities --within the boundaries of the national forests and grasslands of the Rocky Mountain region.

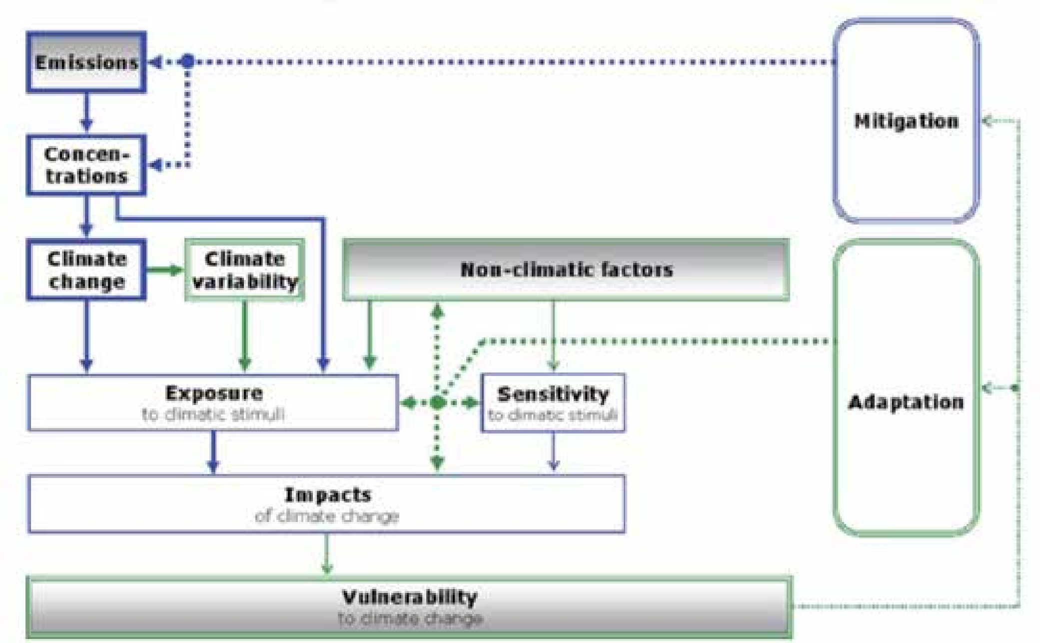
Analysis approach and indicators

Vulnerability assessment, beginning at the Regional scale is a "top-down" approach and is recommended.

Beginning at the regional scale (top-down) is appropriate, so that climatic exposures can be described, methods established, and priorities for specific areas set.

This assessment is focused on road and trail systems and recreation facilities, and their relative sensitivity to climatic stresses, and the treatments that can increased infrastructure resilience and decrease vulnerability. Infrastructure is tallied and reported by HUC-6 --subwatersheds--for each of the National Forests and Grasslands in the Rocky Mountain Region. Dams, water systems, and administrative structures and other infrastructure are outside the scope of this analysis.

Vulnerability is a combination of exposure, sensitivity, and adaptive capacity. This analysis is focused on the sensitivity of infrastructure based on its proximity to streams and rivers, as well as methods and approaches to adapt infrastructure to increase its resilience and reduce its vulnerability to climatic stresses.



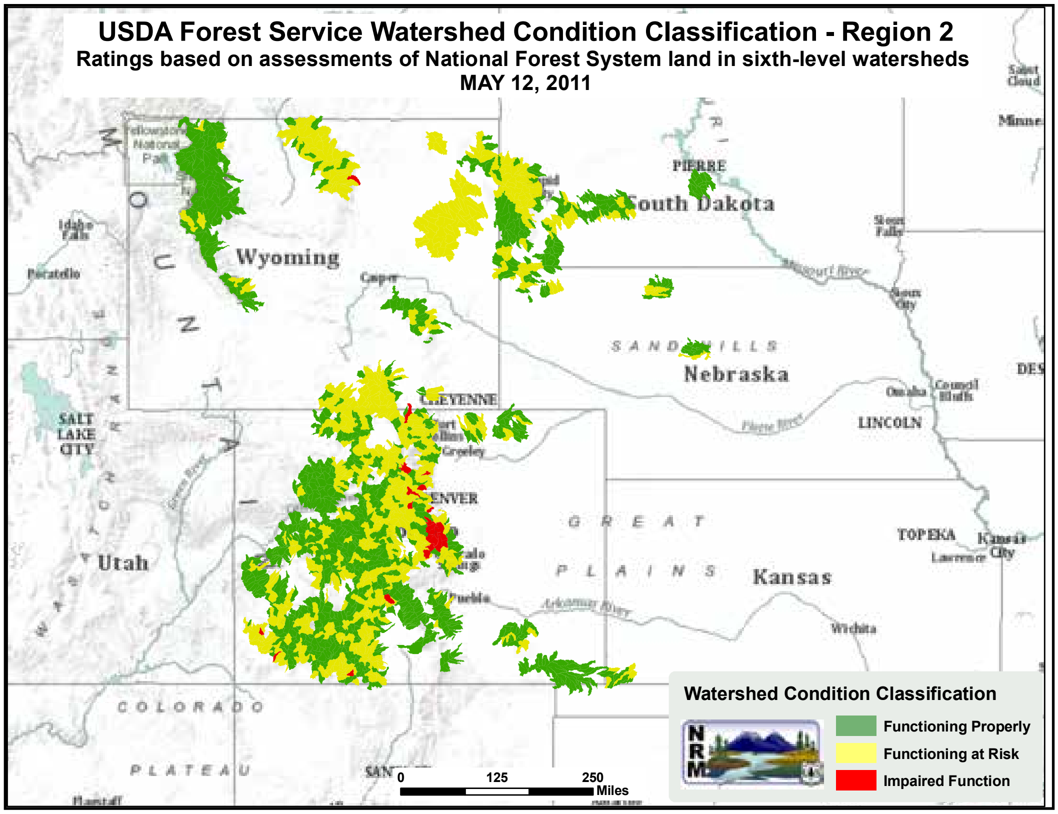
Climate vulnerability model from Fussel and Klein 2006.
This analysis is focused on the most useful and tractable factors: sensitivity and adaptation.

This approach is to compliment other assessments and analyses

National Forests and Grasslands can efficiently complete more localized analysis by building on foundations of existing work. Three notable and highly relevant analysis and planning efforts are referenced here: Watershed Condition Assessment; Transportation Analysis Process, and; Pilot Watershed Vulnerability Assessments.

Watershed Condition Assessment

In 2010, every national forest and grassland in the U.S. completed a Watershed Condition Assessment (WCA) at the subwatershed (HUC-6, 10-40k acre) scale. This was conducted using a national watershed condition model that rated various factors that can influence watershed conditions. The model was based on 12 watershed condition indicators, each comprised of various attributes. Each attribute was rated as good, fair, or poor for each subwatershed based on standard quantitative and qualitative criteria. Results from those attribute ratings were then integrated into a rating for each of the 12 indicators. These were combined into a rating for each ecological process domain and then into an overall watershed condition score. Details regarding the assessment process and watershed condition model are provided in the Watershed Condition Classification Technical Guide (USFS, 2011).



Overall watershed condition classification for the Rocky Mountain Region. Roads contributed strongly to the ratings, though only higher-standard roads were included in the analysis.

Transportation Analysis Process

The assessment provided here is best integrated with the TAP reports and updates, as appropriate. FSH 7709.55 – TRAVEL PLANNING HANDBOOK was published in 2008.

This handbook directs and analysis that will include:

- A map displaying the recommended minimum road system;
- A list of unneeded roads;
- A list of the key issues;
- A prioritized list of the risks and benefits associated with changing the part of the forest transportation system under analysis;
- A prioritized list of opportunities for addressing those risks and benefits;
- A prioritized list of actions or projects that would implement the minimum road system; and
- A list of proposed changes to current travel management direction, including proposed additions to or deletions from the forest transportation system.

Some of the features of the analysis include:

- The minimum road system should be smaller than the current system.
- After 2015, roads that have not undergone this analysis no longer qualify for road maintenance funding.
- The analysis must include all maintenance level 1-5 roads, and must be science-based.

- The final report should include both a map of the minimum road system and a list of roads to be decommissioned.
- The national lead for the process is the Director of Watersheds, Fish, Wildlife, Air and Rare Plants; the Directors of Engineering and Recreation are also on the national team.
- Each region should set up a regional leadership team following the same format, and that regional leadership team will certify that each forest's final travel analysis meets the requirements.
- This process should be interactive with the ongoing Watershed Condition Framework process and vice versa.

The Transportation Analysis Process has a primary goal of reducing road mileage to levels that can be supported by available funding and to reduce environmental effects.

This vulnerability assessment can be used to help set priorities for upgrading roads to increase their resilience and reduce their environmental effects.

Pilot Watershed Vulnerability Assessment

In 2011, the Forest Service published an assessment of the vulnerability of water resources and aquatic ecosystems to climate change (Furniss, 2011). This was done as a rapid, pilot approach to determine methods and resources needed for assessment. Eleven pilot National Forests were assessed, including two in the Rocky Mountain Region: The GMUG and the White River. The assessment reports and the summary report are included in the Project Folder (Howe et al. 2011; and Weinhold 2011)

This assessment of the vulnerability of roads, trails, and recreation facilities is based on three factors: the presence of infrastructure, its proximity to streams, and its intersection with streams.

At the regional scale, the specific environmental, social, administrative, and biological context and field condition of roads, trails, stream crossings, campgrounds, and other recreational facilities are, by and large, not recorded or tracked in regionally consistent detail, so it is not possible or appropriate to conduct a specific hazard-risk assessment for each road, trail, or other feature at this scale of analysis. Specific values, such as community and administrative access, threatened species, and special habitats, and water quality concerns are beyond the scope of a regional scale assessment, and are not resolved or identified here. These are more appropriate and accurate when derived at Forest-Grassland scales and smaller, such as for HUC-5 (watershed scale) or HUC-6 (subwatershed scale). Recommended finer-scale analysis results can be aggregated to statewide or regional scales as appropriate.

At the regional scale we do have access to the locations of infrastructure, and can determine the proximity of infrastructure to streams and points where roads, trails, and streams intersect, using GIS analysis. This is the essence of this analysis.

The presence of infrastructure and its location is a first-order indicator of vulnerability. That is, if the improvements exist, they generally have value and represent an investment and capacity, and are vulnerable to climatic stresses, prima facie. There are very few if any roads, trails or recreational facilities that have no risk of damage or destruction by climatic forces. That is, our long experience shows that any infrastructure is subject to climatic stresses and can fail or be substantially damaged. Thus, the simple existence and location of infrastructure is a useful indicator of vulnerability.

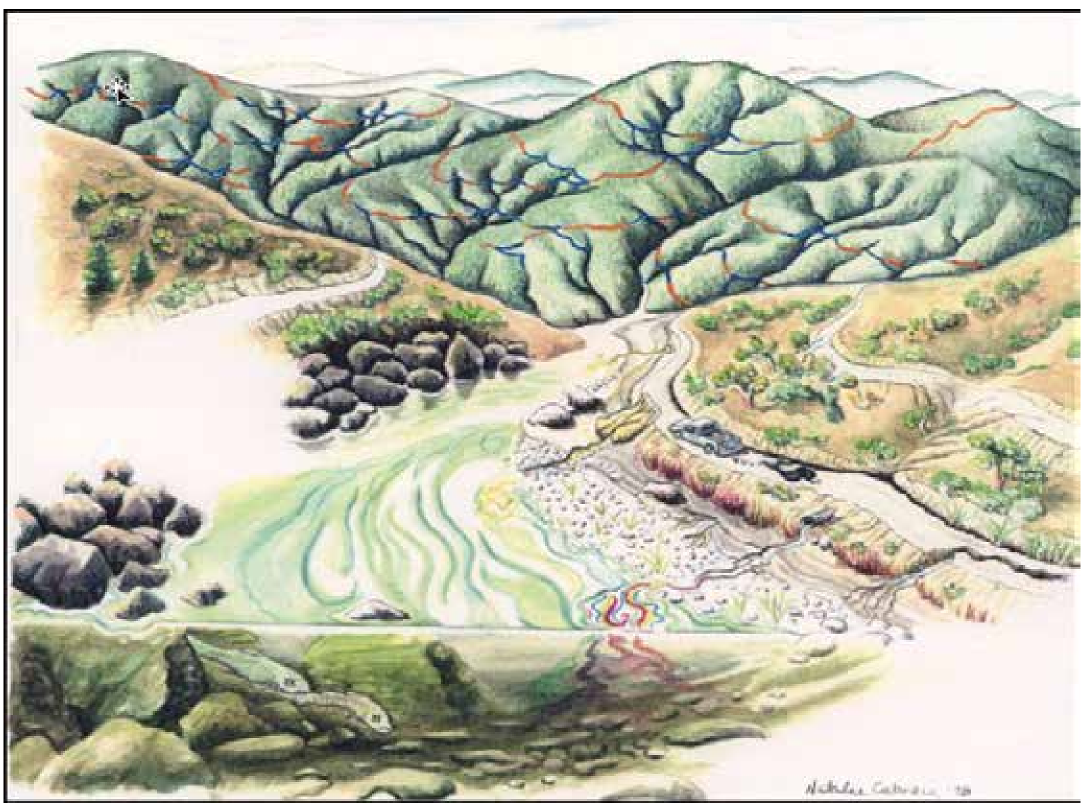
Increased flooding and fluvial failure is the primary expected exposure and impact of climate change to infrastructure.

Some additional mechanisms of impact are likely, but are relatively minor and contingent, compared to fluvial failure, are these are detailed in the Exposure section following (See" Non-fluvial climatic exposures and treats to infrastructure).

Stream proximity and road-stream intersection are effective indicators for several reasons:

Roads, trails, campgrounds, water systems, and other infrastructure that is near streams or rivers and/or intersects streams (stream crossings) is subject to fluvial erosive forces that can cause damage. Most recorded failures are proximate to streams. Landslides that damage or destroy infrastructure can be important exceptions, more distant from streams, but these too most often occur near or in streams or declivities in the landscape. Most of the road damage in the 2013 Boulder floods occurred proximate to streams and road-stream crossings.

Proximity to streams and stream intersections indicate the potential for infrastructure to affect water quality and quantity, aquatic ecosystems, and to transmit damage downstream and off-site. Road proximity to streams provides an approximation of the degree of "hydrologic connectivity" (Furniss 2000), that indicates the hazard of sedimentation, pollutants, and peak flow changes that roads can pose to streams.



Roads near streams are usually much more vulnerable to damage than roads that are distant from streams, and usually have a much greater effects or potential to affect streams, water quality, and aquatic ecosystems. The proximity of roads to streams is an effective coarse-scale indicator of both vulnerability and potential environmental impact. We can determine road-stream proximity at large scales and derive a basic spatial indication of overall risks.

Roads and trails adjacent to streams are the most vulnerable and pose the most risk and problems for water quality and aquatic habitats. Images from Google Earth.

This assessment gathered road damage/failure data (ERFO records) where it was readily available to attempt to discern relationships between stream proximity, terrain slope, and road failures. However, sufficient data was not available to draw these relations. We expect that relationships established elsewhere also hold and operate in the Rocky Mountain Region. (See: Road-Stream Proximity Indicator in the Project Folder).

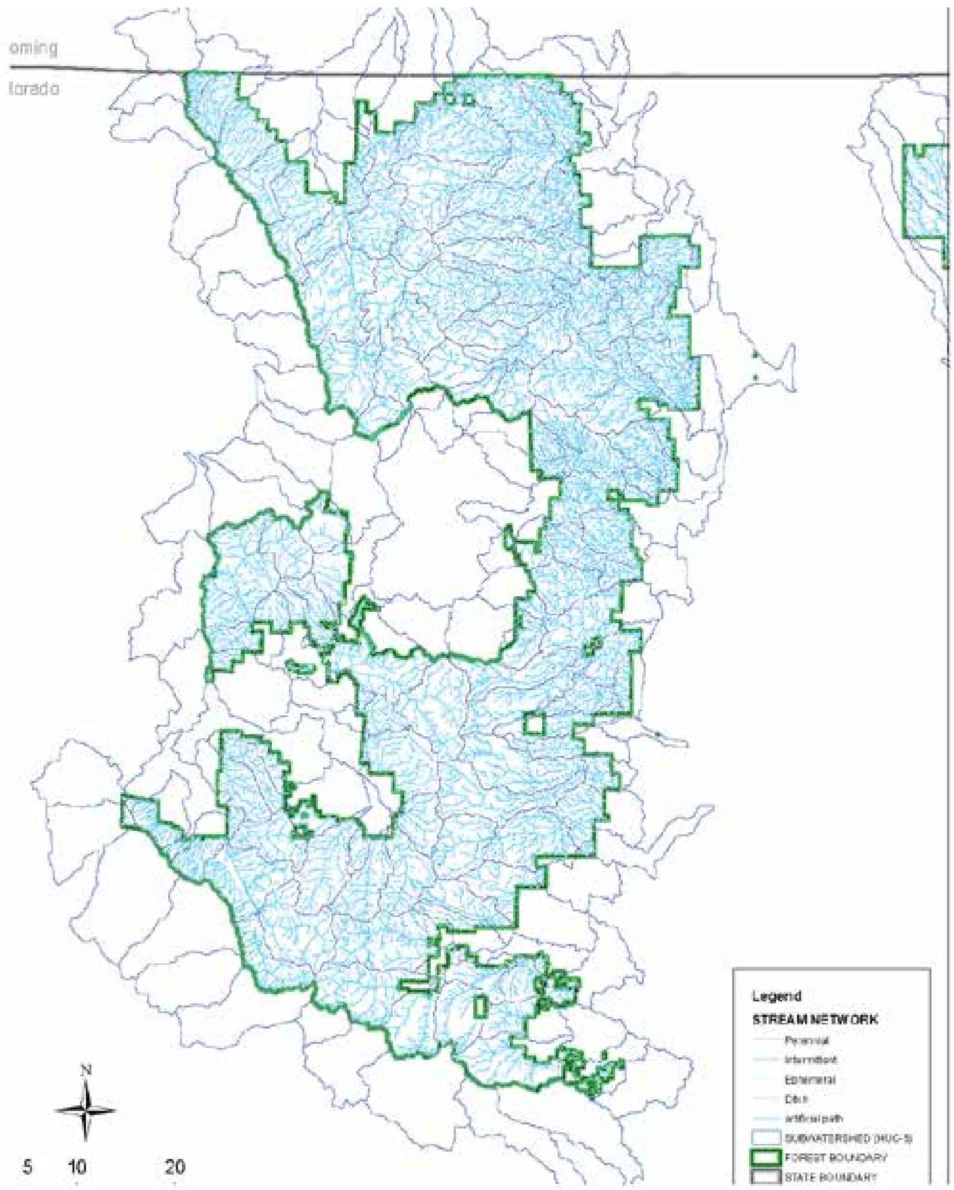
The presence of road-stream crossings is especially relevant to vulnerability. Many road and trail problems, risks and failures involve stream crossings. Even small streams, like the one shown here, can cause road damage and failure during large storms or slope instability. Stream crossings were derived by GIS analysis and are the intersection of the road and stream layers. Photo from Sarah Hines.

Regional-scale analysis is coarse and provides relative risk assessments. Accurate risk assessment requires further smaller-scale analyses including site-scale field assessment.

It is important to note that at the regional scale, only coarse indications of vulnerable infrastructure can be made. More detailed information about environmental and administrative context, road and trail conditions, and values is needed for accurate determinations of risk; and this must be conducted at smaller scales, such as the national forest, Ranger District, or HUC-5 watersheds. To determine, for example, the economic and safety risks posed by road, trail, or water system failure, the communities served and alternatives to the road or water supply must be known and factored into the risk assessment. This would be done at smaller than regional scales. To determine the environmental risks, finding the intersections between sensitive infrastructure, sensitive terrain, biological resources, and water use values is needed, and demonstrated in the pilot watershed vulnerability assessments (Howe et al. 2011, Weinhold et al. 2011).

The “subwatershed” or HUC-6 is a primary unit of analysis and priority setting

HUC-6 (subwatersheds, 10,000-40,000 acres) was used in the recently conducted Watershed Condition Assessment, as the unit of analysis and is also used in most TAP analyses. While there is no such thing the “ideal scale”, HUC-6 is a good combination of context and detail, and matches well the scales at which management is planned, funded, and conducted. Priority setting can often be best accomplished at HUC-6 or HUC-5. Using the same units and scales across assessment, analysis, priority setting, and planning efforts goes a long way toward integration and efficiency in long-term management. The image below shows the stream network of the Arapaho-Roosevelt National Forest and the HUC_6, subwatershed delineations.



Stream network and subwatersheds (HUC-6). Subwatersheds are a good choice for units and scale of anlaysis and reporting for many purposes.

How infrastructure is exposed and resulting environmental impacts

Climate changes that can affect infrastructure

The most important climatic exposure of infrastructure is extreme storms and related flooding. For each increase of 1 degree centigrade in average global temperature, the atmosphere will hold 6-7% more water vapor, due to increased evapotranspiration and increased ability of the air to hold water vapor; and therefore, more water vapor is available for heavy and extreme rainfall. With substantially more water it in the atmosphere, it follows that precipitation will be greater, with greater extremes; though with a likely highly heterogeneous spatial and temporal distribution. Observations over the past century for the region do not show a trend in extreme rainfall and flooding, but this means little, as the data (sample size) for rare events is very small; and substantial increases in GHG emissions and the related rapid atmospheric warming have largely occurred in just the last few decades. Nearly all climate scientists conclude that the rapid climate warming now underway will bring increases in extreme rainfall based on the physics of climate warming (though none can quantify a projection): Warming intensifies many of the gradients that drive weather, and this can intensify those weather patterns that give rise to extreme rainfall. Some recent research (Mily 2002) demonstrates this effect, but the relations are tentative, and climate models are not capable of reliable projections of climate variability or extremes.

Natural climate variability and cyclic patterns are not fully understood, but are clearly important to the probabilities of large storm events and flooding. For example, synchronization of El Niño and the Pacific Decadal Oscillation in the Pacific Ocean may produce periods of especially high probability for large storms, and the coming water year therefore might see more large storms than under less unusual conditions.

Quantitative projections of increases in large storms and flooding are not available.

Climate modeling provides quantitative projections of temperature and average precipitation. All models agree that temperatures in the region will increase markedly over the next century, but do not agree as to the direction of changes in total precipitation. Climate models do not provide quantitative projections of the changes in extreme precipitation, or heavy precipitation, and so the related flooding and associated risk and impacts cannot be quantified at this time.

Globally, precipitation is expected to increase with rapid climate warming, but in the Rocky Mountain Region, the projections are uncertain and the changes in total precipitation are likely to be relatively small. IPCC notes that observed and projected changes are more acute at high elevations (IPCC 2007).

According to IPCC (2012):

> *“We do not have a quantitative projection of how the frequency, duration, and magnitude of extreme events may change in response to rapid climate warming.”*

> *“Extreme events are rare, which means there are few data available to make assessments regarding changes in their frequency or intensity. The more rare the event the more difficult it is to identify long-term changes. Global-scale trends in a specific extreme may be either more reliable (e.g., for temperature extremes) or less reliable (e.g., for droughts) than some regional-scale trends, depending on the geographical uniformity*

of the trends in the specific extreme.

There have been statistically significant trends in the number of heavy precipitation events in some regions. It is likely that more of these regions have experienced increases than decreases, although there are strong regional and subregional variations in these trends.

There is limited to medium evidence available to assess climate-driven observed changes in the magnitude and frequency of floods at regional scales because the available instrumental records of floods at gauge stations are limited in space and time, and because of confounding effects of changes in land use and engineering. Furthermore, there is low agreement in this evidence, and thus overall low confidence at the global scale regarding even the sign of these changes.

The physics of radiative forcing leading to rapid climate warming indicates an intensification of the hydrologic cycle and thus an increase in large storms and related flooding. Huntington (2006) described evidence for a generalized intensification of the water cycle, including large storms and floods.

This assessment for Colorado is important consider:

Ray, Andrea J., et al. **"Climate change in Colorado: a synthesis to support water resources management and adaptation."** *Report for the Colorado Water Conservation Board. University of Colorado, Boulder (2008).*

This document is recommended as the primary reference for EXPOSURE for climate vulnerability assessments in the Region, but may not apply well to areas in the plains where violent convective storms occur regularly. The report can be found in the Project Folder. More localized information can be used if available and as credible. We find this to be the best available reference for the Region at this time. From this report:

"**Heavy precipitation events**

Warmer temperatures tend to cause more water vapor will be evaporated and held in the atmosphere. Globally, there has been an increase in water vapor of 3–5% since the 1970s (IPCC 2013). Whether this increased water vapor is translated into more frequent heavy or extreme precipitation events depends on a complex interplay of factors at different spatial scales. Heavy and extreme precipitation events may not necessarily show the same trend over time as total annual precipitation.

In the United States, heavy precipitation events-- those occurring once every year or less often-- have increased in the past 50 years in some regions, especially the Northeast and the Midwest (Peterson et al. 2013, Walsh et al. 2014a). The six-state Southwest region, however, has experienced no detectable trends in 1-day heavy precipitation events or 5-day heavy precipitation events (Hoerling et al. 2013).

The same indices of heavy precipitation events for Colorado, based on daily *precipitation records from 12 long-term observing stations, also show no statistically significant trends over the past 30, 50, or 100 years. The threshold for 1-day events varies by station but is generally 1"–2" of precipitation in 24 hours for western Colorado, and 2"–3" in 24 hours for eastern Colorado. About half of these events occurred in summer (June– August), about one-third in spring (March–May), and most of the rest in fall. A different index, based on the proportion of annual precipitation coming in the largest*

1% of all precipitation events, also shows no trend for Colorado since 1900 (Kunkel 2013b). In summary, there are no clear trends in heavy precipitation events for Colorado, and like annual precipitation, there is considerable variability at annual and decadal time scales. (Including the September 2013 Front Range rainfall event in the trend analyses would not change this conclusion.)

Floods

While the occurrence of flooding is usually dependent on heavy precipitation, the trends in flood events may not necessarily track the trends in heavy precipitation events as expressed in the indices described above.

Additional factors such as precipitation intensity, soil moisture and snow conditions, and basin topography are also important in determining the occurrence and severity of flooding. And while many floods are immediate responses to precipitation events, whether flash floods from individual thunderstorms or larger- scale flooding, Colorado can also experience flooding from rapid spring melting of the mountain snowpack, without any additional precipitation.

The evidence in Colorado is limited, but suggests there has been no increase in flood events over the past 100 years. Two recent studies have together assessed eight long-term near-natural streamflow records in Colorado for trends in annual peak daily discharges (i.e., the highest discharge observed in each year), as part of national analyses (Villarini et al. 2009, Hirsch and Ryberg 2012). No increasing trends over time in annual peak discharges were detected at any of the eight Colorado gages. Because both of these analyses included all annual peak discharges over the period of record, neither study necessarily speaks to trends in less frequent and more severe floods, such as the September 2013 flood event in eastern Colorado."

Changes in flood peak flows due to changes in snowpack can be estimated

Streamflow responds rapidly to rainfall but slowly to snow, as runoff from snow is delayed until snow melts. The timing of streamflow is strongly influenced by the type of precipitation.

Climate warming is shifting precipitation type from snow to rain in lower and middle elevations. Snowpacks melt sooner in the Spring due to higher temperatures. As climate warming progresses, the elevations affected by this shift from snow to rain and more rapid snowmelt will become lower. Snow usually melts and enters the soil slowly and produces muted runoff hydrographs, while rainfall enters the soil readily and contributes to rapid runoff. So, the shift from snow to rain changes stream runoff to a more "flashy" type and increasing erosive stress to drainage structures such as culverts and cross-drains, thereby increasing the probability of erosion and road failure. This produces increases "chronic" effects" where infrastructure is routinely affected, as well as increases in larger floods in mid- and higher-elevation watershed. It effects cannot be quantified without additional detailed research and modeling, but the presence of infrastructure in proximity or crossing streams indicates its relative magnitude and locations.

Some storm events can produce a "rain-on-snow" effect, whereby snowmelt causes by warm storms and rainfall adds to runoff and increases flood peaks. The elevations at which these events may happen will change as the rainfall/snowfall regimes change. The considerations are complex and the uncertainties are high. This effect does add to the risk of infrastructure failure by fluvial mechanisms.

New research from US Forest Service Pacific Northwest Region shows that estimates of increases in peak flow magnitudes can be made for this mechanism -- increases due to changes in snowpack and its effects on rain-on-snow runoff mechanisms (Safeeq et al. 2015). The increases would be most pronounced in the mid-to-high elevation areas where significant snowpack accumulates and are subject to warm storms. The highest elevations would be less likely to see this mechanism of increase, as rainfall is rare, even for warm storms.

> *"Our analysis suggests that temperature-induced changes in snowpack dynamics will result in large (>30–40%) increases in peak flow magnitude in some areas, principally the Cascades, Olympics, and Blue Mountains and parts of the western edge of the Rocky Mountains.*
>
> *Muzik (2002), for example, reported a 40% and 80% increase in the 2-year and 100-year flows, respectively, in a Rocky Mountain subalpine watershed as a result of 25% increase in the mean and standard deviation of 6- and 48-hour precipitation alone."* (Safeeq et al. 2015)v

Detailed consideration of changes to the rainfall/snowfall regimes and how this can affect streamflows, aquatic ecosystems, and risks to infrastructure in the Rocky Mountain Region is ripe for further research.

Watershed conditions influence peak flows

The presence of roads, high-standard trails, recreation development, residential development, and other impermeable or low-permeability surfaces can increase peakflows substantially and thereby subject infrastructure to greater stresses than they may be designed for. More densely roaded and developed watersheds should be considered higher risk for infrastructure damage and failure. Subwatersheds with high road density and large areas of private lands can be considered relatively more vulnerable.

Large, destructive storms happen. They are likely to happen more frequently as climate change progresses

Road and trail systems and recreational facilities are frequently damaged or destroyed by rainfall, snowmelt, runoff, and flooding: This is their primary vulnerability. They may be damaged chronically by runoff and/or snowmelt in sensitive locations, or more catastrophically by large storms and flooding and associated landsliding and erosion and stream channel avulsion.

The 2013 in the Colorado Front Range provided a vivid example of large-scale failure of road systems and the consequent environmental and economic consequences.
(See: Arapaho_Roosevelt_Flood_Damage_Report.pdf in the Project Folder)

Summary of Damages from the 2013 Boulder floods

10 fatalities (most in CO flood since 1976)
18 counties declared in disaster
16,000+ damaged homes
1,882 destroyed homes
750 damaged businesses
200 destroyed businesses
120 miles of state highways damaged
$2.9 billion of damages*

- Colorado Water Conservation Board

For the Arapaho-Roosevelt NFs and Pawnee NG, preliminary estimated total costs for infrastructure and facilities repair are as follows:

Roads - $10,609,025
Bridges - $2,784,954
Trails - $425,693
Facilities - $3,025,031
Estimated Total Costs All – $16,844,703

These costs are subject to change depending on design, construction and market demand and could potentially double. This does not account for costs of damage to the environment or costs of lost access.

Non-fluvial climatic exposures and threats to infrastructure

Wildfire

Climate change is expected to result in more area burned, more severe wildfires, and longer fire seasons, due to increased drought, warmer summer temperatures drying of soils and vegetation, and increased insect mortality in forest stands. This increases the value of road, trail, and water systems in their use in fire suppression, and increases streamflows and entrained wood and sediment in streamflows, increasing the hazards of infrastructure failure and damage. These increases cannot be quantified, but are likely expected occur.

Increasing temperature

Temperature and heat is determinative to physical and biological systems, affecting nearly everything. Increasing temperature alone will not damage infrastructure (with some exceptions noted on the next page), but will strongly affect the entire forest and grassland environment through increase rainfall variability, increased drought, increases fire hazards and wildfire, increased insect mortality to forests, decreased snowpack, and so on.

Other climate changes can influences infrastructure

Other climatic effects to infrastructure are not expected be negligible, but are judged to be of low significance or very low predictability, or both, at this time. They may include:

- Increase in very hot days
- Increase in frequency and duration of wildfire incident management activities
- Lengthening of snow-free season at mid-elevation facilities, and related increases in the visitor access seasons
- Increased intermittency of water supplies for campgrounds, road watering, fire suppression
- Increase in drought tree mortality and hazard trees in and near roads, trails, and recreation facilities
- Damaged infrastructure can increase safety hazards
- Softening and buckling of pavements
- Thermal expansion of bridge expansion joints
- Rail–track deformities related to heating
- Limitations on periods of construction activity due to health and safety concerns
- Vehicle overheating (resulting in roadway incidents)
- Diversion of human and financial resources for emergency restoration of access
- Sedimentation of rivers and streams, adversely affecting water quality and aquatic ecosystems

Other infrastructure, including dams, administrative facilities, and water systems will likely have increased vulnerability to climatic stresses as the climate warms, but these are beyond the scope of this assessment. Regional databases were examined and found to be inadequate or not sufficiently accessible to evaluate these features.

Sensitivity and Vulnerability

Generalizations: Where is infrastructure more vulnerable?

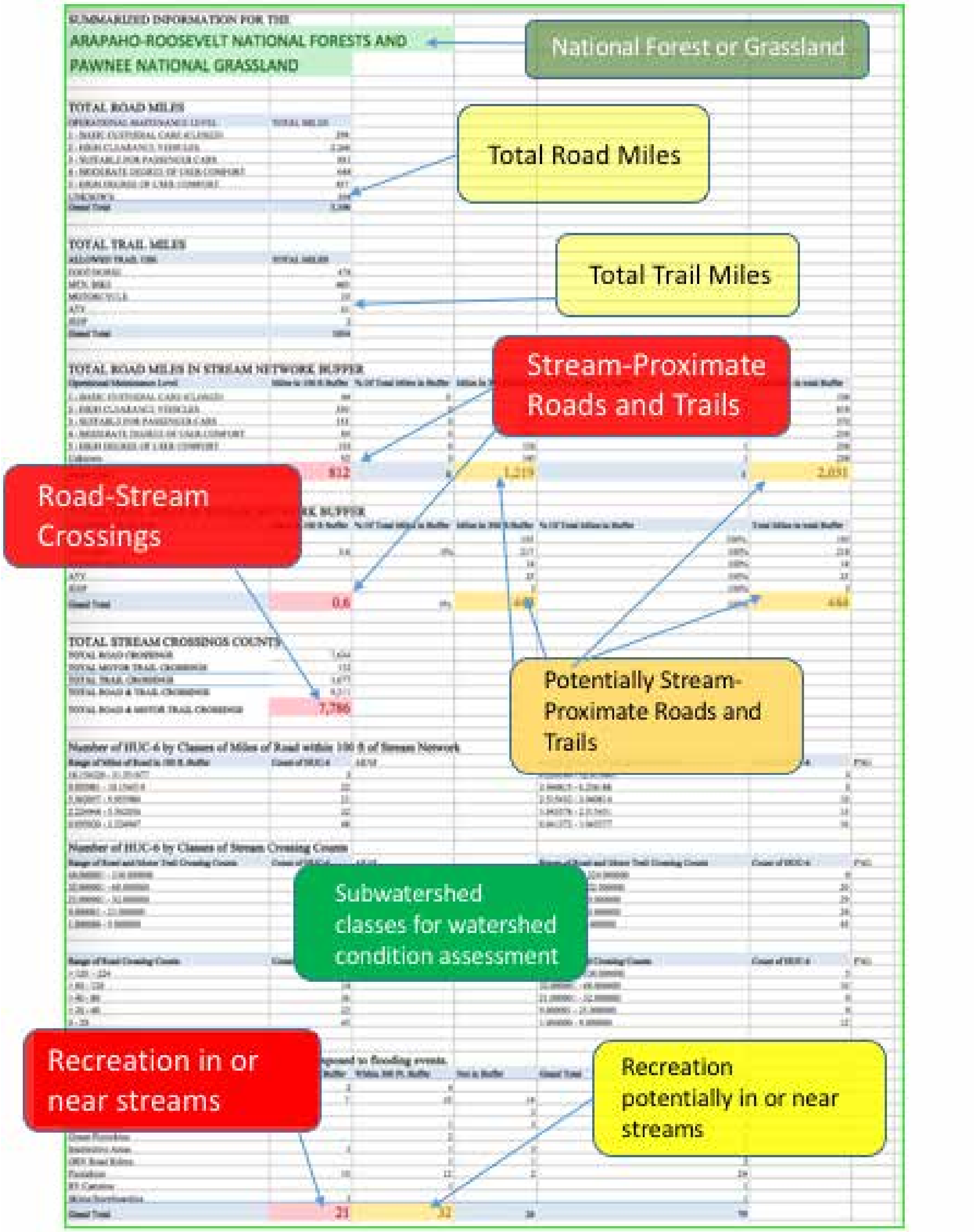
Roads and trails are more vulnerable where they:

- Are close to streams and rivers
- Cross streams and rivers
- Built on steep, unstable slopes
- Built in steep wet areas
- Have crossings located in depositional areas
- Have diversion potential (drainage failure will result in stream capture)
- Have the potential for “cascading failure” (a failure will likely cause failures down-road)
- Have unstable fills and sidecast
- Subject to diverted drainage from other roads and facilities
- Built in geologic materials that are unstable, have abundant interflow (shallow drainage), or are difficult to compact
- Have infrequent cross-drainage
- Are at or beyond their design life
- Have designs that are maintenance dependent
- Have little or no regular maintenance
- Have high use without concomitant maintenance
- Are very wide and intercept abundant drainage

Lotic ecosystems that are subject to impacts from infrastructure are more vulnerable when:

- Have rare species sensitive to changes in sediment or flow
- Have species or communities that are sediment sensitive
- Multiple crossings pose barriers to community or species connectivity
- Infrastructure is located in or near key habitat locations (e.g., spawning areas)
- Infrastructure provides or encourages public access to sensitive sites
- Multiple crossings or road or trail segments in near stream locations remove shade, and large wood recruitment to the extent that in-channel processes are affected
- Improper maintenance activities (e.g. sidecasting) periodically disturb habitats
- Other stressors are impacting communities and habitats
- Have lotic habitats that are fragmented by road-stream crossings or other barriers that restrict migration and movement (connectivity) of aquatic organisms.

Interpreting the spatial analysis



All infrastructure has inherent vulnerability. If it exists on the landscape, it is vulnerable to climatic stresses. If roads or campground are close to streams, their relative vulnerability is greater, and the likelihood of environemental impacts is relatively greater. Roads and recreation facilities within 100 feet of streams or rivers (this corresponds to the "Water Influence Zone" in the Rocky Mountian Regional Water Conservation Practices Handbook (2006) -- are considered high vulerability, and roads and campgrounds within 300 feet of streams or rivers are considered as potentially high vulnerabilty at this scale of assessment.

The ideal way to interpret and derive management-relevant meaning from the spatial analysis in this report is to convene local and regional experts and managers and review the analysis, asking questions in the context of known conditions and how the information can be used.

Some of the questions to ask are arranged in a Worksheet that follows.

===

WORKSHEET FOR
INTERPRETATION *OF REGIONAL-SCALE AND FINER SCALE RESULTS*

What information and interpretation from TAP is relevant to the vulnerability of roads to climatic stressors (large storms and flooding)?

Do the TAP recommendations to reduce road systems address the screened hydrologically connected roads (as indicated by proximity and crossings)?

What patterns of road-stream crossings are apparent?

What patterns of road-stream proximity are apparent?

Which routes, based on stream proximity and crossings (and any other pertinent known information), appear to be particularly vulnerable to washouts or other damage that would disrupt transportation?

Which communities might be stranded if a road or trailwashes out?

Do they have alternative routes? Are the alternatives less vulnerable?

Which subwatersheds have especially high aquatic biological value?

Are some of these especially valuable subwatersheds also high in relatively high vulnerability infrastructure (near streams, crossing steams?)

Which watersheds and sub-watersheds provide domestic water supplies?

Are these vulnerable to pollution by roads due to their hydrologic connectivity (as indicated by proximity and crossings, and/or local data)?

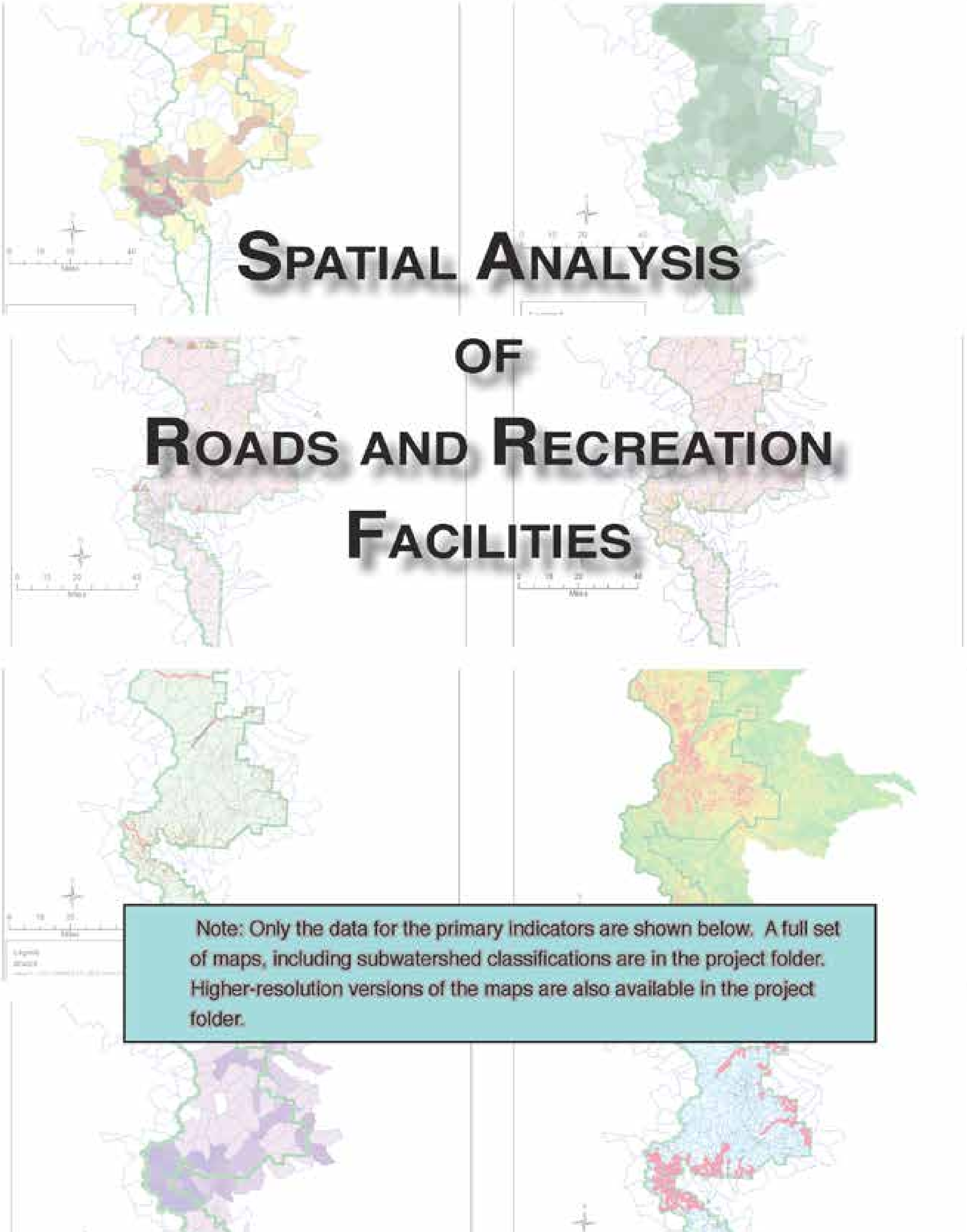
How many campgrounds or other recreational facilities are within 100 feet of streams or rivers? Within 300 feet of streams or rivers?

Do we know if they have campsites of other attractive features within a floodplain that is subject to inundation or landsliding that could harm forest visitors?

Who will conduct the risk assessments of un-assessed campgrounds, if any?

When and how will the risk assessment be conducted?

How will reporting of any discovered safety hazards be done?



Spatial Analysis of Roads and Recreation Facilities

Note: Only the data for the primary indicators are shown below. A full set of maps, including subwatershed classifications are in the project folder. Higher-resolution versions of the maps are also available in the project folder.

This is a low-resolution version of this report: A high-resolution version that allows zooming to GIS detail (~230MB), the Appendixes and the component GIS analyses are available at: http://bit.ly/R2_InfrastructureVA

REGIONAL SUMMARY

TOTAL STREAM CROSSING COUNTS

UNIT NAME	TOTAL ROAD CROSSINGS	TOTAL MOTOR TRAIL CROSSINGS	TOTAL TRAIL CROSSINGS	TOTAL ROAD & TRAIL CROSSINGS	TOTAL ROAD & MOTOR TRAIL CROSSINGS	Average road crossings per mile of road
Arapaho-Roosevelt NF & Pawnee NG	7,634	152	1,677	9,311	7,786	1.50
Bighorn NF	1,469	193	955	2,424	1,662	0.80
Black Hills NF	5,956	443	726	6,682	6,399	0.79
Grand Mesa, Uncompahgre & Gunnison NFs	6,103	1,623	4,676	10,779	7,726	1.48
Medicine Bow-Routt NF & Thunder Basin NG	17,211	433	2,610	19,821	17,644	2.08
Nebraska NF	2,376	63	448	2,824	2,439	0.87
Pike-San Isabel NF & Cimarron-Comanche NG	11,866	842	3,910	15,776	8,962	2.02
Rio Grande NF	5,089	421	2,697	7,786	5,510	2.08
San Juan NF	4,920	886	3,384	8,304	5,806	1.59
Shoshone NF	2,578	2	2,365	4943	2,580	1.58
White River NF	4,325	342	3,069	7,394	4,667	1.77
Totals	69,527	5,400	26,517	96,044	71,181	1.54

MILES OF STREAM-PROXIMATE ROAD (WITHIN STREAM BUFFER)

UNIT NAME	MILES IN 100 FT BUFFER	% Of Total Road Miles in 100' Buffer	MILES IN 300 FT BUFFER*	% Of Tota Road Miles in 300' Buffer	TOTAL MILES IN BUFFER	Total Road Miles
Arapaho-Roosevelt NF & Pawnee NG	812	16%	1,219	24%	2,031	5,106
Bighorn NF	144	8%	355	19%	500	1,837
Black Hills NF	1,532	20%	1,498	20%	3,030	7,537
Grand Mesa, Uncompahgre & Gunnison NFs	689	17%	1,110	27%	1,799	4,137
Medicine Bow-Routt NF & Thunder Basin NG	1,326	16%	2,844	34%	4,170	8,279
Nebraska NF	165	6%	1,973	72%	2,138	2,747
Pike-San Isabel NF & Cimarron-Comanche NG	1,111	19%	1,617	27%	2,728	5,880
Rio Grande NF	464	19%	687	28%	1,151	2,442
San Juan NF	403	13%	807	26%	1,210	3,086
Shoshone NF	239	15%	469	29%	707	1,635
White River NF	404	16%	759	31%	1,163	2,449
Totals	7,289	16%	13,339	30%	20,628	45,136

Arapaho-Roosevelt National Forests & Pawnee National Grassland

SUMMARIZED INFORMATION FOR THE

ARAPAHO-ROOSEVELT NATIONAL FORESTS AND PAWNEE NATIONAL GRASSLAND

TOTAL ROAD MILES

OPERATIONAL MAITENANCE LEVEL	TOTAL MILES
1 - BASIC CUSTODIAL CARE (CLOSED)	294
2 - HIGH CLEARANCE VEHICLES	2,266
3 - SUITABLE FOR PASSENGER CARS	881
4 - MODERATE DEGREE OF USER COMFORT	644
5 - HIGH DEGREE OF USER COMFORT	457
UNKNOWN	564
Grand Total	**5,106**

TOTAL TRAIL MILES

ALLOWED TRAIL USE	TOTAL MILES
FOOT/HORSE	478
MTN. BIKE	460
MOTORCYCLE	33
ATV	61
JEEP	2
Grand Total	**1034**

TOTAL ROAD MILES IN STREAM NETWORK BUFFER

Operational Maintenance Level	Miles in 100 ft Buffer	% Of Total Miles in Buffer	Miles In 300 ft Buffer	% Of Total Miles in Buffer	Total Miles in total Buffer
1 - BASIC CUSTODIAL CARE (CLOSED)	44	0	64	1	108
2 - HIGH CLEARANCE VEHICLES	330	0	489	1	818
3 - SUITABLE FOR PASSENGER CARS	153	0	217	1	370
4 - MODERATE DEGREE OF USER COMFORT	89	0	149	1	238
5 - HIGH DEGREE OF USER COMFORT	103	0	156	1	258
Unknown	92	0	145	1	238
Grand Total	812	**0**	1,219	**1**	2,031

TOTAL TRAIL MILES IN STREAM NETWORK BUFFER

ALLOWED TRAIL USE	Miles in 100 ft Buffer	% Of Total Miles in Buffer	Miles In 300 ft Buffer	% Of Total Miles in Buffer	Total Miles in total Buffer
FOOT/HORSE			185	100%	185
MTN. BIKE	0.6	0%	217	100%	218
MOTORCYCLE			14	100%	14
ATV			25	100%	25
JEEP			2	100%	2
Grand Total	0.6	0%	443	100%	444

TOTAL STREAM CROSSINGS COUNTS

TOTAL ROAD CROSSINGS	7,634
TOTAL MOTOR TRAIL CROSSINGS	152
TOTAL TRAIL CROSSINGS	1,677
TOTAL ROAD & TRAIL CROSSINGS	9,311
TOTAL ROAD & MOTOR TRAIL CROSSINGS	7,786

Number of HUC-6 by Classes of Miles of Road within 100 ft of Stream Network

Range of Miles of Road in 100 ft. Buffer	Count of HUC-6	ARNF
18.154320 - 31.351677	3	
9.955981 - 18.154319	22	
5.562057 - 9.955980	21	
2.224948 - 5.562056	32	
0.055920 - 2.224947	48	

Range of Miles of Road in 100 ft. Buffer	Count of HUC-6
6.236189 - 12.813645	3
3.940815 - 6.236188	3
2.515432 - 3.940814	10
1.043578 - 2.515431	13
0.041372 - 1.043577	16

Number of HUC-6 by Classes of Stream Crossing Counts

Range of Road and Motor Trail Crossing Counts	Count of HUC-6	ARNF
68.000001 - 138.000000	5	
32.000001 - 68.000000	10	
21.000001 - 32.000000	9	
9.000001 - 21.000000	9	
1.000000 - 9.000000	12	

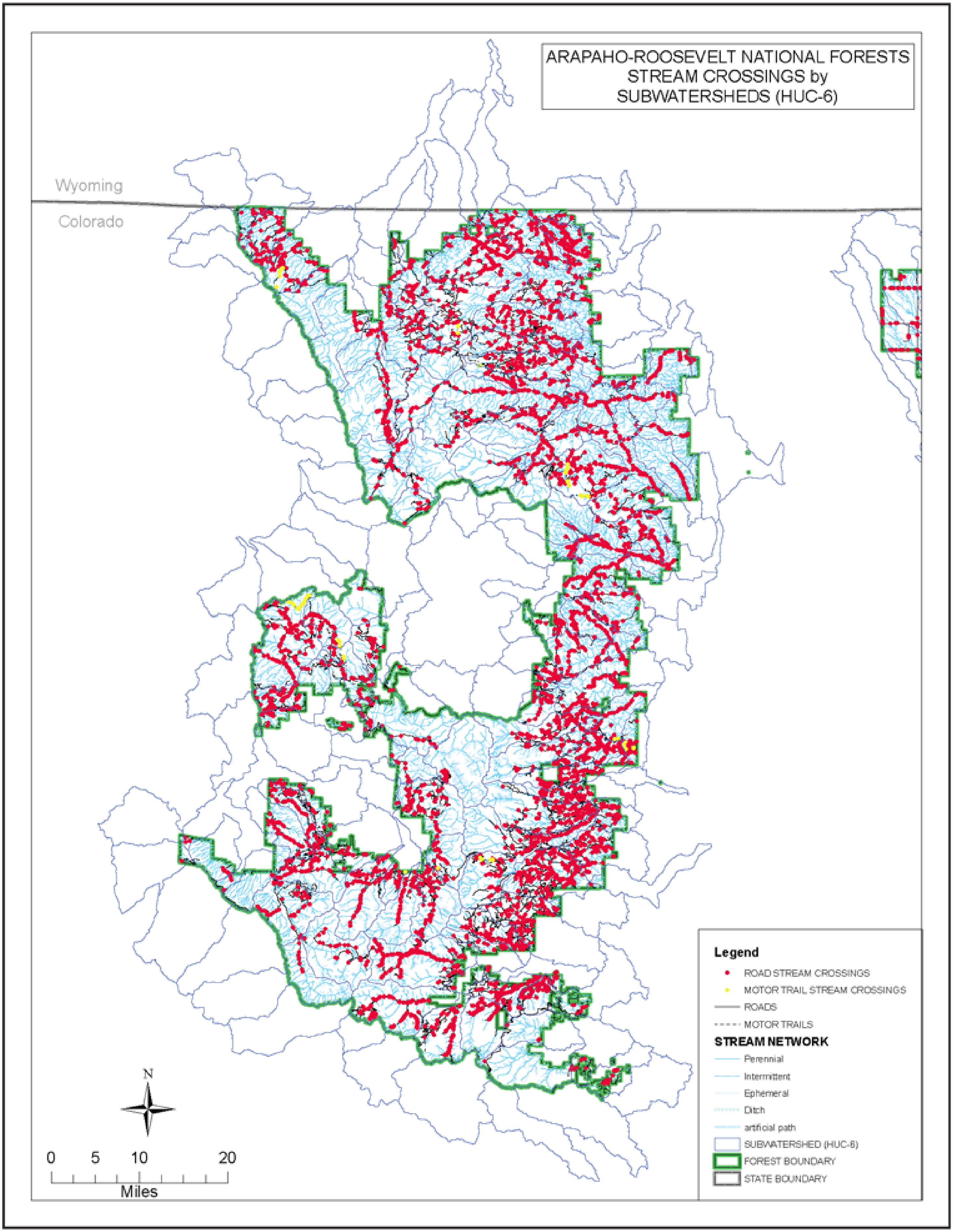
Range of Road and Motor Trail Crossing Counts	Count of HUC-6
122.000001 - 224.000000	9
75.000001 - 122.000000	20
43.000001 - 75.000000	29
19.000001 - 43.000000	24
0.000000 - 19.000000	45

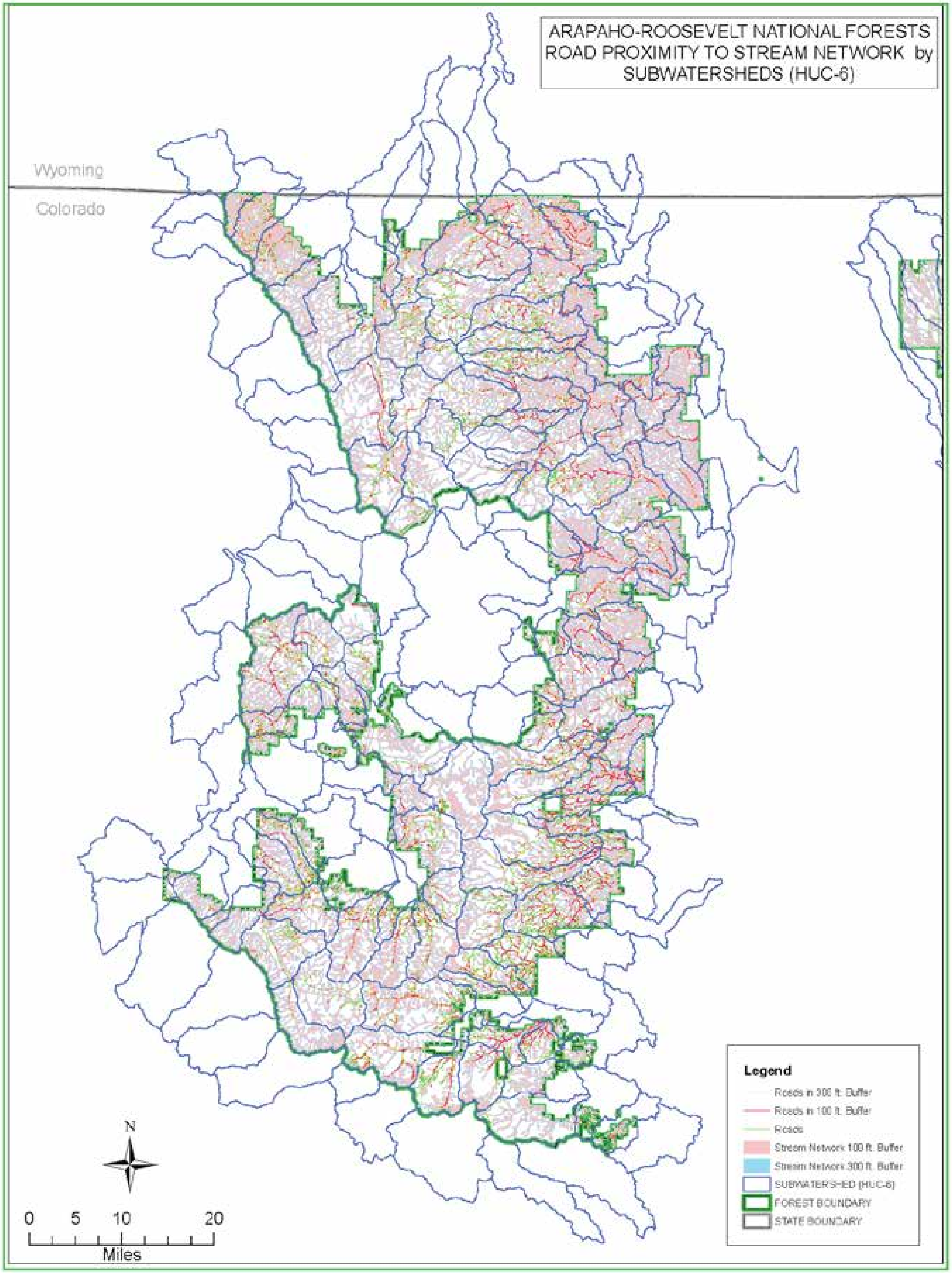
Range of Road Crossing Counts	Count of HUC-6	ARNF
> 120 - 224	10	
> 80 - 120	14	
> 40 - 80	36	
> 20 - 40	22	
0 - 20	45	

Range of Road Crossing Counts	Count of HUC-6
68.000001 - 138.000000	5
32.000001 - 68.000000	10
21.000001 - 32.000000	9
9.000001 - 21.000000	9
1.000000 - 9.000000	12

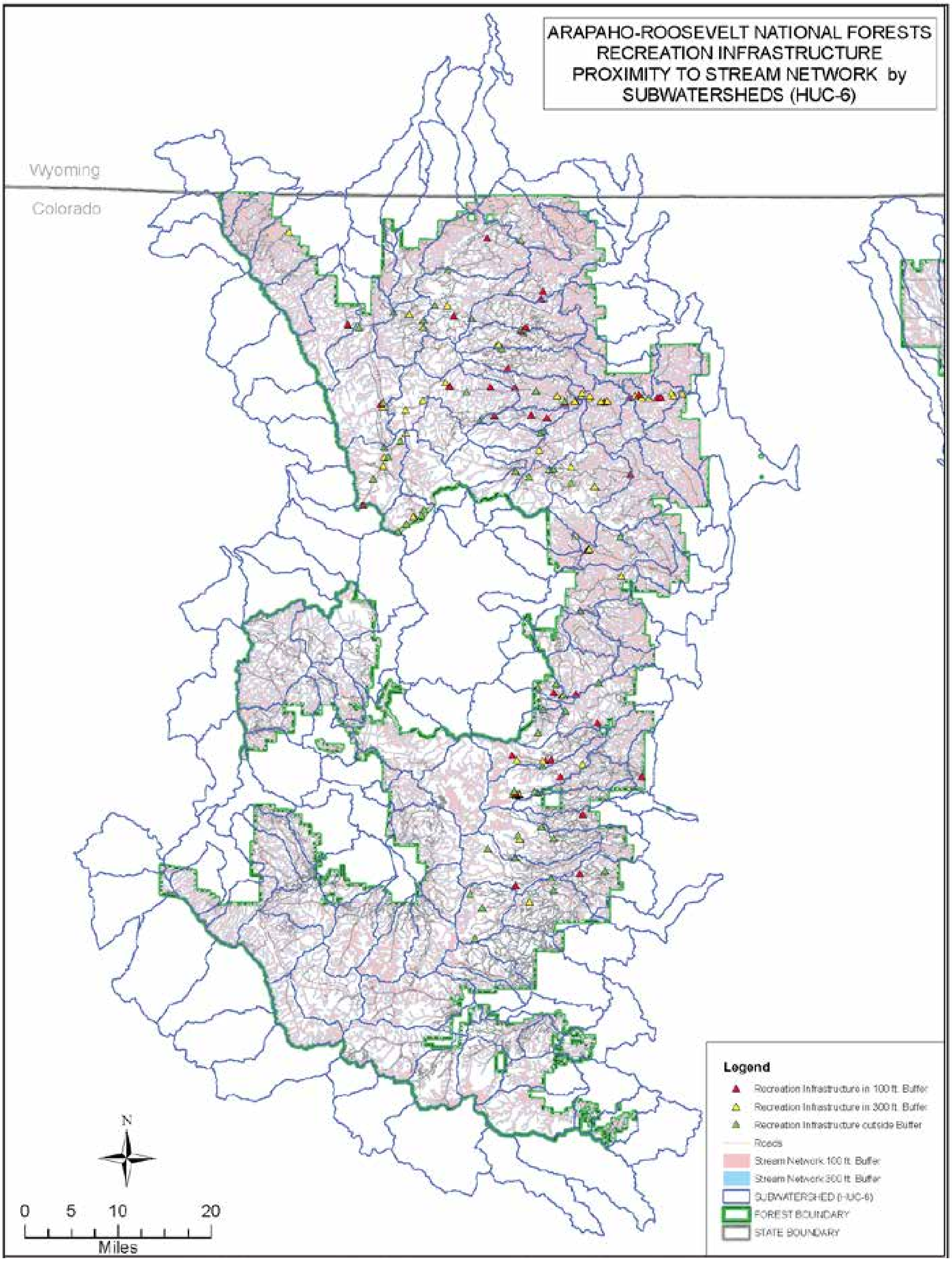
Recreation activities where infrastructure could be exposed to flooding events.

Recreation Infrastructure	Within 100 ft. Buffer	Within 300 Ft. Buffer	Not in Buffer	Grand Total
Boating - Non-Motorized	2	4		6
Campground Camping	7	10	14	31
Dispersed Camping			3	3
Group Camping		1	3	4
Group Picnicking		2		2
Interpretive Areas	1	1	3	5
OHV Road Riding		1	1	2
Picnicking	10	12	2	24
RV Camping		1		1
Skiing/Snowboarding	1			1
Grand Total	21	32	**26**	**79**


ARAPAHO-ROOSEVELT NATIONAL FORESTS
STREAM CROSSINGS by
SUBWATERSHEDS (HUC-6)
Wyoming
Colorado
Legend
ROAD STREAM CROSSINGS
MOTOR TRAIL STREAM CROSSINGS
ROADS
MOTOR TRAILS
STREAM NETWORK
Perennial
Intermittent
Ephemeral
Ditch
artificial path
SUBWATERSHED (HUC-6)
FOREST BOUNDARY
STATE BOUNDARY
N
0 5 10 20
Miles



ARAPAHO-ROOSEVELT NATIONAL FORESTS
ROAD PROXIMITY TO STREAM NETWORK by
SUBWATERSHEDS (HUC-6)
Wyoming
Colorado
Legend
Roads in 300 ft. Buffer
Roads in 100 ft. Buffer
Roads
Stream Network 100 ft. Buffer
Stream Network 300 ft. Buffer
SUBWATERSHED (HUC-6)
FOREST BOUNDARY
STATE BOUNDARY
N
0
5
10
20
Miles


ARAPAHO-ROOSEVELT NATIONAL FORESTS
RECREATION INFRASTRUCTURE
PROXIMITY TO STREAM NETWORK by
SUBWATERSHEDS (HUC-6)
Wyoming
Colorado
Legend
Recreation Infrastructure in 100 ft. Buffer
Recreation Infrastructure in 300 ft. Buffer
Recreation Infrastructure outside Buffer
Roads
Stream Network 100 ft. Buffer
Stream Network 300 ft. Buffer
SUBWATERSHED (HUC-6)
FOREST BOUNDARY
STATE BOUNDARY
N
0 5 10 20
Miles

Pawnee National Grassland

SUMMARIZED INFORMATION FOR THE

ARAPAHO-ROOSEVELT NATIONAL FORESTS AND PAWNEE NATIONAL GRASSLAND

TOTAL ROAD MILES

OPERATIONAL MAITENANCE LEVEL	TOTAL MILES
1 - BASIC CUSTODIAL CARE (CLOSED)	294
2 - HIGH CLEARANCE VEHICLES	2,266
3 - SUITABLE FOR PASSENGER CARS	881
4 - MODERATE DEGREE OF USER COMFORT	644
5 - HIGH DEGREE OF USER COMFORT	457
UNKNOWN	564
Grand Total	**5,106**

TOTAL TRAIL MILES

ALLOWED TRAIL USE	TOTAL MILES
FOOT/HORSE	478
MTN. BIKE	460
MOTORCYCLE	33
ATV	61
JEEP	2
Grand Total	**1034**

TOTAL ROAD MILES IN STREAM NETWORK BUFFER

Operational Maintenance Level	Miles in 100 ft Buffer	% Of Total Miles in Buffer	Miles In 300 ft Buffer	% Of Total Miles in Buffer	Total Miles in total Buffer
1 - BASIC CUSTODIAL CARE (CLOSED)	44	0	64	1	108
2 - HIGH CLEARANCE VEHICLES	330	0	489	1	818
3 - SUITABLE FOR PASSENGER CARS	153	0	217	1	370
4 - MODERATE DEGREE OF USER COMFORT	89	0	149	1	238
5 - HIGH DEGREE OF USER COMFORT	103	0	156	1	258
Unknown	92	0	145	1	238
Grand Total	812	**0**	1,219	**1**	2,031

TOTAL TRAIL MILES IN STREAM NETWORK BUFFER

ALLOWED TRAIL USE	Miles in 100 ft Buffer	% Of Total Miles in Buffer	Miles In 300 ft Buffer	% Of Total Miles in Buffer	Total Miles in total Buffer
FOOT/HORSE			185	100%	185
MTN. BIKE	0.6	0%	217	100%	218
MOTORCYCLE			14	100%	14
ATV			25	100%	25
JEEP			2	100%	2
Grand Total	0.6	0%	443	100%	444

TOTAL STREAM CROSSINGS COUNTS

TOTAL ROAD CROSSINGS	7,634
TOTAL MOTOR TRAIL CROSSINGS	152
TOTAL TRAIL CROSSINGS	1,677
TOTAL ROAD & TRAIL CROSSINGS	9,311
TOTAL ROAD & MOTOR TRAIL CROSSINGS	7,786

Number of HUC-6 by Classes of Miles of Road within 100 ft of Stream Network

Range of Miles of Road in 100 ft. Buffer	Count of HUC-6	ARNF	Range of Miles of Road in 100 ft. Buffer	Count of HUC-6
18.154320 - 31.351677	3		6.236189 - 12.813645	3
9.955981 - 18.154319	22		3.940815 - 6.236188	3
5.562057 - 9.955980	21		2.515432 - 3.940814	10
2.224948 - 5.562056	32		1.043578 - 2.515431	13
0.055920 - 2.224947	48		0.041372 - 1.043577	16

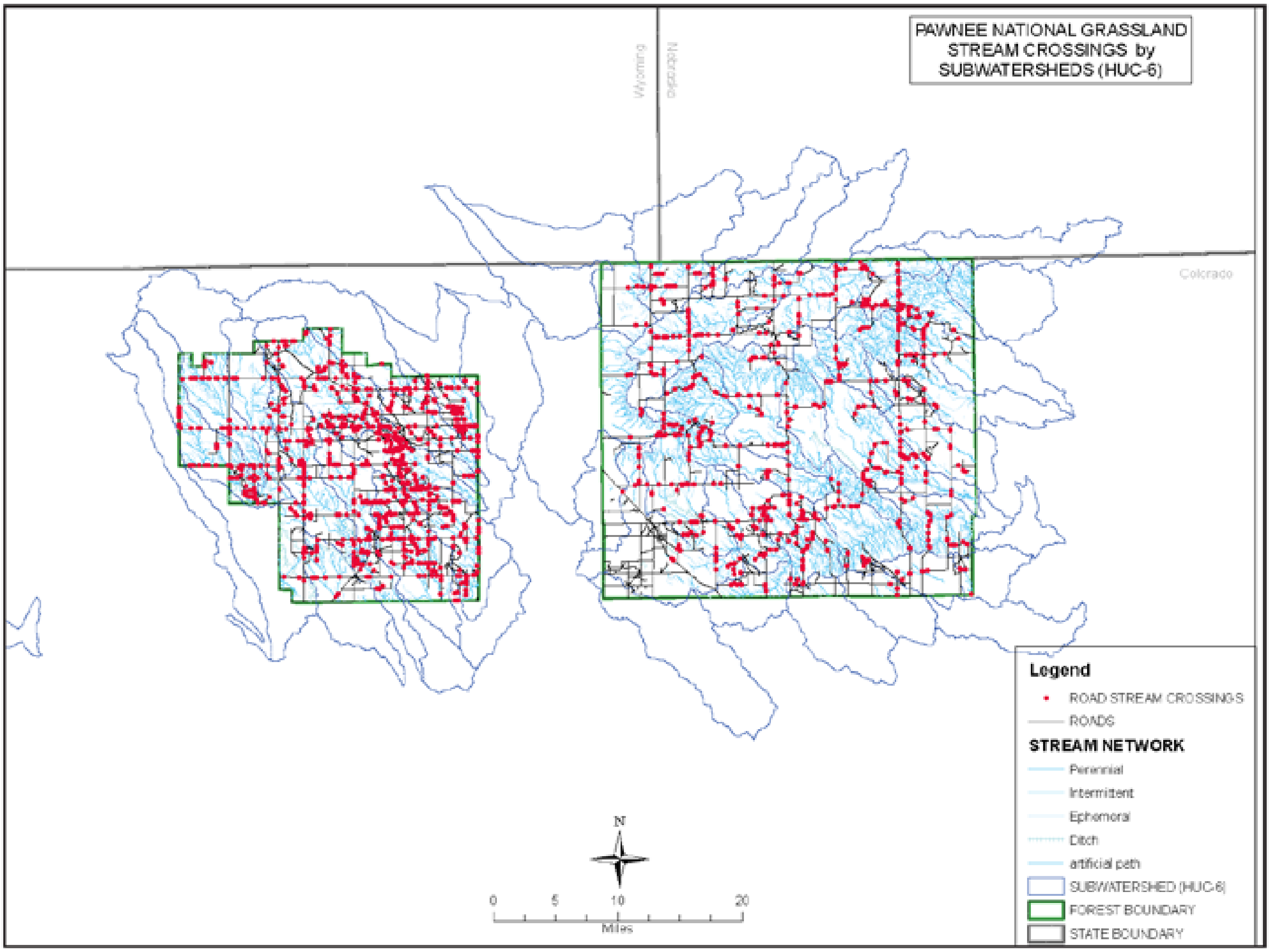
Number of HUC-6 by Classes of Stream Crossing Counts

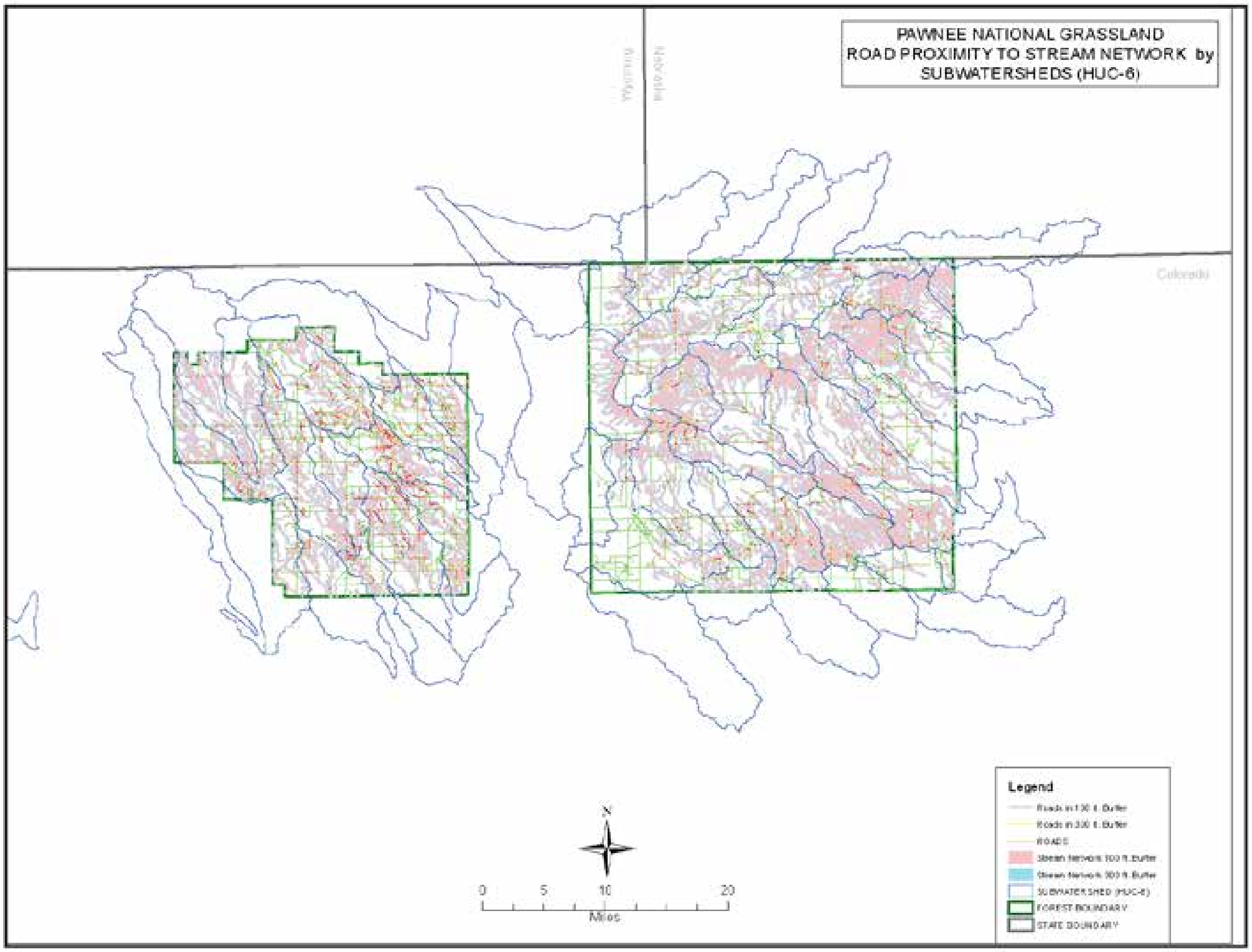
Range of Road and Motor Trail Crossing Counts	Count of HUC-6	ARNF	Range of Road and Motor Trail Crossing Counts	Count of HUC-6
68.000001 - 138.000000	5		122.000001 - 224.000000	9
32.000001 - 68.000000	10		75.000001 - 122.000000	20
21.000001 - 32.000000	9		43.000001 - 75.000000	29
9.000001 - 21.000000	9		19.000001 - 43.000000	24
1.000000 - 9.000000	12		0.000000 - 19.000000	45

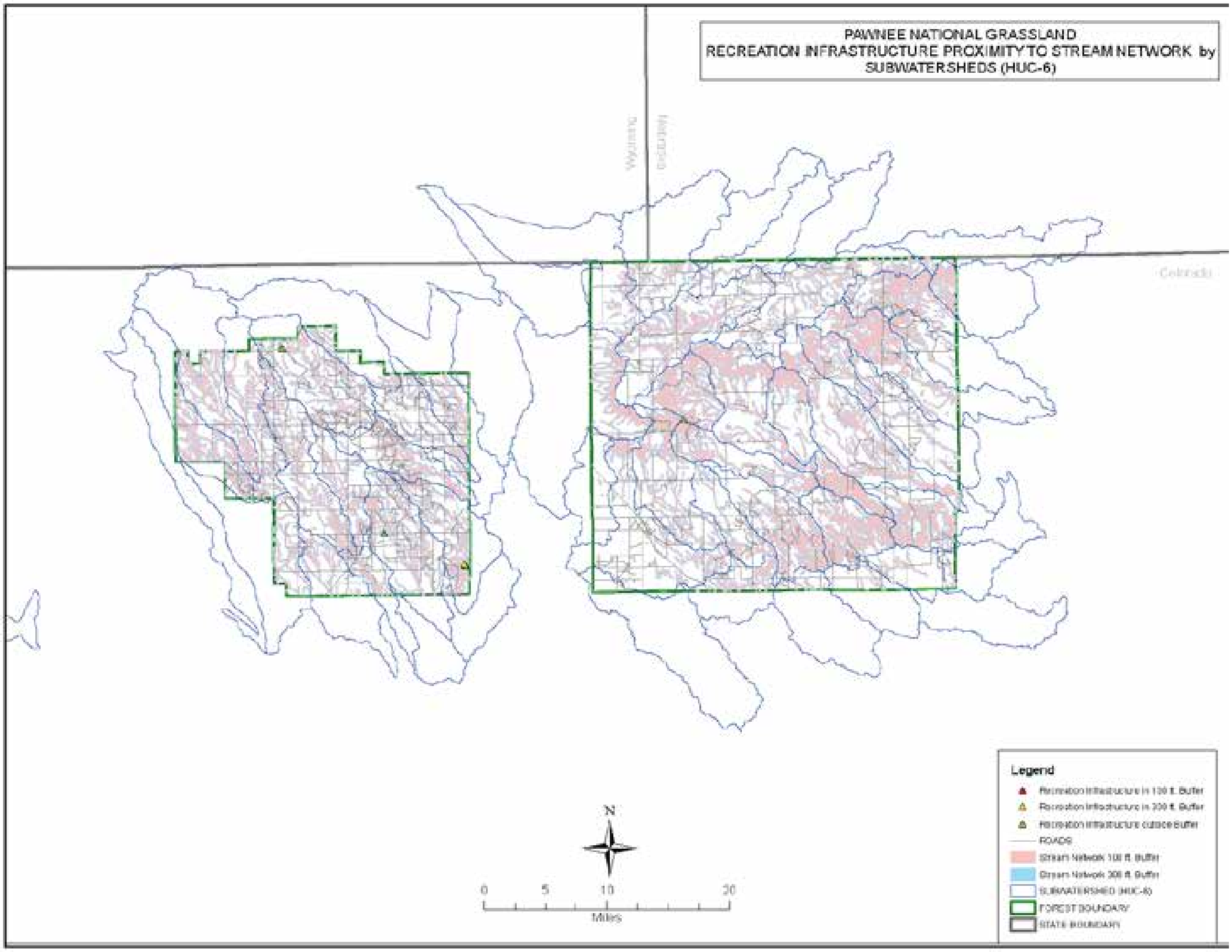
Range of Road Crossing Counts	Count of HUC-6	ARNF	Range of Road Crossing Counts	Count of HUC-6
> 120 - 224	10		68.000001 - 138.000000	5
> 80 - 120	14		32.000001 - 68.000000	10
> 40 - 80	36		21.000001 - 32.000000	9
> 20 - 40	22		9.000001 - 21.000000	9
0 - 20	45		1.000000 - 9.000000	12

Recreation activities where infrastructure could be exposed to flooding events.

Recreation Infrastructure	Within 100 ft. Buffer	Within 300 Ft. Buffer	Not in Buffer	Grand Total
Boating - Non-Motorized	2	4		6
Campground Camping	7	10	14	31
Dispersed Camping			3	3
Group Camping		1	3	4
Group Picnicking		2		2
Interpretive Areas	1	1	3	5
OHV Road Riding		1	1	2
Picnicking	10	12	2	24
RV Camping		1		1
Skiing/Snowboarding	1			1
Grand Total	21	32	**26**	**79**


PAWNEE NATIONAL GRASSLAND
STREAM CROSSINGS by
SUBWATERSHEDS (HUC-6)
Wyoming
Nebraska
Colorado
Legend
ROAD STREAM CROSSINGS
ROADS
STREAM NETWORK
Perennial
Intermittent
Ephemeral
Ditch
artificial path
SUBWATERSHED (HUC-6)
FOREST BOUNDARY
STATE BOUNDARY
N
0
5
10
20
Miles


PAWNEE NATIONAL GRASSLAND
ROAD PROXIMITY TO STREAM NETWORK by
SUBWATERSHEDS (HUC-6)
Legend
ROADS
SUBWATERSHED (HUC-6)
FOREST BOUNDARY
STATE BOUNDARY
N
0
5
10
20
Miles


PAWNEE NATIONAL GRASSLAND
RECREATION INFRASTRUCTURE PROXIMITY TO STREAM NETWORK by
SUBWATERSHEDS (HUC-6)
Colorado
N
0
5
10
20
Miles
Legend
ROADS
FOREST BOUNDARY
STATE BOUNDARY

Bighorn National Forest

SUMMARIZED INFORMATION FOR THE

BIGHORN NATIONAL FOREST

TOTAL ROAD MILES

Operational Maintenance Level	Total Miles
1 - BASIC CUSTODIAL CARE (CLOSED)	505
2 - HIGH CLEARANCE VEHICLES	713
3 - SUITABLE FOR PASSENGER CARS	236
4 - MODERATE DEGREE OF USER COMFORT	10
5 - HIGH DEGREE OF USER COMFORT	3
UNKNOWN	370
Grand Total	**1,837**

TOTAL TRAIL MILES

ALLOWED TRAIL USE	TOTAL MILES
Horse/Foot (21)	127
Mtn Bike (321)	405
Motorcycle (4321)	34
ATV (54321)	151
Grand Total	**717**

TOTAL ROAD MILES IN STREAM NETWORK BUFFER

Operational Maintenance Level	Miles in 100 ft Buffer	% Of Total Miles in Buffer	Miles In 300 ft Buffer	% Of Total Miles in Buffer	Total Miles in total Buffer
1 - BASIC CUSTODIAL CARE (CLOSED)	27	26%	75	74%	102
2 - HIGH CLEARANCE VEHICLES	61	31%	139	69%	201
3 - SUITABLE FOR PASSENGER CARS	20	25%	60	75%	79
4 - MODERATE DEGREE OF USER COMFORT	1	22%	3	78%	4
5 - HIGH DEGREE OF USER COMFORT	1	53%	0	47%	1
Unknown	35	31%	78	69%	113
Grand Total	144	29%	355	71%	500

TOTAL TRAIL MILES IN STREAM NETWORK BUFFER

Allowed Trail Use	MILES IN 100 FT BUFFER
Foot/Horse	252
Mtn. bike	1,286
Motorcycle	105
ATV	246
Grand Total	1,889

Note: 0 miles in 300ft. Buffer

TOTAL STREAM CROSSINGS COUNTS

TOTAL ROAD CROSSINGS	1,469
TOTAL MOTOR TRAIL CROSSINGS	193
TOTAL TRAIL CROSSINGS	955
TOTAL ROAD & TRAIL CROSSINGS	2,424
TOTAL ROAD & MOTOR TRAIL CROSSINGS	1,662

Number of HUC-6 by Classes of Miles of Road within 100 ft of Stream Network

Range of Miles of Road in 100 ft. Buffer	Count of HUC-6
5.900024 - 9.431447	5
2.576746 - 5.900023	11
1.364821 - 2.576745	17
0.593369 - 1.364820	20
0.038586 - 0.593368	14

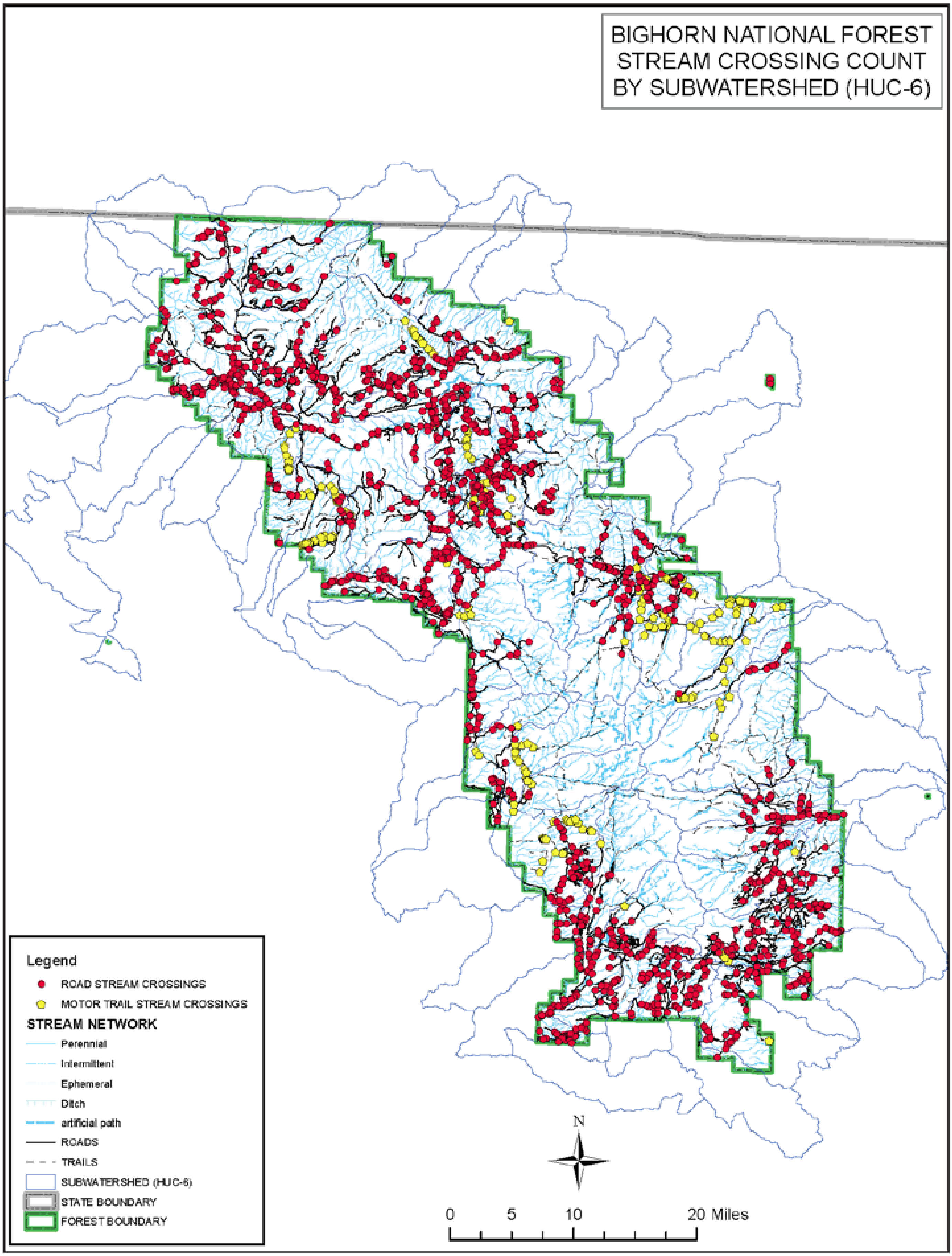
Number of HUC-6 by Classes of Stream Crossing Counts

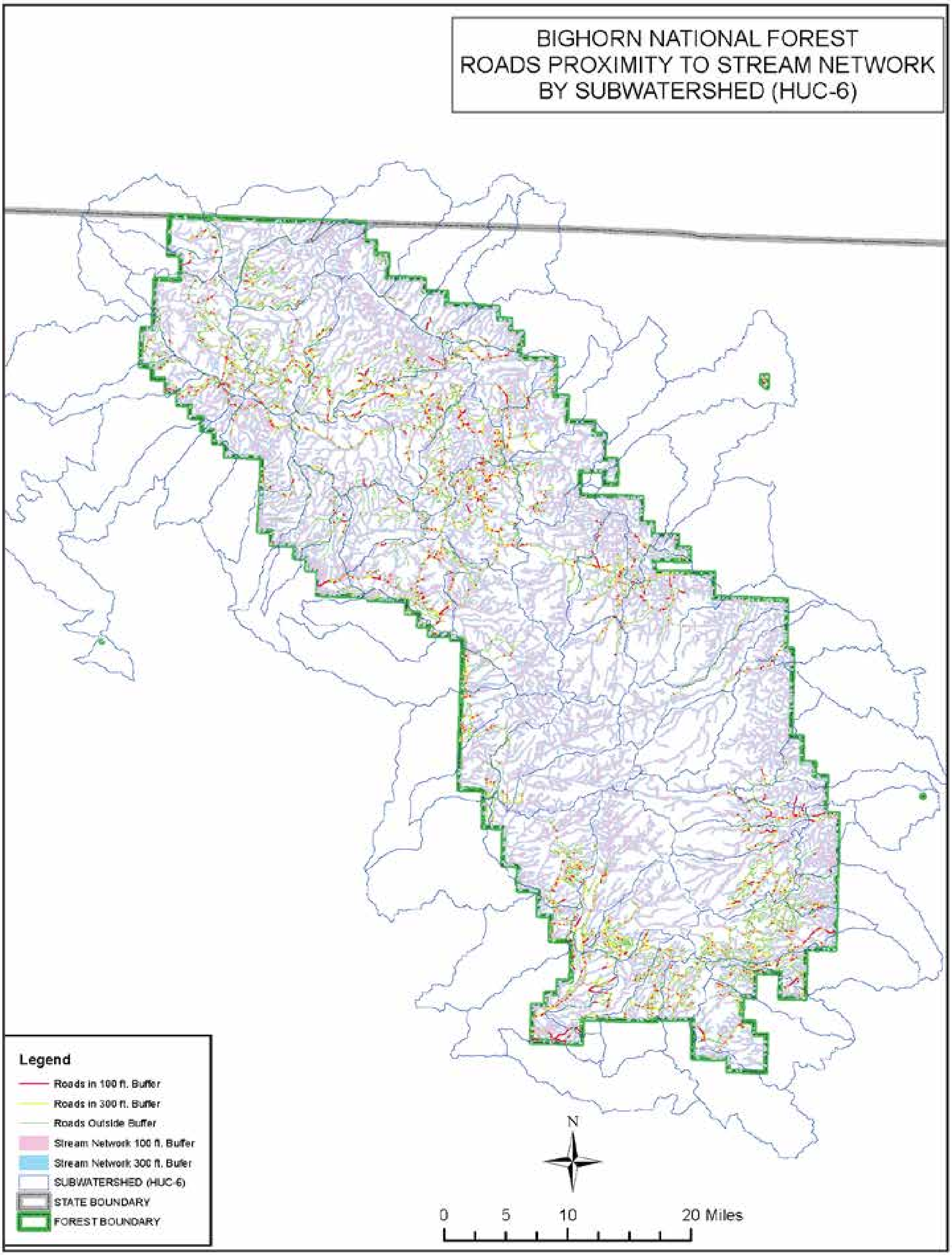
Range of Road and Motor Trail Crossing Counts	Count of HUC-6
41.000001 - 110.000000	11
27.000001 - 41.000000	8
17.000001 - 27.000000	13
7.000001 - 17.000000	20
0.000000 - 7.000000	17

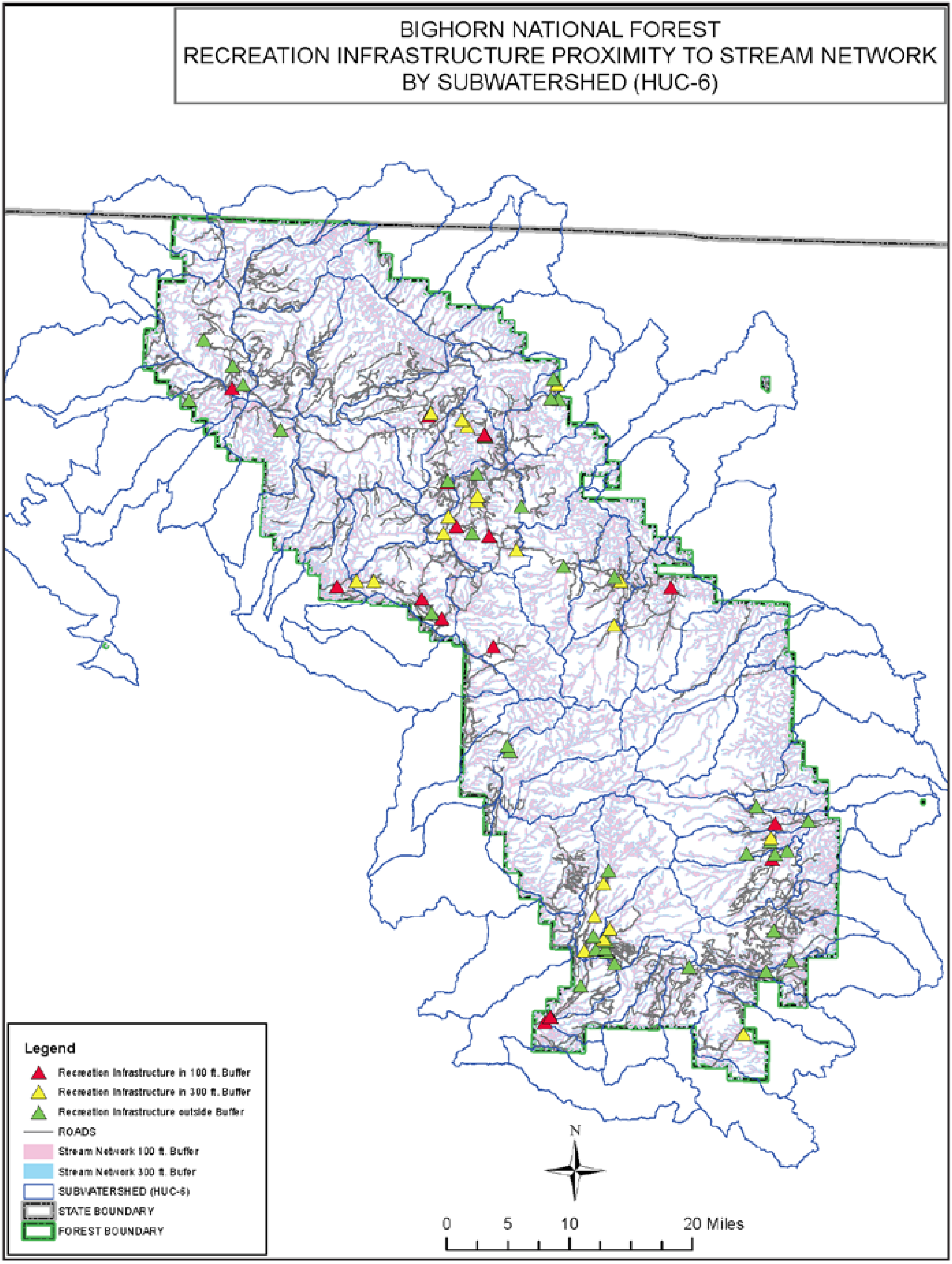
Range of Road Crossing Counts	Count of HUC-6
50.000001 - 98.000000	9
26.000001 - 50.000000	11
15.000001 - 26.000000	12
7.000001 - 15.000000	15
1.000000 - 7.000000	16

Recreation activities where infrastructure could be exposed to flooding events.

Recreation Infrastructure	Within 100 ft. Buffer	Within 300 Ft. Buffer	Not in Buffer	Grand Total
Boating - Motorized		1		1
Cabin Rentals			2	2
Campground Camping	8	10	12	30
Dispersed Camping	1			1
Group Camping		1	2	3
Horse Camping			1	1
Interpretive Areas	3	7	15	25
Picnicking	4	2	3	9
Skiing/Snowboarding			1	1
Viewing Scenery		2	5	7
Visitor Centers		1		1
XC skiing/Snowshoeing		1	1	2
Grand Total	16	25	**42**	**83**


BIGHORN NATIONAL FOREST
STREAM CROSSING COUNT
BY SUBWATERSHED (HUC-6)
Legend
ROAD STREAM CROSSINGS
MOTOR TRAIL STREAM CROSSINGS
STREAM NETWORK
Perennial
Intermittent
Ephemeral
Ditch
artificial path
ROADS
TRAILS
SUBWATERSHED (HUC-6)
STATE BOUNDARY
FOREST BOUNDARY
N
0
5
10
20 Miles


BIGHORN NATIONAL FOREST
ROADS PROXIMITY TO STREAM NETWORK
BY SUBWATERSHED (HUC-6)
Legend
Roads in 100 ft. Buffer
Roads in 300 ft. Buffer
Roads Outside Buffer
Stream Network 100 ft. Buffer
Stream Network 300 ft. Bufer
SUBWATERSHED (HUC-6)
STATE BOUNDARY
FOREST BOUNDARY
N
0
5
10
20 Miles


BIGHORN NATIONAL FOREST
RECREATION INFRASTRUCTURE PROXIMITY TO STREAM NETWORK
BY SUBWATERSHED (HUC-6)
Legend
Recreation Infrastructure in 100 ft. Buffer
Recreation Infrastructure in 300 ft. Buffer
Recreation Infrastructure outside Buffer
ROADS
Stream Network 100 ft. Buffer
Stream Network 300 ft. Bufer
SUBWATERSHED (HUC-6)
STATE BOUNDARY
FOREST BOUNDARY
N
0 5 10 20 Miles

BLACK HILLS NATIONAL FOREST

SUMMARIZED INFORMATION FOR THE

BLACK HILLS NATIONAL FOREST

TOTAL ROAD MILES

OPERATIONAL MAITENANCE LEVEL	TOTAL MILES
1 - BASIC CUSTODIAL CARE (CLOSED)	2,005
2 - HIGH CLEARANCE VEHICLES	2,467
3 - SUITABLE FOR PASSENGER CARS	604
4 - MODERATE DEGREE OF USER COMFORT	456
5 - HIGH DEGREE OF USER COMFORT	348
UNKNOWN	1,656
Grand Total	**7,537**

TOTAL TRAIL MILES

ALLOWED TRAIL USE	TOTAL MILES
FOOT/HORSE	29
MTN. BIKE	297
MOTORCYCLE	83
ATV	403
JEEP	151
Grand Total	**962**

TOTAL ROAD MILES IN STREAM NETWORK BUFFER

Operational Maintenance Level	Miles in 100 ft Buffer	% Of Total Miles in Buffer	Miles In 300 ft Buffer	% Of Total Miles in Buffer	Total Miles in total Buffer
1 - BASIC CUSTODIAL CARE (CLOSED)	397	54%	335	46%	732
2 - HIGH CLEARANCE VEHICLES	552	55%	443	45%	995
3 - SUITABLE FOR PASSENGER CARS	149	45%	180	55%	329
4 - MODERATE DEGREE OF USER COMFORT	90	37%	150	63%	239
5 - HIGH DEGREE OF USER COMFORT	69	37%	116	63%	185
Unknown	276	50%	273	50%	549
Grand Total	1,532	**51%**	1,498	**49%**	3,030

TOTAL TRAIL MILES IN STREAM NETWORK BUFFER

Allowed Trail Use	MILES IN 100 FT BUFFE	% Of Total Miles in Buffer	Miles In 300 ft Buffer	% Of Total Miles in Buffer	Total Miles in total Buffer
FOOT/HORSE	7	61%	4	39%	11
MTN. BIKE	73	63%	43	37%	116
MOTORCYCLE	7	45%	9	55%	16
ATV	76	57%	57	43%	133
JEEP	39	59%	27	41%	66
Grand Total	202	**59%**	140	**41%**	342

TOTAL STREAM CROSSINGS COUNTS

TOTAL ROAD CROSSINGS	5,956
TOTAL MOTOR TRAIL CROSSINGS	443
TOTAL TRAIL CROSSINGS	726
TOTAL ROAD & TRAIL CROSSINGS	6,682
TOTAL ROAD & MOTOR TRAIL CROSSINGS	6,399

Number of HUC-6 by Classes of Miles of Road within 100 ft of Stream Network

Range of Miles of Road in 100 ft. Buffer	Count of HUC-6
47.212123 - 71.528190	5
29.282499 - 47.212122	11
17.220621 - 29.282498	15
7.470165 - 17.220620	23
0.007058 - 7.470164	50

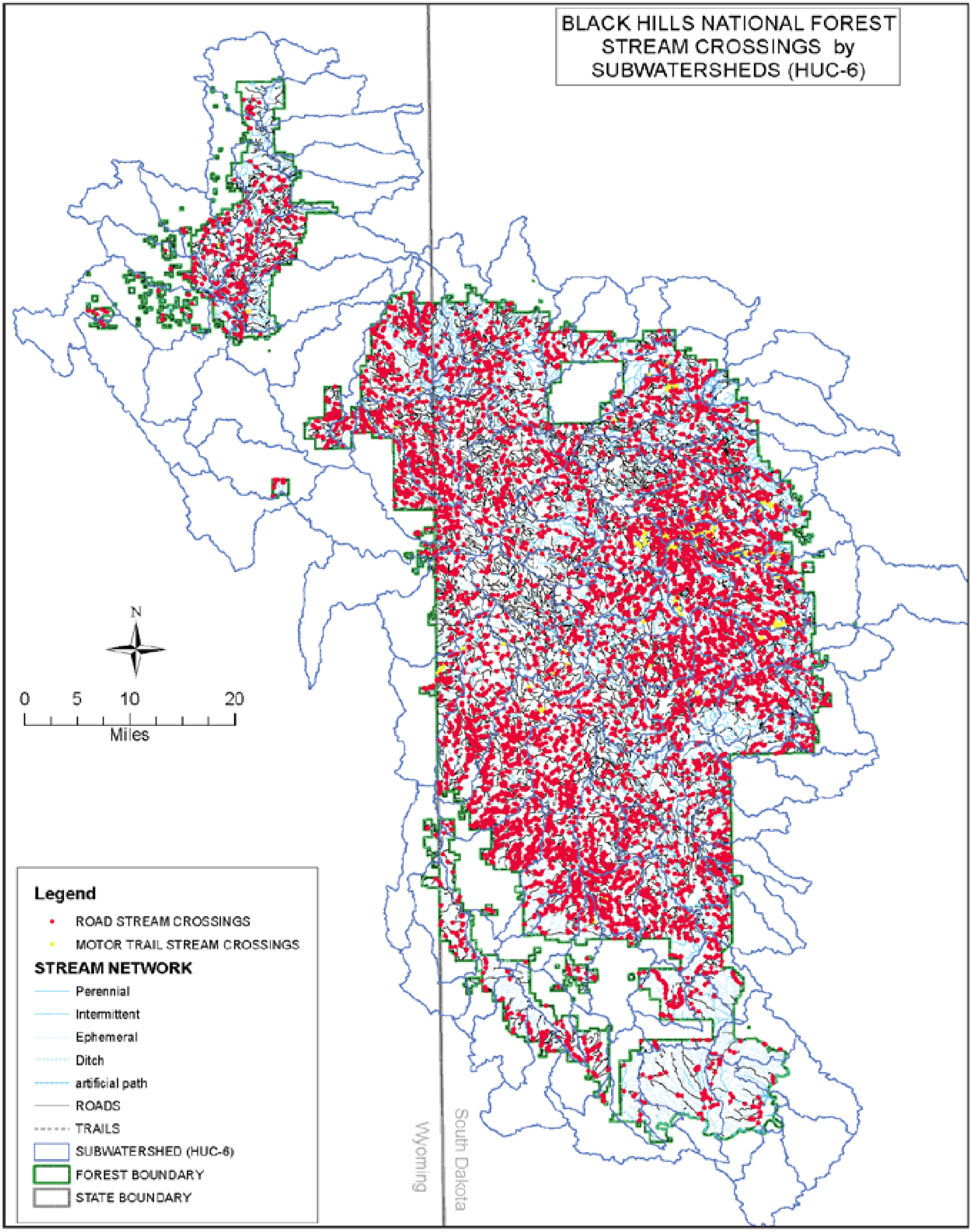
Number of HUC-6 by Classes of Stream Crossing Counts

Range of Road and Motor Trail Crossing Counts	Count of HUC-6
143.000001 - 221.000000	13
96.000001 - 143.000000	10
55.000001 - 96.000000	21
22.000001 - 55.000000	24
0.000000 - 22.000000	33

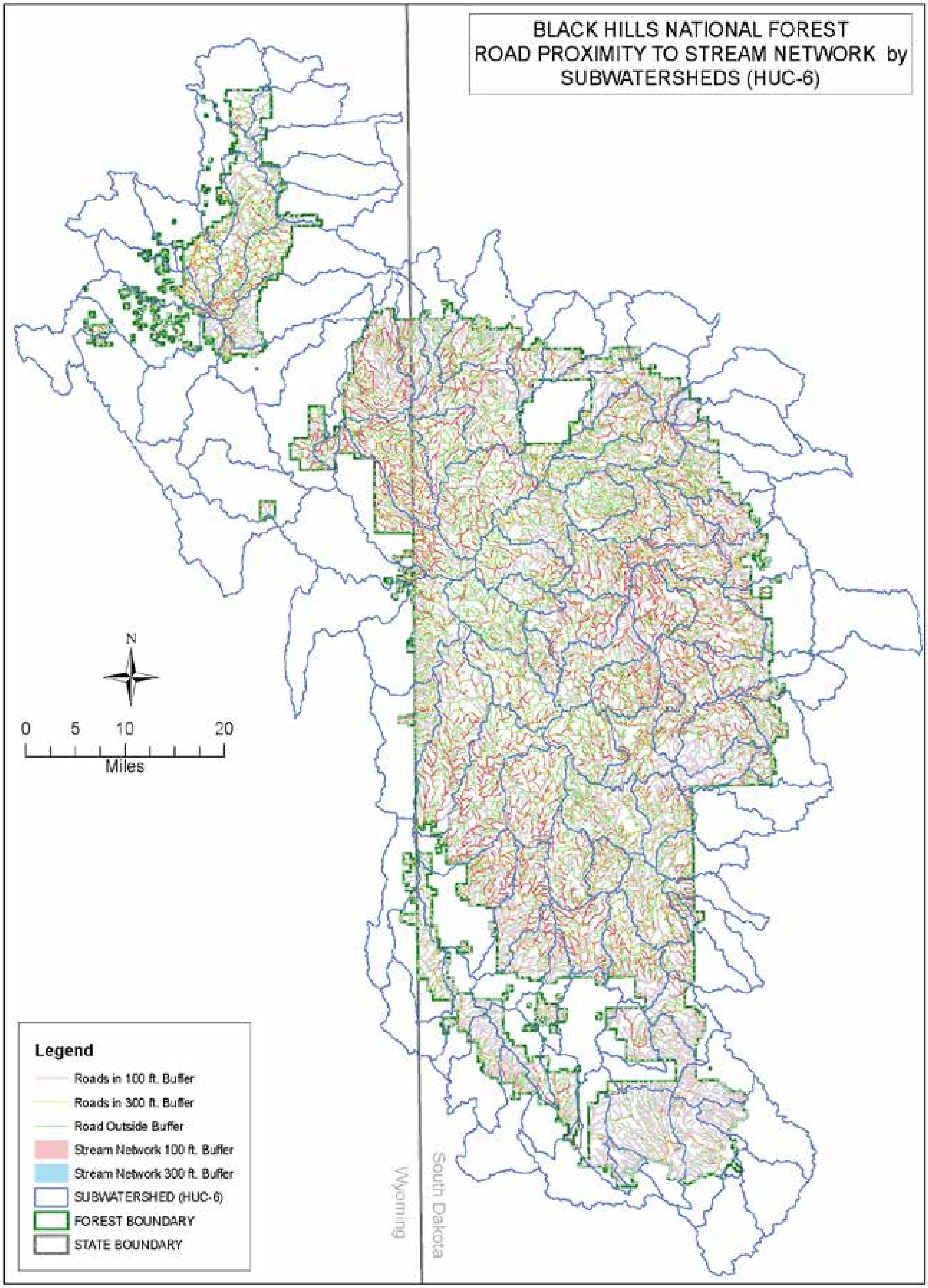
Range of Road Crossing Counts	Count of HUC-6
132.000001 - 212.000000	11
95.000001 - 132.000000	11
51.000001 - 95.000000	22
22.000001 - 51.000000	24
2.000000 - 22.000000	31

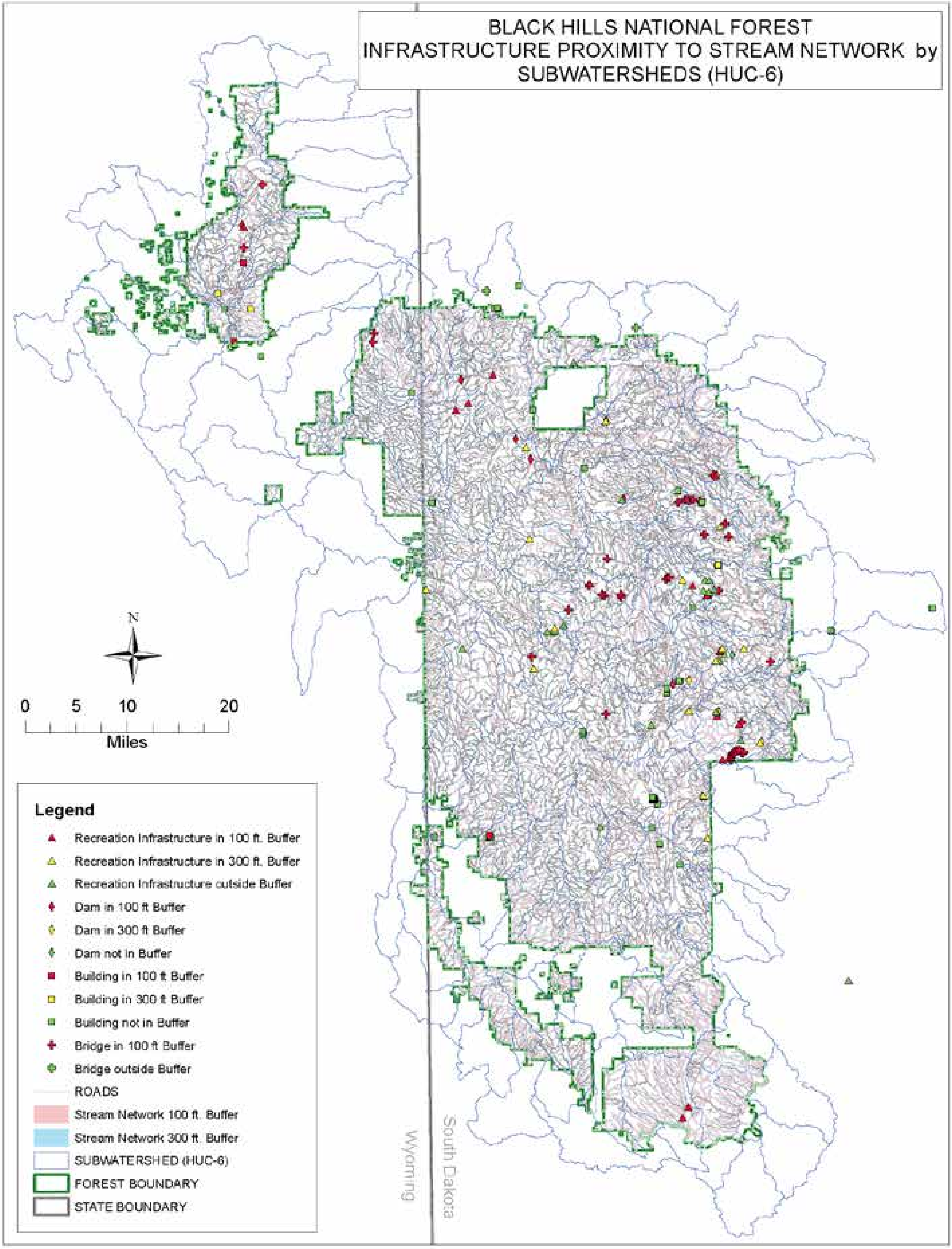
Recreation activities where infrastructure could be exposed to flooding events.

Recreation Infrastructure	Within 100 ft. Buffer	Within 300 Ft. Buffer	Not in Buffer	Grand Total
Boating - Motorized	2		1	3
Boating - Non-Motorized		1		1
Cabin Rentals			1	1
Campground Camping	6	5	11	22
Group Camping	1	1		2
Horse Camping	1	1	1	3
Lake and Pond Fishing	1	3	3	7
Picnicking	6	8	7	21
Swimming		3	3	6
Visitor Centers			1	1
Grand Total	17	22	**28**	**67**



BLACK HILLS NATIONAL FOREST
STREAM CROSSINGS by
SUBWATERSHEDS (HUC-6)
N
0
5
10
20
Miles
Legend
ROAD STREAM CROSSINGS
MOTOR TRAIL STREAM CROSSINGS
STREAM NETWORK
Perennial
Intermittent
Ephemeral
Ditch
artificial path
ROADS
TRAILS
SUBWATERSHED (HUC-6)
FOREST BOUNDARY
STATE BOUNDARY
Wyoming
South Dakota


BLACK HILLS NATIONAL FOREST
ROAD PROXIMITY TO STREAM NETWORK by
SUBWATERSHEDS (HUC-6)
N
0
5
10
20
Miles
Legend
Roads in 100 ft. Buffer
Roads in 300 ft. Buffer
Road Outside Buffer
Stream Network 100 ft. Buffer
Stream Network 300 ft. Buffer
SUBWATERSHED (HUC-6)
FOREST BOUNDARY
STATE BOUNDARY
Wyoming
South Dakota


BLACK HILLS NATIONAL FOREST
INFRASTRUCTURE PROXIMITY TO STREAM NETWORK by
SUBWATERSHEDS (HUC-6)
N
0 5 10 20
Miles
Legend
Recreation Infrastructure in 100 ft. Buffer
Recreation Infrastructure in 300 ft. Buffer
Recreation Infrastructure outside Buffer
Dam in 100 ft Buffer
Dam in 300 ft Buffer
Dam not in Buffer
Building in 100 ft Buffer
Building in 300 ft Buffer
Building not in Buffer
Bridge in 100 ft Buffer
Bridge outside Buffer
ROADS
Stream Network 100 ft. Buffer
Stream Network 300 ft. Buffer
SUBWATERSHED (HUC-6)
FOREST BOUNDARY
STATE BOUNDARY
Wyoming
South Dakota

Grand Mesa, Umcompadre & Gunnison National Forests

SUMMARIZED INFORMATION FOR THE

GRAND MESA, UNCOMPAHGRE AND GUNNISON NATIONAL FORESTS

TOTAL ROAD MILES

Operational Maintenance Level	Total Miles
1 - BASIC CUSTODIAL CARE (CLOSED)	260
2 - HIGH CLEARANCE VEHICLES	2,593
3 - SUITABLE FOR PASSENGER CARS	714
4 - MODERATE DEGREE OF USER COMFORT	309
5 - HIGH DEGREE OF USER COMFORT	252
UNKNOWN	8
Grand Total	**4,137**

TOTAL TRAIL MILES

ALLOWED TRAIL USE	TOTAL MILES
Foot/Horse	912
Mtn. Bike	649
Motorcycle	441
ATV	471
Jeep	111
Grand Total	**2,584**

TOTAL ROAD MILES IN STREAM NETWORK BUFFER

Operational Maintenance Level	Miles in 100 ft Buffe	% Of Total Miles in Buffer	Miles In 300 ft Buffer	% Of Total Miles in Buffer	Total Miles in total Buffe
1 - BASIC CUSTODIAL CARE (CLOSED)	35	38%	57	62%	92
2 - HIGH CLEARANCE VEHICLES	460	42%	637	58%	1,097
3 - SUITABLE FOR PASSENGER CARS	123	33%	247	67%	370
4 - MODERATE DEGREE OF USER COMFORT	35	30%	82	70%	117
5 - HIGH DEGREE OF USER COMFORT	36	30%	86	70%	122
Unknown	1	41%	1	59%	2
Grand Total	689	38%	1,110	62%	1,799

TOTAL TRAIL MILES IN STREAM NETWORK BUFFER

Allowed Trail Use	MILES IN 100 FT BU	% Of Total Miles in Buffer	MILES IN 300 FT BUFFER*	% Of Total Miles in Buffer	TOTAL MILES IN BUFFER
Foot/Horse	203	40%	304	60%	507
Mtn. Bike	131	42%	183	58%	314
Motorcycle	95	48%	102	52%	197
ATV	90	43%	121	57%	211
Jeep	19	45%	23	55%	42
Grand Total	538	**42%**	733	**58%**	1,272

TOTAL STREAM CROSSINGS COUNTS

TOTAL ROAD CROSSINGS	6,103
TOTAL MOTOR TRAIL CROSSINGS	1,623
TOTAL TRAIL CROSSINGS	4,676
TOTAL ROAD & TRAIL CROSSINGS	10,779
TOTAL ROAD & MOTOR TRAIL CROSSINGS	7,726

Number of HUC-6 by Classes of Miles of Road within 100 ft of Stream Network

Range of Miles of Road in 100 ft. Buffer	Count of HUC-6
14.677289 - 30.164220	4
8.352590 - 14.677288	11
4.419037 - 8.352589	36
1.712831 - 4.419036	63
0.018378 - 1.712830	106

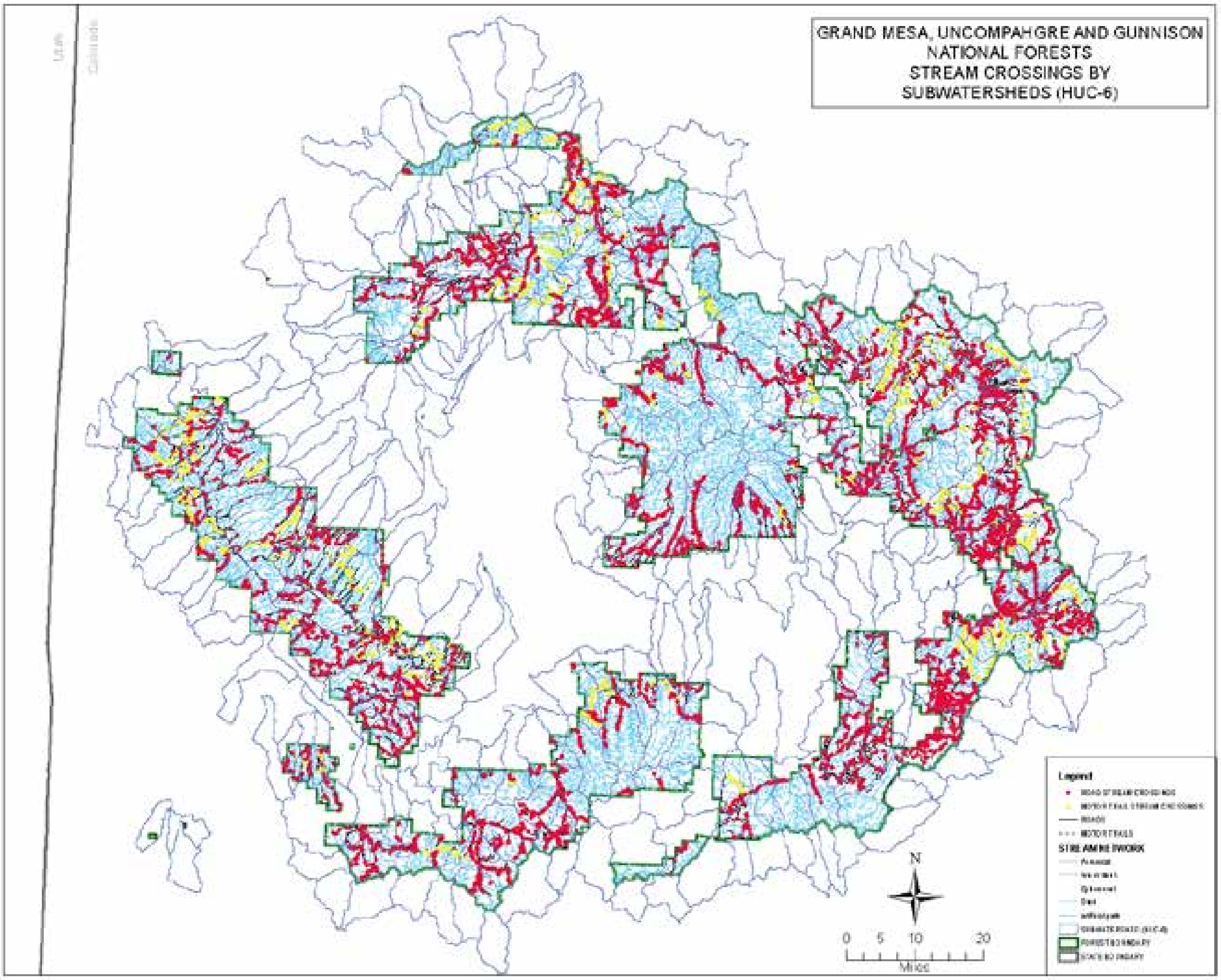
Number of HUC-6 by Classes of Stream Crossing Counts

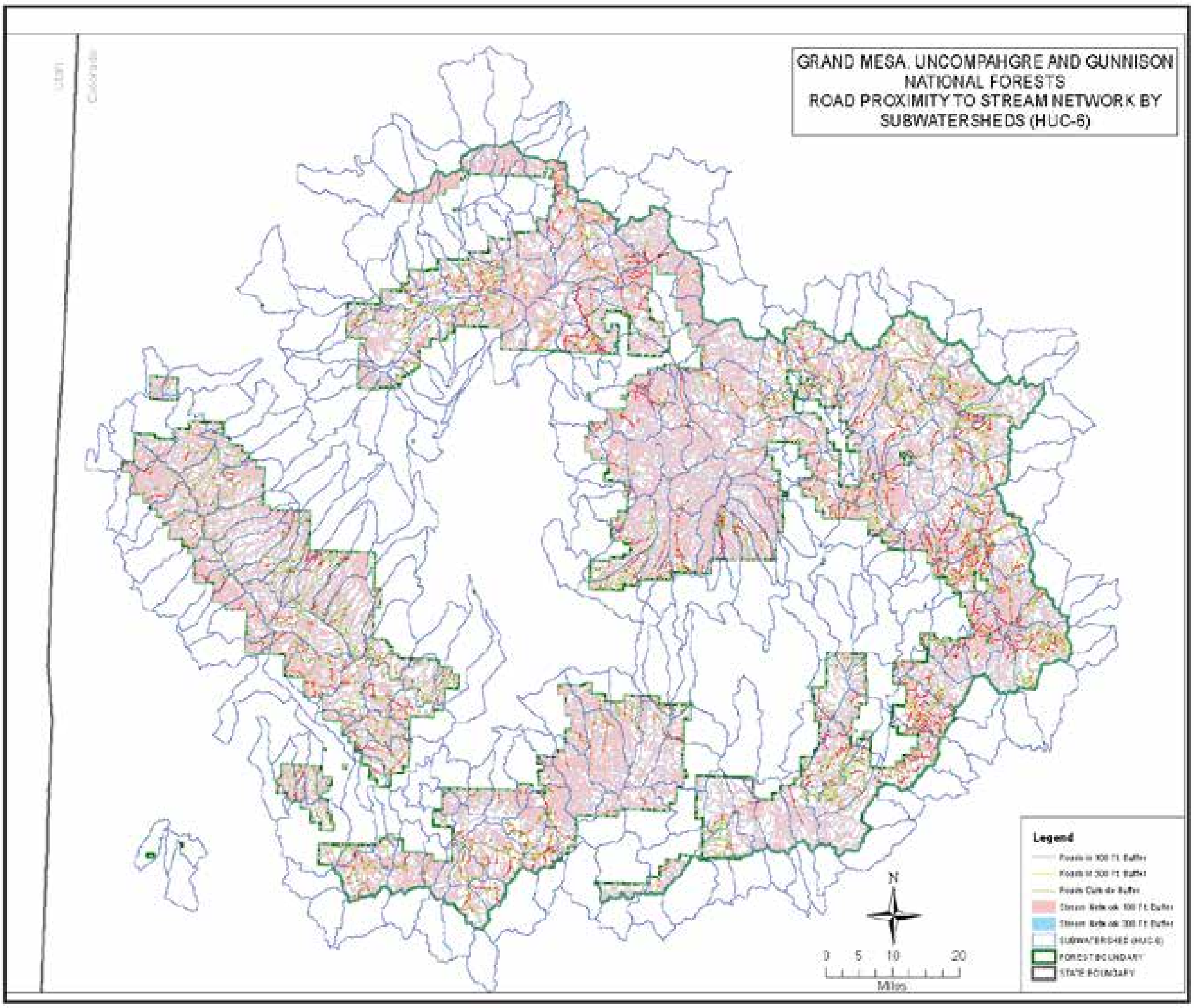
Range of Road and Motor Trail Crossing Counts	Count of HUC-6
117 - 213	5
71 - 116	24
41 - 70	47
17 - 40	62
1.0-16	86

Range of Road Crossing Counts	Count of HUC-6
105 - 203	5
65 - 104	13
35 - 64	47
15 - 34	64
1.0 - 14	76

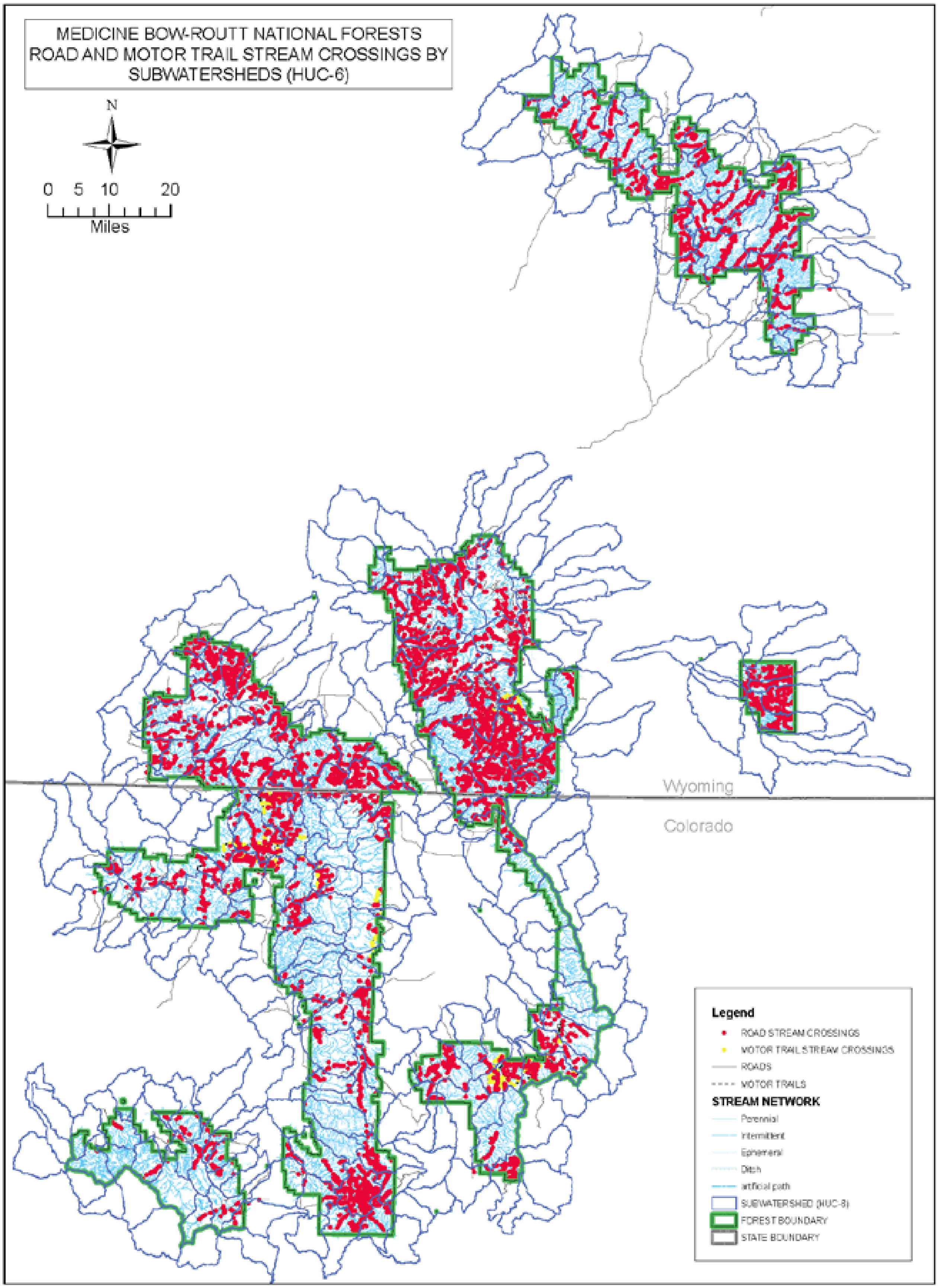
Recreation activities where infrastructure could be exposed to flooding events.

Recreation Infrastructure	Within 100 ft. Buffe	Within 300 Ft. Buffer	Not in Buffer	Grand Total
Boating - Motorized		3	4	7
Boating - Non-Motorized		2	2	4
Cabin Rentals		2	4	6
Campground Camping	11	18	27	56
Dispersed Camping			1	1
Horse Camping		2	1	3
Interpretive Sites	5	4	7	16
Picnicking	1	7	5	13
Visitor Centers			1	1
Grand Total	17	38	**52**	**107**


GRAND MESA, UNCOMPAHGRE AND GUNNISON
NATIONAL FORESTS
STREAM CROSSINGS BY
SUBWATERSHEDS (HUC-6)
Utah
Colorado
Legend
N
0 5 10 20
Miles



GRAND MESA, UNCOMPAHGRE AND GUNNISON
NATIONAL FORESTS
ROAD PROXIMITY TO STREAM NETWORK BY
SUBWATERSHEDS (HUC-6)
Utah
Colorado
Legend
FOREST BOUNDARY
STATE BOUNDARY
N
0 5 10 20
Miles


MEDICINE BOW-ROUTT NATIONAL FORESTS
ROAD AND MOTOR TRAIL STREAM CROSSINGS BY
SUBWATERSHEDS (HUC-6)
N
0 5 10 20
Miles
Wyoming
Colorado
Legend
ROAD STREAM CROSSINGS
MOTOR TRAIL STREAM CROSSINGS
ROADS
MOTOR TRAILS
STREAM NETWORK
Perennial
Intermittent
Ephemeral
Ditch
artificial path
SUBWATERSHED (HUC-6)
FOREST BOUNDARY
STATE BOUNDARY

Medicine Bow-Routt National Forests & Thunder Basin National Grassland

SUMMARIZED INFORMATION FOR THE

MEDICINE BOW-ROUTT NATIONAL FORESTS AND THUNDER BASIN NATIONAL GRASSLAND

TOTAL ROAD MILES

OPERATIONAL MAINTENANCE LEVEL	TOTAL MILES
1 - BASIC CUSTODIAL CARE (CLOSED)	2,130
2 - HIGH CLEARANCE VEHICLES	3,740
3 - SUITABLE FOR PASSENGER CARS	1,042
4 - MODERATE DEGREE OF USER COMFORT	863
5 - HIGH DEGREE OF USER COMFORT	347
UNKNOWN	157
Grand Total	**8,279**

TOTAL TRAIL MILES

Allowed Trail Use	Total Miles
Foot/Horse	299
Mountain Bike	765
Motorcycle	229
Grand Total	**1,293**

	Total Miles
Non-motorized	1,064.4
Motor Trails	229.0

TOTAL ROAD MILES IN STREAM NETWORK BUFFER

OPERATIONAL MAINTENANCE LEVEL	MILES IN 100 FT BUFFER	% Of Total Miles in Buffer	MILES IN 300 FT BUFFER*	% Of Total Miles in Buffer	TOTAL MILES IN BUFFER
1 - BASIC CUSTODIAL CARE (CLOSED)	326	31%	724	69%	1,050
2 - HIGH CLEARANCE VEHICLES	447	32%	954	68%	1,401
3 - SUITABLE FOR PASSENGER CARS	138	30%	329	70%	467
4 - MODERATE DEGREE OF USER COMFORT	66	31%	148	69%	214
5 - HIGH DEGREE OF USER COMFORT	27	33%	56	67%	83
UNKNOWN	321	34%	634	66%	956
Grand Total	1,326	**32%**	2,844	**68%**	4,170

TOTAL TRAIL MILES IN STREAM NETWORK BUFFER

Allowed Trail Use	MILES IN 100 FT BUFFER	% Of Total Miles in Buffer	MILES IN 300 FT BUFFER*	% Of Total Miles in Buffer	TOTAL MILES IN BUFFER
Foot/Horse	65	40%	96	60%	161
Mountain Bike	160	39%	248	61%	408
Motorcycle	38	36%	67	64%	106
Grand Total	263	**39%**	411	**61%**	675

TOTAL STREAM CROSSINGS COUNTS

COUNT OF ROAD CROSSINGS	17,211
COUNT MOTOR TRAIL CROSSINGS	433
TOTAL TRAIL CROSSINGS	2,610
TOTAL ROAD & TRAIL CROSSINGS	19,821
TOTAL ROAD & MOTOR TRAIL CROSSINGS	17,644

Number of HUC-6 by Classes of Miles of Road within 100 ft of Stream Network

Range of Miles of Road in 100 ft. Buffer	Count of HUC-6
18.548452 - 33.780460	6
10.749925 - 18.548451	27
5.509646 - 10.749924	56
2.120676 - 5.509645	74
0.002756 - 2.120675	132

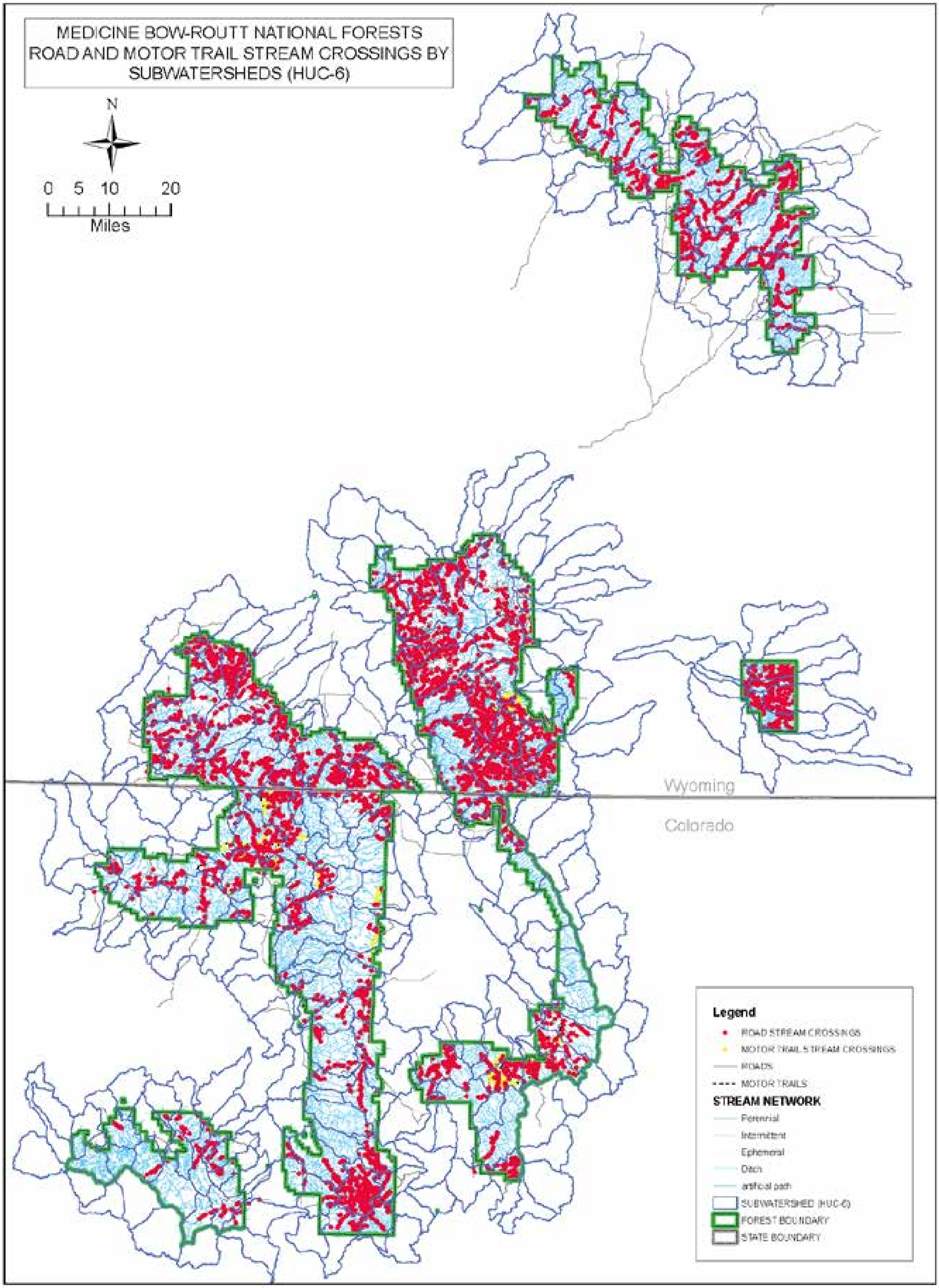
Number of HUC-6 by Classes of Stream Crossing Counts

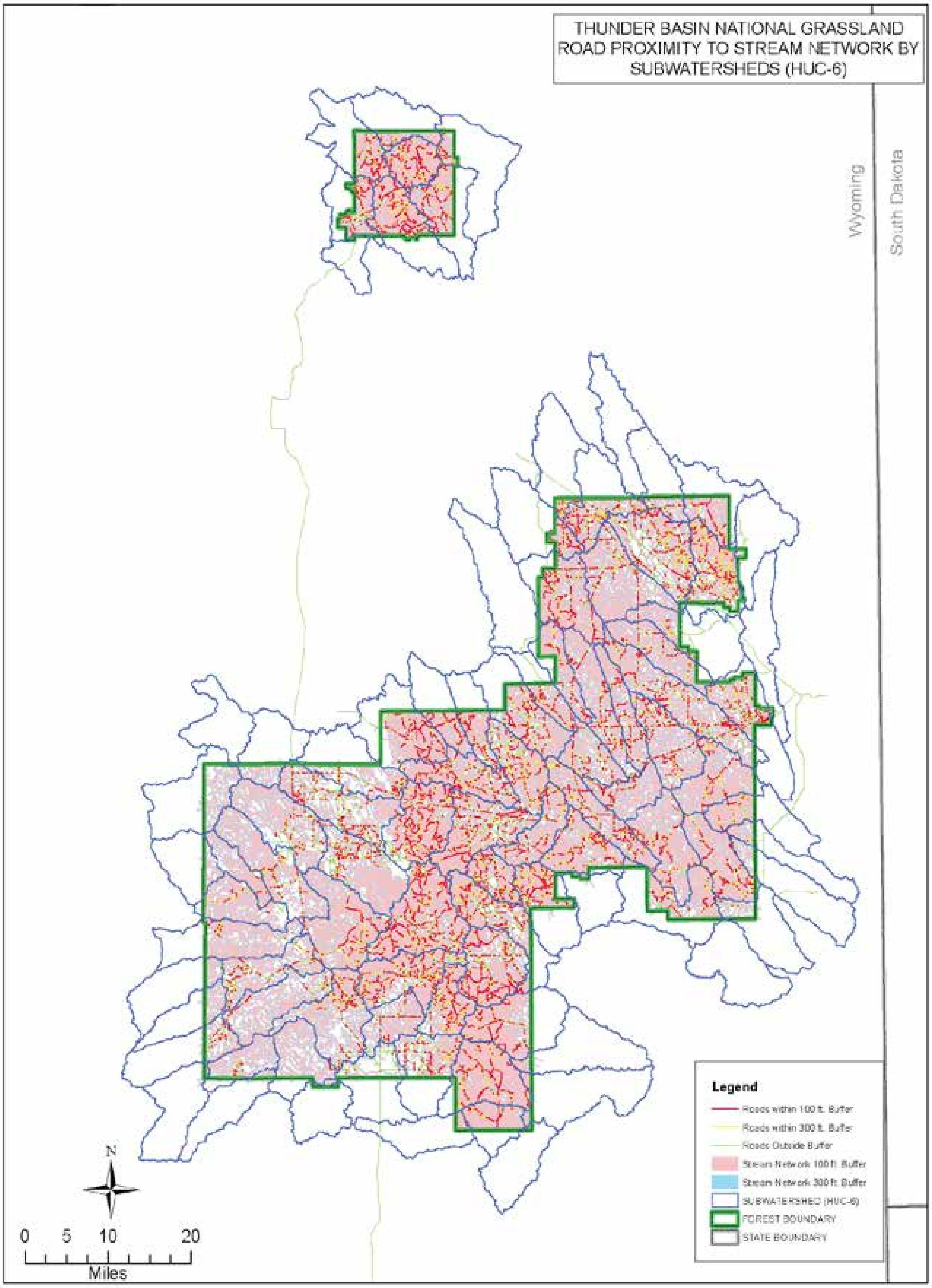
Range of Road and Motor Trail Crossing Counts	Count of HUC-6
256.000001 - 501.000000	5
150.000001 - 256.000000	26
82.000001 - 150.000000	48
32.000001 - 82.000000	72
0.000000 - 32.000000	139

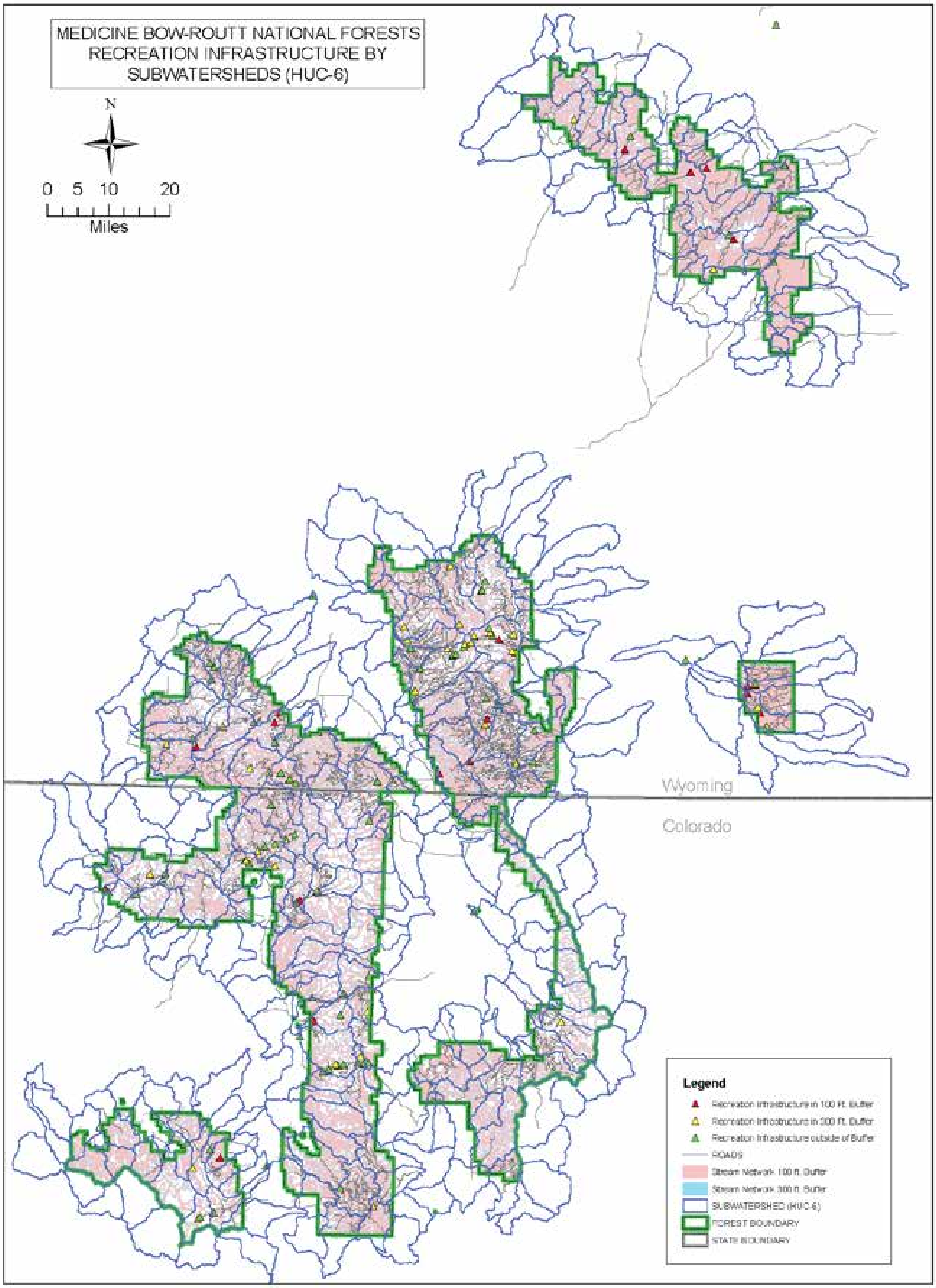
Range of Road Crossing Counts	Count of HUC-6
257 - 501	4
151 - 256	25
83 - 150	50
33 - 82	70
0 - 32	130
	279

Recreation Sites where infrastructure could be exposed to flooding events.

Recreation Infrastructure	Within 100 ft. Buffer	Within 300 Ft. Buffer	Not in Buffer	Grand Total
Boating - Motorized			1	1
Cabin Rentals	2	4	4	10
Campground Camping	11	18	26	55
Group Camping	1	1		2
Group Picnicking	1			1
Interpretive Areas		1		1
Picnicking	5	9	5	19
Grand Total	20	33	**36**	**89**


MEDICINE BOW-ROUTT NATIONAL FORESTS
ROAD AND MOTOR TRAIL STREAM CROSSINGS BY
SUBWATERSHEDS (HUC-6)
N
0 5 10 20
Miles
Wyoming
Colorado
Legend
ROAD STREAM CROSSINGS
MOTOR TRAIL STREAM CROSSINGS
ROADS
MOTOR TRAILS
STREAM NETWORK
Perennial
Intermittent
Ephemeral
Ditch
artificial path
SUBWATERSHED (HUC-6)
FOREST BOUNDARY
STATE BOUNDARY


THUNDER BASIN NATIONAL GRASSLAND
ROAD PROXIMITY TO STREAM NETWORK BY
SUBWATERSHEDS (HUC-6)
Wyoming
South Dakota
Legend
Roads within 100 ft. Buffer
Roads within 300 ft. Buffer
Roads Outside Buffer
Stream Network 100 ft. Buffer
Stream Network 300 ft. Buffer
SUBWATERSHED (HUC-6)
FOREST BOUNDARY
STATE BOUNDARY
N
0 5 10 20
Miles


MEDICINE BOW-ROUTT NATIONAL FORESTS
RECREATION INFRASTRUCTURE BY
SUBWATERSHEDS (HUC-6)
N
0 5 10 20
Miles
Wyoming
Colorado
Legend
Recreation Infrastructure in 100 Ft. Buffer
Recreation Infrastructure in 300 Ft. Buffer
Recreation Infrastructure outside of Buffer
ROADS
Stream Network 100 ft. Buffer
Stream Network 300 ft. Buffer
SUBWATERSHED (HUC-6)
FOREST BOUNDARY
STATE BOUNDARY

Thunder Basin National Grassland

SUMMARIZED INFORMATION FOR THE

MEDICINE BOW-ROUTT NATIONAL FORESTS AND THUNDER BASIN NATIONAL GRASSLAND

TOTAL ROAD MILES

OPERATIONAL MAINTENANCE LEVEL	TOTAL MILES
1 - BASIC CUSTODIAL CARE (CLOSED)	2,130
2 - HIGH CLEARANCE VEHICLES	3,740
3 - SUITABLE FOR PASSENGER CARS	1,042
4 - MODERATE DEGREE OF USER COMFORT	863
5 - HIGH DEGREE OF USER COMFORT	347
UNKNOWN	157
Grand Total	8,279

TOTAL TRAIL MILES

Allowed Trail Use	Total Miles
Foot/Horse	299
Mountain Bike	765
Motorcycle	229
Grand Total	1,293

	Total Miles
Non-motorized	1,064.4
Motor Trails	229.0

TOTAL ROAD MILES IN STREAM NETWORK BUFFER

OPERATIONAL MAINTENANCE LEVEL	MILES IN 100 FT BUFFER	% Of Total Miles in Buffer	MILES IN 300 FT BUFFER*	% Of Total Miles in Buffer	TOTAL MILES IN BUFFER
1 - BASIC CUSTODIAL CARE (CLOSED)	326	31%	724	69%	1,050
2 - HIGH CLEARANCE VEHICLES	447	32%	954	68%	1,401
3 - SUITABLE FOR PASSENGER CARS	138	30%	329	70%	467
4 - MODERATE DEGREE OF USER COMFORT	66	31%	148	69%	214
5 - HIGH DEGREE OF USER COMFORT	27	33%	56	67%	83
UNKNOWN	321	34%	634	66%	956
Grand Total	1,326	32%	2,844	68%	4,170

TOTAL TRAIL MILES IN STREAM NETWORK BUFFER

Allowed Trail Use	MILES IN 100 FT BUFFER	% Of Total Miles in Buffer	MILES IN 300 FT BUFFER*	% Of Total Miles in Buffer	TOTAL MILES IN BUFFER
Foot/Horse	65	40%	96	60%	161
Mountain Bike	160	39%	248	61%	408
Motorcycle	38	36%	67	64%	106
Grand Total	263	39%	411	61%	675

TOTAL STREAM CROSSINGS COUNTS

COUNT OF ROAD CROSSINGS	17,211
COUNT MOTOR TRAIL CROSSINGS	433
TOTAL TRAIL CROSSINGS	2,610
TOTAL ROAD & TRAIL CROSSINGS	19,821
TOTAL ROAD & MOTOR TRAIL CROSSINGS	17,644

Number of HUC-6 by Classes of Miles of Road within 100 ft of Stream Network

Range of Miles of Road in 100 ft. Buffer	Count of HUC-6
18.548452 - 33.780460	6
10.749925 - 18.548451	27
5.509646 - 10.749924	56
2.120676 - 5.509645	74
0.002756 - 2.120675	132

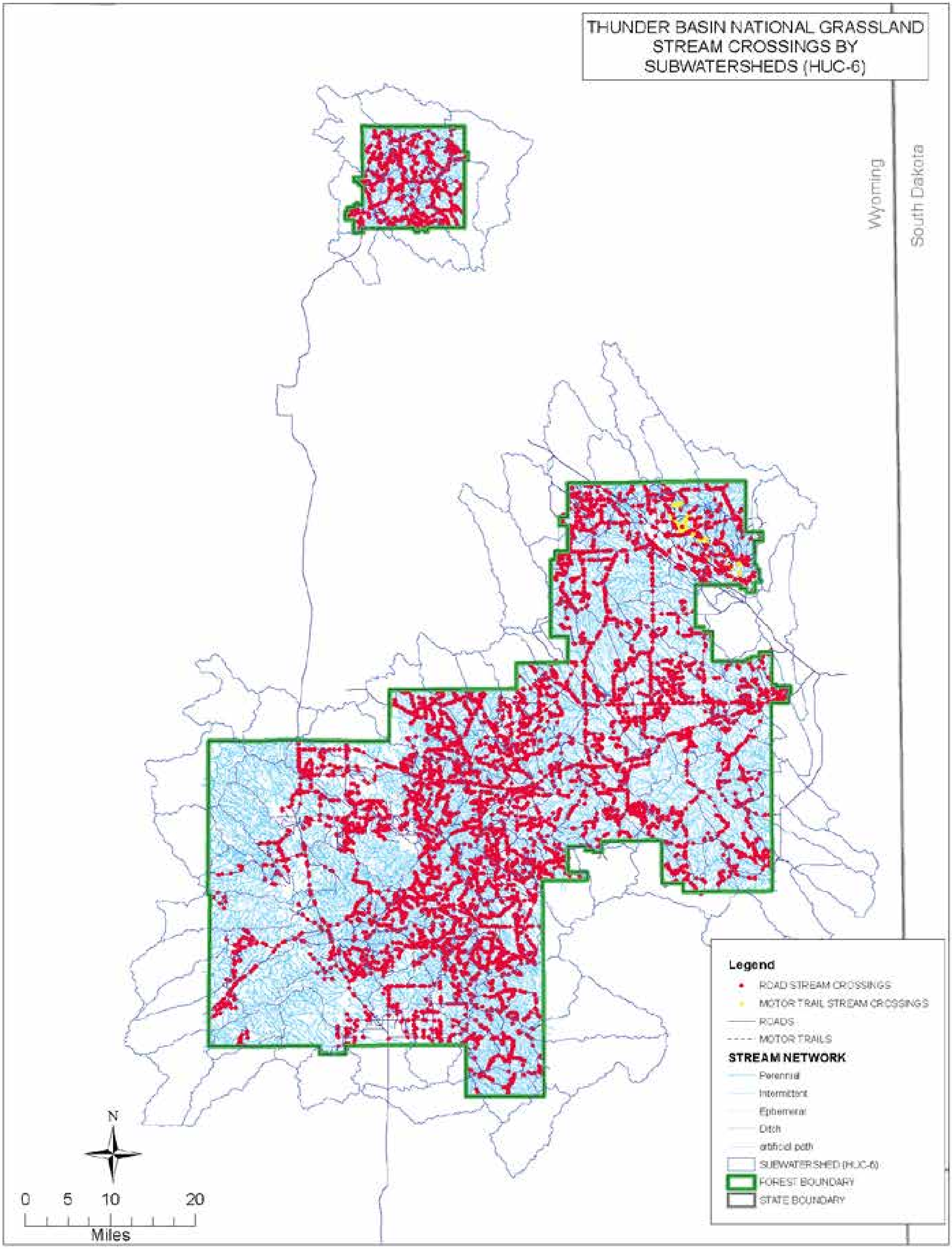
Number of HUC-6 by Classes of Stream Crossing Counts

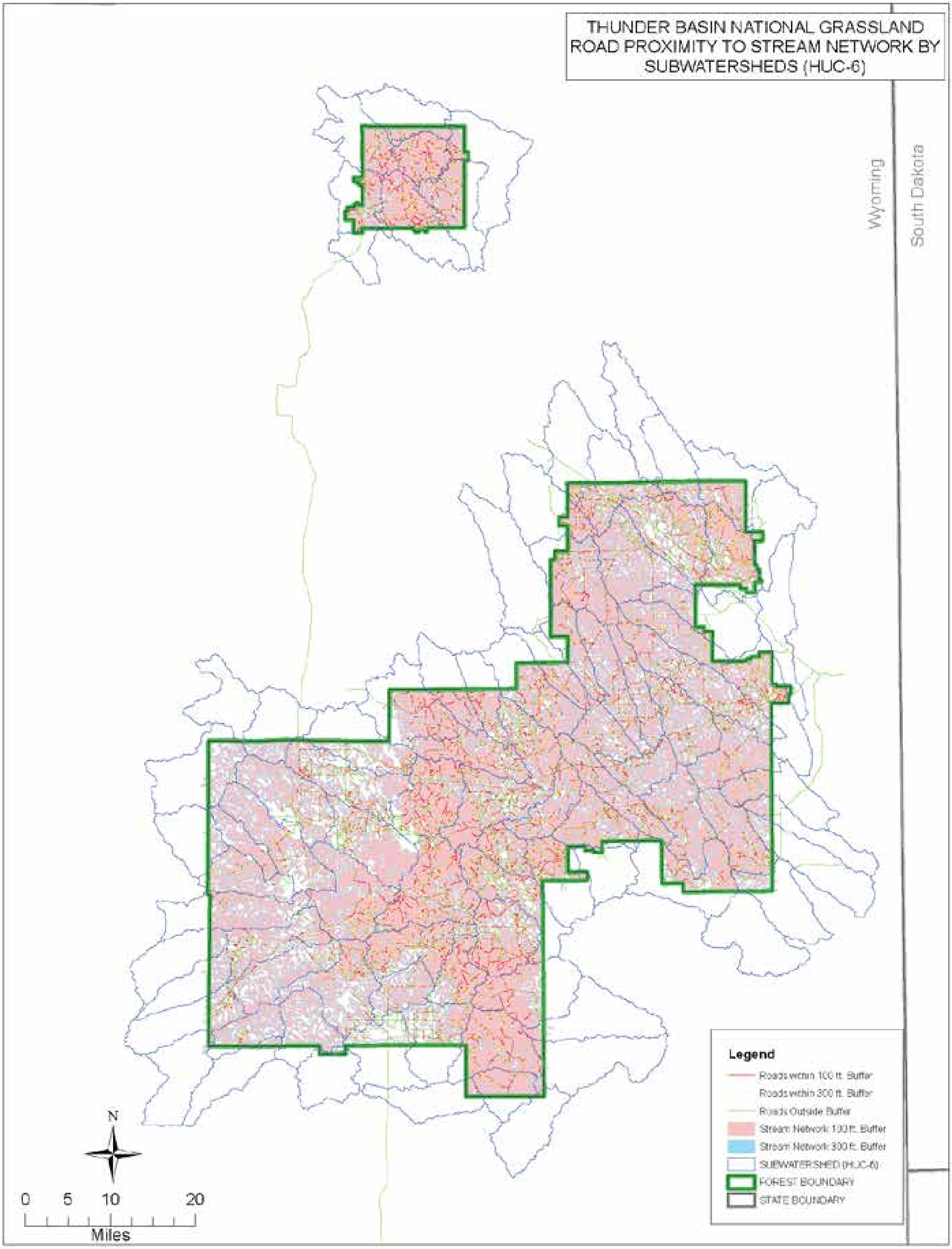
Range of Road and Motor Trail Crossing Counts	Count of HUC-6
256.000001 - 501.000000	5
150.000001 - 256.000000	26
82.000001 - 150.000000	48
32.000001 - 82.000000	72
0.000000 - 32.000000	139

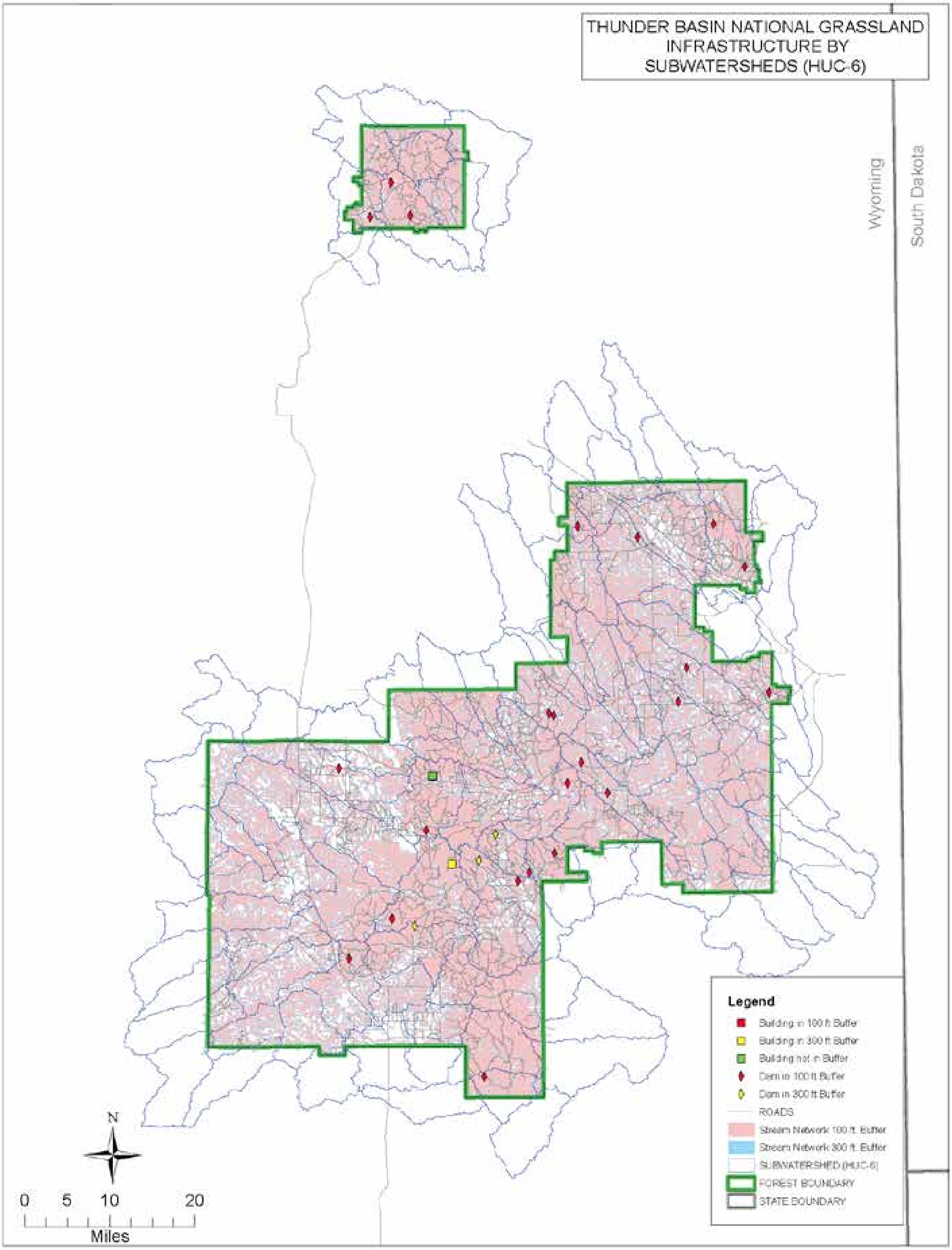
Range of Road Crossing Counts	Count of HUC-6
257 - 501	4
151 - 256	25
83 - 150	50
33 - 82	70
0 - 32	130
	279

Recreation Sites where infrastructure could be exposed to flooding events.

Recreation Infrastructure	Within 100 ft. Buffer	Within 300 Ft. Buffer	Not in Buffer	Grand Total
Boating - Motorized			1	1
Cabin Rentals	2	4	4	10
Campground Camping	11	18	26	55
Group Camping	1	1		2
Group Picnicking	1			1
Interpretive Areas		1		1
Picnicking	5	9	5	19
Grand Total	20	33	36	89


THUNDER BASIN NATIONAL GRASSLAND
STREAM CROSSINGS BY
SUBWATERSHEDS (HUC-6)
Wyoming
South Dakota
Legend
ROAD STREAM CROSSINGS
MOTOR TRAIL STREAM CROSSINGS
ROADS
MOTOR TRAILS
STREAM NETWORK
Perennial
Intermittent
Ephemeral
Ditch
artificial path
SUBWATERSHED (HUC-6)
FOREST BOUNDARY
STATE BOUNDARY
N
0 5 10 20
Miles


THUNDER BASIN NATIONAL GRASSLAND
ROAD PROXIMITY TO STREAM NETWORK BY
SUBWATERSHEDS (HUC-6)
Wyoming
South Dakota
Legend
Roads within 100 ft. Buffer
Roads within 300 ft. Buffer
Roads Outside Buffer
Stream Network 100 ft. Buffer
Stream Network 300 ft. Buffer
SUBWATERSHED (HUC-6)
FOREST BOUNDARY
STATE BOUNDARY
N
0 5 10 20
Miles



THUNDER BASIN NATIONAL GRASSLAND
INFRASTRUCTURE BY
SUBWATERSHEDS (HUC-6)
Wyoming
South Dakota
Legend
Building in 100 ft Buffer
Building in 300 ft Buffer
Building not in Buffer
Dam in 100 ft Buffer
Dam in 300 ft Buffer
ROADS
Stream Network 100 ft. Buffer
Stream Network 300 ft. Buffer
SUBWATERSHED (HUC-6)
FOREST BOUNDARY
STATE BOUNDARY
N
0 5 10 20
Miles

Nebraska National Forest

SUMMARIZED INFORMATION FOR THE
NEBRASKA NATIONAL FOREST

TOTAL ROAD MILES

Operational Maintenance Level	Total Road Miles
1 - BASIC CUSTODIAL CARE (CLOSED)	6
2 - HIGH CLEARANCE VEHICLES	850
3 - SUITABLE FOR PASSENGER CARS	587
4 - MODERATE DEGREE OF USER COMFORT	87
5 - HIGH DEGREE OF USER COMFORT	305
Unknown	912
Grand Total	**2,747**

TOTAL TRAIL MILES

ALLOWED TRAIL USE	TOTAL MILES
Foot/Horse	10
Mtn. Bike	303
Motorcycle	27
ATV	2
Jeep	3
Grand Total	**345**

TOTAL ROAD MILES IN STREAM NETWORK BUFFER

Operational Maintenance Level	Miles in 100 ft Buffer	% Of Total Miles in Buffer	Miles In 300 ft Buffer	% Of Total Miles in Buffer	Total Miles in total Buffer
1 - BASIC CUSTODIAL CARE (CLOSED)	1	10%	6	90%	7
2 - HIGH CLEARANCE VEHICLES	46	7%	605	93%	651
3 - SUITABLE FOR PASSENGER CARS	38	7%	481	93%	519
4 - MODERATE DEGREE OF USER COMFORT	6	7%	76	93%	82
5 - HIGH DEGREE OF USER COMFORT	19	6%	277	94%	297
(blank)	55	9%	528	91%	583
Grand Total	165	8%	1,973	92%	2,138

TOTAL TRAIL MILES IN STREAM NETWORK BUFFER

Allowed Trail Use	MILES IN 100 FT BUFFE	% Of Total Miles in Buffer	MILES IN 300 FT BUFFE	% Of Total Miles in Buffer	TOTAL MILES IN BUFFER
FOOT/HORSE	2	38%	3	62%	5
MTN. BIKE	35	32%	73	68%	108
MOTORCYCLE	11	61%	7	39%	19
JEEP	1	62%	0	38%	1
Grand Total	49	**37%**	84	**63%**	133

TOTAL STREAM CROSSINGS COUNTS

TOTAL ROAD CROSSINGS	2,376
TOTAL MOTOR TRAIL CROSSINGS	63
TOTAL TRAIL CROSSINGS	448
TOTAL ROAD & TRAIL CROSSINGS	2,824
TOTAL ROAD & MOTOR TRAIL CROSSINGS	2,439

Number of HUC-6 by Classes of Miles of Road within 100 ft of Stream Network

Range of Miles of Road in 100 ft. Buffer	Count of HUC-6
5.589547 - 9.415154	3
2.552327 - 5.589546	12
1.358708 - 2.552326	21
0.569686 - 1.358707	44
0.006997 - 0.569685	70

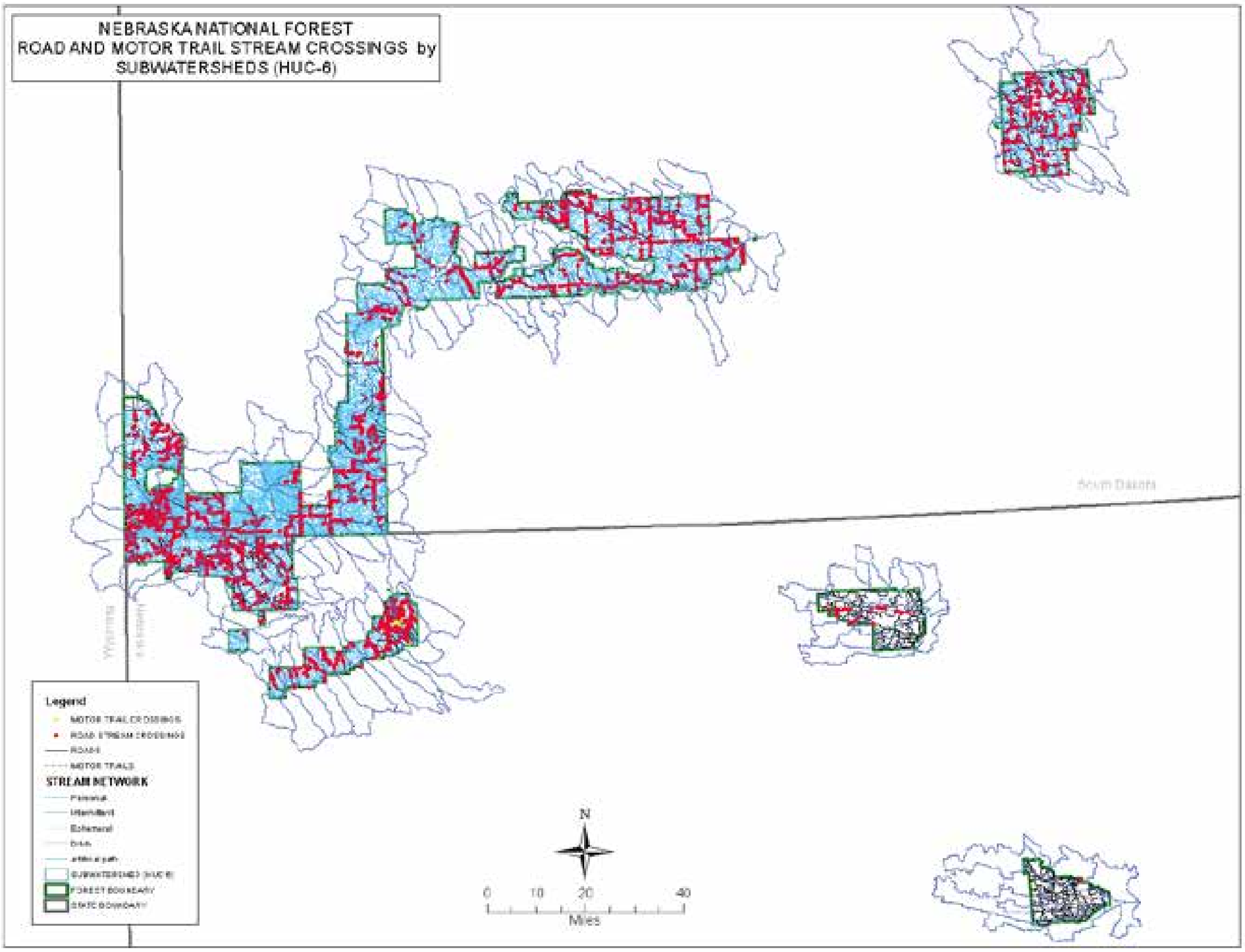
Number of HUC-6 by Classes of Stream Crossing Counts

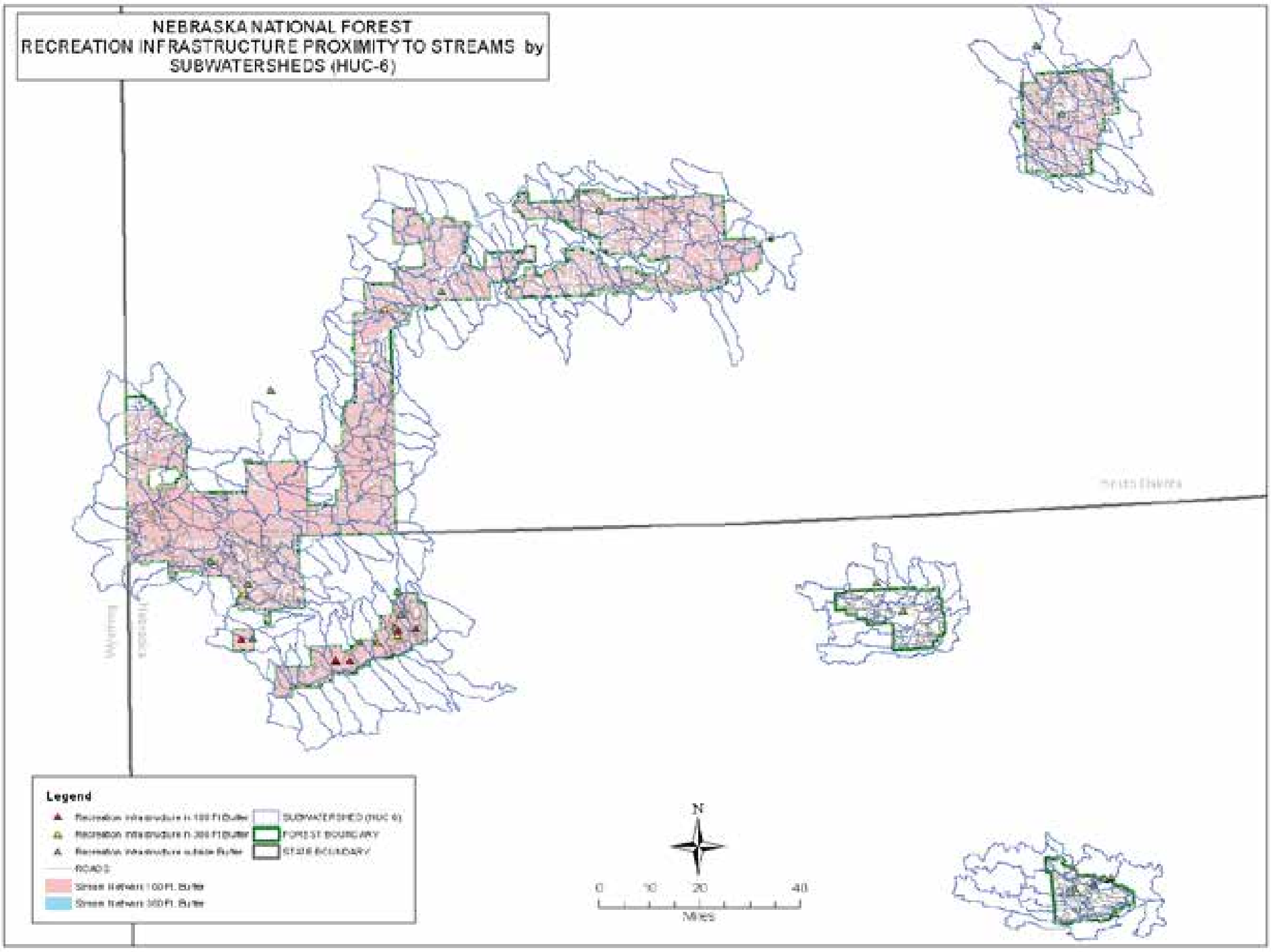
Range of Road and Motor Trail Crossing Counts	Count of HUC-6
76.000001 - 118.000000	3
36.000001 - 76.000000	14
18.000001 - 36.000000	25
7.000001 - 18.000000	48
1.000000 - 7.000000	46

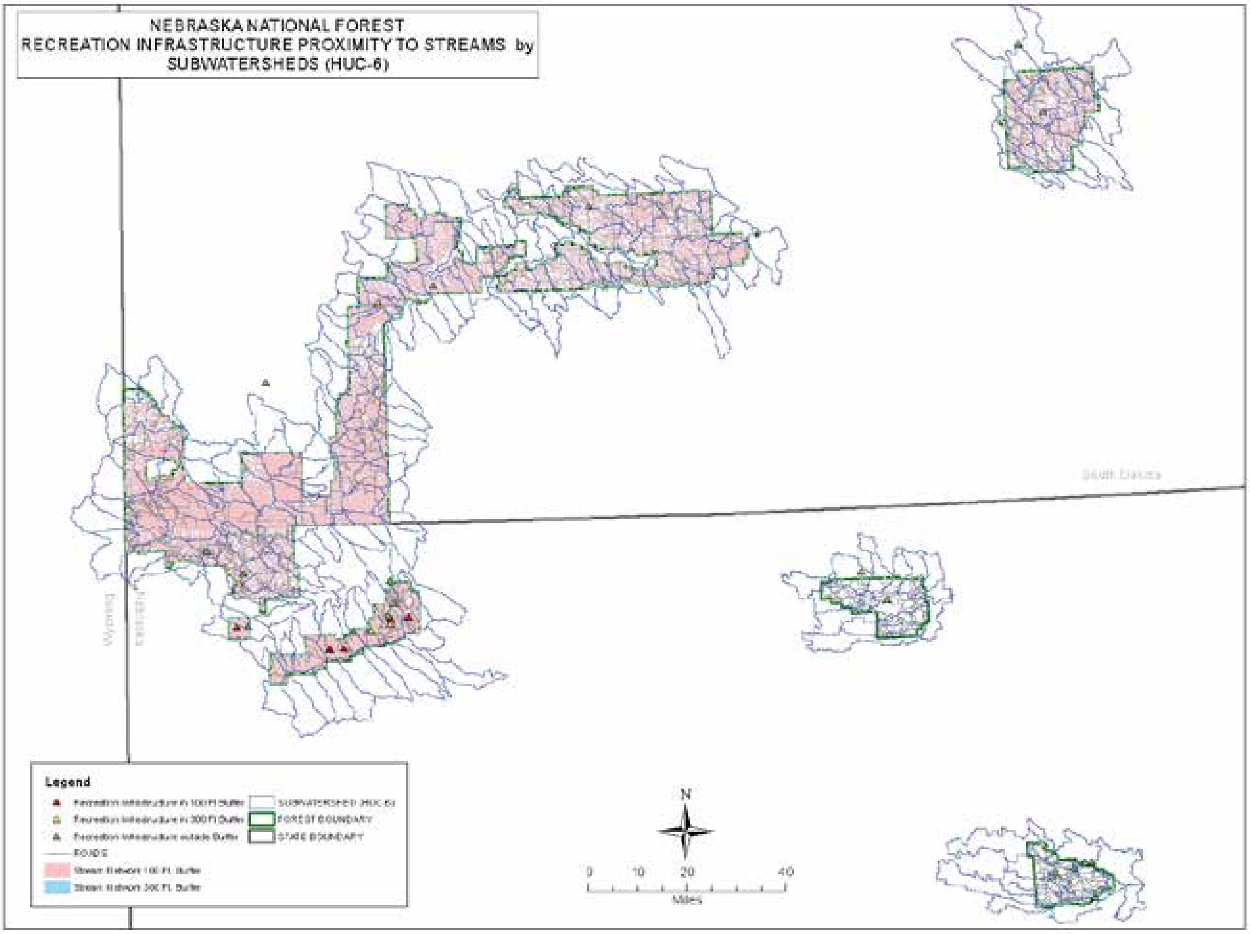
Range of Road Crossing Counts	Count of HUC-6
61.000001 - 118.000000	4
36.000001 - 61.000000	12
18.000001 - 36.000000	26
7.000001 - 18.000000	48
1.000000 - 7.000000	46

Recreation activities where infrastructure could be exposed to flooding events.

Recreation Infrastructure	Within 100 ft. Buffer	Within 300 Ft. Buffer	Not in Buffer	Grand Total
Boating - Non-Motorized			1	1
Campground Camping		2	5	7
Dispersed Camping		1		1
Group Camping			1	1
Horse Camping			2	2
Interpretive Areas			1	1
Picnicking	1		1	2
Visitor Centers		1	1	2
Grand Total	1	4	**12**	**17**


NEBRASKA NATIONAL FOREST
ROAD AND MOTOR TRAIL STREAM CROSSINGS by
SUBWATERSHEDS (HUC-6)
Legend
MOTOR TRAIL CROSSINGS
ROAD STREAM CROSSINGS
MOTOR TRAILS
STREAM NETWORK
N
0 10 20 40
Miles


NEBRASKA NATIONAL FOREST
RECREATION INFRASTRUCTURE PROXIMITY TO STREAMS by
SUBWATERSHEDS (HUC-6)
Legend
ROADS
SUBWATERSHED (HUC 6)
FOREST BOUNDARY
STATE BOUNDARY
N
0
10
20
40
Miles


NEBRASKA NATIONAL FOREST
RECREATION INFRASTRUCTURE PROXIMITY TO STREAMS by
SUBWATERSHEDS (HUC-6)
South Dakota
Wyoming
Nebraska
Legend
FOREST BOUNDARY
STATE BOUNDARY
ROADS
N
0 10 20 40
Miles

Pike-San Isabel National Forests & Cimarron-Comanche National Grasslands

SUMMARIZED INFORMATION FOR THE

PIKE-SAN ISABEL NATIONAL FORESTS AND CIMARRON-COMANCHE NATIONAL GRASSLANDS

TOTAL ROAD MILES

OPERATIONAL MAINTENANCE LEVEL	TOTAL MILES
1 - BASIC CUSTODIAL CARE (CLOSED)	144
2 - HIGH CLEARANCE VEHICLES	3,023
3 - SUITABLE FOR PASSENGER CARS	1,869
4 - MODERATE DEGREE OF USER COMFORT	377
5 - HIGH DEGREE OF USER COMFORT	438
UNKNOWN	30
Grand Total	**5,880**

TOTAL TRAIL MILES

ALLOWED TRAIL USE	TOTAL MILES
FOOT/HORSE	411
MTN. BIKE	865
MOTORCYCLE	141
ATV	147
Grand Total	**1,564**

	Total Miles
Non-motorized trails	1,276
Motor Trails	288
Total	1,564

TOTAL ROAD MILES IN STREAM NETWORK BUFFER

Operational Maintenance Level	Miles in 100 ft Buffer	% Of Total Miles in Buffer	Miles In 300 ft Buffer	% Of Total Miles in Buffer	Total Miles in total Buffer
1 - BASIC CUSTODIAL CARE (CLOSED)	43	49%	45	51%	88
2 - HIGH CLEARANCE VEHICLES	610	41%	874	59%	1,484
3 - SUITABLE FOR PASSENGER CARS	294	39%	457	61%	752
4 - MODERATE DEGREE OF USER COMFORT	92	43%	121	57%	213
5 - HIGH DEGREE OF USER COMFORT	62	36%	109	64%	171
UNKNOWN	10	47%	11	53%	21
Grand Total	1,111	**41%**	1,617	**59%**	2,728

TOTAL TRAIL MILES IN STREAM NETWORK BUFFER

Allowed Trail Use	MILES IN 100 FT BUFFE	% Of Total Miles in Buffer	MILES IN 300 FT BUFFE	% Of Total Miles in Buffer	TOTAL MILES IN BUFFER
Foot/Horse	79	39%	125	61%	204
Mtn. Bike	248	47%	282	53%	530
Motorcycle	39	48%	42	52%	81
ATV	47	41%	66	59%	113
Grand Total	413	**44%**	515	**56%**	928

TOTAL STREAM CROSSINGS COUNTS

TOTAL ROAD CROSSINGS	11,866
TOTAL MOTOR TRAIL CROSSINGS	842
TOTAL TRAIL CROSSINGS	3,910
TOTAL ROAD & TRAIL CROSSINGS	15,776
TOTAL ROAD & MOTOR TRAIL CROSSINGS	8,962

Number of HUC-6 by Classes of Miles of Road within 100 ft of Stream Network

Range of Miles of Road in 100 ft. Buffer	Count of HUC-6
16.462021 - 41.449953	8
8.977862 - 16.462020	20
4.895436 - 8.977861	38
1.981149 - 4.895435	91
0.003528 - 1.981148	123

Number of HUC-6 by Classes of Stream Crossing Counts Pike-San Isabel NF

Range of Road and Motor Trail Crossing Counts	Count of HUC-6
180.000001 - 360.000000	9
101.000001 - 180.000000	13
54.000001 - 101.000000	24
20.000001 - 54.000000	73
0.000000 - 20.000000	64

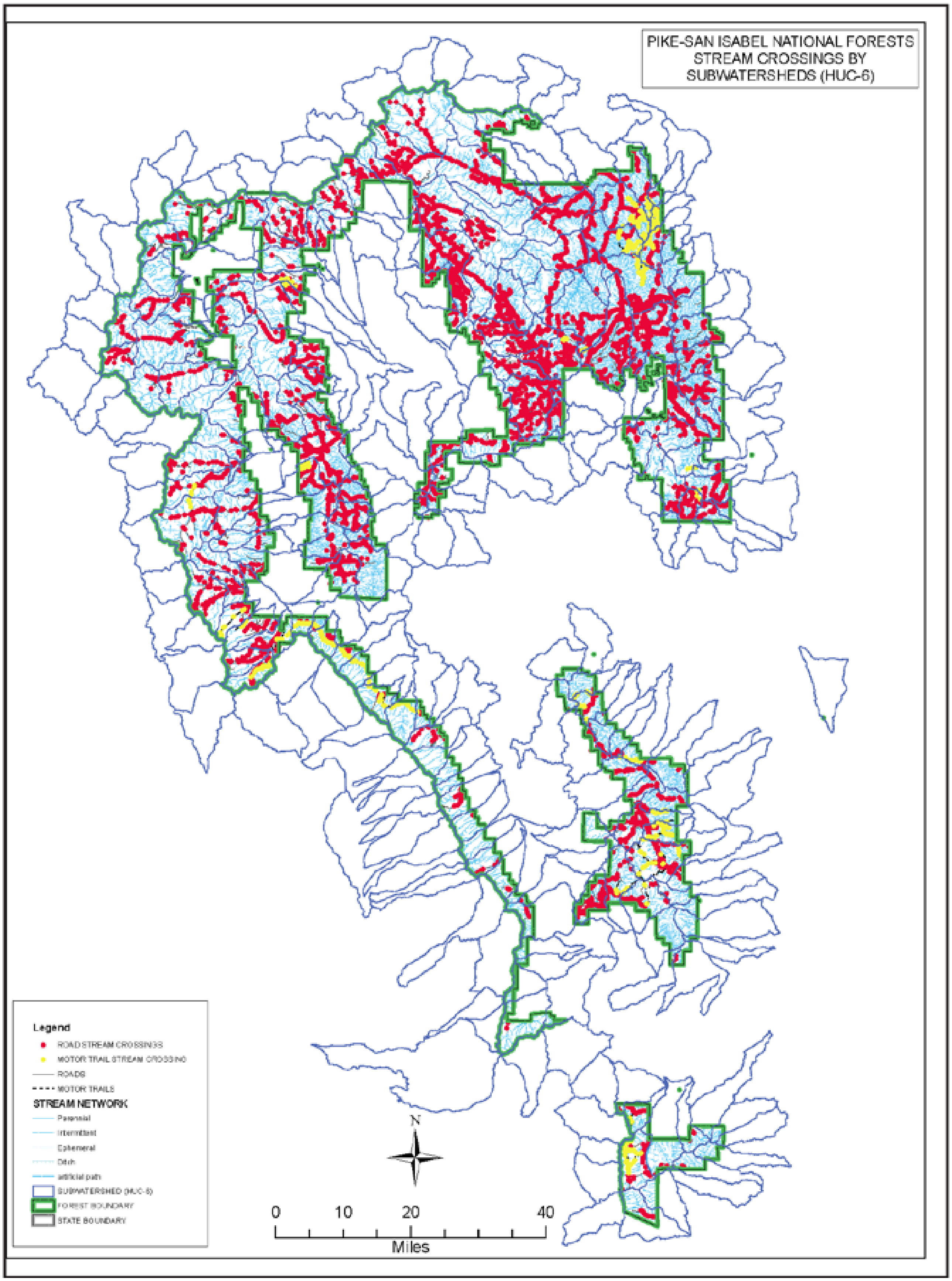
Range of Road Crossing Counts	Count of HUC-6
174 - 360	7
102 - 173	11
55 - 101	25
23 - 54	62
1.0 - 22	70

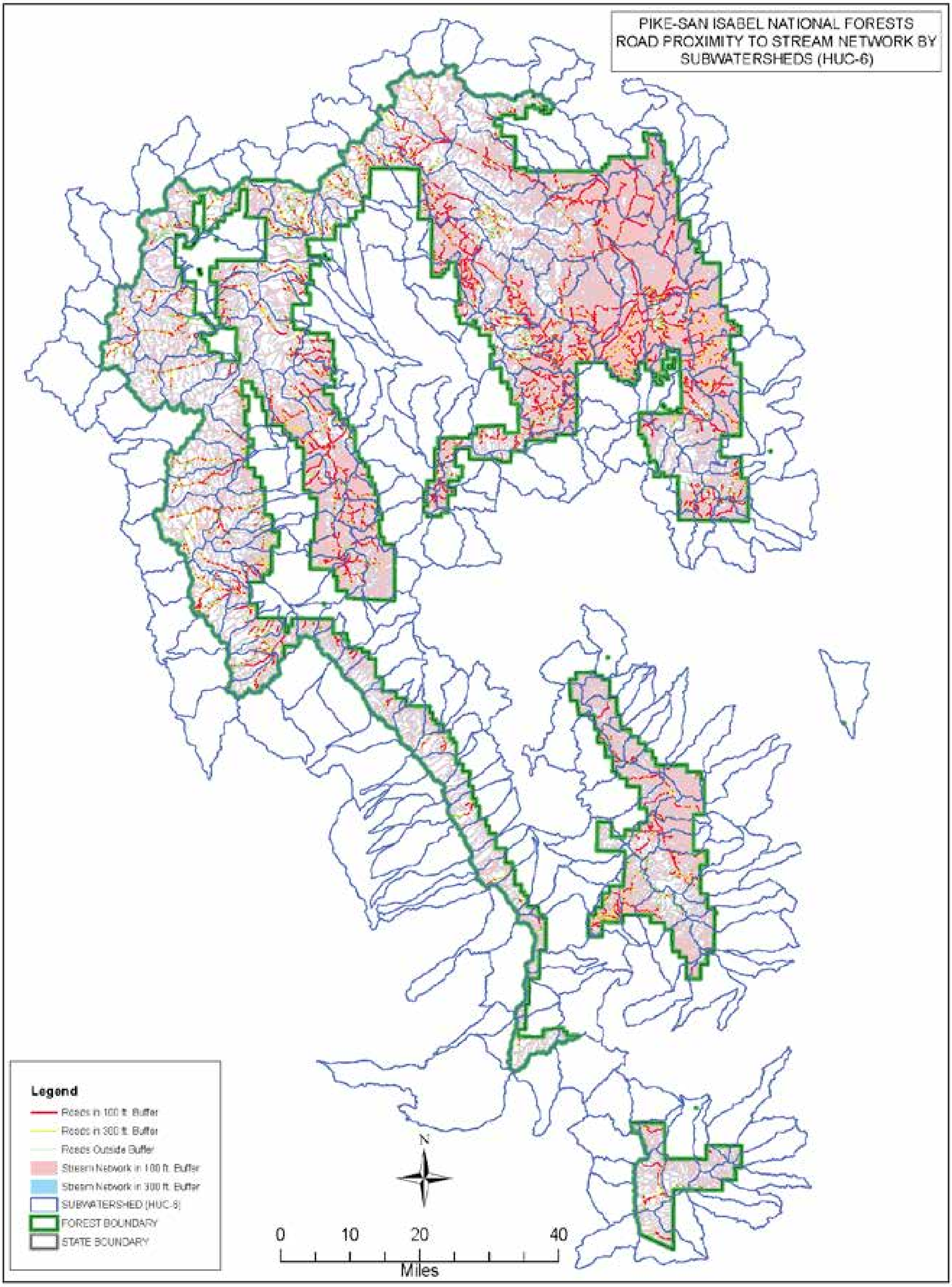
Number of HUC-6 by Classes of Stream Crossing Counts Cimarron Comanche National Grassland

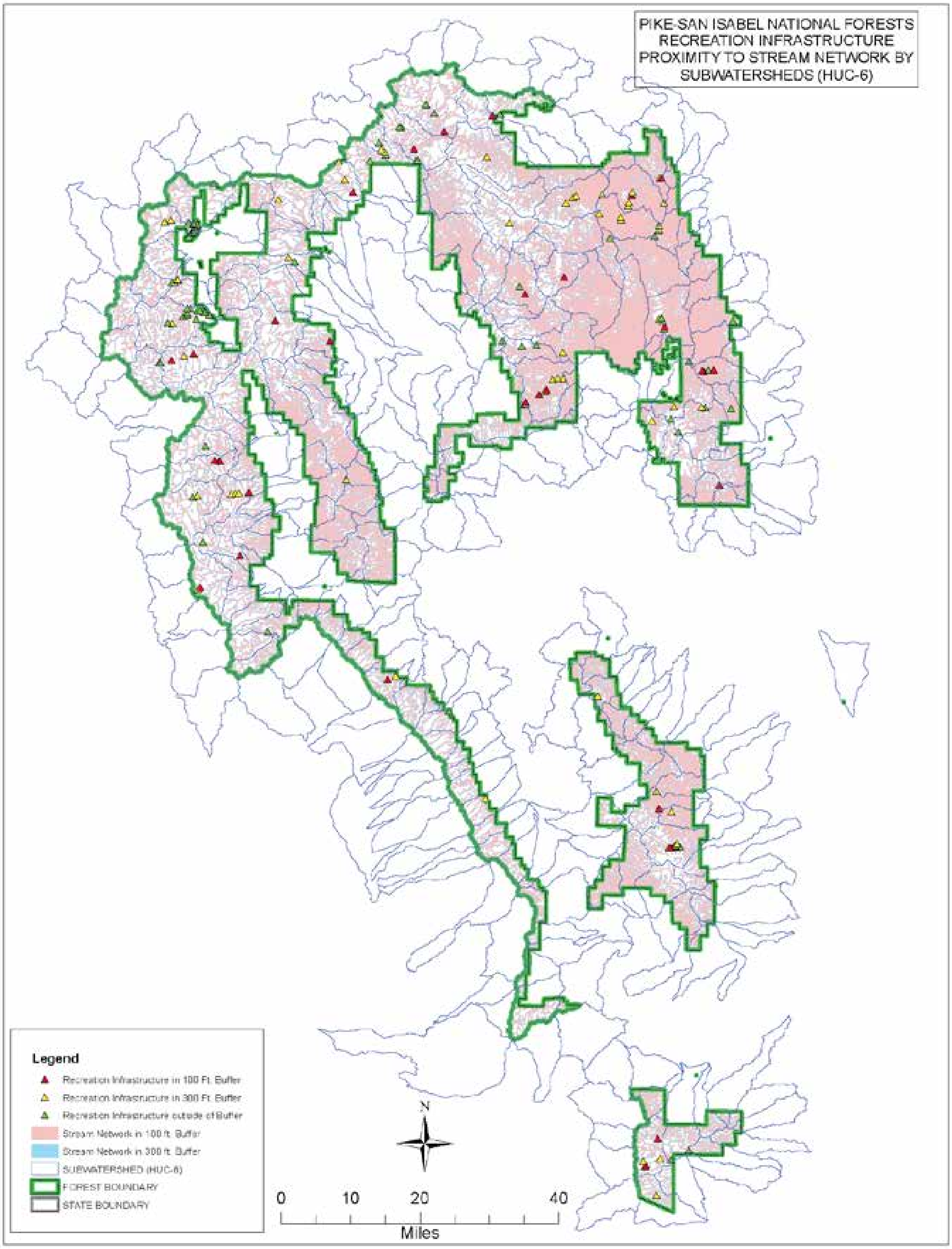
Range of Road Crossin	Count of HUC-6
132 - 212	2
72 - 131	13
41 - 71	19
18 - 40	24
1.0 - 17	40

Recreation activities where infrastructure could be exposed to flooding events.

Recreation Infrastructure	Within 100 Ft. Buffer	Within 300 Ft. Buffer	Outside Buffer	Grand Total
Boating - Non-Motorized	2		4	6
Cabin Rentals	3	2	3	8
Campground Camping	19	32	28	79
Day Use Area	1	3	1	5
Dispersed Camping		1	1	2
Group Camping	1	2	2	5
Group Picnicking			2	2
Horse Camping		1		1
Interpretive Areas	2	4	14	20
OHV Camping		1	2	3
Picnicking	5	15	14	34
RV Camping	2	3	6	11
Ski Area		1	1	2
Target Shooting		1		1
Visitor Center			1	1
Grand Total	35	66	**79**	**180**


PIKE-SAN ISABEL NATIONAL FORESTS
STREAM CROSSINGS BY
SUBWATERSHEDS (HUC-6)
Legend
ROAD STREAM CROSSINGS
MOTOR TRAIL STREAM CROSSING
ROADS
MOTOR TRAILS
STREAM NETWORK
Perennial
Intermittent
Ephemeral
Ditch
artificial path
SUBWATERSHED (HUC-6)
FOREST BOUNDARY
STATE BOUNDARY
N
0
10
20
40
Miles


PIKE-SAN ISABEL NATIONAL FORESTS
ROAD PROXIMITY TO STREAM NETWORK BY
SUBWATERSHEDS (HUC-6)
Legend
Roads in 100 ft. Buffer
Roads in 300 ft. Buffer
Roads Outside Buffer
Stream Network in 100 ft. Buffer
Stream Network in 300 ft. Buffer
SUBWATERSHED (HUC-6)
FOREST BOUNDARY
STATE BOUNDARY
N
0
10
20
40
Miles


PIKE-SAN ISABEL NATIONAL FORESTS
RECREATION INFRASTRUCTURE
PROXIMITY TO STREAM NETWORK BY
SUBWATERSHEDS (HUC-6)
Legend
Recreation Infrastructure in 100 Ft. Buffer
Recreation Infrastructure in 300 Ft. Buffer
Recreation Infrastructure outside of Buffer
Stream Network in 100 ft. Buffer
Stream Network in 300 ft. Buffer
SUBWATERSHED (HUC-6)
FOREST BOUNDARY
STATE BOUNDARY
N
0
10
20
40
Miles

Cimarron-Comanche National Grasslands

SUMMARIZED INFORMATION FOR THE

PIKE-SAN ISABEL NATIONAL FORESTS AND CIMARRON-COMANCHE NATIONAL GRASSLANDS

TOTAL ROAD MILES

OPERATIONAL MAINTENANCE LEVEL	TOTAL MILES
1 - BASIC CUSTODIAL CARE (CLOSED)	144
2 - HIGH CLEARANCE VEHICLES	3,023
3 - SUITABLE FOR PASSENGER CARS	1,869
4 - MODERATE DEGREE OF USER COMFORT	377
5 - HIGH DEGREE OF USER COMFORT	438
UNKNOWN	30
Grand Total	5,880

TOTAL TRAIL MILES

ALLOWED TRAIL USE	TOTAL MILES
FOOT/HORSE	411
MTN. BIKE	865
MOTORCYCLE	141
ATV	147
Grand Total	1,564

	Total Miles
Non-motorized trails	1,276
Motor Trails	288
Total	1,564

TOTAL ROAD MILES IN STREAM NETWORK BUFFER

Operational Maintenance Level	Miles in 100 ft Buffer	% Of Total Miles in Buffer	Miles In 300 ft Buffer	% Of Total Miles in Buffer	Total Miles in total Buffer
1 - BASIC CUSTODIAL CARE (CLOSED)	43	49%	45	51%	88
2 - HIGH CLEARANCE VEHICLES	610	41%	874	59%	1,484
3 - SUITABLE FOR PASSENGER CARS	294	39%	457	61%	752
4 - MODERATE DEGREE OF USER COMFORT	92	43%	121	57%	213
5 - HIGH DEGREE OF USER COMFORT	62	36%	109	64%	171
UNKNOWN	10	47%	11	53%	21
Grand Total	1,111	41%	1,617	59%	2,728

TOTAL TRAIL MILES IN STREAM NETWORK BUFFER

Allowed Trail Use	MILES IN 100 FT BUFFE	% Of Total Miles in Buffer	MILES IN 300 FT BUFFE	% Of Total Miles in Buffer	TOTAL MILES IN BUFFER
Foot/Horse	79	39%	125	61%	204
Mtn. Bike	248	47%	282	53%	530
Motorcycle	39	48%	42	52%	81
ATV	47	41%	66	59%	113
Grand Total	413	44%	515	56%	928

TOTAL STREAM CROSSINGS COUNTS

TOTAL ROAD CROSSINGS	11,866
TOTAL MOTOR TRAIL CROSSINGS	842
TOTAL TRAIL CROSSINGS	3,910
TOTAL ROAD & TRAIL CROSSINGS	15,776
TOTAL ROAD & MOTOR TRAIL CROSSINGS	8,962

Number of HUC-6 by Classes of Miles of Road within 100 ft of Stream Network

Range of Miles of Road in 100 ft. Buffer	Count of HUC-6
16.462021 - 41.449953	8
8.977862 - 16.462020	20
4.895436 - 8.977861	38
1.981149 - 4.895435	91
0.003528 - 1.981148	123

Number of HUC-6 by Classes of Stream Crossing Counts Pike-San Isabel NF

Range of Road and Motor Trail Crossing Counts	Count of HUC-6
180.000001 - 360.000000	9
101.000001 - 180.000000	13
54.000001 - 101.000000	24
20.000001 - 54.000000	73
0.000000 - 20.000000	64

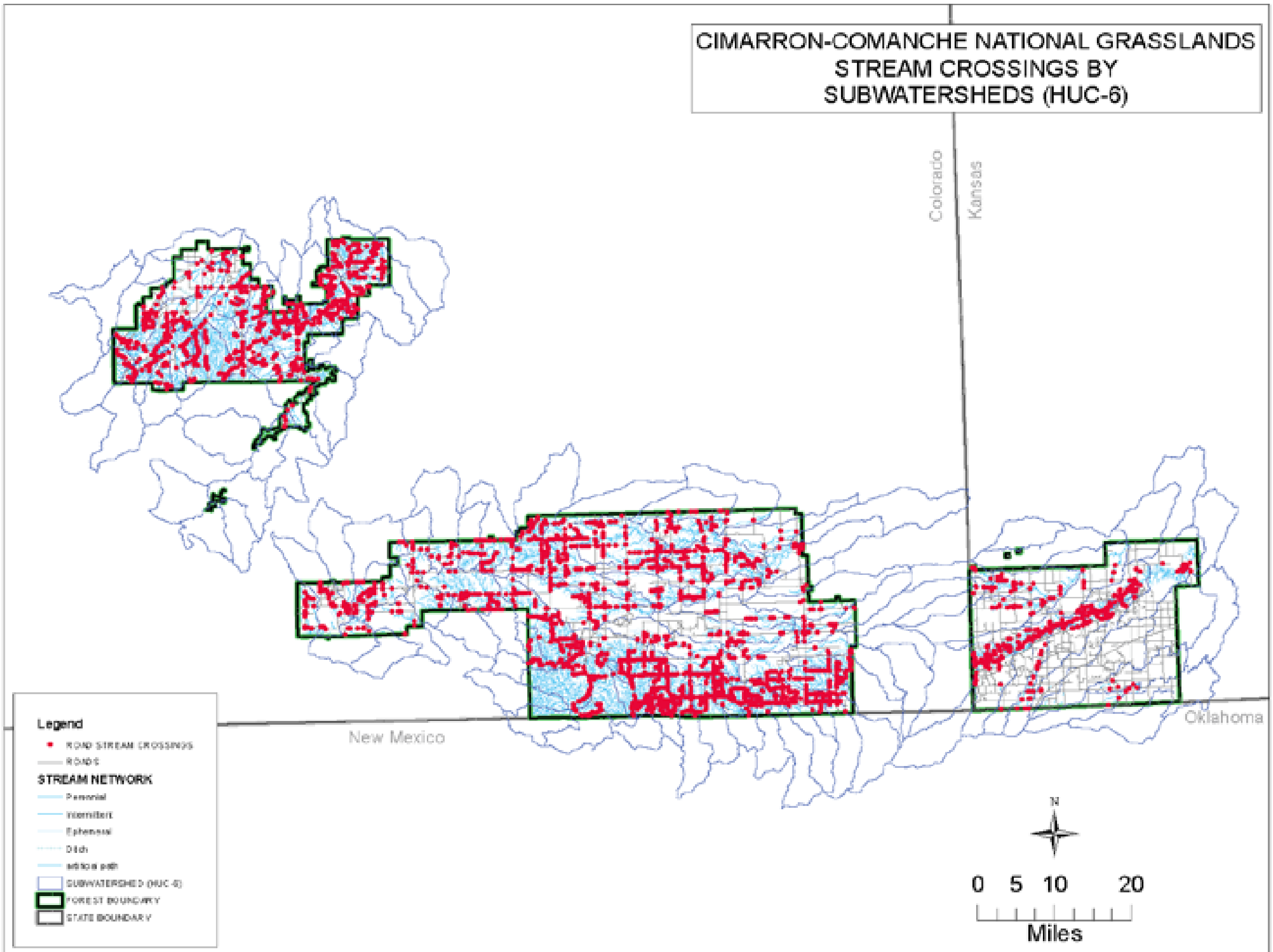
Range of Road Crossing Counts	Count of HUC-6
174 - 360	7
102 - 173	11
55 - 101	25
23 - 54	62
1.0 - 22	70

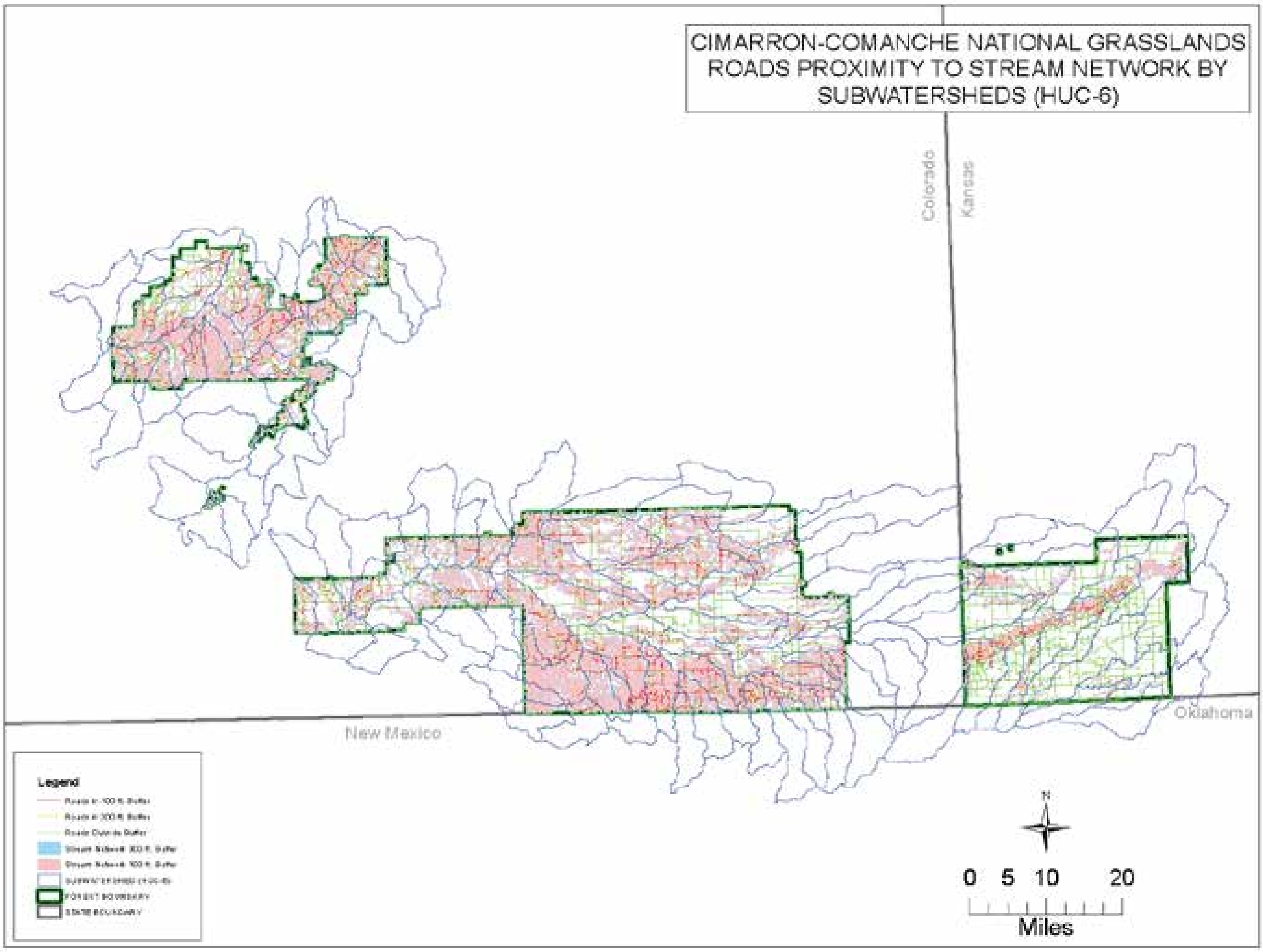
Number of HUC-6 by Classes of Stream Crossing Counts Cimarron Comanche National Grassland

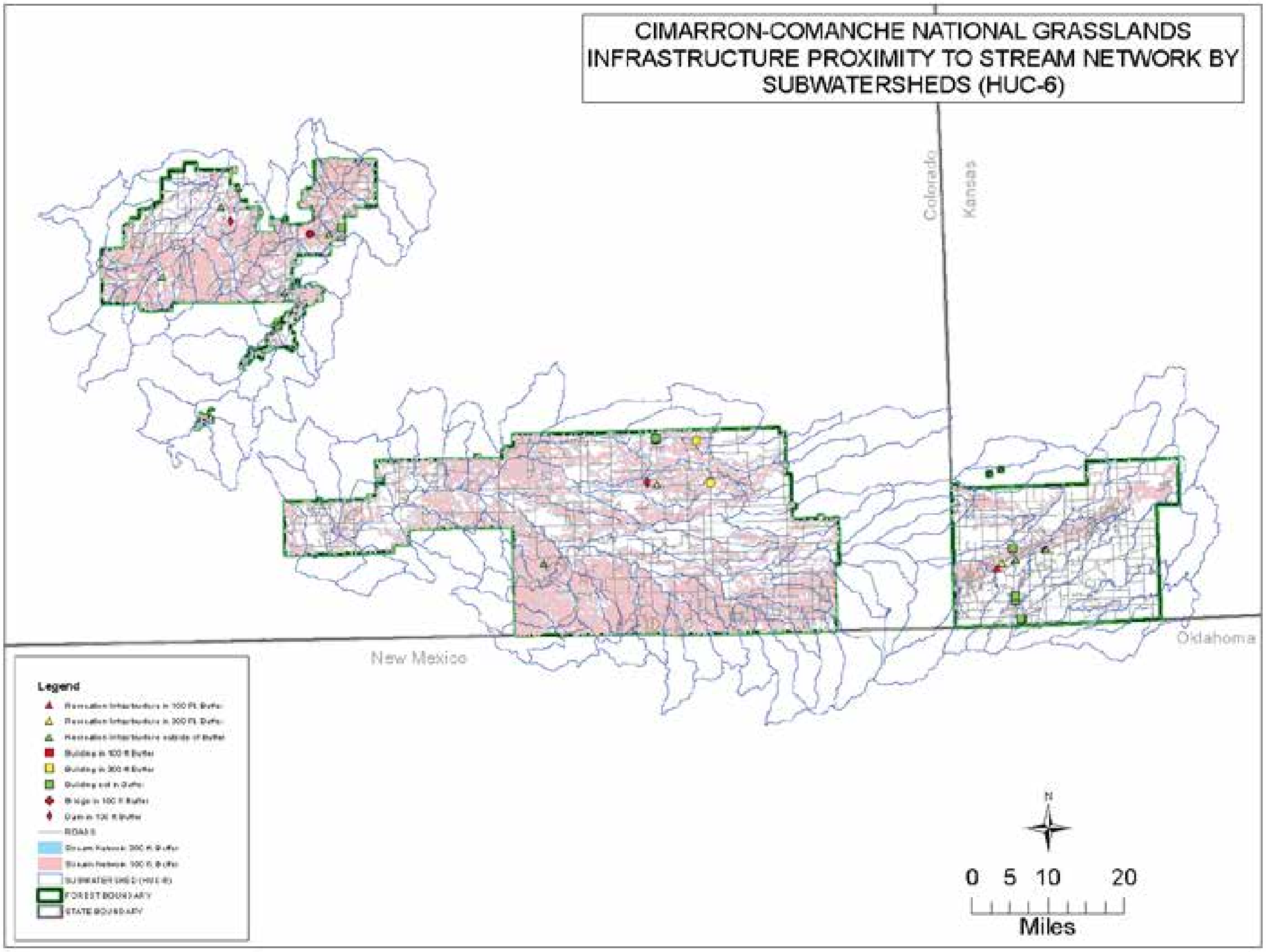
Range of Road Crossing	Count of HUC-6
132 - 212	2
72 - 131	13
41 - 71	19
18 - 40	24
1.0 - 17	40

Recreation activities where infrastructure could be exposed to flooding events.

Recreation Infrastructure	Within 100 Ft. Buffer	Within 300 Ft. Buffer	Outside Buffer	Grand Total
Boating - Non-Motorized	2		4	6
Cabin Rentals	3	2	3	8
Campground Camping	19	32	28	79
Day Use Area	1	3	1	5
Dispersed Camping		1	1	2
Group Camping	1	2	2	5
Group Picnicking			2	2
Horse Camping		1		1
Interpretive Areas	2	4	14	20
OHV Camping		1	2	3
Picnicking	5	15	14	34
RV Camping	2	3	6	11
Ski Area		1	1	2
Target Shooting		1		1
Visitor Center			1	1
Grand Total	35	66	79	180


CIMARRON-COMANCHE NATIONAL GRASSLANDS
STREAM CROSSINGS BY
SUBWATERSHEDS (HUC-6)
Colorado
Kansas
New Mexico
Oklahoma
Legend
ROAD STREAM CROSSINGS
ROADS
STREAM NETWORK
Perennial
Intermittent
Ephemeral
Ditch
artificial path
SUBWATERSHED (HUC-6)
FOREST BOUNDARY
STATE BOUNDARY
N
0 5 10 20
Miles


CIMARRON-COMANCHE NATIONAL GRASSLANDS
ROADS PROXIMITY TO STREAM NETWORK BY
SUBWATERSHEDS (HUC-6)
Colorado
Kansas
New Mexico
Oklahoma
Legend
N
0 5 10 20
Miles


CIMARRON-COMANCHE NATIONAL GRASSLANDS
INFRASTRUCTURE PROXIMITY TO STREAM NETWORK BY
SUBWATERSHEDS (HUC-6)
Colorado
Kansas
New Mexico
Oklahoma
Legend
N
0 5 10 20
Miles

Rio Grande National Forest

SUMMARIZED INFORMATION FOR THE

RIO GRANDE NATIONAL FOREST

TOTAL ROAD MILES

Operational Maintenance Level	Total Road Miles
1 - BASIC CUSTODIAL CARE (CLOSED)	597
2 - HIGH CLEARANCE VEHICLES	1,036
3 - SUITABLE FOR PASSENGER CARS	640
4 - MODERATE DEGREE OF USER COMFORT	1
5 - HIGH DEGREE OF USER COMFORT	169
Grand Total	**2,442**

TOTAL TRAIL MILES

ALLOWED TRAIL USE	TOTAL MILES
FOOT/HORSE	401
MTN. BIKE	595
MOTORCYCLE	157
ATV	53
Grand Total	**1,206**

TOTAL ROAD MILES IN STREAM NETWORK BUFFER

Operational Maintenance Level	Miles in 100 ft Buffer	% Of Total Miles in Buffer	Miles In 300 ft Buffer	% Of Total Miles in Buffer	Total Miles in total Buffer
1 - BASIC CUSTODIAL CARE (CLOSED)	83	37%	142	63%	225
2 - HIGH CLEARANCE VEHICLES	244	45%	296	55%	539
3 - SUITABLE FOR PASSENGER CARS	116	37%	196	63%	311
4 - MODERATE DEGREE OF USER COMFORT	0	63%	0	37%	0
5 - HIGH DEGREE OF USER COMFORT	22	29%	54	71%	75
Grand Total	464	**40%**	687	**60%**	1,151

TOTAL TRAIL MILES IN STREAM NETWORK BUFFER

Allowed Trail Use	MILES IN 100 FT BUFFE	% Of Total Miles in Buffer	MILES IN 300 FT BUFFE	% Of Total Miles in Buffer	TOTAL MILES IN BUFFER
Foot/Horse	101	42%	138	58%	240
Mtn. Bike	167	52%	154	48%	321
Motorcycle	45	50%	44	50%	89
ATV	10	46%	12	54%	22
Grand Total	**323**	48%	**349**	52%	**672**

TOTAL STREAM CROSSINGS COUNTS

TOTAL ROAD CROSSINGS	5,089
TOTAL MOTOR TRAIL CROSSINGS	421
TOTAL TRAIL CROSSINGS	2,697
TOTAL ROAD & TRAIL CROSSINGS	7,786
TOTAL ROAD & MOTOR TRAIL CROSSINGS	5,510

Number of HUC-6 by Classes of Miles of Road within 100 ft of Stream Network

Range of Miles of Road in 100 ft. Buffer	Count of HUC-6
6.976763 - 17.110886	15
4.248580 - 6.976762	29
2.477935 - 4.248579	23
1.076098 - 2.477934	31
0.007695 - 1.076097	41

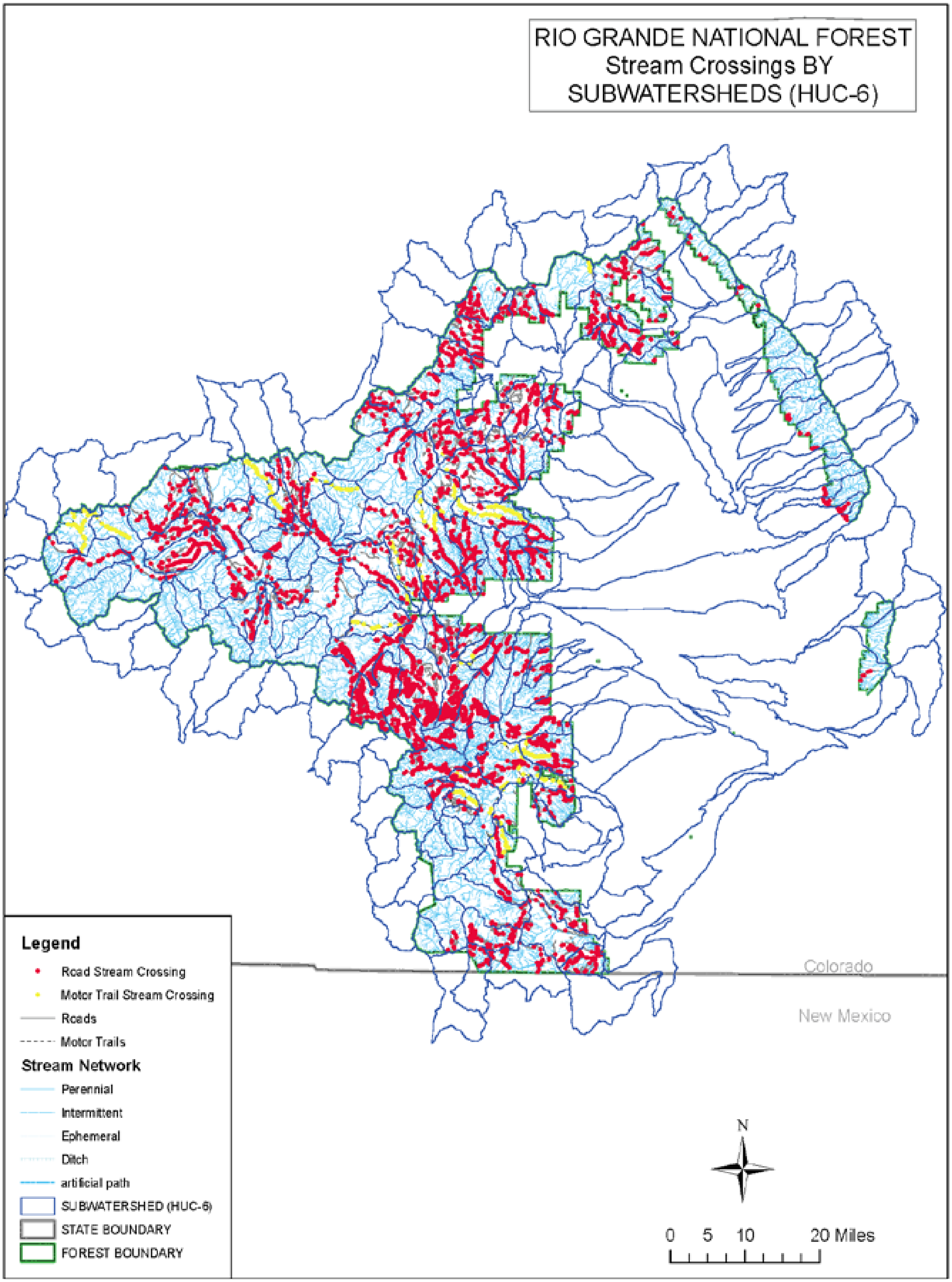
Number of HUC-6 by Classes of Stream Crossing Counts

Range of Road and Motor Trail Crossing Counts	Count of HUC-6
169.000001 - 311.000000	3
82.000001 - 169.000000	10
45.000001 - 82.000000	29
18.000001 - 45.000000	45
0.000000 - 18.000000	48

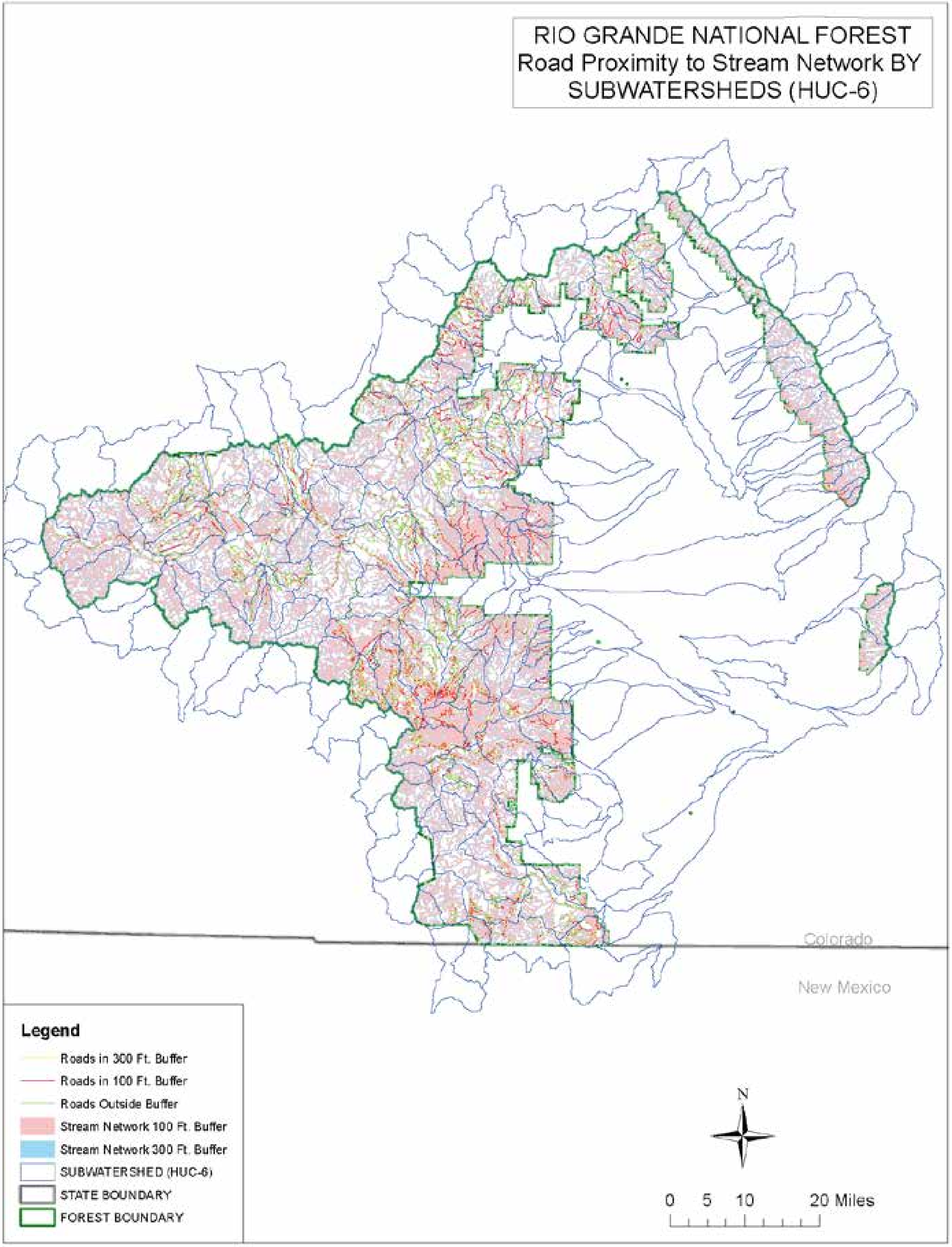
Range of Road Crossing Counts	Count of HUC-6
167 - 311	3
85 - 166	8
46 - 84	28
20 - 45	39
1.0 - 19	52

Recreation activities where infrastructure could be exposed to flooding events.

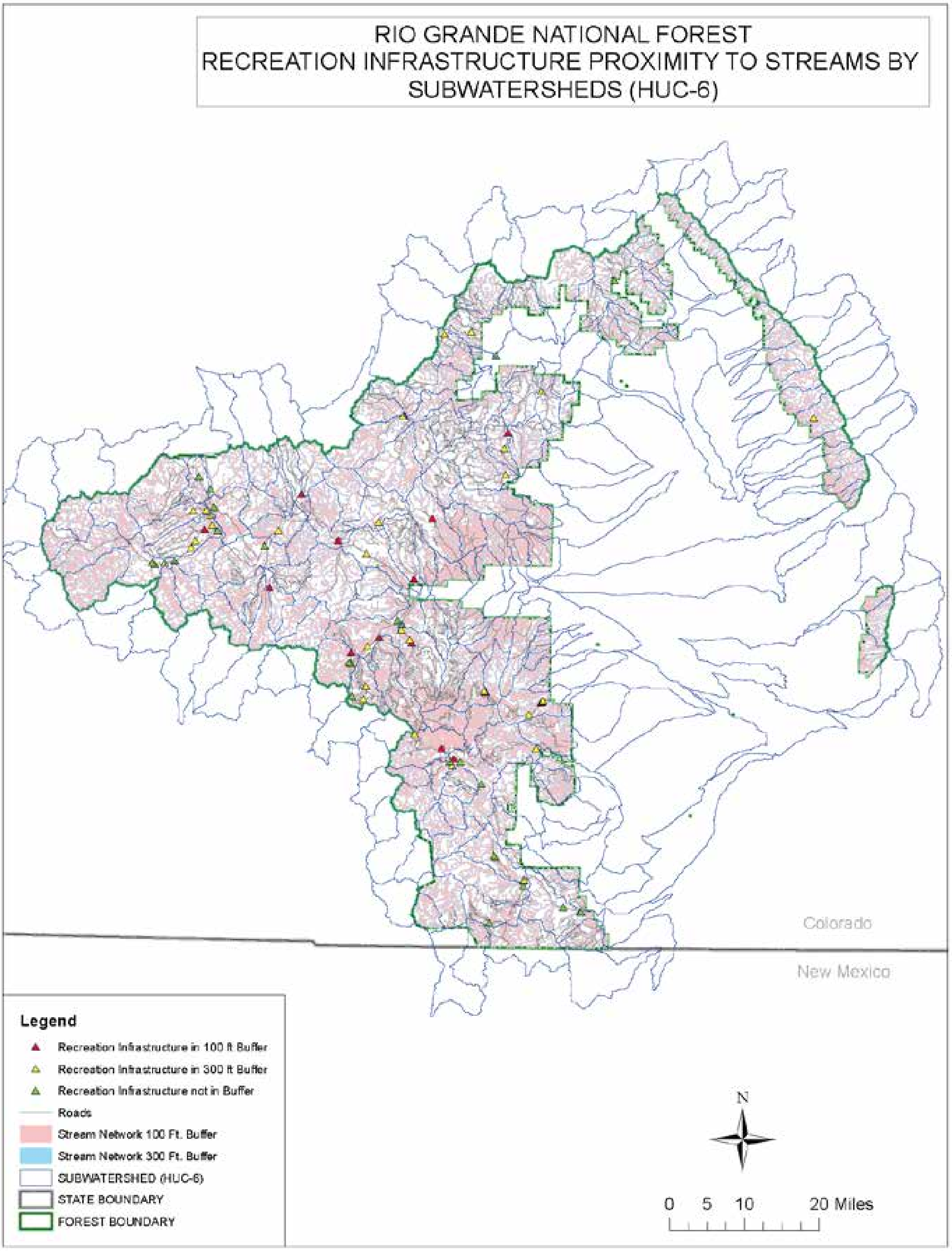
Recreation Infrastructure	Within 100 ft. Buffer	Within 300 Ft. Buffer	Not in Buffer	Grand Total
Boating - Motorized	1	2	3	6
Boating - Non-Motorized		2	1	3
Cabin Rentals	3	3	4	10
Campground Camping	8	19	11	38
Dispersed Camping	1			1
Group Camping			1	1
Group Picnicking		2	1	3
Horse Camping		1		1
Interpretive Areas	2	2	3	7
Picnicking	3	7	2	12
Skiing/Snowboarding			1	1
Grand Total	18	38	**27**	**83**



RIO GRANDE NATIONAL FOREST
Stream Crossings BY
SUBWATERSHEDS (HUC-6)
Colorado
New Mexico
Legend
Road Stream Crossing
Motor Trail Stream Crossing
Roads
Motor Trails
Stream Network
Perennial
Intermittent
Ephemeral
Ditch
artificial path
SUBWATERSHED (HUC-6)
STATE BOUNDARY
FOREST BOUNDARY
N
0 5 10 20 Miles



RIO GRANDE NATIONAL FOREST
Road Proximity to Stream Network BY SUBWATERSHEDS (HUC-6)
Colorado
New Mexico
Legend
Roads in 300 Ft. Buffer
Roads in 100 Ft. Buffer
Roads Outside Buffer
Stream Network 100 Ft. Buffer
Stream Network 300 Ft. Buffer
SUBWATERSHED (HUC-6)
STATE BOUNDARY
FOREST BOUNDARY
N
0 5 10 20 Miles



RIO GRANDE NATIONAL FOREST
RECREATION INFRASTRUCTURE PROXIMITY TO STREAMS BY SUBWATERSHEDS (HUC-6)
Colorado
New Mexico
Legend
Recreation Infrastructure in 100 ft Buffer
Recreation Infrastructure in 300 ft Buffer
Recreation Infrastructure not in Buffer
Roads
Stream Network 100 Ft. Buffer
Stream Network 300 Ft. Buffer
SUBWATERSHED (HUC-6)
STATE BOUNDARY
FOREST BOUNDARY
N
0 5 10 20 Miles

San Juan National Forest

SUMMARIZED INFORMATION FOR THE

SAN JUAN NATIONAL FOREST

TOTAL ROAD MILES

Operational Maintenance Level	Total Road Miles
1 - BASIC CUSTODIAL CARE (CLOSED)	1,134
2 - HIGH CLEARANCE VEHICLES	860
3 - SUITABLE FOR PASSENGER CARS	683
4 - MODERATE DEGREE OF USER COMFORT	87
5 - HIGH DEGREE OF USER COMFORT	323
Grand Total	**3,086**

TOTAL TRAIL MILES

Allowed Trail Use	Total Miles
FOOT/HORSE	409
MTN. BIKE	702
MOTORCYCLE	204
ATV	257
JEEP	23
Grand Total	**1,594**

TOTAL ROAD MILES IN STREAM NETWORK BUFFER

Operational Maintenance Level	Miles in 100 ft Buffer	% Of Total Miles in Buffer	Miles In 300 ft Buffer	% Of Total Miles in Buffer	Total Miles in total Buffer
1 - BASIC CUSTODIAL CARE (CLOSED)	130	35%	241	65%	371
2 - HIGH CLEARANCE VEHICLES	129	36%	234	64%	362
3 - SUITABLE FOR PASSENGER CARS	88	31%	196	69%	284
4 - MODERATE DEGREE OF USER COMFORT	9	29%	22	71%	31
5 - HIGH DEGREE OF USER COMFORT	47	29%	114	71%	161
Grand Total	403	**33%**	807	**67%**	1,210

TOTAL TRAIL MILES IN STREAM NETWORK BUFFER

Allowed Trail Use	MILES IN 100 FT BUFFI	% Of Total Miles in Buffer	MILES IN 300 FT BUFFI	% Of Total Miles in Buffer	TOTAL MILES IN BUFFER
Foot/Horse	85	37%	145	63%	231
Mtn. Bike	154	44%	198	56%	352
Motorcycle	42	43%	55	57%	97
ATV	40	43%	54	57%	94
Jeep	3	28%	8	72%	11
Grand Total	324	**41%**	461	**59%**	785

TOTAL STREAM CROSSINGS COUNTS

TOTAL ROAD CROSSINGS	**4,920**
TOTAL MOTOR TRAIL CROSSINGS	**886**
TOTAL TRAIL CROSSINGS	3,384
TOTAL ROAD & TRAIL CROSSINGS	8,304
TOTAL ROAD & MOTOR TRAIL CROSSINGS	5,806

Number of HUC-6 by Classes of Miles of Road within 100 ft of Stream Network

Range of Miles of Road in 100 ft. Buffer	Count of HUC-6
8.099048 - 20.148565	4
5.323101 - 8.099047	20
3.167495 - 5.323100	24
1.246298 - 3.167494	42
0.005236 - 1.246297	35

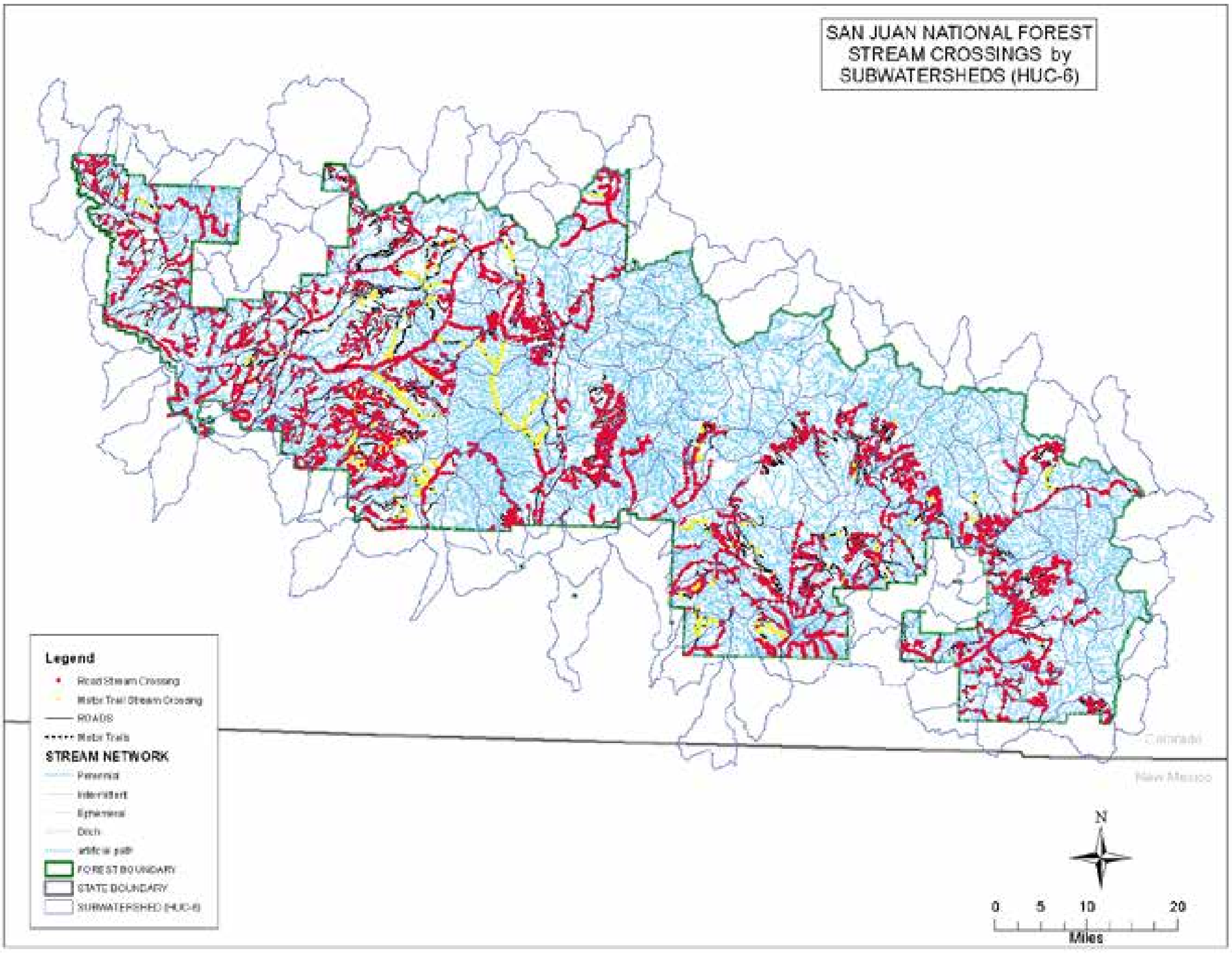
Number of HUC-6 by Classes of Stream Crossing Counts

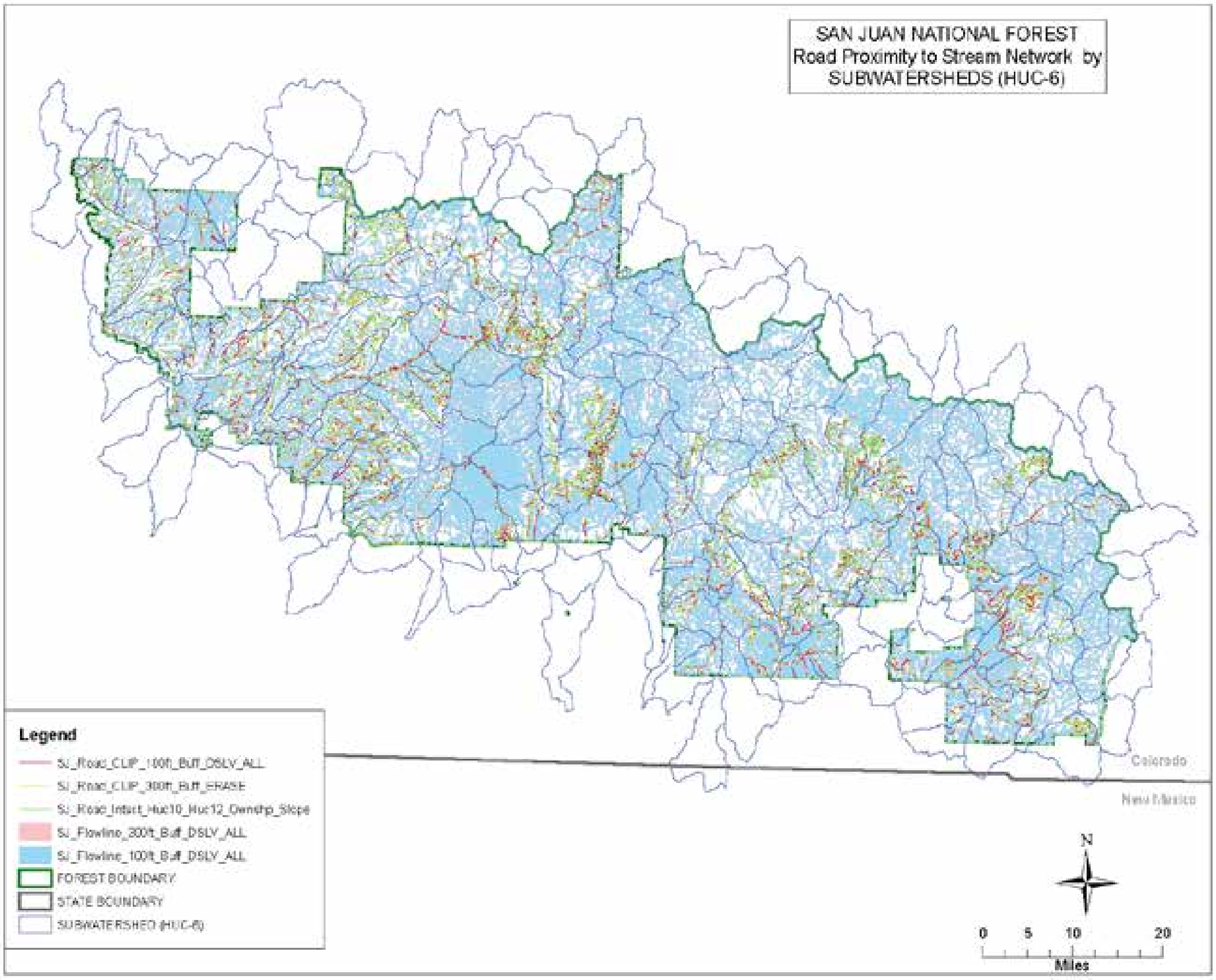
Range of Road and Motor Trail Crossing Counts	Count of HUC-6
119 - 231	4
73 - 118	20
41 - 72	39
17 - 40	30
1.0 - 16	33

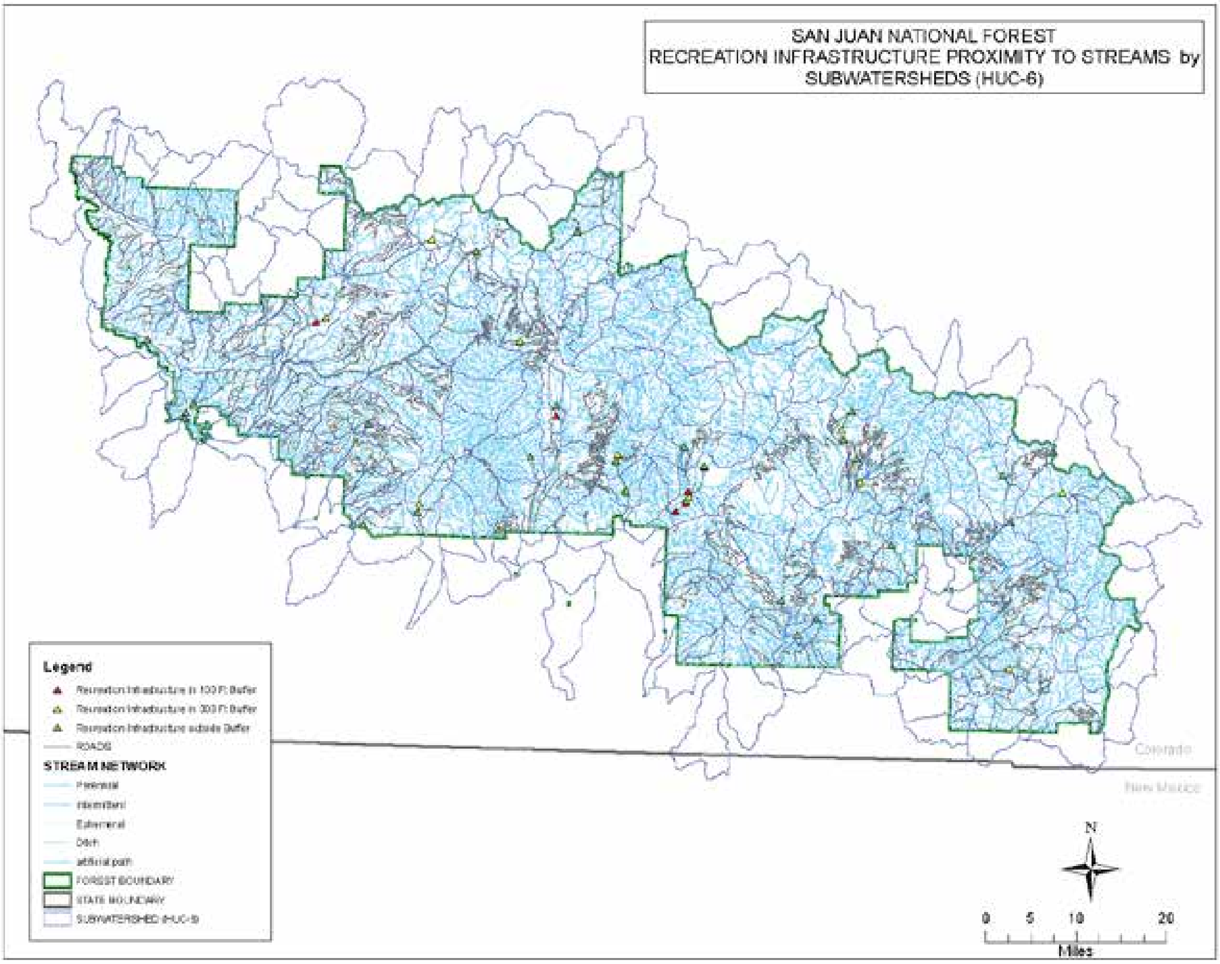
Range of Road Crossing Counts	Count of HUC-6
112 - 212	4
69 - 111	14
38 - 68	38
18 - 37	32
1.0 - 17	32

Recreation activities where infrastructure could be exposed to flooding events.

Recreation Infrastructure	Within 100 ft. Buffer	Within 300 ft. Buffer	Not in Buffer	Grand Total
Boating - Motorized			3	3
Cabin Rentals		1	1	2
Campground Camping	3	11	20	34
Dispersed Camping			1	1
Group Camping	1			1
Group Picnicking	1	1		2
Interpretive Areas		1	2	3
Picnicking		1		1
Grand Total	5	15	**27**	**47**


SAN JUAN NATIONAL FOREST
STREAM CROSSINGS by
SUBWATERSHEDS (HUC-6)
Legend
Road Stream Crossing
Motor Trail Stream Crossing
ROADS
Motor Trails
STREAM NETWORK
Perennial
Intermittent
Ephemeral
Ditch
artificial path
FOREST BOUNDARY
STATE BOUNDARY
SUBWATERSHED (HUC-6)
Colorado
New Mexico
N
0 5 10 20
Miles


SAN JUAN NATIONAL FOREST
Road Proximity to Stream Network by
SUBWATERSHEDS (HUC-6)
Legend
SJ_Road_CLIP_100ft_Buff_DSLV_ALL
SJ_Road_CLIP_300ft_Buff_ERASE
SJ_Road_Intact_Huc10_Huc12_Ownshp_Slope
SJ_Flowline_300ft_Buff_DSLV_ALL
SJ_Flowline_100ft_Buff_DSLV_ALL
FOREST BOUNDARY
STATE BOUNDARY
SUBWATERSHED (HUC-6)
Colorado
New Mexico
N
0 5 10 20
Miles


SAN JUAN NATIONAL FOREST
RECREATION INFRASTRUCTURE PROXIMITY TO STREAMS by
SUBWATERSHEDS (HUC-6)
Legend
ROADS
STREAM NETWORK
FOREST BOUNDARY
STATE BOUNDARY
Colorado
New Mexico
N
0 5 10 20
Miles

Shoshone National Forest

SUMMARIZED INFORMATION FOR THE

SHOSHONE NATIONAL FOREST

TOTAL ROAD MILES

Operational Maintenance Level	Sum of LengthMI
1 - BASIC CUSTODIAL CARE (CLOSED)	173
2 - HIGH CLEARANCE VEHICLES	720
3 - SUITABLE FOR PASSENGER CARS	172
4 - MODERATE DEGREE OF USER COMFORT	16
5 - HIGH DEGREE OF USER COMFORT	136
Unknown	419
Grand Total	**1,635**

TOTAL TRAIL MILES

Allowed Trail Use	Total Miles
Foot_Horse	507
Mtn_Bike	489
Motorcycle	2
Grand Total	**998**

	Total Miles
Non-Motorized	995.7
Motor Trails	2.0
	997.7

TOTAL ROAD MILES IN STREAM NETWORK BUFFER

Operational Maintenance Level	Miles in 100 ft Buffer	% Of Total Miles in Buffer	Miles In 300 ft Buffer	% Of Total Miles in Buffer	Total Miles in total Buffer
1 - BASIC CUSTODIAL CARE (CLOSED)	26	36%	47	64%	74
2 - HIGH CLEARANCE VEHICLES	109	34%	210	66%	319
3 - SUITABLE FOR PASSENGER CARS	21	27%	56	73%	76
4 - MODERATE DEGREE OF USER COMFORT	2	23%	7	77%	9
5 - HIGH DEGREE OF USER COMFORT	12	26%	34	74%	46
Unknown	69	37%	115	63%	185
Grand Total	239	**34%**	469	**66%**	707

TOTAL TRAIL MILES IN STREAM NETWORK BUFFER

Allowed Trail Use	MILES IN 100 FT BUFFI	% Of Total Miles in Buffer	MILES IN 300 FT BUFFI	% Of Total Miles in Buffer	TOTAL MILES IN BUFFER
Foot_Horse	113	34%	221	66%	334
Mtn_Bike	101	39%	158	61%	260
Motorcycle	0	35%	1	65%	1
Grand Total	215	**36%**	380	**64%**	595

TOTAL STREAM CROSSINGS COUNTS

TOTAL ROAD CROSSINGS	2578
TOTAL MOTOR TRAIL CROSSINGS	2
TOTAL TRAIL CROSSINGS	2365
TOTAL ROAD & TRAIL CROSSINGS	4943
TOTAL ROAD & MOTOR TRAIL CROSSINGS	2580

Number of HUC-6 by Classes of Miles of Road within 100 ft of Stream Network

Range of Miles of Road in 100 ft. Buffer	Count of HUC-6
5.800392 - 10.477453	9
3.817845 - 5.800391	11
2.157947 - 3.817844	21
0.876514 - 2.157946	25
0.001125 - 0.876513	41

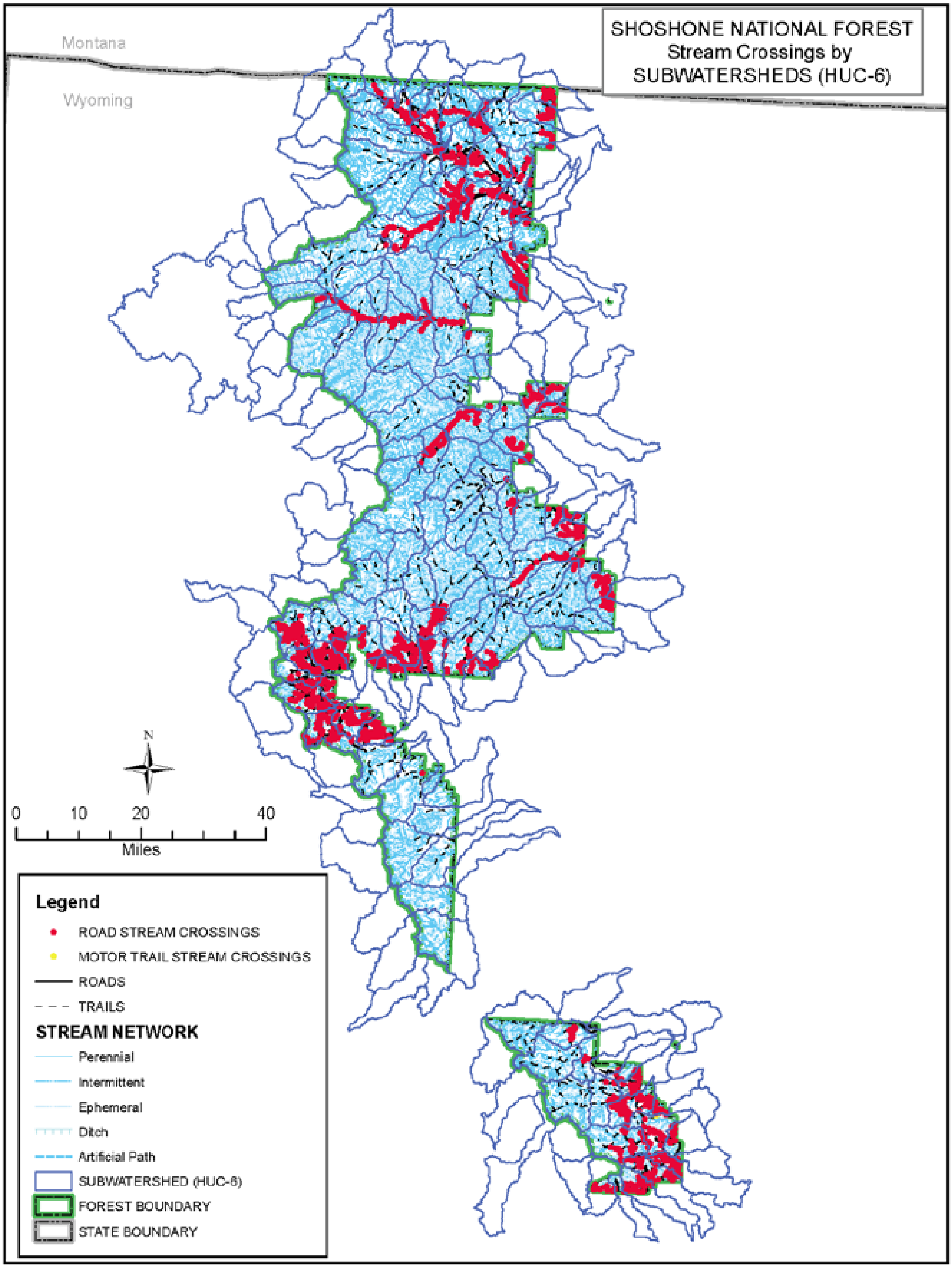
Number of HUC-6 by Classes of Stream Crossing Counts

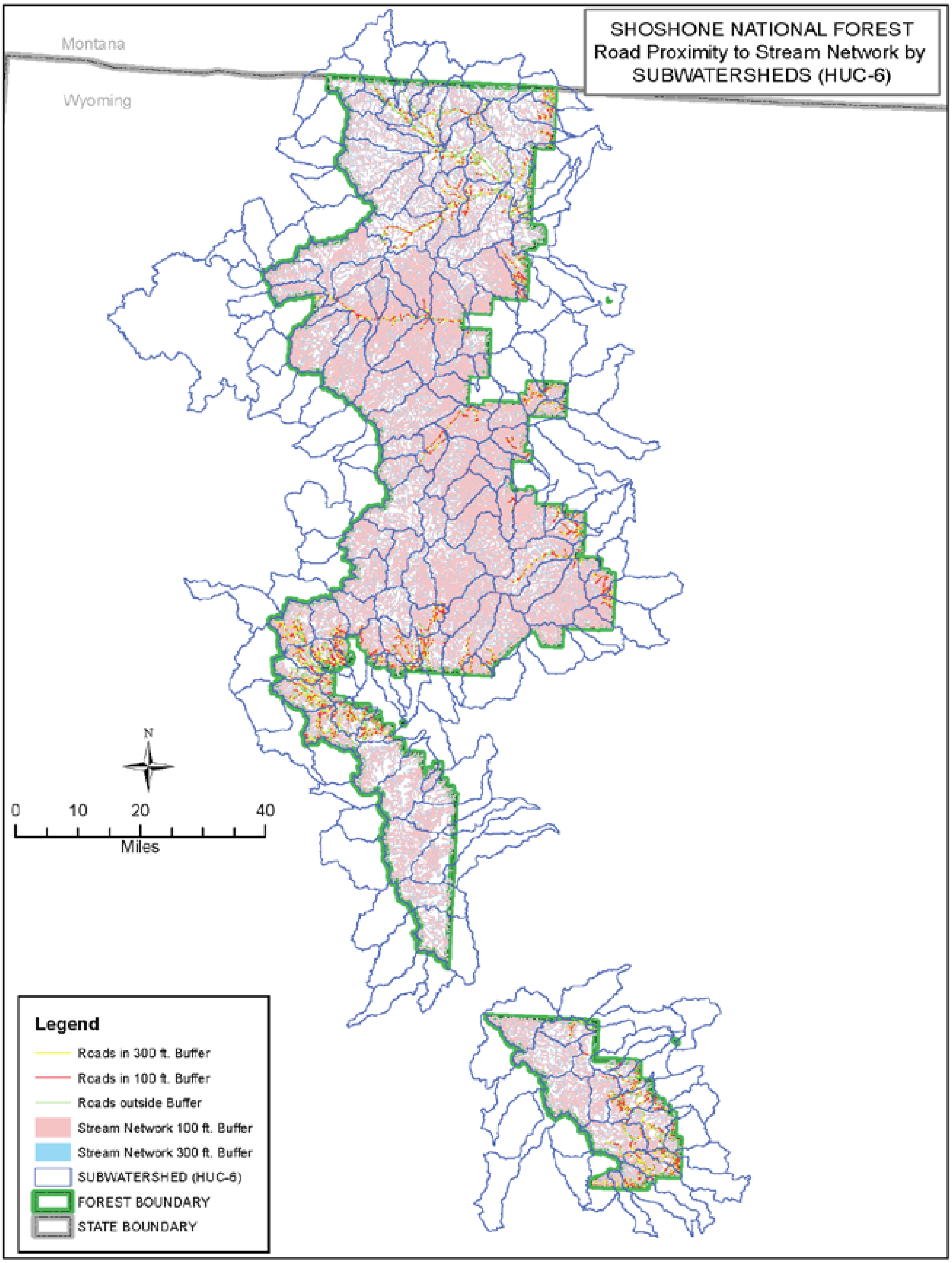
Range of Road and Motor Trail Crossing Counts	Count of HUC-6
61-95	11
31-60	23
21-30	13
11.0 - 20	20
0-10	37

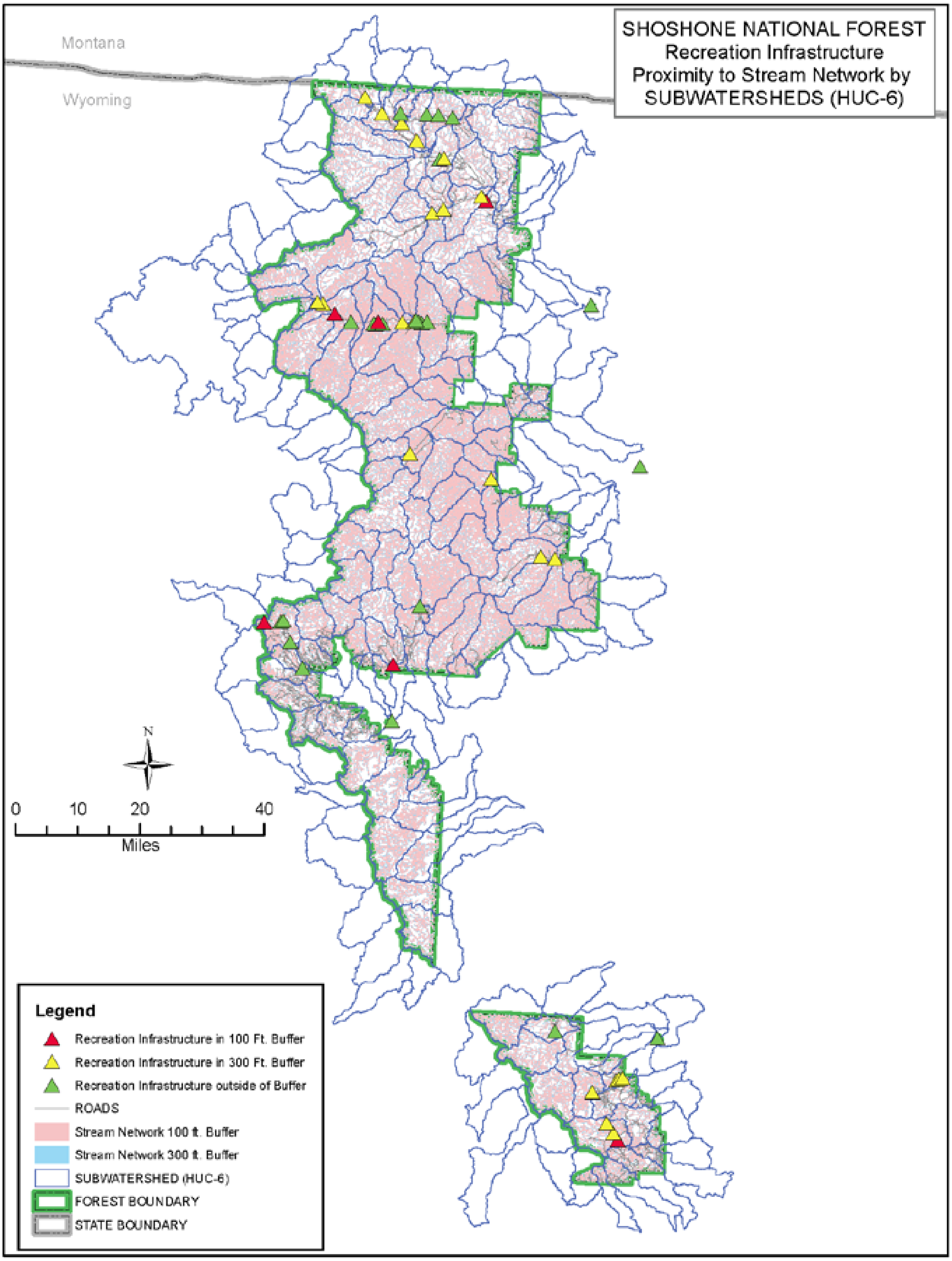
Range of Road Crossing Counts	Count of HUC-6
56.000001 - 95.000000	12
33.000001 - 56.000000	18
22.000001 - 33.000000	12
10.000001 - 22.000000	25
1.000000 - 10.000000	29

Recreation activities where infrastructure could be exposed to flooding events.

Recreation Infrastructure	Within 100 ft. Buffer	Within 300 ft. Buffer	Outside of Buffer	Grand Total
Cabin Rentals		1		1
Campground Camping	4	15	11	30
Dispersed Camping		2	1	3
Group Camping		1		1
Horse Camping			1	1
Interpretive Areas			1	1
Picnicking	3	5	3	11
Viewing Scenery			1	1
Visitor Centers			1	1
Grand Total	7	24	**19**	**50**


SHOSHONE NATIONAL FOREST
Stream Crossings by
SUBWATERSHEDS (HUC-6)
Montana
Wyoming
N
0
10
20
40
Miles
Legend
ROAD STREAM CROSSINGS
MOTOR TRAIL STREAM CROSSINGS
ROADS
TRAILS
STREAM NETWORK
Perennial
Intermittent
Ephemeral
Ditch
Artificial Path
SUBWATERSHED (HUC-6)
FOREST BOUNDARY
STATE BOUNDARY


SHOSHONE NATIONAL FOREST
Road Proximity to Stream Network by
SUBWATERSHEDS (HUC-6)
Montana
Wyoming
N
0
10
20
40
Miles
Legend
Roads in 300 ft. Buffer
Roads in 100 ft. Buffer
Roads outside Buffer
Stream Network 100 ft. Buffer
Stream Network 300 ft. Buffer
SUBWATERSHED (HUC-6)
FOREST BOUNDARY
STATE BOUNDARY


SHOSHONE NATIONAL FOREST
Recreation Infrastructure
Proximity to Stream Network by
SUBWATERSHEDS (HUC-6)
Montana
Wyoming
N
0
10
20
40
Miles
Legend
Recreation Infrastructure in 100 Ft. Buffer
Recreation Infrastructure in 300 Ft. Buffer
Recreation Infrastructure outside of Buffer
ROADS
Stream Network 100 ft. Buffer
Stream Network 300 ft. Buffer
SUBWATERSHED (HUC-6)
FOREST BOUNDARY
STATE BOUNDARY

White River National Forest

SUMMARIZED INFORMATION FOR THE
WHITE RIVER NATIONAL FOREST

TOTAL ROAD MILES

OPERATIONAL MAINTENANCE LEVEL	TOTAL MILES
1 - BASIC CUSTODIAL CARE (CLOSED)	39
2 - HIGH CLEARANCE VEHICLES	1,228
3 - SUITABLE FOR PASSENGER CARS	467
4 - MODERATE DEGREE OF USER COMFORT	107
5 - HIGH DEGREE OF USER COMFORT	608
Grand Total	**2,449**

TOTAL TRAIL MILES

Allowed Trail Use	Total Miles
Foot/Horse	611
Mountain Bike	729
Motorcycle	35
ATV	28
Jeep	106
Grand Total	**1,508**

	Total Miles
Non-Motorized	1,339.2
Motor Trails	168.4
	1,507.6

TOTAL ROAD MILES IN STREAM NETWORK BUFFER

Operational Maintenance Level	Miles in 100 ft Buffer	% Of Total Miles in Buffer	Miles In 300 ft Buffer	% Of Total Miles in Buffer	Total Miles in total Buffer
1 - BASIC CUSTODIAL CARE (CLOSED)	5	30%	11	70%	16
2 - HIGH CLEARANCE VEHICLES	202	38%	325	62%	527
3 - SUITABLE FOR PASSENGER CARS	75	34%	149	66%	224
4 - MODERATE DEGREE OF USER COMFORT	18	36%	32	64%	49
5 - HIGH DEGREE OF USER COMFORT	104	30%	242	70%	346
Grand Total	404	**35%**	759	**65%**	1,163

TOTAL TRAIL MILES IN STREAM NETWORK BUFFER

Allowed Trail Use	MILES IN 100 FT BUFFI	% Of Total Miles in Buffer	MILES IN 300 FT BUFFER*	% Of Total Miles in Buffer	TOTAL MILES IN BUFFER
Foot/Horse	117	36%	210	64%	327.7
Mountain Bike	169	44%	214	56%	383.6
Motorcycle	8	45%	10	55%	17.2
ATV	7	44%	9	56%	16.2
Jeep	20	42%	27	58%	47.5
Grand Total	322	**41%**	471	**59%**	792.2

TOTAL STREAM CROSSINGS COUNTS

TOTAL ROAD CROSSINGS	4,325
TOTAL MOTOR TRAIL CROSSINGS	342
TOTAL TRAIL CROSSINGS	3,069
TOTAL ROAD & TRAIL CROSSINGS	7,394
TOTAL ROAD & MOTOR TRAIL CROSSINGS	4,667

Number of HUC-6 by Classes of Miles of Road within 100 ft of Stream Network

Range of Miles of Road in 100 ft. Buffer	Count of HUC-6
7.827983 - 14.999825	6
4.660650 - 7.827982	25
2.587592 - 4.660649	28
1.029903 - 2.587591	38
0.000263 - 1.029902	45

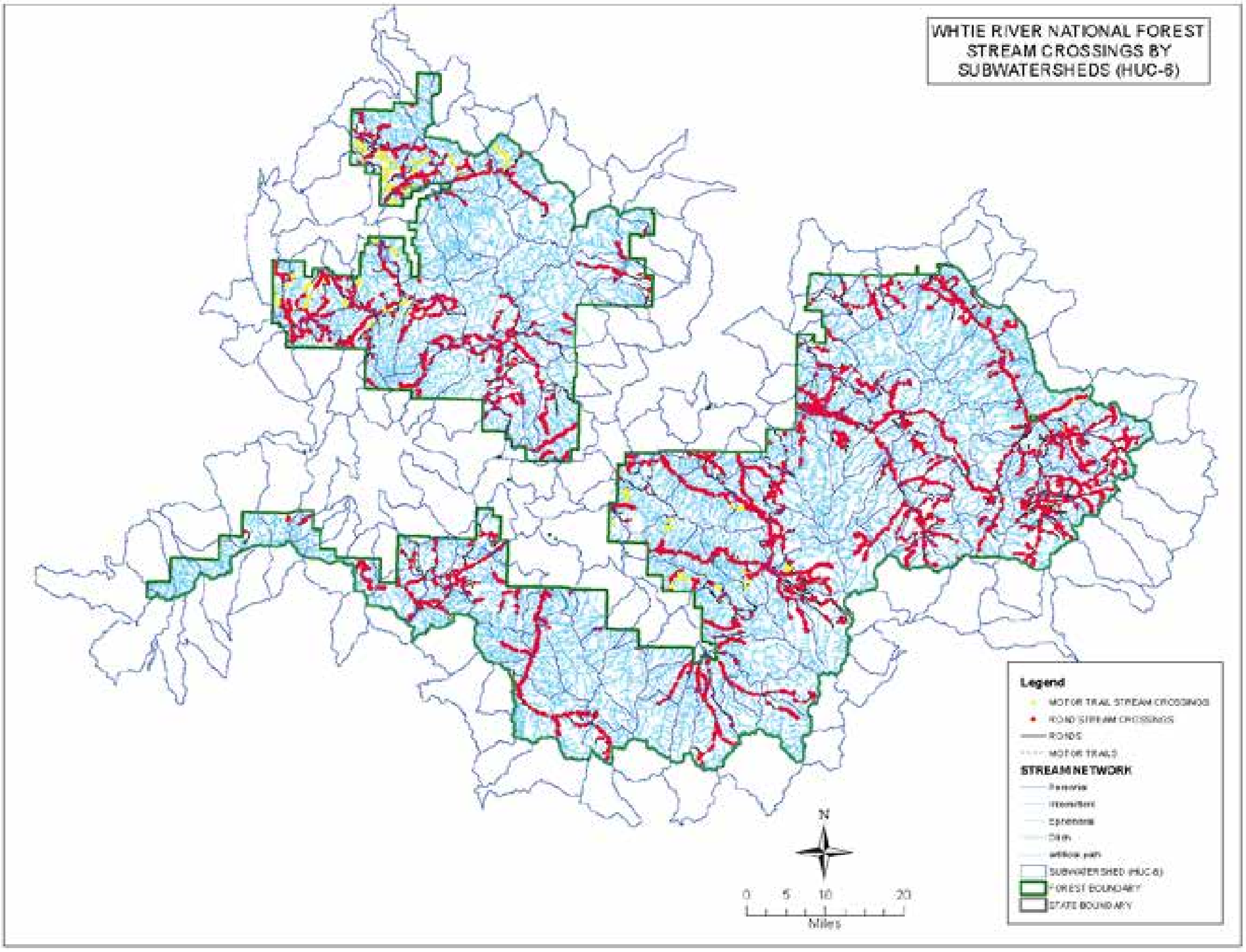
Number of HUC-6 by Classes of Stream Crossing Counts

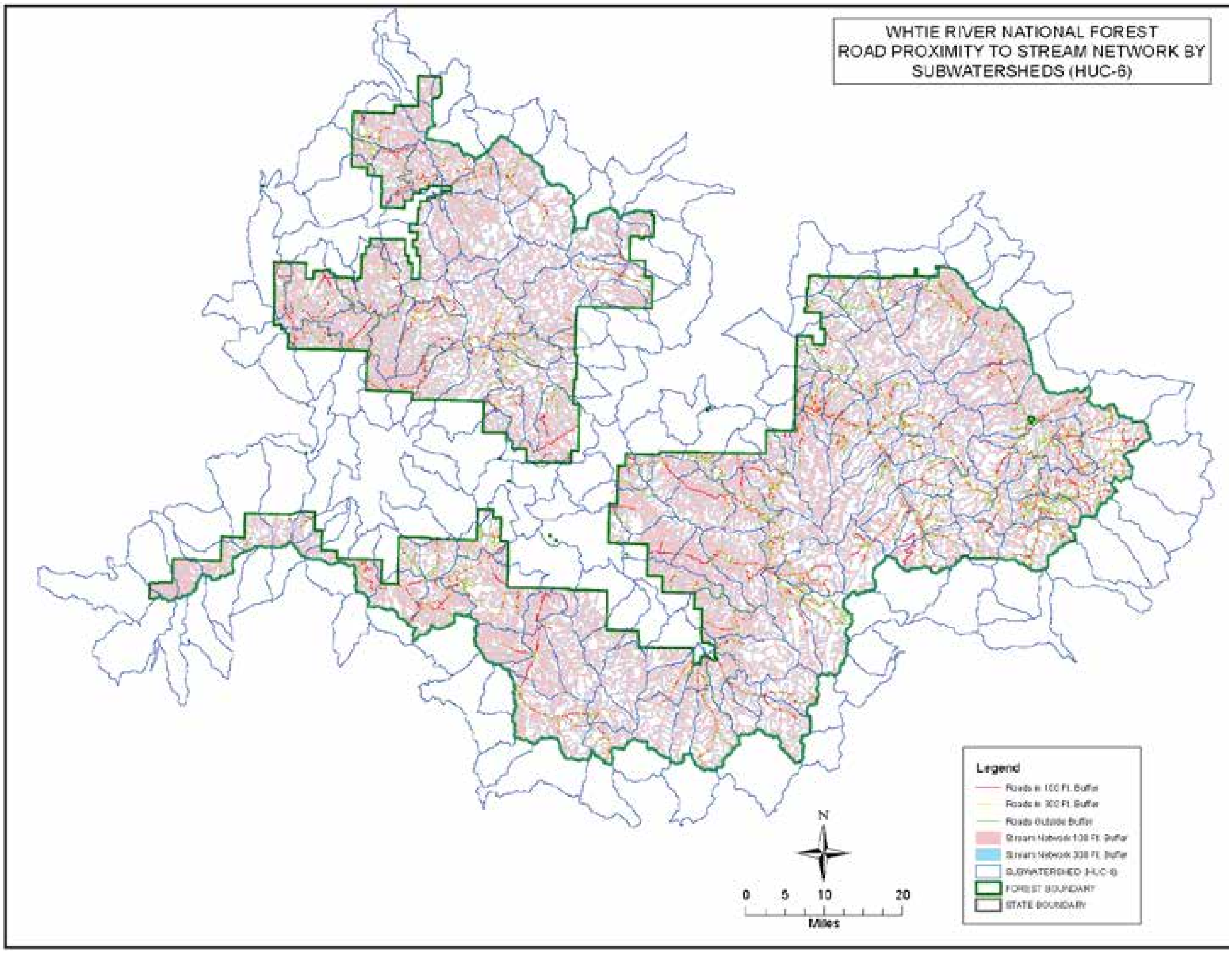
Range of Road and Motor Trail Crossing Counts	Count of HUC-6
108.000001 - 177.000000	4
61.000001 - 108.000000	17
34.000001 - 61.000000	30
13.000001 - 34.000000	43
0.000000 - 13.000000	47

Range of Road Crossing Counts	Count of HUC-6
107 - 165	3
60 - 106	15
34 - 59	30
14 - 33	43
0 - 13	44

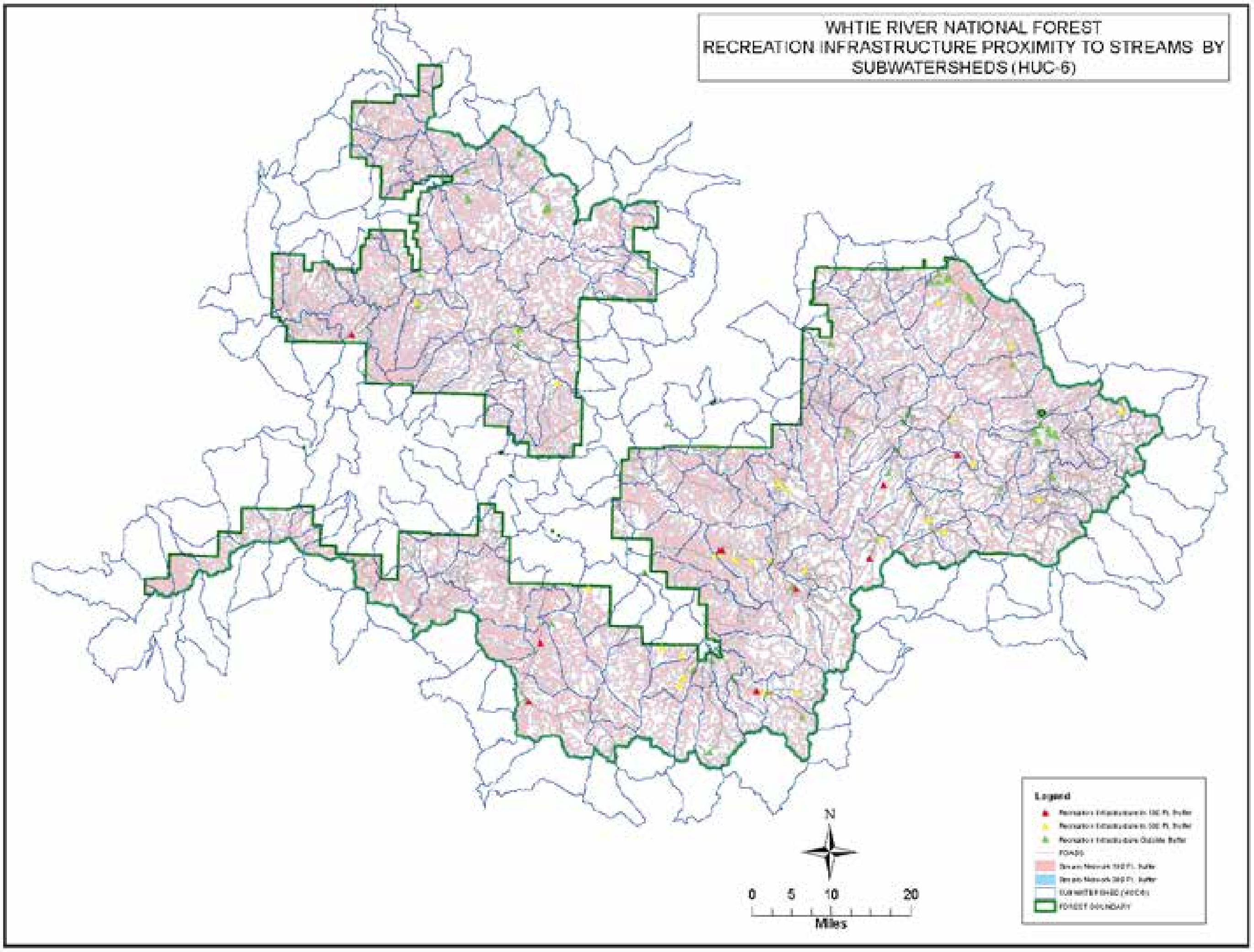
Recreation activities where infrastructure could be exposed to flooding events.

Recreation Infrastructure	In 100 ft Buffer	In 300 ft Buffer	Outside Buffer	Grand Total
Boating - Motorized		1	2	3
Cabin Rentals			2	2
Campground Camping	6	18	31	55
Day Use Area	2	1	5	8
Dispersed Camping		2	1	3
Group Camping	1	1	2	4
Group Picnicking		1		1
Interpretive Areas		1	1	2
Picnicking	1	7	2	10
Skiing/Snowboarding		4	7	11
Target Shooting			1	1
Visitor Centers			2	2
Grand Total	10	36	**56**	**102**


WHTIE RIVER NATIONAL FOREST
STREAM CROSSINGS BY
SUBWATERSHEDS (HUC-6)
Legend
MOTOR TRAIL STREAM CROSSINGS
ROAD STREAM CROSSINGS
ROADS
MOTOR TRAILS
STREAM NETWORK
SUBWATERSHED (HUC-6)
FOREST BOUNDARY
STATE BOUNDARY
N
0 5 10 20
Miles



WHTIE RIVER NATIONAL FOREST
ROAD PROXIMITY TO STREAM NETWORK BY
SUBWATERSHEDS (HUC-6)
Legend
Roads in 100 Ft. Buffer
Roads in 300 Ft. Buffer
Roads Outside Buffer
Stream Network 100 Ft. Buffer
Stream Network 300 Ft. Buffer
FOREST BOUNDARY
STATE BOUNDARY
N
0
5
10
20
Miles


WHTIE RIVER NATIONAL FOREST
RECREATION INFRASTRUCTURE PROXIMITY TO STREAMS BY
SUBWATERSHEDS (HUC-6)
Legend
N
0 5 10 20
Miles

Recommendations for Adaptation and Increasing the Resilience of Infrastructure

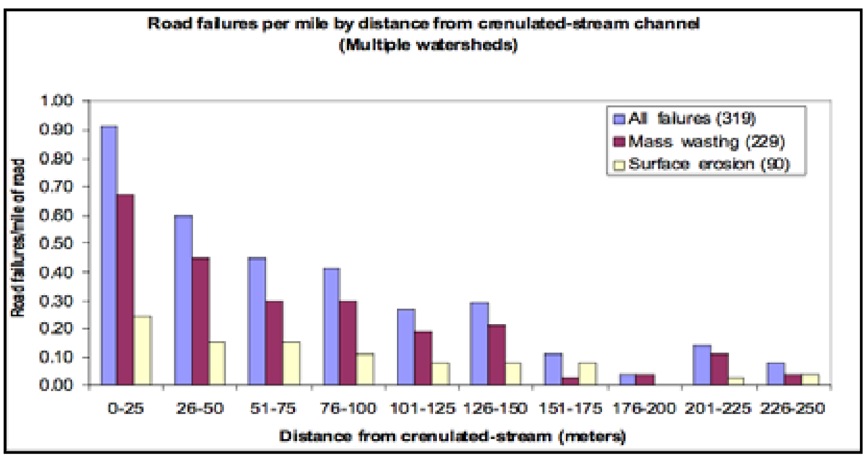
Scaling the analyses

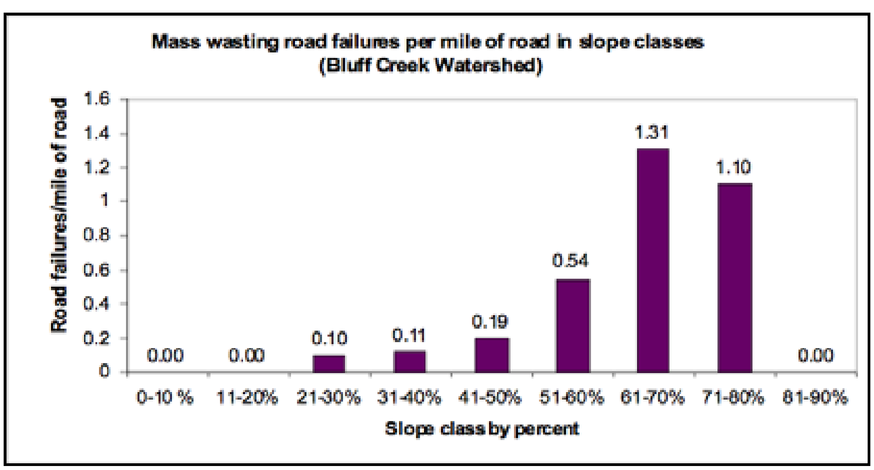
This broad-scale regional analysis may be used to discern and display broad patterns of the presence of vulnerable infrastructure, and indicate those watersheds that may be especially vulnerable.

For most cases, Forest-Scale assessment is needed before priorities can be set that recognize actual conditions on the ground and any special conditions present that inform or control priorities.

Create and maintain a database and spatial coverage of infrastructure failure and risks in GIS at Forest and Regional scales, to accomplish effective, efficient performance monitoring.

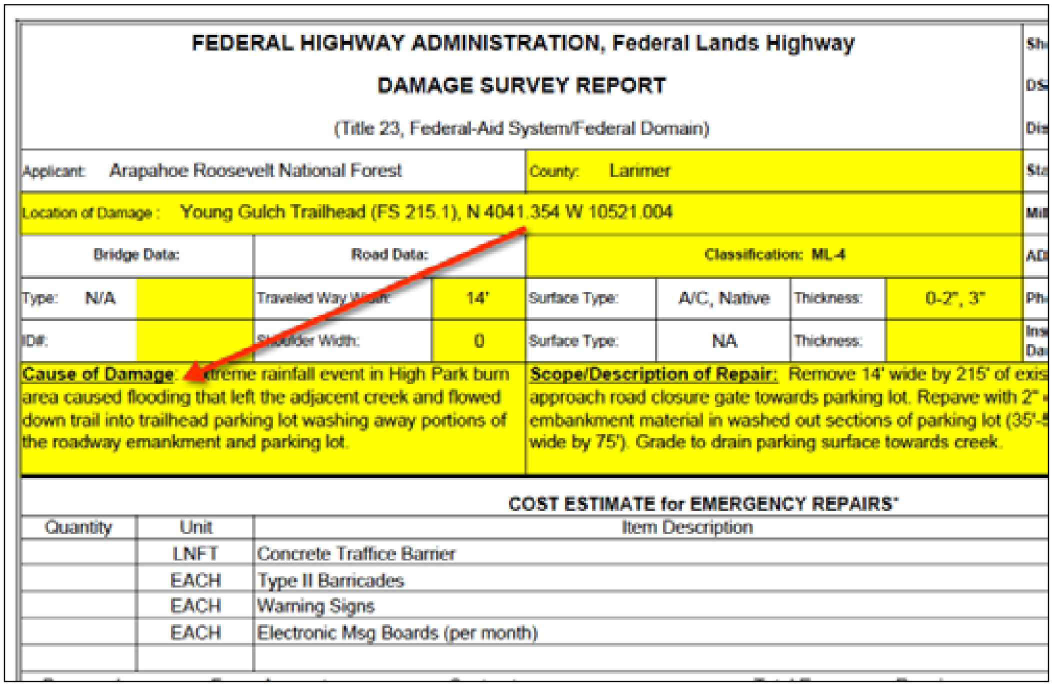
After storms, road systems are usually examined to determine the levels of damage and the needs for repair. For the large damage sites, a Federal Highways "Damage Survey Report is done that includes a field visit and estimates of repair costs. Many Forests conduct detailed storm damage assessments. Together, these data sets constitute highly valuable road performance monitoring and reveal what the places and road features that repeatedly fail. This is extraordinarily valuable information – most roads do not fail, but some do chronically, and some types of landscapes are highly prone to failure. It is worth knowing where these are. The kind of relationships that can be readily discerned from storm damage surveys, with the help of GIS include, for example:





A dataset of road failures can be analyzed to show important relationships, such as how the proximity to streams or terrain slope affects failure rates. Data from R5 and R6.

However, it is essential that the type and basic description of the failures be accurately recorded so that categorical analysis is possible. This is currently difficult with the FHWA DSRs, because the field for “Cause of Damage” is not categorical and is subject to great variability in how it is filled out. Some field examiners produce good descriptions (as shown below) but others produce useless descriptions, and there is no consistency. To solve this, a simple supplemental data sheet (DSR+) was developed and tested in R6 so that categorical failure types and causes could be derived. Use of this supplemental data sheet is recommended. The DSR+ form is provided in Appendix 2.



FEDERAL HIGHWAY ADMINISTRATION, Federal Lands Highway

DAMAGE SURVEY REPORT

(Title 23, Federal-Aid System/Federal Domain)

Applicant: Arapahoe Roosevelt National Forest				County: Larimer			
Location of Damage: Young Gulch Trailhead (FS 215.1), N 4041.354 W 10521.004							
Bridge Data:		Road Data:		Classification: ML-4			
Type: N/A		Traveled Way Width:	14'	Surface Type:	A/C, Native	Thickness:	0-2", 3"
ID#:		Shoulder Width:	0	Surface Type:	NA	Thickness:	
Cause of Damage: Extreme rainfall event in High Park burn area caused flooding that left the adjacent creek and flowed down trail into trailhead parking lot washing away portions of the roadway emankment and parking lot.				Scope/Description of Repair: Remove 14' wide by 215' of exis approach road closure gate towards parking lot. Repave with 2" embankment material in washed out sections of parking lot (35'-5 wide by 75'). Grade to drain parking surface towards creek.			

COST ESTIMATE for EMERGENCY REPAIRS*

Quantity	Unit	Item Description
	LNFT	Concrete Traffice Barrier
	EACH	Type II Barricades
	EACH	Warning Signs
	EACH	Electronic Msg Boards (per month)

Note that the “Cause of Damage” field is to be completed in prose, not categorically, and so in practice the data are highly inconsistent, reducing the monitor-ing value of the DSR surveys. This is easily remedied with a simple DSR+ form, provided in Appendix 1.

The Forest Service publication **“National Best Management Practices for Water Quality Management on National Forest System Lands, Volume 1” (USDA, Forest Service, 2012)** provides a general set of best practices for most aspects of forest management, including roads. This National Core BMP guidance should be used in new planning efforts, NEPA analysis, and evaluation of proposed activities, particularly if those projects affect water resources. The National Program will contain the National Core BMPs, standardized monitoring protocols, national directives, and the data management structure. The Core National Best Management Practices Guide is available at: http://www.fs.fed.us/biology/resources/pubs/watershed/FS_National_Core_BMPs_Apri l2012.pdf

The new national core Best Management Practices require that Road Storm-Damage Surveys be conducted. This BMP should now be implemented routinely. It is given below:

Road-11. Road Storm-Damage Surveys

FSM 7730 and FSM 2350.

Monitor road conditions following storm events to detect road failures; assess damage or potential damage to waterbodies, riparian resources, and watershed functions; determine the causes of the failures; and identify potential remedial actions at the damaged sites and preventative actions at similar sites.

Large storms stress road systems in multiple ways: large volumes of water are transported on road surfaces and through its drainage systems; significant volumes of water and debris are transported through stream crossings; and elevated pore pressures on unstable hillslopes, road cutslopes, and fillslopes sometimes generate mass failures. All road drainage systems, stream crossings with culverts, and unstable slopes have the potential to fail during periods of high runoff. The probabilities of failure differ greatly, and the potential consequences to water quality and designated uses vary dramatically from no impacts to severe and long-term impacts to aquatic systems.

Surveying roads during or soon after storms is critical to timely detection of these problems. Observation of problems caused by storm runoff is of great value in understanding both the causes of failure and in adapting designs and prescriptions that reduce both the probability and consequences of future road failures. Over time, this kind of monitoring illustrates how and where roads can fail and points readily to practice modifications that can reduce adverse effects to water quality and watershed function.

The Emergency Relief for Federally Owned Roads (ERFO) Program is intended to help assess and fund the unusually heavy expenses associated with repairing and reconstructing Federal roads and bridges seriously damaged by a natural disaster over a wide area or catastrophic failure. To qualify for this type of funding, applications for repair must be submitted to the Federal Highways Administration through the ERFO program (FSM 7700).

ERFO-Related Damage Surveys

- Complete a Damage Survey Report (DSR) at damaged sites potentially eligible for ERFO funds.

Complete the Forest Service-developed supplemental form DSR+ in the field to more thoroughly describe, in categorical terms, the cause(s) and consequences of the damage.

- The DSR+ form and instructions may be found at http://www.stream.fs.fed.us/bmp/damagesurveys

Record the following information from damage sites that have been documented on the DSR and

- DSR+ forms in appropriate corporate database(s), including geographic information systems:
- The geographic locations (points or road segments) where damage occurred.
- The date of occurrence (year and month, if available).
- The type of failure and its cause.

Special Storm Damage Surveys

Determine the need to do more comprehensive surveys and analysis of road damage after particularly large storm events.

- Survey all roads in the area, typically an entire watershed, ranger district, or national forest or grassland, affected by the storm or those roads that may be particularly susceptible to failure.

All Damage Surveys

- Analyze results from EFRO surveys, routine damage reconnaissance, and special surveys for patterns of damage and causes.
- Use these patterns of road damage to formulate recommendations of practice changes to reduce the incidence of future damage. Consider practice changes such as—
  - Locating or relocating roads to more stable terrain (see BMP Road-2 [Road Location and Design]);
  - Disconnecting road surface drainage from crossings and channels (see BMP Road-3 [Road Construction and Reconstruction]);
  - Using special protections in locations on unstable landforms or areas with high erosion potential (see BMP Road-3 [Road Construction and Reconstruction]);
  - Increasing the capacity of stream-crossing structures to pass water, debris, and sediment to reduce the probabilities of failure (see BMP Road-7 [Stream Crossings]);
  - Building or rebuilding stream crossings to eliminate or reduce diversion potential (see BMP Road-7 [Stream Crossings]);
  - Building or rebuilding stream crossings to improve aquatic species passage (see BMP Road-7 [Stream Crossings]); or
  - Decommissioning or storing roads in a hydrologically benign condition (see BMP Road-6 [Road Storage and Decommissioning]).
- Enter and store the results of data analysis in corporate data management systems to facilitate sharing among units that have similar terrain and road practices.

Key Guidance Document for storm-proofing roads

Reducing the risk of flood damage to roads and trails often has been termed “storm-proofing”. Watersheds and road systems are ideally prioritized for this work, so that investments are most beneficial. A wide variety of treatments are available to accomplish this. A comprehensive guide has recently been prepared by the Forest Service, and is expected to be published soon.

Keller, G. and G. Ketcheson. In prep. Storm Damage Risk Reduction Guide for Low-Volume Roads. 1277 1814. San Dimas, CA: U.S. Department of Agriculture, Forest Service, San Dimas Technology and Development Center. 215 p.

This may be found in the Project Folder

Making road systems more resilient

Existing policy and direction provide methods and practices that will promote resilience to changes in climate and increased climatic stresses

Watershed Conservation Practices Handbook for the Rocky Mountain Region -The FSH 2509.25, (2006), provides a wealth of policy, practices, and advice for protecting water quality and conserving fundamental resources. These are the same policies and practices that will make infrastructure more resilient, less vulnerable. Rigorous, conscientious application of the Handbook direction is the primary recommended approach to climate adaptation for infrastructure. The direction in the handbook is also reflected in the National Core Best Management Practices (2013). A detailed national system for monitoring the implementation and effectiveness of the core BMPs is in the final stages of publication. This monitoring highly refined and thoroughly tested, and can readily discover shortcomings and highlight adaptations to continuously improve our practices, their implementation and effectiveness in conserving fundamental resources. Some practices and measures are highlighted below, but implementing existing direction that is in place is the overall ideal approach for adapting to climate change.
We recommend that the Region 2 Handbook be revised to be fully consistent with the new National Core BMPs.

The Handbook can be found in the Project Folder.

Highlighted Practices to Maintain and Improve Resilience

Based on: R-2 Watershed Conservation Practices Handbook , Keller and Ketcheson, 2012. Furniss 2011, SDTDC Water-Road Interaction Series, and National Core BMPs

This section is organized into three categories: Thinking, Collaborating, and Acting.

THINK: INFORMATION AND KNOWLEDGE

Use HUC-6 as the unit of watershed/landscape analysis whenever appropriate.

This is the scale and unit used in watershed condition assessment, and is being used in many other assessments, monitoring systems, databases, and tracking systems. It is highly beneficial for integration and efficient, effective management to coordinate on specific units of landscape and specific scales. While multiple-scale assessment is often needed, an emphasis on HUC-6 (subwatersheds) has been shown to be important, as it is a good balance between context and detail; and is highly relevant to management, as it is the scale at which many decisions are made and most project planning happens.

Continue to develop Regional- and Forest-scale databases to keep track of infrastructure and its performance over time.

Great strides have been made in the inventory and spatial database storage and retrieval of information about infrastructure. This analysis was possible because of this progress and the readiness and accessibility of relevant spatial datasets. Further development and refinement of these databases are of great value in land and water stewardship, and are a sound investment.

Monitor road performance using the new national BMP Implementation and Effectiveness Monitoring System

It is important to monitor the performance of BMPs to know if they are working to protect water quality. Monitoring systems that can detect failure and shortcomings are necessary for adaptive management. Indeed, success cannot be verifed unless a system that can reliably detect failure is in place.
A road or campground that protects water quality will also be resilient to climate change. The draft National Core BMP Monitoring Technical Guide is currently in review and publication is expected in CY 2015.

Integrate assessments to achieve effective, well thought-out solutions and stewardship

Managing landscapes and watersheds is always a multi-disciplinary challenge. It is of paramount importance that all knowledge about NFS lands be integrated and considered together. This is not easy, but is crucial to effective and efficient stewardship of public lands and waters. There are many “leftside" assessments and monitoring systems in the Forest Service, focused on specific resources and challenges. While the timing is not ideal, integrating the information in this report with Forest-level TAP results will increase the utility of each.

Prioritize road systems for storm-proofing treatments

To get the greatest return for limited funds set priorities for investments and treatments to increase resilience. This requires field inventories to determine problems and risks. The following features are typically inventoried:

Stream crossings

- Culvert capacity
- Plugging potential
- Diversion potential
- Site erosion (cmp outlet, streambanks, fillslopes, and so on)

Road-related landslides

- Potential road and landing fill failures
- Debris slides from steep swales
- Larger deeper landslides

Road surface runoff and related erosion

- Hydrologically connected roads and ditches
- Gullies

Inventories can be conducted at a variety of scales.

- Prioritize by watershed or sub-watershed
- Prioritize by proximity to valuable aquatic ecosystems
- Prioritize by hillslope position (upper, middle, streamside)
- Prioritize by or within road maintenance class
- Prioritize individual roads (e.g., by frequency of sites with high treatment immediacy or by future sediment delivery or by cost-effectiveness)
- Prioritize logical treatment units
- Prioritize by individual sites (for example, urgent sites such as those with both high future delivery volumes and high treatment immediacy)

Strategies for setting priorities differ and should be carefully considered and the inventory and priority setting based on strategies, such as.

- Roads with unmaintained sites (abandoned roads)
- High site frequency (sites/mi)
- High future sediment delivery volume
- Cost-effectiveness of treatments
- Number of high priority sites
- Susceptible stream crossings
- Roads displaying high rates of fine sediment delivery
- Roads in high density sediment delivery zones

Employ systematic, repeatable, quantitative data collection and measurement techniques in the inventory.

We recommend the GRAIP system developed by the Rocky Mountain Research Station to conduct inventory. http://www.fs.fed.us/GRAIP

Identify areas of historic or potential vulnerability.

Most high risk sites are well known, others may require a large storm to become obvious. A “corporate” database of sites that fail can enable identifying trouble spots, unstable geology, and areas where special measures must be taken. Such a dataset ensures that the “memory of these areas is conserved when personnel changes. Chronically undersized culverts will have a history of failure. Geologically unstable materials or slopes, roads on steep slopes with sidecast fills or roads that cross steep channels subject to debris flows, wet slopes, areas subject to flooding, or areas of high soil erosion near streams (inner gorges) all have high vulnerability.

In new construction and relocation, avoid local problematic and high risk areas.

New roads should be located in the most stable locations possible. That is, higher, drier, flatter areas without inherent instability should be favored over lower, wetter, steeper, and less stable locations. For existing roads, consider road closure or relocation to avoid problematic areas and poor road locations.

COLLABORATE

Collaborate among engineering, recreation, and earth science staffs at Regional, sub-regional, Forest, and Ranger District scales to solve problems, determine and apply best practices, and conserve lessons learned.

The best management of infrastructure occurs when there is interdisciplinary considerations of the conditions, challenges and solutions that are best applied. Best practices and solutions are seldom from a single disciplinary domain. All efforts to encourage and facilitate discussion and problem solving between earth science, engineering, and recreation staffs are worthwhile and will contribute to better stewardship. Collaboration between National Forest and Grassland staff, as well as regional staffs will help ensure that lessons are learned and conserved and innovations are shared among units.

Collaborate with road managers in other agencies and ownerships to create contingency plans and agree to employ best practices to employ after disasters occur.

After disasters, such as the Boulder floods of 2013, rapid response to repair critical infrastructure is usually called for. The rapidity of response presents special risks that best practices and environmental protection will be sacrificed for expediency, as has been often observed. This can be avoided by looking forward and anticipating large-scale infrastructure damage, develop communications and relationships, and make contingency plans to ensure that at least a minimum of best practice and environmental stewardship will occur, even when rapid responds is needed to rebuild roads and other infrastructure.

Modify watershed condition protocols for the next iteration of classification

The watershed condition ratings for roads should include all roads and all streams. Using only Maintenance Level (ML) 3-5 roads gives highly incomplete results. In the Rocky Mountain region there are many more miles of road in ML 1 and 2 than the combined length of ML 3-5. Not including ML 1 and 2 roads does not make good sense. The next iterative of WCA should review the results of this and similar analyses and adjust the roads indicators accordingly.

ACT

When repairing, rebuilding, or relocating roads after flood damage, use best available design and construction practices to make the road more resilient and lower environmental impact.

After major road damage, it is unfortunately common that roads are rebuilt to similar standards, with similar or the same vulnerability. This sets up the road system for the same failures, and is far from ideal. Most roads were built decades ago to now-outdated standards and the weak points that are susceptible to failure are best addressed during rebuilding. The best approach is to reckon risks based on the experience, and adjust standards and practices to avoid or minimize risks of future flooding events.

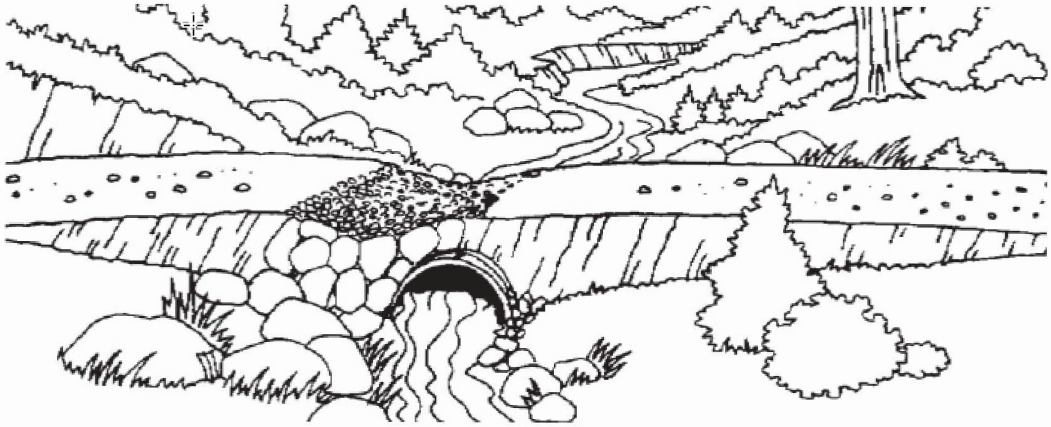
Use appropriate minimum design standards.

Road standards, particularly road width, should be minimized, while considering traffic safety and road user needs. Storm-proofing treatments may be used to lower the standard as appropriate and result in less earthwork, lower cuts and fills, and less concentration of runoff, all of which reduce risk of damage or failure during storms.

Eliminate stream diversion potential at road stream crossings.

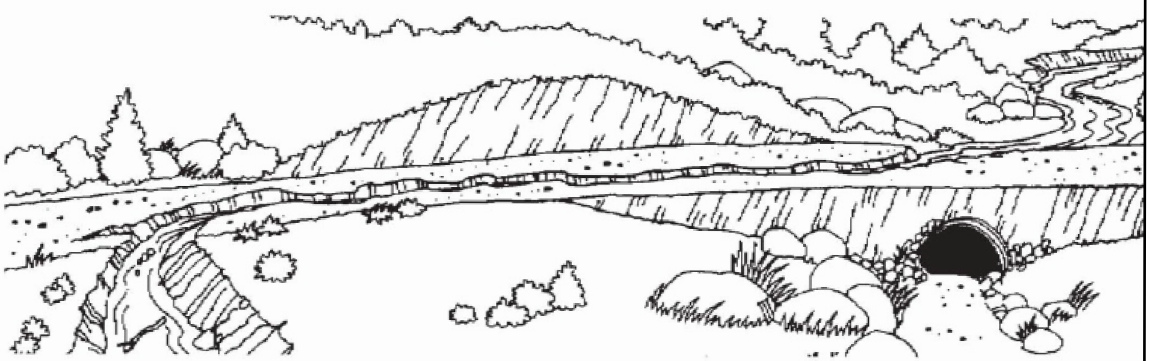
Experience indicates that this is the most economically remediable risk posed by most road systems on NFS lands. The risk is substantial and the fix is usually inexpensive.
All stream crossings, especially culvert crossings, should be designed and constructed (or upgraded) to have NO diversion potential. Stream crossings in steep stream channels that are subject to debris flows should be designed and constructed (or upgraded) to withstand such debris flows without being washed out or resulting in subsequent streamflow diversion. Structure damage from a plugged culvert may be minimal, but road damage from a stream diverted down the road can be extensive, often 10 or 100-fold greater than if no stream diversion potential exists.

Good Installation

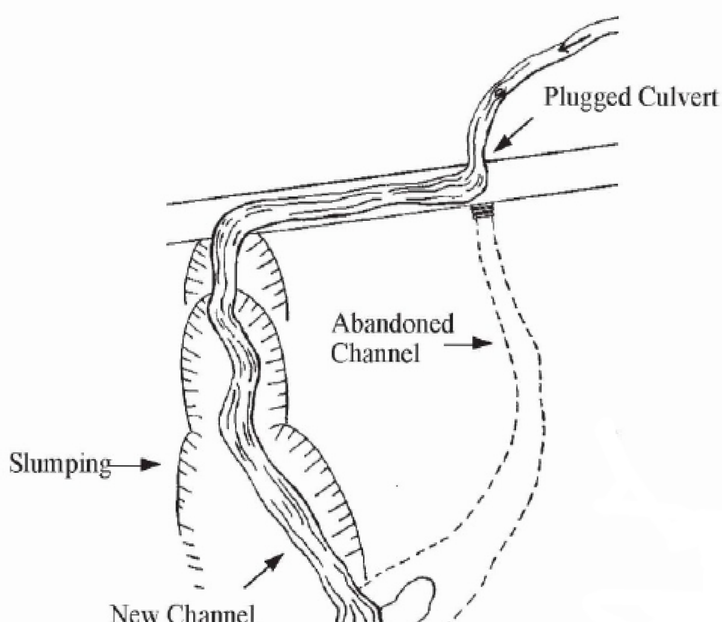


Armored dip over a low fill to prevent stream diversion.

Poor Installation



Sketch of a stream diverted down the road, forming a new channel.



Consequence of stream diversion out of its natural channel.

Reduce road hydrologic connectivity to limit or eliminate sedimentation impacts to lotic ecosystems.

Sediment delivery occurs where road surfaces and ditches are "hydrologically-connected" to stream channels. Hydrologic connectivity is treated by road surface shaping and the installation of road surface and ditch drainage structures. The Rocky Mountain Region Watershed Conservation Measures Handbook (2006) directs that:

> *"In each watershed containing a 3-rd order and larger stream, limit connected disturbed areas so the total stream network is not expanded by more than 10%. Progress toward zero connected disturbed area as much as practicable. Where it is impossible or impracticable to disconnect a particular connected disturbed area, minimize the areal extent of the individual connected disturbed area as much as practicable. In watersheds that contain stream reaches in diminished stream health class, allow only those actions that will maintain or reduce watershed-scale Connected Disturbed Area."*

Where roads are "hydrologically connected" to streams, water quality impacts are inevitable and vulnerability is usually high. Experience has shown that road-stream connectivity can be reduced to 10-15% of road length, even where roads are located close to streams, with frequent cross-drainage and employing the forest floor as a filter and infiltration area.

Design stream crossings and other water-related infrastructure to be resilient in the face of non-stationarity and uncertainty of future extreme events.

Estimating the probability of failure for water resources infrastructure, such as culverts and bridges, requires the "stationarity assumption". That is, that the climate varies in a fixed, time-invariate envelope, and that the future will thus mirror the past. This is no longer valid in a rapidly changing climate. While it is still prudent to check for the 100-year flood for designs, a much better approach is to size structures to match the morphology of streams, using the "bankfull dimensions". This results in resilient crossings and is a Best Management Practice for the Rocky Mountain Region:

> *"Install stream crossings to sustain bankfull dimensions of width, depth, and slope and keep streambeds and banks resilient. Favor bridges, bottomless arches or buried pipe-*

arches for those streams with identifiable flood plains and elevated road prisms, instead of pipe culverts. Favor armored fords for those streams where vehicle traffic is either seasonal or temporary, or the ford design maintains the channel pattern, profile and dimension." (Region 2. Watershed Conservation Practices Handbook. 2006).

Employ "self-maintaining" concepts into the selection and implementation of treatments.

Resources for road maintenance are often severely limited and the road systems are extensive. Implementing those treatments that reduce the amount of road miles that need frequent and costly maintenance will allow limited resources to be applied to more of the road system where it is needed. Outsloping (on appropriate soil types), additional cross-drains, and redundant (back-up) or larger drainage structures are often highly cost-effective measures and can add greatly to resilience.

"Construct roads where practicable, with outslope and rolling grades instead of ditches and culverts." (Region 2. Watershed Conservation Practices Handbook. 2006).

Incorporate relevant, cost-effective technology.

Apply current appropriate technology to improve identification of priorities and for planning, design, and reconstruction practices. This includes the use of ARC- GIS and GPS technology; geosynthetics for filters, separation, and reinforcement; mechanically stabilized earth retaining structures; current riprap sizing criteria for bank stabilization; bioengineered and biotechnical slope stabilization and erosion control measures, and so on.

Perform scheduled maintenance.

Scheduled maintenance should be performed at a regularly planned frequency, to be prepared for storms. Insure that culverts have their maximum capacity, ditches drain well, and channels are free of excessive debris and brush that can plug structures. Keep the roadway surface shaped to disperse water rapidly and avoid areas of water concentration. Avoid outside berms that tend to appear during road grading. There is seldom sufficient time to do the routine work as a storm is approaching.

Use simple, positive, frequent roadway surface drainage measures and use restrictions.

Good roadway surface drainage should be provided so that water is dispersed off the road frequently and water concentration is minimized. Where soil properties are insufficient to support traffic when wet (i.e. volcanic ash), restrict use during wet seasons to prevent rutting and gullying. Outslope roads whenever appropriate and practical and use rolling dip cross-drains for surface drainage rather than a system of ditches and culverts that require more maintenance and can easily plug during major storm events. Frequent cross-drains, insloping and outsloping, and rolling road grades all need to be in good working order. Failed cross-drain culverts are very common after major storm events.

"Install cross drains to disperse runoff into filter strips and minimize connected disturbed areas. Make cuts, fills, and road surfaces strongly resistant to erosion between each stream crossing and at least the nearest cross drain." (Region 2. Watershed Conservation

Practices Handbook. 2006).

Properly size, install, and maintain culverts.

Improperly installed, undersized, and plugged pipes are common reasons for culvert failure during storms. Improper alignment or grade relative to channels and ditchlines, excessive channel constriction and allowable headwater elevation (we recommend < 0.7), excessively wide inlet areas, and inadequate capacity all contribute to plugging and failure. Another common cause of culvert failure is a lack of proper maintenance. Maintaining inlet configurations and removing debris that can plug inlets are essential for proper function during peak flows.

Use simple fords or vented low-water crossings where feasible.

Simple fords or vented low-water crossings (vented fords) should be used as often as appropriate for small or low-flow stream crossings on low-volume roads, instead of culverts that are more susceptible to plugging and failure. Protect the entire (100+ yr.) wetted perimeter of the structure, and the downstream edge of the structure against scour, and provide for aquatic organism passage as needed.

Stabilize and maintain roads to limit erosion and sedimentation of streams

Unstable fillslopes should be removed or treated as necessary to improve stability. Cut and fillslopes should be stabilized with vegetation, to minimize surface instability problems as well as minimize surface erosion. Uncompacted sliver fills and settling or cracking fills are a high priority for stabilization or removal. Fill slopes may also be undercut and over-steepened by a stream or channel. Failing over-steep slopes from road construction where material enters a stream can cause downstream problems, both to the watershed and by promoting plugging of structures. *From: Region 2. Watershed Conservation Practices Handbook. 2006).*

Build erosion resistance into project design to reduce costly maintenance and restoration (Clean Water Act Sections 402(p) and 404). Mitigate concurrently with construction. Obtain stormwater (402) and 404 permits as required.

1. *Design Criteria.*
   a. *Do not encroach fills or introduce soil into streams, swales, lakes, or wetlands.*

   b. *Properly compact fills and keep woody debris out of them. Revegetate cuts and fills upon final shaping to restore ground cover, using certified local native plants as practicable; avoid persistent or invasive exotic plants. Provide sediment control until erosion control is permanent.*

   c. *Do not disturb ditches during maintenance unless needed to restore drainage capacity or repair damage. Do not undercut the cut slope.*

   d. *Space cross drains according to road grade and soil type Do not divert water from one stream to another.*

e. Empty cross drains onto stable slopes that disperse runoff into filter strips. On soils that may gully, armor outlets to disperse runoff. Tighten cross-drain spacing so gullies are not created.

f. Armor rolling dips as needed to prevent rutting damage to the function of the rolling dips. Ensure that road maintenance provides stable surfaces and drainage.'

(Region 2. Watershed Conservation Practices Handbook. 2006).

Public Safety at Campgrounds and Other Recreation Facilities

Forest visitors are attracted to water features: streams, rivers, lakes, ponds, and so on. Recreation facilities appropriately cater to this, and are frequently located adjacent to water features. Where they are located in or near floodplains, they are subject to flooding risks, depending on the setting of facilities and characteristics of the stream or river.

The primary concern at campgrounds and other developed recreation facilities is visitor safety. The Albert Pike incident in June of 2010, where a flash flood caused the death of 20 campers. The event was judged to be of a 500-year return period magnitude. A variety of shortcomings by the Forest Service were revealed in an inquiry that followed. The report is included in the project file (Albert_Pike_Review_Team_Report_September_24_2010-a)

Infrastructure value at campgrounds is relatively minor. Fire rings, picnic tables, and spur roads are easily replaced and do not represent a major vulnerability or liability to the Forest Service. However, if forest visitors are attracted to areas subject to flooding, such as at campsites or special interest areas, a small but real risk of injury and death may be present.

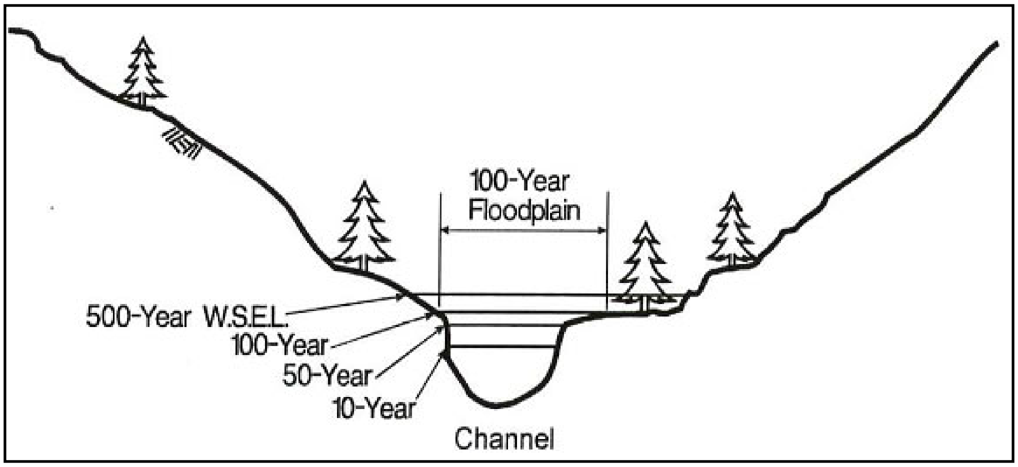
Flooding at the Camp Dick Campground on the Boulder Ranger District. Campgrounds are often located in or near flood-prone riparian areas, and are vulnerable to potentially dangerous flash flooding. (From: Flood Impact Assessment Report, Arapaho and Roosevelt National Forests and Pawnee National Grassland, October 2013)

We recommend the following to reduce risk and improve visitor safety:

At units for which these measures have not already been accomplished:

- All recreation managers in the Rocky Mountain Region review the review of the Ouachita NF flash flood report, paying special attention to the recommendations, and implement measures to protect forest visitors from avoidable flooding hazards at developed recreation sites.
- Review the stream-river proximity screening in this analysis to develop workplans for site field reviews.

- All developed recreation sites be assessed for the presence of floodplains that are subject to the 500-year flow, as per the new federal directive (Federal Flood Risk Management Standard, January 2015 (See: https://www.whitehouse.gov/the-press-office/2015/01/30/executive-order-establishing-federal-flood-risk-management-standard-and-) This document can be found in the Project Folder.
- The assessments should be conducted by a qualified earth scientist (hydrologist, soil scientist, or geologist); and presented to recreation management officers for action.
- Identify 500-year flood elevation (see new Federal Flood standard) for all campgrounds and areas that attract forest visitors.
- Remove or relocate CG and other facilities, or create adequate warning information for visitors (signs, handouts, early warning systems for managers, and so on).



A qualified earth scientist can locate and map areas subject to the 500-year flood level to inform managers which facilities require signing, early warning systems, communications, and possible relocation to reduce hazards to forest visitors.

Implement and monitor Best Management Practices for Recreation Facilities.

We recommend that Best Management Practices for recreation facilities be carefully implemented, and their implementation and effectiveness be monitored. Many of the required BMPs will not only protect water quality and soils, but also make recreation facilities more resilient and less vulnerable to climatic stresses. (See: FS_National_Core_BMPs_April v2012 in Project Folder).

Recreation Activities BMPs

Rec-1	Recreation Planning
Rec-2	Developed Recreation Sites
Rec-3	Dispersed Use Recreation
Rec-4	Motorized and Nonmotorized Trails
Rec-5	Motorized Vehicle Use Areas
Rec-6	Pack and Riding Stock Use Areas
Rec-7	Over-Snow Vehicle Use
Rec-8	Watercraft Launches
Rec-9	Recreation Special Use Authorizations
Rec-10	Ski Runs and Lifts
Rec-11	Ski Area Snowmaking
Rec-12	Ski Area Facilities

References

Flanagan, Sam A., et al. "Methods for inventory and environmental risk assessment of road drainage crossings." San Dimas T&D Center, USDA-Forest Service (1998).

Furniss, Michael J., S. Flanagan, and Bryan McFadin. 2000 "Hydrologically-connected roads: an indicator of the influence of roads on chronic sedimentation, surface water hydrology, and exposure to toxic chemicals."Stream Notes (2000): 1-2.

Furniss, Michael J.; Roby, Ken B.; Cenderelli, Dan; Chatel, John; Clifton, Caty F.; Clingenpeel, Alan; Hays, Polly E.; Higgins, Dale; Hodges, Ken; Howe, Carol; Jungst, Laura; Louie, Joan; Mai, Christine; Martinez, Ralph; Overton, Kerry; Staab, Brian P.; Steinke, Rory; Weinhold, Mark. 2013. "Assessing the vulnerability of watersheds to climate change: results of national forest watershed vulnerability pilot assessments." Gen. Tech. Rep. PNW-GTR-884. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 32 p. plus appendix. http://www.treesearch.fs.fed.us/pubs/43898

Füssel, Hans-Martin, Klein, Richard J. T. 2006. "Climate Change Vulnerability Assessments: An Evolution of Conceptual Thinking." Climatic Change: Volume 75, Issue 3, pp 301-329.

Howe, Carol S., John Almy, Clay Speas, Warren Young and Ben Stratton. 2012 "Assessment of Watershed Vulnerability to Climate Change. Grand Mesa, Uncompahgre and Gunnison National Forests." USDA-Forest Service. **in**: Furniss, Michael J.; Roby, Ken B.; Cenderelli, Dan; Chatel, John; Clifton, Caty F.; Clingenpeel, Alan; Hays, Polly E.; Higgins, Dale; Hodges, Ken; Howe, Carol; Jungst, Laura; Louie, Joan; Mai, Christine; Martinez, Ralph; Overton, Kerry; Staab, Brian P.; Steinke, Rory; Weinhold, Mark. 2013. Assessing the vulnerability of watersheds to climate change: results of national forest watershed vulnerability pilot assessments. Gen. Tech. Rep. PNW-GTR-884. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 32 p. plus appendix. http://www.treesearch.fs.fed.us/pubs/43898

Huntington, Thomas G. "Evidence for intensification of the global water cycle: review and synthesis." *Journal of Hydrology* 319.1 (2006): 83-95.

Keller, G. and G. Ketcheson. In prep. "Storm Damage Risk Reduction Guide for Low-Volume Roads." 1277 1814. San Dimas, CA: U.S. Department of Agriculture, Forest Service, San Dimas Technology and Development Center. 215 p

Milly, P. Christopher D., et al. "Increasing risk of great floods in a changing climate." *Nature* 415.6871 (2002): 514-517.

Potyondy, J. P. and Geier, T. W.: "Watershed condition classification technical guide, FS-978", United States Department of Agriculture, Forest Service, Washington, D.C., 2011.http://www.fs.fed.us/publications/watershed/watershed_classification_guide.pdf

Ray, Andrea J., et al. "Climate change in Colorado: a synthesis to support water resources management and adaptation.” Report for the Colorado Water Conservation Board. University of Colorado, Boulder (2008).

Safeeq, Mohammad, et al. “Predicting landscape sensitivity to present and future floods in the Pacific Northwest, USA.” Hydrological Processes (2015).

Slide deck. in: 2014 Colorado Flood Proofing and Flood Recovery Workshops September 16-18, 2014 Review of 2013 Flood Recovery. Colorado Water Conservation Board

USDA-Forest Service 2013. “Flood Impact Assessment Report: Arapaho and Roosevelt National Forests and Pawnee National Grassland” October 2013 –DRAFT

USDA-Forest Service. National Best Management Practices Program.
(1) The National Core BMP Technical Guide (Volume 1, FS-990a, April 2012),
(2) The National Core BMP Monitoring Technical Guide (Volume 2, FS-990b, in prep),
(3) Revised National Direction, and
(4) A national data management and reporting system

Weinhold, M. 2012. “Assessment of Watershed Vulnerability to Climate Change White River National Forest.” USDA-Forest Service/ **in:** Furniss, Michael J.; Roby, Ken B.; Cenderelli, Dan; Chatel, John; Clifton, Caty F.; Clingenpeel, Alan; Hays, Polly E.; Higgins, Dale; Hodges, Ken; Howe, Carol; Jungst, Laura; Louie, Joan; Mai, Christine; Martinez, Ralph; Overton, Kerry; Staab, Brian P.; Steinke, Rory; Weinhold, Mark. 2013. Assessing the vulnerability of watersheds to climate change: results of national forest watershed vulnerability pilot assessments. Gen. Tech. Rep. PNW-GTR-884. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 32 p. plus appendix. http://www.treesearch.fs.fed.us/pubs/43898

Acknowledgements: Thanks to Trey Schille and Sarah Hines for framing the task and providing valuable advice and context; and to Polly Hays, Joan Carlson, Mark Weinhold, Ann-Marie Verde, and Dan Cenderelli for techincal guidance and suggestions.

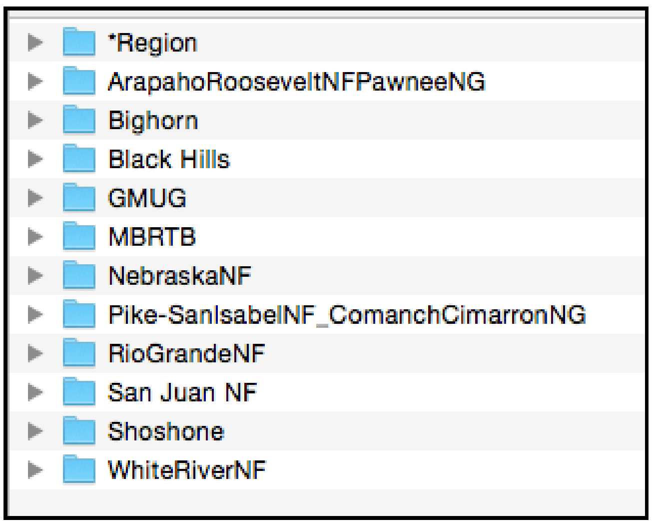
Appendix 1: The Project Folder

A folder on Dropbox was established to provide the references and resources to document this assessment and assist with further smaller-scale assessments.

Access to this folder is by invitation. Please contact Trey Schille if access is required.

CONTENTS

Albert_Pike_Review_Team_Report_September_24_2010-a.pdf
Arapaho_Roosevelt_Flood_Damage_Report.pdf
BMP_Road_11_Road_Damage_Surveys.docx
Climate_Change_In_COLORADO_2014_FinalReport.pdf
Colorado_vulnerability_study_2015_final.pdf
DSR Supplemental Data Sheet.docx
DSR Supplemental Data Sheet.pdf
Federal_Flood_Risk_Management_Standard.pdf
FS_National_Core_BMPs_April2012.pdf
GIS Analysis Folder


*Region
ArapahoRooseveltNFPawneeNG
Bighorn
Black Hills
GMUG
MBRTB
NebraskaNF
Pike-SanIsabelNF_ComanchCimarronNG
RioGrandeNF
San Juan NF
Shoshone
WhiteRiverNF

Howe et al. 2011_WVA
Hydrologically connected road.pdf
R2_Watershed_Conservation_Practices_Handbook
    2509.25_20_1.doc
    2509.25_20.doc
    2509.25_zero_code.doc
Report Folder - Contains this report and appendixes
Road_Inventory_Methods_Furniss-Gerstein.doc
Roads InventorySanDimas.pdf
StormDamageRiskReductionGuideDraft
Stream_Proximity_Indicator_RoadsAnalysis.pdf
Travel Planning Handbook.pdf
VA_infrastructureApproachDeck.pptx - from oral presentation at RO in June
Watershed_Classification_Guide.pdf
Weinhold_2011_WVA

DSR+
DSR Supplemental Data Sheet
(Replaces "Description of Damage" Block)

DSR Reference ___________________

Type and cause of failure

- ❑ Stream crossing
  - ☐ Plugged
    - ☐ By wood
    - ☐ By sediment
    - ☐ By wood and sediment
  - ☐ Too much water for culvert
  - ☐ Fill erosion
    - % of fill removed ______
  - ☐ Diversion of stream down road or ditch
    - Approx. length of diversion______ ft.
    - Receiving feature
      - ☐ Next crossing
      - ☐ Cross-drain
      - ☐ Hillslope
- ❑ Cross-drain
  - ☐ Plugged
  - ☐ Diverted
- ❑ Landslide from above
  - ☐ Within 100 feet
  - ☐ 100-1000 feet above
  - ☐ > 1000 feet
- ❑ Landslide originating at road
  - ☐ Cutslope failure
  - ☐ Fill or sidecase failure
  - ☐ Running surface slump
- ❑ Stream undercutting

- ❑ Gully
    - Excessive road surface runoff
    - Excessive ditch flow
    - Cascading cross-drain failure
    - Gully from above
    - Other: ___________________________

Estimated Volume

Estimated total volume of earth moved by the erosional event

- ☐ <10 yds
- ☐ 10-100
- ☐ 100-1000
- ☐ 1000-10,000
- ☐ >10,000

Estimated Delivery

Estimated % of material that

______ Is on road

______ Is within 50 feet of a stream*

______ Was deposited within 50 of a stream

______ Was deposited in a stream

Notes:____ _______________

____

____

____

____

____

____

** Any stream, including draws and ephemeral streams. Does not need to be "live" or flowing at the time of inspection.*

Appendix 2: Road-Motor Trail Density and Stream Crossing Density by HUC-6

Appendix 3: Summary Tables for Indicators

Appendix 3 & 4 are found in two additional separate documents, to keep the file size of this document managable.

Acknowledgements: Thanks to Trey Schille and Sarah Hines for framing the task and providing valuable advice and context; and to Polly Hays, Joan Carlson, Mark Weinhold, Ann-Marie Verde, Brian Staab, and Dan Cenderelli for techincal guidance and suggestions.

This is a low-resolution version of this report: A high-resolution version that allows zooming to GIS detail (~230MB), the Appendixes, and the component GIS analyses are available at: http://bit.ly/R2_InfrastructureVA