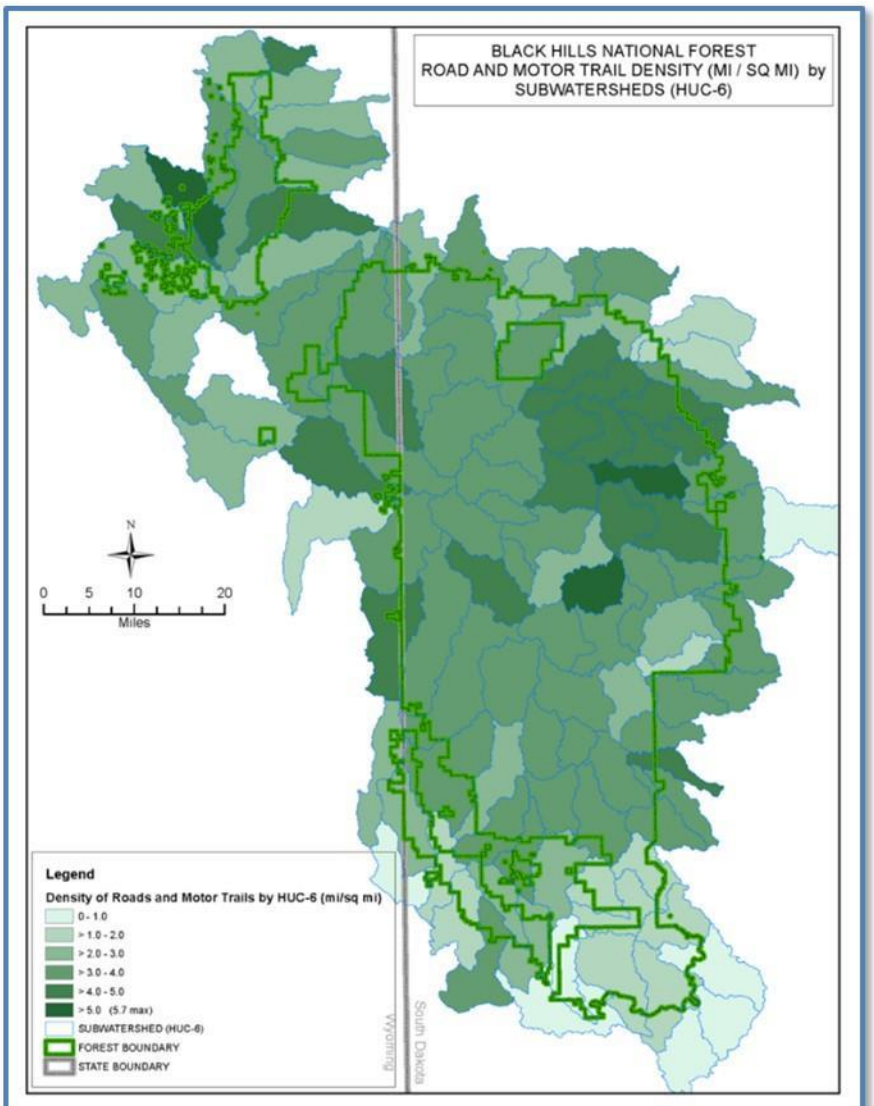
Forest Service
U.S. DEPARTMENT OF AGRICULTURE

Rocky Mountain Region / Black Hills National Forest June 2022

Black Hills National Forest

Draft Forest Assessments:

Infrastructure



Road and motor trail density by subwatershed, Black Hills National Forest

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Chapter 1. Introduction

Roads are a valuable asset that provide access to National Forest System lands, private inholdings, and other lands and attractions. Immense investments have been made in developing road systems to access wildlands for management and recreation. At the same time, roads pose problems and risks to valued resources such as water, soils, visitor experience, and wildlife.

However, the value of any road[1] for access and the potential problems and risks to valued resources depend on many factors such as location, the design and maintenance of the road, road failures and repair, road uses, proximity to valued resources, and other factors.

Other infrastructure, such as developed recreation sites, administrative buildings, dams, and water and wastewater systems represent large investments and are vulnerable to climatic stressors and can present safety and health hazards to people. A summary of infrastructure in the Black Hills National Forest is provided in figure 1. Please note that road and trail mileage totals in this assessment may vary from other assessments because this report draws largely on from an infrastructure vulnerability assessment conducted in 2016. Other assessments may be using information compiled in corporate datasets that might reflect changes from 2016 to current.

Key Infrastructure Issues

- The Black Hills are extremely popular, a top regional and national destination, visited and highly valued by many. Visits and associated recreation are increasing. Supporting visitors requires robust, sustainable, and well-maintained facilities and transportation systems.
- The Black Hills National Forest is extensively roaded with at least 10,000 miles of roads; substantially more than most national forests of similar size. Water quality, aquatic and terrestrial wildlife, and visitor experiences are often strongly affected by road and trail networks.
- Many "non-system" roads exist on the Black Hills National Forest that have not been inventoried, are unmaintained, and have significant effects on valued resources. Most are user-created roads and likely have greater overall impacts than National Forest System roads (system roads).
- Road and facility maintenance depends on adequate funding, but funding levels are typically inadequate to keep up with identified maintenance needs, resulting in risks and problems to roads, facilities, and the resource values and visitor experiences that are affected by them.
- Many roads were constructed to facilitate forest management. Harvest revenues have supported most road construction and maintenance. Revenues from forest harvest have declined and may decline further, resulting in more shortfalls in maintenance unless appropriated funds are increased and substituted.
- A rapidly warming climate presents increased climatic exposures to infrastructure with potential consequential associated damages and expenses.

[1] References to "roads" in this report also include motorized trails and parking lots, which have similar impacts to hydrology, water quality, and management concerns as roads for cars and trucks.

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**

Figure 1. Tabular summary of the Black Hills National Forest infrastructure elements, including roads, trails, campgrounds, and dams, and proximity (within 100 or 300 feet) to mapped watercourses

Chapter 2. Current Status of Infrastructure

Indicators of Infrastructure Vulnerability

Infrastructure is costly to build and maintain and can result in serious disruption to management and the public when damaged. Its vulnerability is therefore of interest to the management of national forests. Furniss et al. (2018) defined three levels of infrastructure vulnerability assessment.

Assessment Level 1—Inventory

The presence of an infrastructure feature is a first approximation of vulnerability. Although exposures and risks differ significantly from place to place, all infrastructure is vulnerable. Hence, an inventory of the amount and spatial distribution of infrastructure is also a first approximation of vulnerability. A description of infrastructure by quantity, type, and feature within Federal lands shows the potentially affected investments by climatic forces. Assessment units, such as national forests, ranger districts, or subwatersheds, with higher infrastructure density or higher levels of infrastructure investment, can be considered more vulnerable than those with little or no infrastructure.

Assessment Level 2—National Forest and Regional Scales

Two indicators of vulnerability that can be discerned at large scales via simple geographic information system (GIS) queries include (1) proximity of infrastructure to streams, and (2) trail and road-stream crossings (figure 5, figure 6). Together, these two indicators depict components associated with moving water that may be vulnerable to extreme climatic events. Although some errors may exist in spatial resolution and mapping, the indicators reliably capture hydrologic connectivity and vulnerability to fluvial processes, which are of greatest concern and potential consequence. Slope steepness and soil type may also be indicators of vulnerability discerned at broad spatial scales. Still, the relationships to vulnerability can be more context-dependent and require local knowledge about potential effects of hydrologic events.

Assessment Level 3—Local Scales

Many vulnerability indicators are best derived at smaller scales—ranger districts, sub-basins, watersheds, subwatersheds—where detailed data about context and conditions are generally available. These indicators are not included in this assessment but can be incorporated into smaller-scale assessments and local project planning and design efforts.

These indicators may include:

- Presence of vulnerable communities that rely on Federal roads for access,
- Local population density and land development patterns,
- Infrastructure value information, such as alternate road routes for community access, investment levels, and historical maintenance costs,
- Road assessments, such as the Forest Service Geomorphic Road Analysis and Inventory Package (GRAIP, Black et al. 2012) surveys and flood damage surveys,
- Landslides and landslide-prone terrain,
- Steep terrain that can lead to rockfalls, debris slides, and drainage failures,
- Stream channels with a high probability of avulsion (sudden cutting off of land by flood, currents, or change in course of water),

- Areas of high wildfire risk and postfire flood risk,
- Presence of sensitive aquatic systems, terrestrial systems, and cultural resources that may be affected by damage, failure, or destruction of infrastructure, and
- Past *Emergency Relief of Federally Owned Roads* projects; these roads are sometimes called "repeat offenders" and illustrate the most troublesome roads and terrains. Most roads do not fail, but those that do are typically in the same vulnerable places. Accumulating geographic and descriptive records of road failures helps Forest Service staffs determine which areas to concentrate on for maintenance and risk reduction, and where to remove or avoid roads in the future.

Infrastructure that is costly to maintain and endures high use is generally considered more vulnerable. Vulnerability is a combination of risk, consequences, and values. For example, roads and road drainage structures are significant investments, facilitate many valued uses, and can be costly to repair if damaged by storms. In contrast, trailheads are typically easily repaired if damaged by wind, water, or heat and may be of little consequence to resource management or national forest visitors if they are out of service for a short time.

This *Infrastructure* assessment is based on Levels 1 and 2 as defined above: Presence and large-scale vulnerability of infrastructure.

Roads

The road and trail systems on the Black Hills National Forest (figure 2) are highly developed, reflecting a long history of uses, visitation, and development. This national forest is extensively roaded, with nearly all territory accessible by road. The Black Hills National Forest has the second largest number of roads in the Rocky Mountain Region and is more roaded than most national forests. Many of the road systems are quite old and were designed and constructed with the design standards and practice of the time, such as 1910-1940, and have culverts and other facilities that are well beyond their design life. Bridges are routinely inspected for safety, and appropriate modifications are made.

The abundance of roads is the result of many factors, including the early development of the Black Hills National Forest, its unique topographic character (an "island" of mountains amidst vast prairies and flatlands), superlative scenery and natural attractions, intensive mineral exploration and mining, a long-term active timber program, the relative ease and low costs of road building in much of the terrain, just one small wilderness (13,426-acres), and extensive and varied recreation demand and activity, much of which is motorized or requires motorized access.

The Black Hills National Forest contains about 7,537 miles of system roads and 962 miles of trails. Roads and motor-trails cross mapped streamcourses in about 6,399 places. A summary of infrastructure of the Black Hills National Forest, with an emphasis on proximity to mapped stream channels, is provided in figure 1. Please note some infrastructure totals from this assessment may slightly vary from other assessments. Figure 1 was derived primarily through a region-wide infrastructure assessment with data from 2016. Other assessments may have used more current data that reflects changes since then. Road-stream proximity and subwatersheds (HUC-6) are shown in figure 3, and two subwatersheds that have widely different road-stream proximity are shown in figure 4. The length of roads and motor trails by subwatershed is shown in figure 7, and the density of roads and motor trails by subwatershed is shown in figure 8. Roads open to all vehicles, both yearlong and seasonal (dry season), are shown in **Error! Reference source not found.**~~figure 20~~; roads open to highway-legal vehicles, both yearlong and seasonal (dry season), are shown in **Error! Reference source not found.**~~figure 21~~; and trail allowable use categories are shown in **Error! Reference source not found.**~~figure 22~~.

Non-system Roads on the Black Hills National Forest

The 2007 Forestwide Transportation Analysis identified 2,612 miles of non-system roads. These are roads in the national forest that are not maintained by the Forest Service, sometimes called “unclassified” roads. This is a large proportion of roads inside the national forest boundary.

According to the 2007 Transportation Analysis:

> "The nature of these roads varies, but they are primarily two-track roads that came into being by vehicles leaving NFS roads. The routes were traveled with sufficient frequency to leave an easily noticeable traveled way. Many of these routes are relatively short. Because they are unplanned, they are more likely to be poorly located on the landscape and more likely to have higher erosion potential. The positions of these routes were obtained primarily from interpretation of aerial photographs and they have not all been ground verified. Attempts are made to close these roads when possible; however, funding and the physical location of the routes often limit these efforts. Some of the non-system routes are also temporary roads that were constructed for vegetation/timber management."

From the Transportation Analysis:

> "Off-road enthusiasts have become accustomed to riding their OHV on any road, trail, or area that is not posted or gated as closed. A portion of these riders have chosen to ignore restrictions and prohibitions. These actions have resulted in a large and growing system of undeveloped trails. Many of these trails are located such that they present risks to natural resources, including soils and water quality. As the number of visitors to the forest increases, so do the incidences of environmental damage and user conflict."

These non-system roads represent a large, unfunded, unmaintained and largely unmanaged liability, and likely cause as much or more resource damage than the more extensive system of managed National Forest System roads.

Costs of Road Maintenance

Road maintenance is generally quite costly, especially when considering the large mileage of roads on the Black Hills National Forest and the high usage of many roads and associated facilities, such as culverts and bridges, that progressively deteriorate with time. Deferred maintenance (maintenance not performed when it is necessary) typically makes the per-mile cost increase when it is done. For years, significant shortfalls in funding to adequately maintain the existing road system have been due to inadequate appropriations and a declining timber program that supported the construction of most of the road system, and which supports road maintenance for timber sale areas.

According to the 2007 Forestwide Transportation Analysis:

> "The overall level of federal funding and timber purchaser expenditures is not sufficient to perform the short- and long-term maintenance needs identified for NFS roads in general. The annual road maintenance funding is approximately 25 percent of what is needed based on the INFRA Database. The deferred maintenance funds are less than 5 percent. The federal portion of that funding cannot be expected to increase significantly. As a result, without new resources, the long-term condition of NFS roads is expected to deteriorate."

Funding levels change frequently, and the particular funding context is beyond the scope of this assessment. Recent analysis is available from Forest Service staff and databases.

Roads and Motor Trails

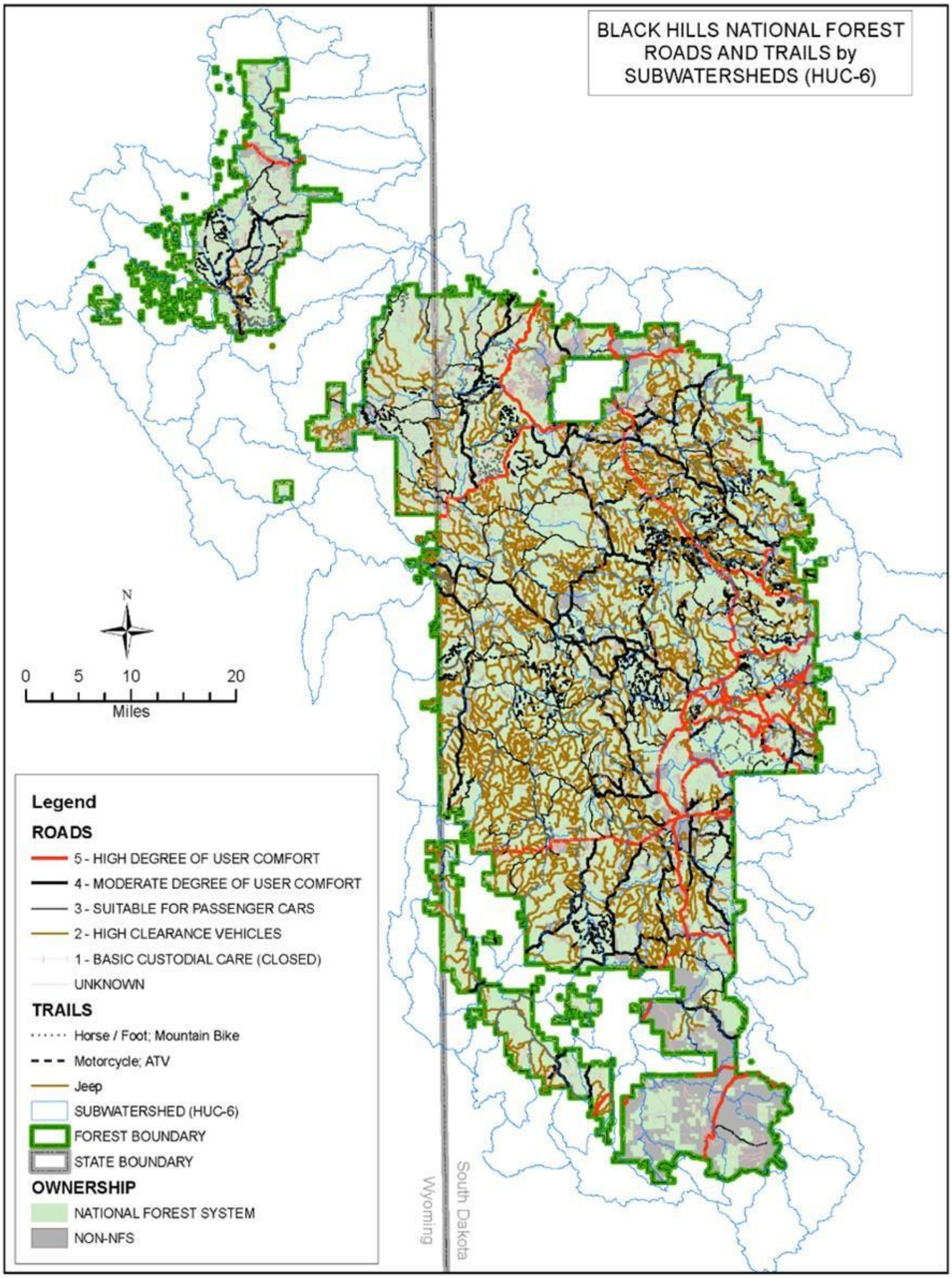
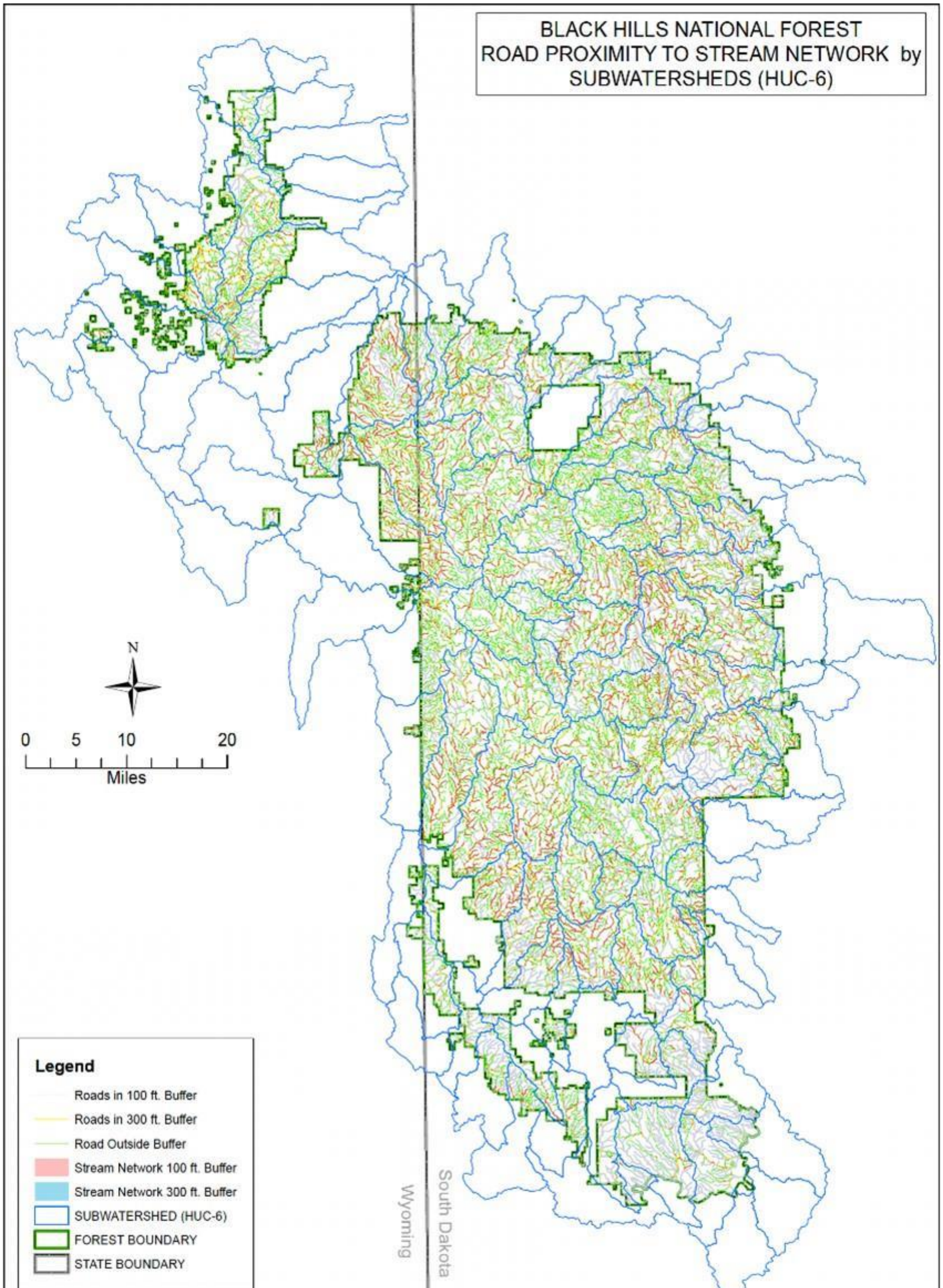


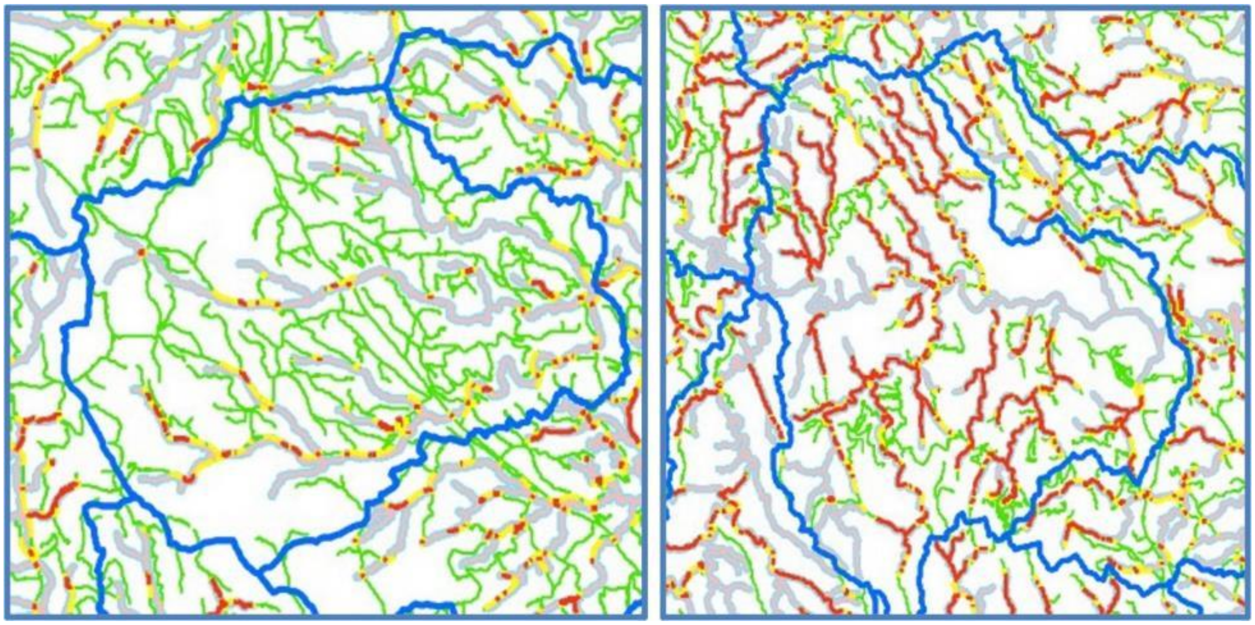
Figure 2. Roads shown by maintenance level and motor trails shown by suitability and allowed uses, Black Hills National Forest

Road-Stream Proximity



Roads in red are within 100 feet of a mapped stream, and in blue are within 300 feet of a mapped stream. Roads close to streams are both more vulnerable to fluvial damage and much more likely to adversely affect water quality and riparian/aquatic habitats.

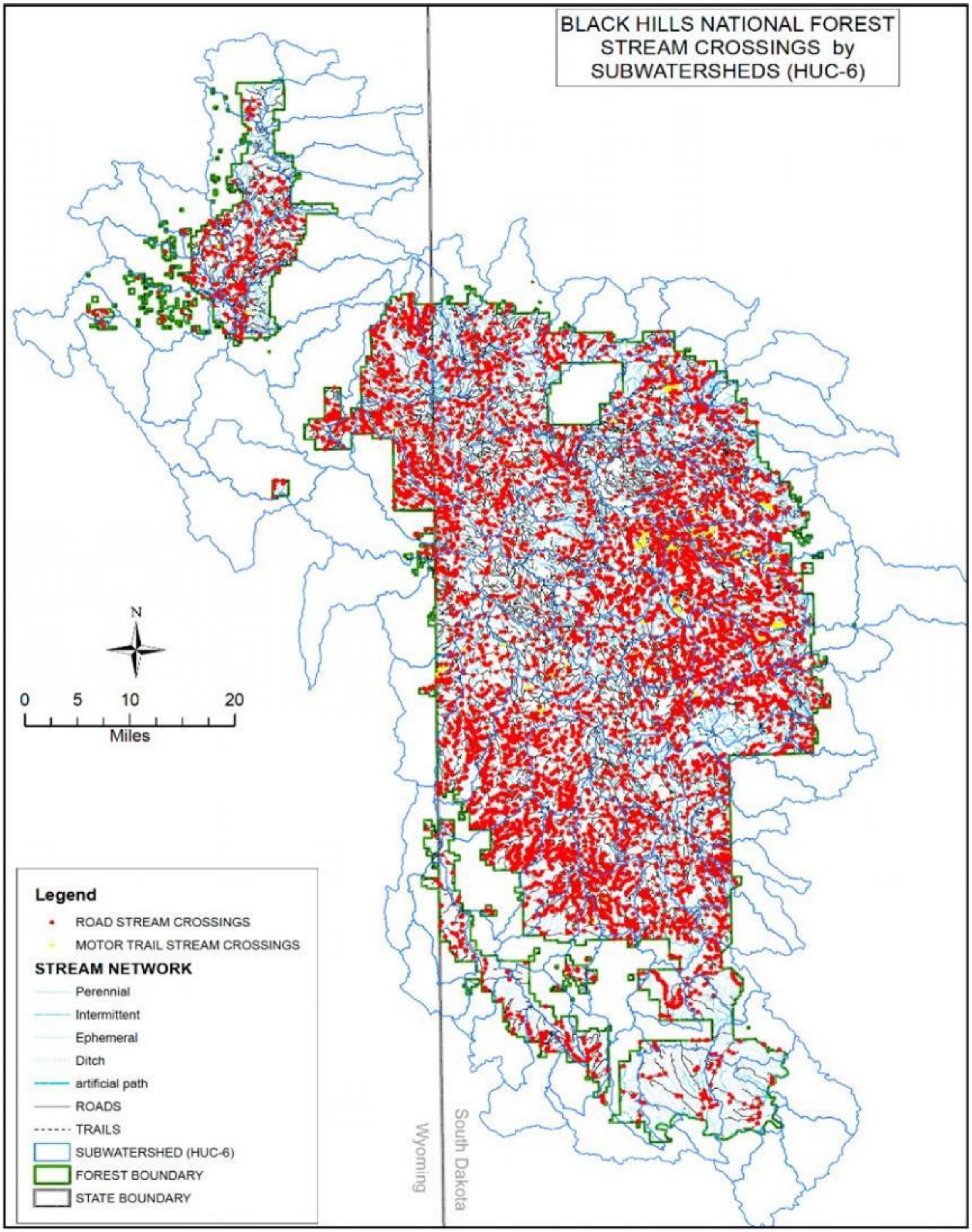
Figure 3. Road-stream proximity and subwatersheds (HUC-6)



On the left, most roads are on broad ridges and far from mapped streams; on the right, most roads are in valley bottoms, adjacent or even within the floodplain of mapped channels. Roads in the subwatershed to the right are much more vulnerable to damage from flooding, pose more problems and risks for water quality and aquatic habitats, and are typically far more troublesome and expensive to maintain.

Figure 4. Two subwatersheds that have widely different road-stream proximity in the southwestern portion of the Black Hills National Forest

Stream Crossings



Where migrating organisms inhabit the crossed streams, migration is often blocked or inhibited by the conditions of the culvert, or less frequently, bridges. Based on GIS analysis, the Black Hills National Forest contains about 6,399 stream crossings. Road-stream crossings are sites of potential impact and disruption of transportation when damaged by flooding, or they divert streamflow into non-drainage terrain, or both.

Figure 5. Road-stream and motor trail stream crossings

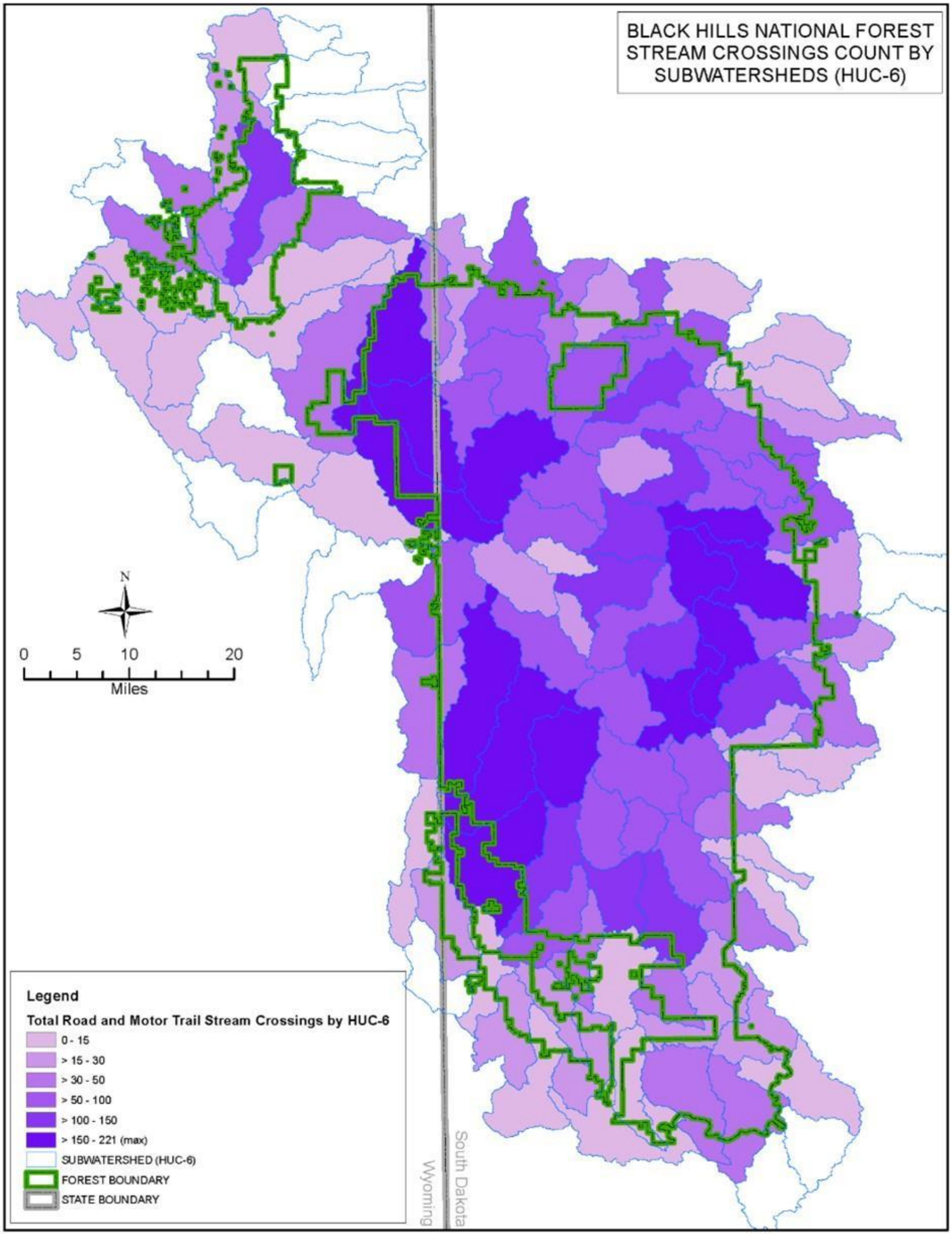


Figure 6. Stream crossing count by subwatershed

Road Density

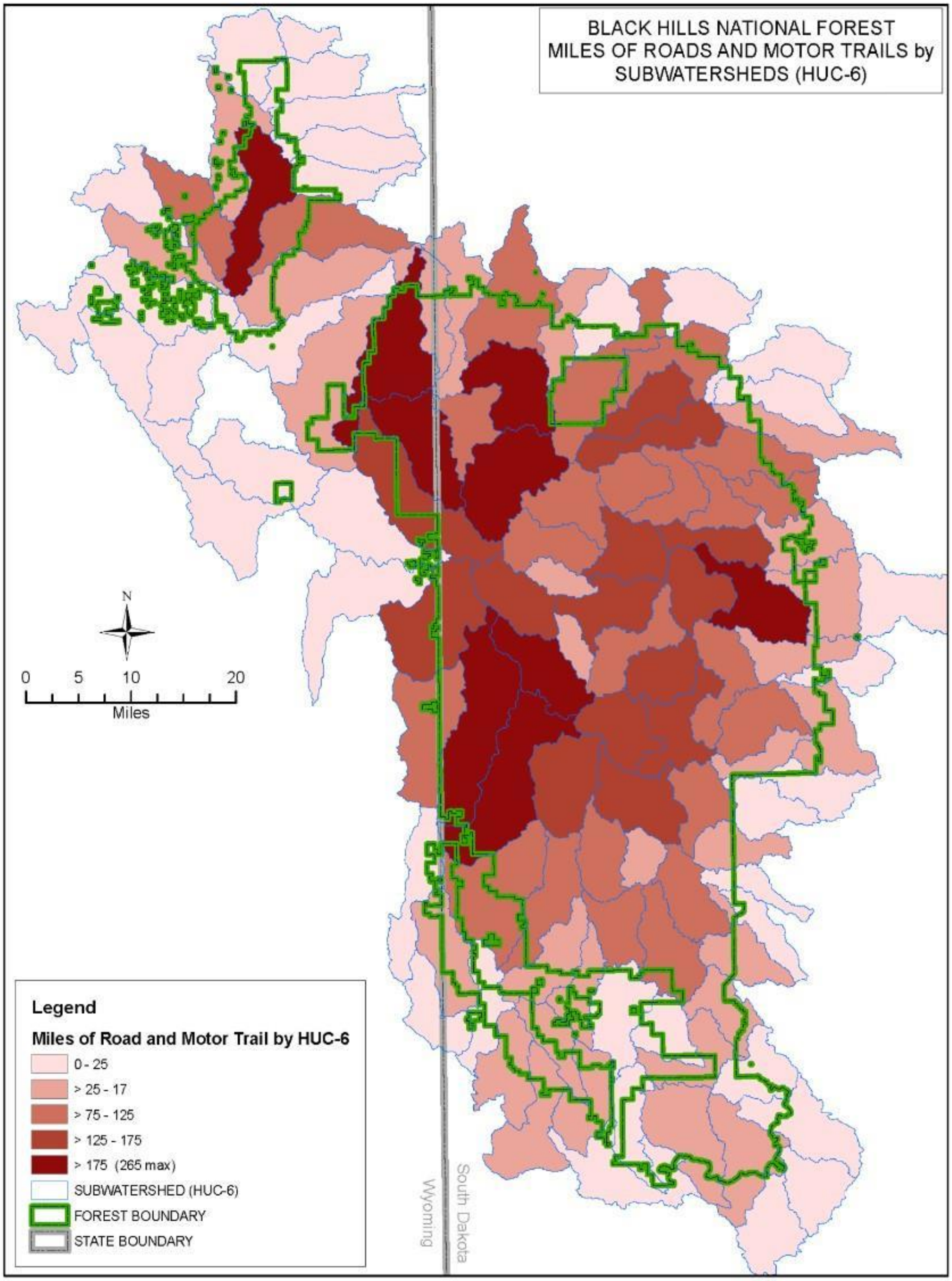


Figure 7. Length of roads and motor trails by subwatershed

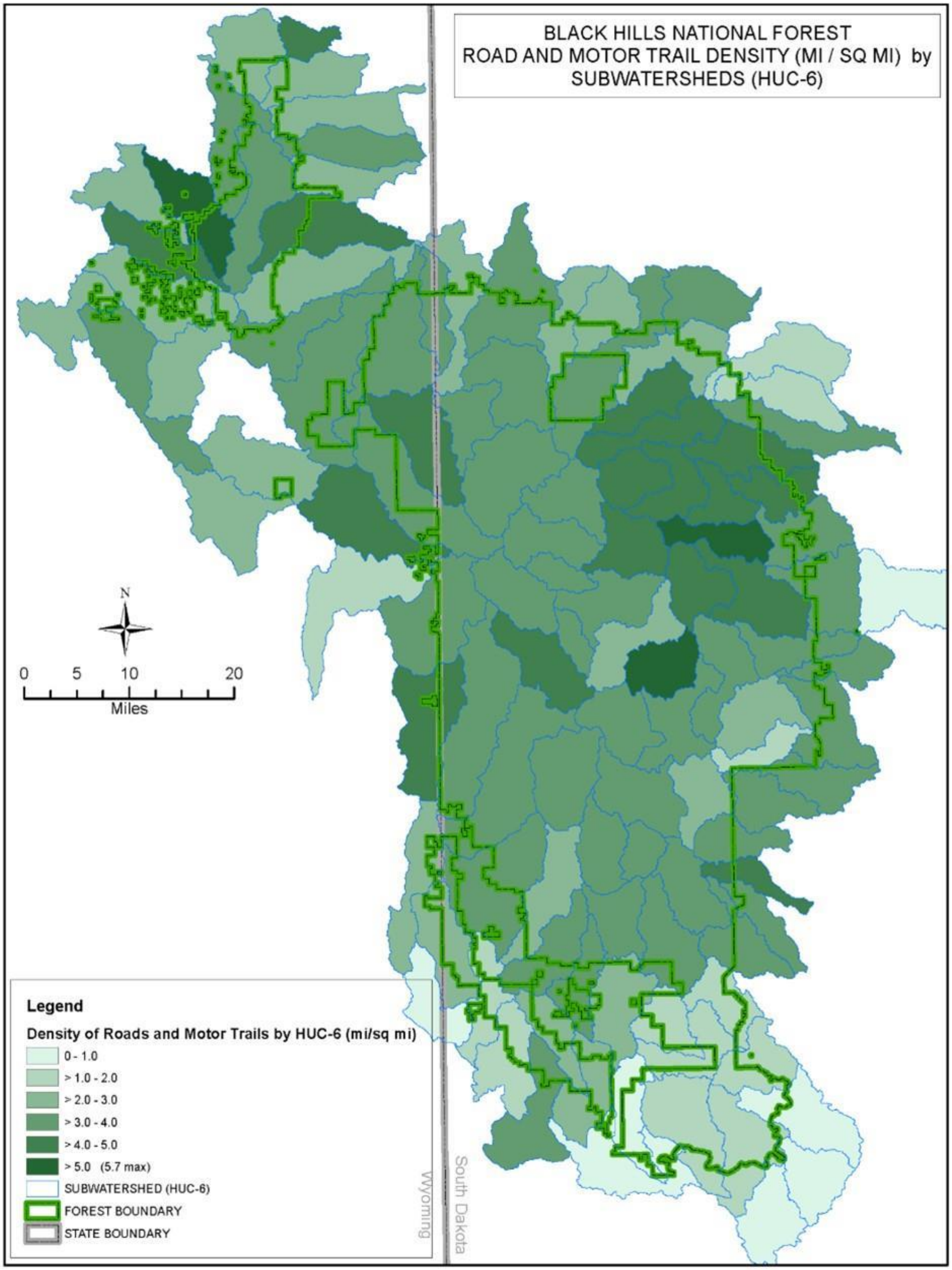


Figure 8. Density of roads and motor trails by subwatershed

Campgrounds, Dams, and Facilities

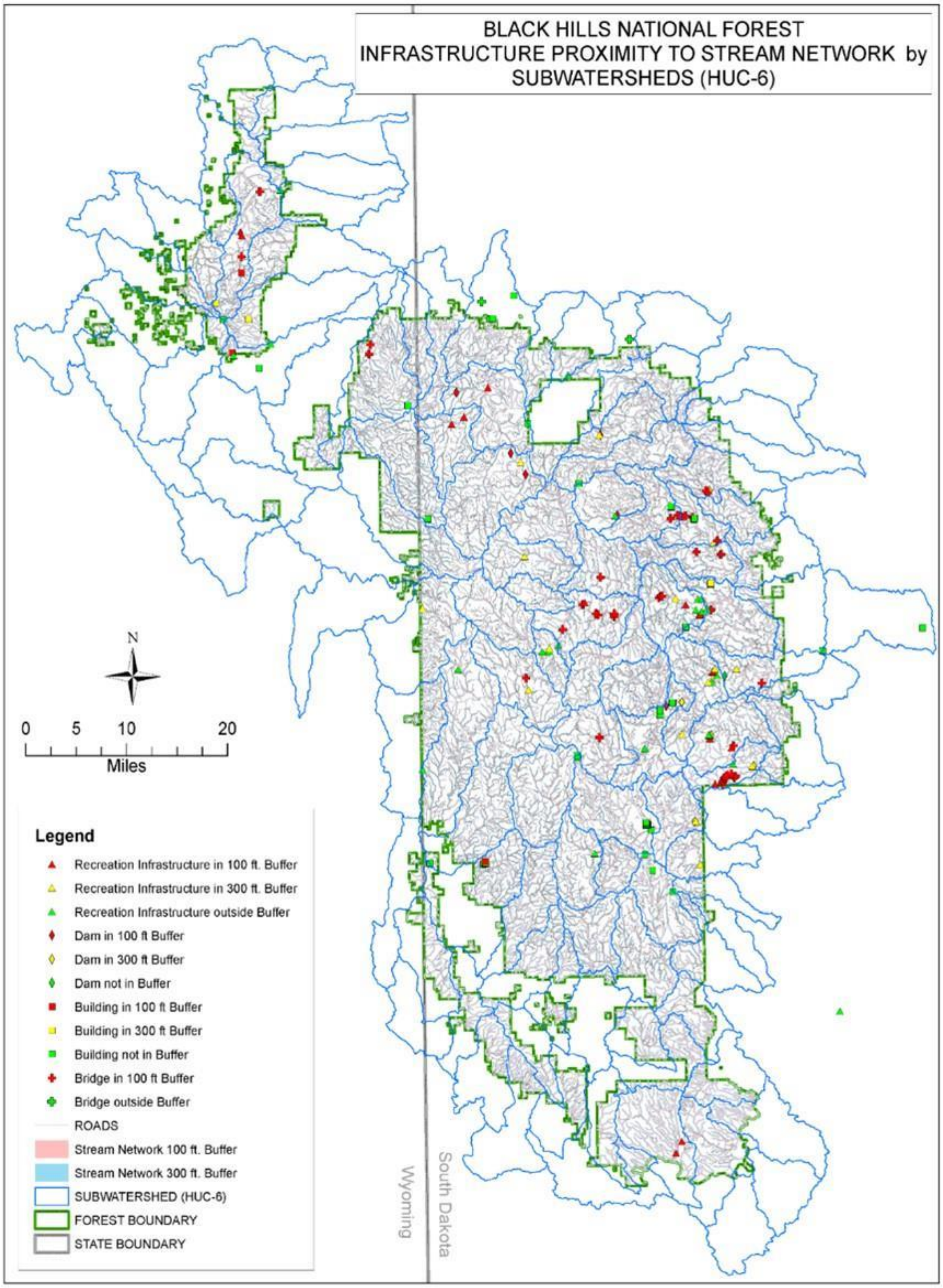


Figure 9. Recreation facilities, dams, buildings, and bridges classified by their proximity to mapped streams, and subwatersheds (HUC-6)

Chapter 3. Sustainability

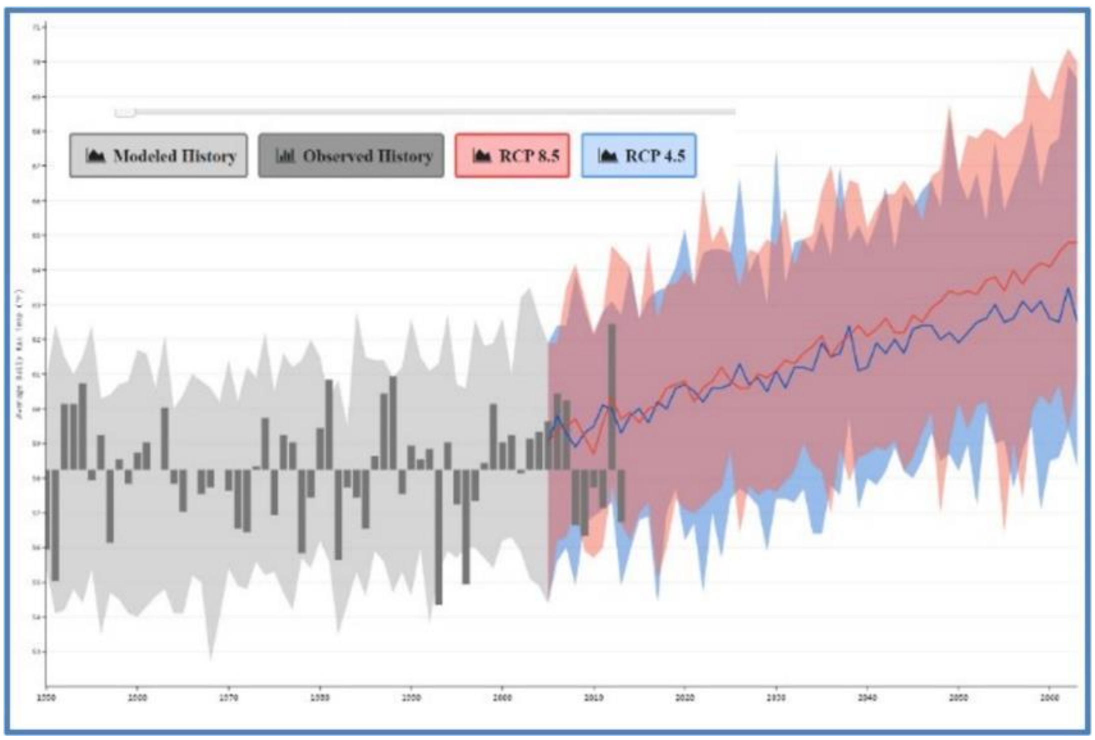
Existing and Projected Climates

Please refer to the *Climate Change* assessment for full details (Timberlake et al. 2021).

Current and historical climates are relatively well known because they constitute summary statistics of existing observations. The projected climate in the future has higher uncertainty because projections are based on climate models.

Temperature

Temperature projections (figure 10) tend to have relatively higher certainty than precipitation projections, and projections of regional and national forest-scale increases in temperature are likely to be reliable.



(See: Timberlake et al. (2021) and [USDA Climate by Forest](#))

Figure 10. Observed and projected average daily maximum temperature

Precipitation and Flooding

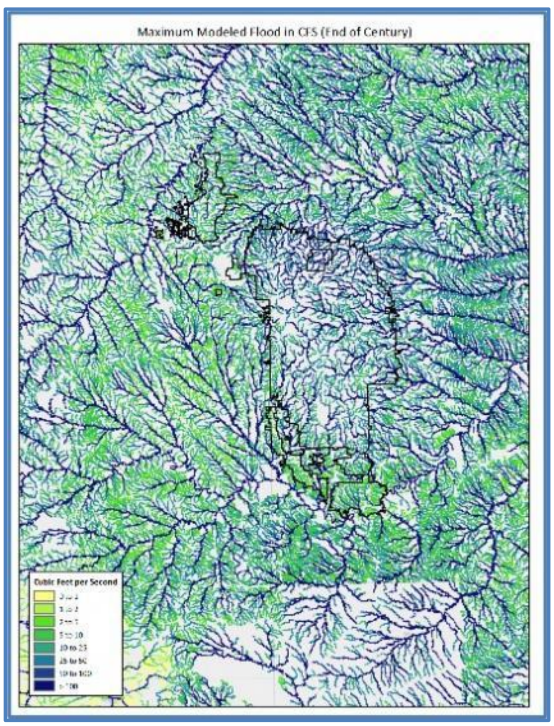
Overall, precipitation is likely to increase, but the magnitude is uncertain. Climate models project increasing precipitation intensity as greenhouse gases and warming increase. Nearly all climate scientists conclude that the rapid climate warming now underway will bring increases in extreme rainfall based on the physics of climate warming. As a result, large storms that lead to flooding and infrastructure damage are expected to become even larger and more frequent, while small storms become less frequent.

Projected precipitation and temperature changes imply increasing flooding, although overall, there is low confidence in projections of fluvial floods. Confidence is low due to limited evidence (rare storms are rare even when they become more frequent), and because the causes of regional changes are complex, although there are exceptions. There is medium confidence (based on physical reasoning) that projected increases in heavy rainfall would contribute to increases in local flooding. Earlier spring peak flows from snowmelt and glacier-fed rivers are very likely.

While projections for extremes of precipitation or the small-scale distribution of large storms and damaging thunderstorms have substantial uncertainty, several lines of evidence and modeling results indicate that precipitation and flooding are very likely to increase markedly (figure 11).

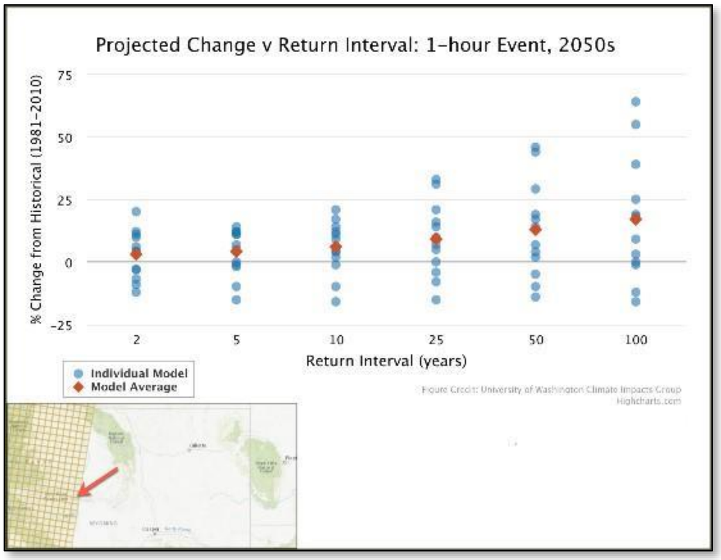
1. The physics of atmospheric warming clearly show that a warmer atmosphere holds more water; therefore, more precipitation will fall. For every degree rise in global average temperature, the atmosphere holds about 7 percent more water (Buis 2022).
2. The incidence of "heavy rain" has been observed to be increasing in many areas. Although this is not necessarily flood-producing, it indicates that rainfall and snowfall will be more intense in warmer climates (Trenberth 2011, Easterling et al. 2000). See figure 12.
3. Modeling results project substantial increases in large flood-producing storms.
4. Increases in heating produce taller thunderheads that produce heavier downpours and hailstorms. (Dai et al. 2017). Thunderstorms and locally very heavy downpours and hail are common in the Black Hills.

Model Results for Increases in Heavy Rainfall and Flooding



The boundary of the Black Hills National Forest is outlined in black. Source: Liang et al. (1994).

Figure 11. Percent of change in the probable maximum flood by 2100 from the Variable Infiltration Capacity (VIC) macroscale hydrologic model



Data are from the far eastern extent of the modeling, as shown by the red arrow. Source: University of Washington Climate Impacts Group (2021).

Figure 12. Projected changes in the return interval for 1-hour precipitation events from the Climate Impacts Group in the Pacific Northwest

Localized, Intense Thunderstorms are Likely the Most Consequential Climatic Exposure of Infrastructure

Extreme but localized thunderstorms (figure 13) are common in the late spring and summer months on the Black Hills National Forest. These storms typically occur over relatively small areas, such as a subwatershed (HUC-6) and they typically deliver extreme rainfall intensities and often, damaging hailstorms. The frequency, intensity, extent, and geographic distribution of these events is not predictable. Observations of these storms over decades indicate that they are a major driver of erosion and hailstorm damage to roads (downpours) and facilities (hailstorms).

Thunderstorms often deliver very intense rainfall and hail and can be especially damaging to infrastructure. Photo credit: Silver Lining Tours.

Figure 13. Thunderstorm in the Black Hills

Uses, Benefits, and Environmental Impacts Associated with Infrastructure

Uses and Benefits

In terms of uses and benefits, access for human activities is the most significant factor, including:

- To access mineral, timber, grazing, energy, recreation, and administrative resources
- To access special forest products and uses
- To access the nearly 800 special uses authorized on the national forest
- To manage forests via silviculture for growth, biodiversity, wildfire resilience, and so on
- To access many forms of outdoor recreation and special attractions
- For commercial developments that can create employment for an array of people to support their families
- To provide access to inholdings
- To assist wildland fire suppression
- To provide access to utility corridors
- To facilitate scientists conducting research
- To provide access to cultural activities, access for First Nations, the cultural value of historic roads themselves, and for archaeological research
- To promote "edge habitats" that are beneficial to some organisms and populations
- To provide jobs associated with designing, building, maintaining, managing, operating, and decommissioning roads, facilities, and a wide variety of other services (Forestwide Transportation Analysis 2007, Gucinski et al. 2001)

Environmental Impacts and Effects of Roads

The environmental effects of roads, motorized trails, and parking lots include biotic and abiotic aspects. Local effects (along a road segment) or widespread effects (affecting the whole network of roads or entire watersheds) can occur.

Below, road-related impacts are grouped to identify effects on (1) terrestrial wildlife and habitat, and (2) soils, water, and aquatic wildlife and habitat. The final subsection highlights other road effects.

Terrestrial Wildlife and Habitat

- Increased road kills and injuries to wildlife. For example, roads warm quickly, making them attractive to reptiles and amphibians for basking, and this can lead to more road deaths and injuries; headlights at night sometimes cause animals to freeze in the roadway; and so on.
- Roads and bridges that bisect wetlands disrupt turtle and amphibian migration patterns and population connections
- Higher mortality and injuries in response to increasing hunting and trapping pressures, poaching, and management actions
- Loss of habitat, species, and vegetation
- Fragmentation of wildlife habitats
- Alterations and disruptions of habitat due to logging, human fire ignitions, fire suppression, fences, fuel-wood collection, recreational activities, and other activities
- Reduced habitat suitability near roads due to edge effects
- Degradation of habitat effectiveness due to increased human disturbance such as noise, traffic, lights, poaching, invasive plants, and so on.
- A rise in human-wildlife conflicts
- Changes in wildlife behavior due to traffic and various human disturbances
- Changes in predator-prey relationships along artificial "hard edges" created by roads (e.g., nest predation by corvids)
- Contaminants, such as road salt, oil, gasoline, heavy metals, tire debris, and so on can extend into roadside vegetation for varying distances, resulting in changes in species composition and contamination of soil, plants, animals, and water. Animals can be attracted to road salt, which can lead to collisions with vehicles. Various contaminants can migrate into water sources and affect downstream wildlife watering areas.
- Resource roads can provide opportunities for negative human actions (e.g., poaching, garbage dumping, introduction of non-native fish to lakes and streams, and so on).

Soil, Water, and Aquatic Biota and Habitats

- Increased erosion leads to sediment and nutrients being delivered to streams and wetlands, adversely affecting aquatic habitats and species
- Increases in landslides and debris flows that can affect both terrestrial and aquatic ecosystems
- Increases in fish mortality due to increased fishing pressures, poaching, and management actions
- Displacement and compaction of soil, contributing to a loss of biomass productivity
- Changes in soil pH, plants, and the vegetative community
- Reconfigured landforms can result in altered hydrologic conditions and regimes including higher water tables, interrupted groundwater flow, higher water temperatures, road-stream hydrologic

connectivity, changes in the timing of natural runoff, drained natural wetlands, artificial wetlands, and restricted or altered channels that can alter streambed materials

- Changes in the flow of streams, including the timing and intensity of high and low flows
- Restricted fish passage as a result of culverts and bridges that can block and impede upstream migration, eliminate or reduce access to spawning sites, and fragment fish habitats
- Reduction in the number, size, and depth of stream pools, reducing habitat for fish and other aquatic organisms
- Disrupted input and movement of large wood to streams, which alters channel morphology and habitat, especially at stream crossings, which frequently do not allow downstream passage of large wood
- Reduced vegetation on streambanks where roads run along riparian areas
- Introduction of non-native fish

From the Draft Soil and Water Assessment (February 2022)

> "Roads and Trails–where roads and trails are rated Fair or Poor it is because road density is high, they are in close proximity to water, and outstanding/lack of/overdue/needed maintenance. This is an indicator of hydrology and sediment regime changes from the natural baseline."

Other Adverse Effects of Roads

- Increased unmanaged recreation (such as unauthorized snowmobiling and use of motorized off-road vehicles, mud-balling, and other damaging uses), which adversely affects wildlife and degrades soil and riparian areas and wetlands
- An increase in invasive non-native plants and animals that establish along the colonization corridors created by roads
- Increased trash dumping
- Increased insect and disease pathogen spread by traffic using roads
- Increased use conflicts and incompatible uses in the same locations
- Loss of solitude
- Increased carbon dioxide emissions into the atmosphere
- Increased dust into the atmosphere from gravel and native roads, and from quarry/pit operations to mine materials used to construct and/or maintain roads.
- Exposure of infrastructure to climatic stressors

Ecosystems Associated with Streams that are Subject to Impacts from Infrastructure

- Have rare species sensitive to changes in sediment or flows, or both
- Have species or communities that are sensitive to sediment
- Infrastructure is located in or near crucial habitat locations (e.g., fish spawning areas)
- Infrastructure encourages public access to sensitive sites
- Improper maintenance activities (e.g., sidecasting) periodically disturb habitats
- Multiple crossings of road or trail segments in near-stream locations removes shade and may reduce large-wood recruitment

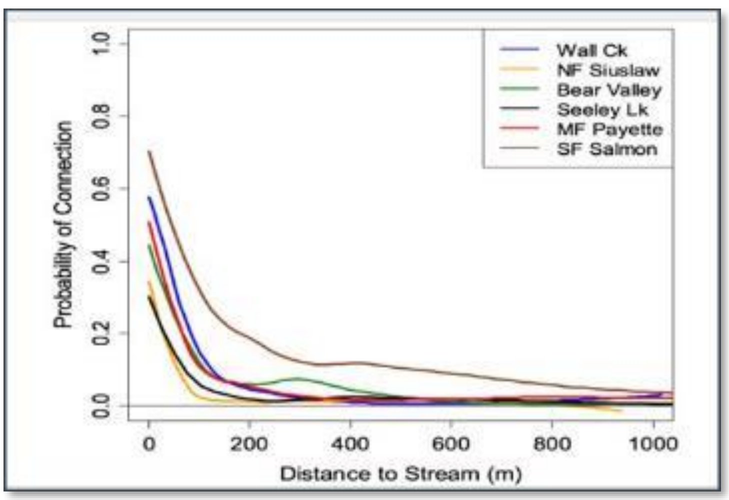
- Riparian habitats along streams are fragmented by road-stream crossings or other barriers that restrict the migration and movement of aquatic organisms

Vulnerability of Roads and Trails to Flooding Hazards and Associated Impacts

All infrastructure has inherent vulnerability to flooding damage and other stressors, such as inadequate maintenance, excessive use, and so on. If it exists on the landscape, it is vulnerable to climatic stresses. If roads or campgrounds are close to streams, their relative vulnerability is nearly always much greater, and the likelihood of environmental impacts is thus greater as well. Roads and recreation facilities within 100 feet of streams or rivers can reliably be considered high vulnerability, and roads and campgrounds within 300 feet of streams or rivers are considered as potentially high vulnerability to flood-related damage and failures. Recreation facilities, dams, buildings, and bridges are classified by proximity to mapped streams, and subwatersheds (HUC-6) (figure 9).

Proximity to streams increases sensitivity to flooding, channel migration, bank erosion, culvert and bridge failure, stream avulsion that removes sections of road, and so on.

Recent research by the Forest Service has shown that nearly all road-derived sediments delivered to streams are derived from road segments close to stream crossings (figure 14). These road segments should therefore be considered a high priority and focus for field inventory and treatments to limit hydrologic connectivity.



Most road-stream crossings use culverts rather than bridges, and culverts are generally more sensitive to increased flood peaks and associated debris. Source: Luce (unpublished, citation pending).

Figure 14. Results of GRAIP surveys

Hydrologic Connectivity

In recent years, a powerful indicator of the effect of roads on water quality and riparian/aquatic ecosystems has come into use: hydrologic connectivity, which occurs when road and ditch runoff is delivered to the natural stream channel system. Roads, and especially parking lots, can generate overland flow due to the relatively impervious surface of the road prism or parking lots and can also intercept flow at cutslopes, effectively converting slow subsurface flows to rapid surface flows. When these surface flows have a continuous flow path between the road prism and a natural stream channel, hydrologic connectivity occurs (Furniss et al. 2000). Essentially, a hydrologically connected road becomes part of the stream network.

Hydrologically connected roads (figure 15) can deliver increased runoff, sediment, and chemicals associated with roads, such as spills or oils generated on the road surface or cutslope. Hydrologic connectivity occurs when runoff from roads directly enters a watercourse. This is a simple and powerful indicator of the effect of roads on water quality and aquatic habitats. At the watershed scale, connections between roads and streams can also alter the drainage density of the watershed and change runoff frequency and magnitude (Furniss et al. 2000).

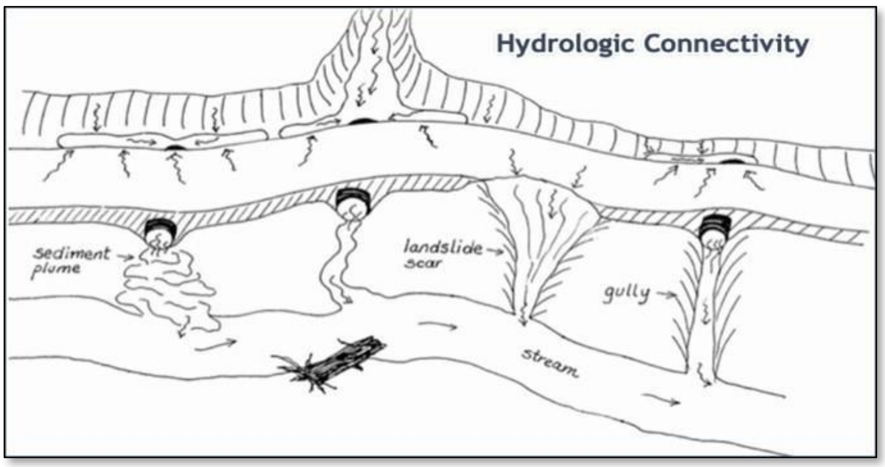
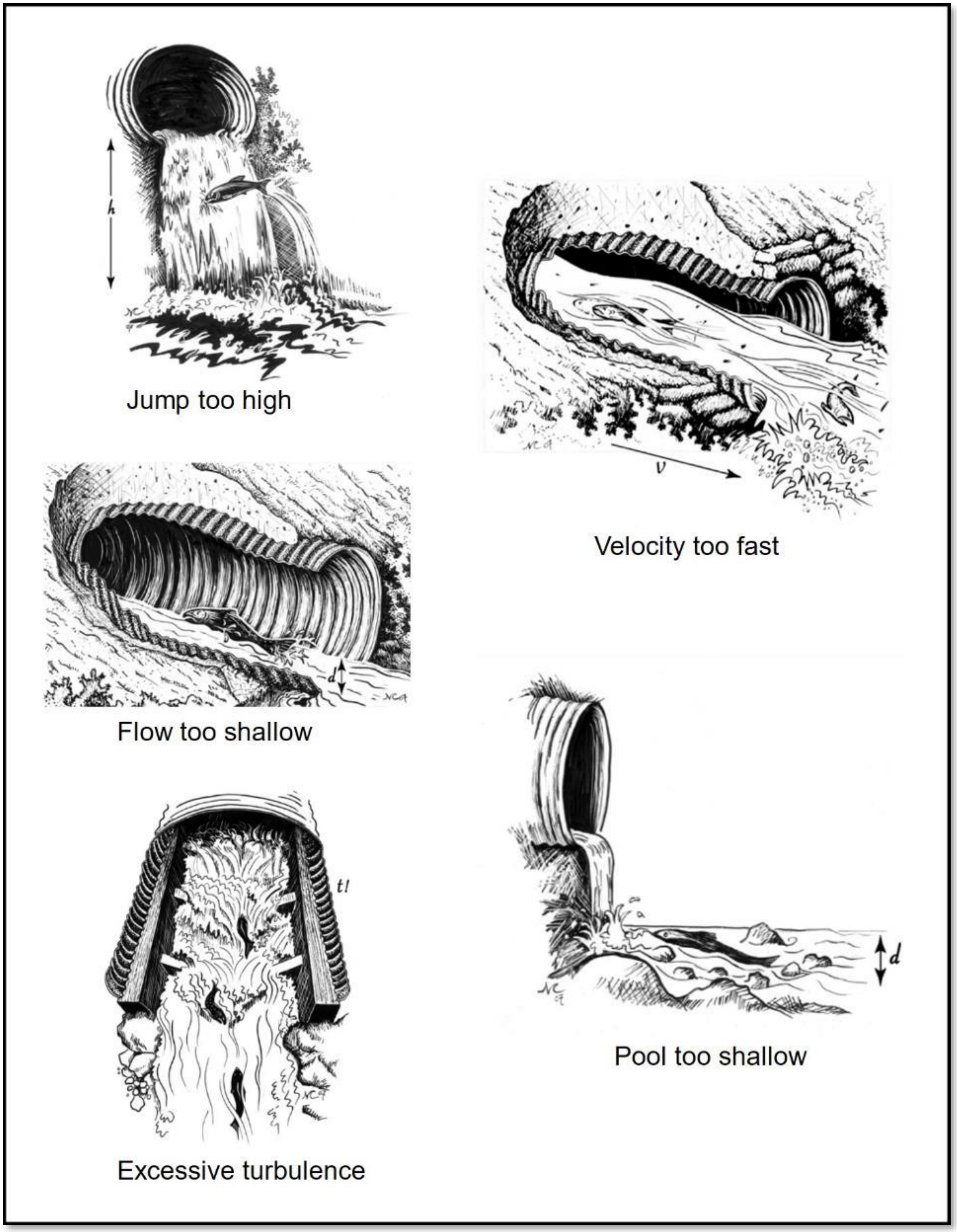


Figure 15. Schematic diagram showing hydrologically connected roads

Aquatic Organism Passage at Road Culverts

The Forest Service has an active and well-supported program of inventory, assessment, and remediation of road-stream crossings that affect the migration of aquatic organisms. (Clarkin et al. 2005). Stream crossings on the Black Hills National Forest have not yet been assessed, but local knowledge of the barriers that most effectively block or impede fish migration exists. Barriers to fish migration caused by road culverts are shown in figure 16.



Source: unpublished illustrations by N. Cabrera, A. Llanos, and M.J. Furniss, FishXing Program

Figure 16. Barriers to fish migration caused by road culverts

Inventory of Road Conditions Affecting Environmental Quality

Forestwide comprehensive field-based road inventories that enable determination of actual or likely effects of roads and trails to the environment are lacking. Because some legacy roads and trails may not be on forest cover maps, roads that are actually on the land are considered a part of the surrounding forest cover timber type. During timber sale analysis and preparation, detailed information is gathered on sale-associated roads, and appropriate repairs and upgrades are typically designed and constructed as part of the sale package.

New methods for efficient and detailed road inventory, such as the Forest Service GRAIP tools (Black et al. 2012) would provide detailed information on high- and low-impact roads and assist in prioritizing road maintenance, upgrading, use restrictions, watershed stewardship, and so on.

Vulnerability of Roads and Trails to High Temperatures

Temperature and heat influence nearly all physical and biological systems. The increase in temperature alone does not strongly affect infrastructure (with a few exceptions) but will significantly affect forest and grassland environments by changing rainfall variability, which results in increased drought, increased fire hazards and wildfire, increased insect mortality to forests, decreased snowpack, and so on.

Heat can be detrimental to paved roads and parking lots. Heat causes asphalt to expand, which increases the likelihood of cracks, potholes, and stress fractures. These let moisture in and can weaken the base course and lead to road failure, soft spots, and depressions. With the water in the base, cold weather causes freezing and expansion, contributing to more cracks and failures.

Other Temperature Effects to Infrastructure

Other temperature effects to infrastructure may include:

- Increase in very hot days, affecting visitation and increasing the burden on Forest Service staff responsible for infrastructure
- Limitations on periods of construction activity due to health and safety concerns
- Increase in frequency and duration of wildfire incident management activities
- Lengthening of the snow-free season at mid-elevation facilities, and related increases in visitor access seasons
- Increased intermittency of water supplies for campgrounds, road watering, fire suppression, and so on
- Increase in drought-related tree mortality and hazard trees in and near roads, trails, and recreation facilities
- Softening and buckling of pavements
- Thermal expansion of bridge expansion joints
- Rail–track deformities related to heating
- Longer construction seasons
- Vehicle overheating resulting in roadway incidents
- Diversion of human and financial resources for emergency restoration of access

Influence of Watershed Conditions on Peak Flows

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

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

Road and trail systems and recreational facilities are often damaged or destroyed by rainfall, snowmelt, runoff, and flooding; this is their primary vulnerability. They can be chronically damaged by runoff and/or snowmelt in sensitive locations or more catastrophically by large storms and flooding, associated landslide activity, erosion, and stream channel avulsion.

Vulnerability of Infrastructure to Extreme Climatic Events

All infrastructure has vulnerability to extreme events, especially flooding and associated erosion and mass movement. The simple presence of roads, campgrounds, dams, and facilities is a coarse-level indicator of vulnerability to damage or destruction as all infrastructure has vulnerability to extreme climatic events. However, the degree of vulnerability depends strongly on the location of the infrastructure feature to natural hazards such as active floodplains, mass movement hazard zones, and proximity to surface waters.

An aging and deteriorating roads and trails network, as evidenced by a substantial amount of deferred maintenance, increases sensitivity to climatic stressors and its consequences to people and ecosystems. This is generally in the form of degradation of drainage features, such as road surface drainage and stream crossing culverts that become obstructed. Hydrologic connectivity generally increases with inadequate maintenance of drainage features. Existing infrastructure is not necessarily designed for future conditions related to climate warming (e.g., culverts are not designed for larger peak flows).

- Roads and trails built on steep topography are more sensitive to landslides, fill failures, intercepted shallow groundwater flow, and washouts.
- A substantial portion of the transportation system is at relatively high elevations, which increases exposure to weather extremes and increases the costs of repairs and maintenance.
- Roads built across or adjacent to waterways are sensitive to high streamflows, stream migration, and sediment movement.
- Funding constraints or insufficient funds, or both, limit the ability of agencies to repair damaged infrastructure or take preventative actions to create a more robust system. As more roads/trails/bridges become damaged/impacted by weather, climate, and increased use, the competition for limited funds increases.
- Design standards or operational objectives unsuited to new climate regimes could increase the frequency of infrastructure failure in the future. Regional or Black Hills National Forest standards could be modified consistent with projected changes in climatic stressors.

Failure of Roads and Trails

Roads and trails are more likely to fail or be damaged when they:

- Are located near streams and rivers
- Cross streams and rivers
- Are built on steep, unstable slopes
- Are constructed in steep, wet areas
- Have crossings located in depositional reaches of streams or on alluvial fans
- Have diversion potential (drainage failure will result in stream capture/diversion)
- Have the potential for “cascading failure” (a failure that causes failures down-road)

- Have unstable fills and sidecast
- Are subject to diverted drainage from other roads and facilities
- Are constructed in geologic materials that are unstable, have abundant interflow (shallow drainage), or are difficult to adequately compact
- Have infrequent cross-drainage
- Are beyond their design life or actual serviceability
- Have designs that are strongly maintenance-dependent
- Have little or no regular maintenance
- Have high use without commensurate maintenance
- Are wide and intercept abundant hillslope drainage
- Are subjected to loads beyond design capacity

Roads located in valley bottoms tend to have the greatest impacts to water and riparian habitats and are more vulnerable to damage from flooding, while roads located on ridgetops tend to have fewer impacts and are less vulnerable to flooding. Campgrounds and other recreational facilities near streams—an often-preferred location—are vulnerable to flooding hazards (figure 17).

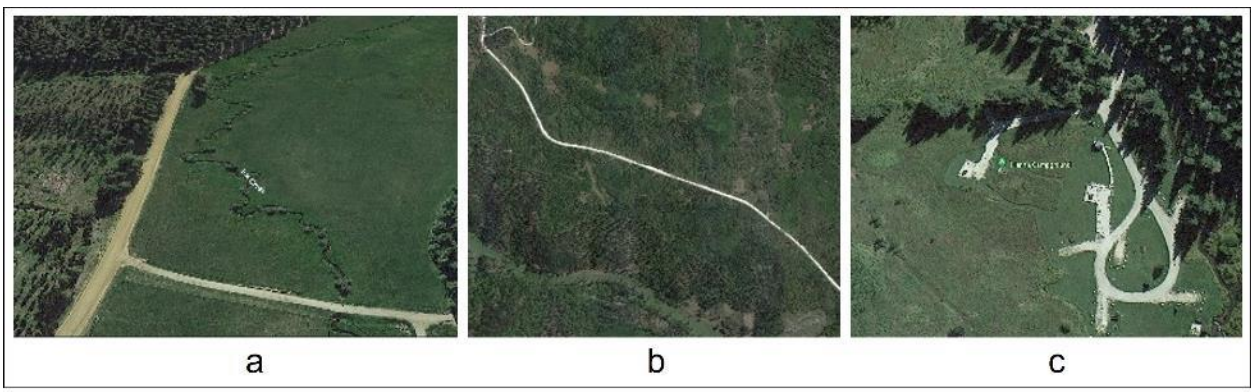


Figure 17. A road located in a valley bottom (a) and on a ridgetop (b), and a campground near a stream (c)

Campgrounds and Developed Recreation

Factors that contribute to the vulnerability of campgrounds, picnic areas, and other developed recreational facilities:

- Are located near lakes, streams, and rivers
- Have facilities that attract public use in areas subject to flooding or landslides, or both
- Are reached by roads or trails that are vulnerable
- Are in locations where changes in snow affect use, drainage, snow-removal, groundwater, drinking water quality, and other related activity
- Offer little or no shade to provide respite from extremes of hot weather
- Have high fuel loading and wildfire vulnerability
- Have high use and overnight use in floodplains creating flash flood hazards to visitors

- Have large amounts of unaddressed maintenance needs of recreation buildings and general recreation features (e.g., signs, interpretive panels, picnic tables, fire rings and other amenities, and so on)
- Have outdated designs and configurations that are not suitable for current vehicle sizes and configurations.

Dams

- Inadequate safety provisions
- Inadequate spillways for extreme storms
- Inadequate structural integrity against aging and extreme events
- Subject to cracking or failure caused by earthquakes, extreme flooding, or landslides
- Subject to new hydrologic regimes in areas where snowfall and snowpack are declining, or where vegetation changes result in hydrologic changes

Facilities (Buildings)

- Are accessed by roads or trails that are vulnerable
- Are located near streams or rivers and subject to flooding
- Are in areas subject to landslide hazards
- Have a high risk of damage or destruction by wildfire
- Older buildings that are poorly insulated
- Have inadequate ventilation
- Have substandard plumbing or plumbing not protected from weather
- Are in locations that are subject to loss or changes due to climatic extremes
- Have outdated and inefficient heating/ventilation/air conditioning (HVAC) systems
- Have inefficient lighting systems (interior and exterior)
- Some lack fire suppression systems where not required by code
- Have equipment and services that are near, at, or past end of typical service life (roofs, siding, windows, doors and locks, plumbing, HVAC, electric, fixtures and furnishings, floor/wall/ceiling coverings, and so on)
- Have exterior improvements that are near, at, or past end of typical service life (parking lots, exterior lights, fences, sidewalks, signage, and so on)
- Have a high backlog of unaddressed maintenance needs (deferred maintenance)
- Are in locations that are subject to loss or changes due to climatic extremes

Chapter 4. Current Planning and Assessment Context for Infrastructure

Land and Resource Management Plan

The Black Hills National Forest is currently managed under a 2006 amendment to the Land and Resource Management Plan for the Black Hills National Forest March 2006, also referred to as the forest plan. The forest plan includes goals and objectives, Forestwide standards and guidelines, management area direction, and a monitoring and evaluation strategy.

Forestwide Travel Analysis

A Forestwide travel analysis was completed provides broad and detailed analysis and related set of decisions encompass a wide range of considerations for the effects and uses of all roads on the Black Hills National Forest. The analysis is based on the publication *Roads Analysis: Informing Decisions About Managing the National Forest Transportation System* (USDA Forest Service 1999).

The Forestwide Travel Analysis is an assessment of roads and trails on the Black Hills National Forest. Because it is nearly 15 years old as of this writing, some of the data and contexts will have changed to some degree, but much of this analysis is still valid and valuable.

Relevant Excerpts from the Forestwide Travel Analysis

The following information is excerpted from the Forestwide Travel Analysis.

Objective of the Analysis

… Travel Analysis Process (TAP) addresses the transportation system within the boundaries of the Black Hills National Forest (BHNF or the Forest), evaluating the existing condition of the system and identifying management opportunities. Recommendations for action apply only to those lands that fall within the boundary of the BHNF. This analysis considers social, cultural, economic, and ecosystem components that may overlap jurisdictional boundaries, but that could be affected by the actions taken on National Forest System (NFS) lands.

Specifically, the objectives of the Travel Analysis Process are to:

- *Provide basic road information to support project and Forest-level decision-making.*
- *Identify the minimum road system needed for access and administration of the Forest*
- *Identify changes to current transportation system.*
- *Identify proposed system designated for pubic motorized use.*

1.2 SCALE OF THE ANALYSIS

This travel analysis will be conducted at a National Forest scale. The analysis concentrates on Maintenance Level (ML) 1 and 2 roads, motorized trails, areas and unauthorized routes. Maintenance Level 3, 4, and 5 roads were addressed in a Forest-Wide Roads Analysis Report in 2005. Existing information is used in conjunction with new significant public input.

…The BHNF, with its numerous private, residential, and tourism-related inholdings, is one of the most developed forested areas in the nation (USDA-Forest Service 1996a). Within the proclaimed National Forest boundary, approximately 19 percent of the land is privately owned with entire towns, (e.g., Custer, Hill City, Keystone, Lead, and Deadwood) located within the

Forest. Custer State Park, Mount Rushmore National Memorial, Wind Cave National Park, Mickelson Trail, and Jewel Cave National Monument are under other jurisdictions but are located within or are adjacent to the Forest. As a result, Forest roads in the BHNF exist within a network of roads included under the jurisdiction of Federal, State, County and private entities.

2.2 EXISTING TRANSPORTATION SYSTEM

2.2.1 General Description

Beginning in the 1880s, railroads and stagecoach lines were built to accommodate the thousands of people who were coming to the Black Hills in response to the discovery of gold. An extensive rail system was developed to haul mining timbers from the forest to the mines. Large tracts of forest were cut in order to provide timber to the growing mining industry and to provide housing for the people living in the Black Hills. In 1897, the Black Hills Forest Reserve was established, and in 1898 the first timber sale was sold to Homestake Mining Company. By the 1920s, a major highway system was developed and a Forest Road System was initiated. Tourism also justified the construction of a transportation system that was adequate for automobiles, which during the 1930s was augmented by the Civilian Conservation Corps (CCC). Subsequent years have seen further augmentation providing a well-spaced, efficient system of roads of all maintenance levels for many different users.

The transportation system currently in place within the Forest is a result of the historic uses described above and the public's expectation that the Forest is available for their use through an extensive road system. The area has since been extensively managed for timber production, livestock grazing, mining activities, big game hunting, wildlife, insect and disease risk, fuels; and for recreational activities along roads and trails that include hiking, horseback riding, mountain bike riding, off-road vehicle use and snowmobile riding.

Most of the BHNF goals within the 1997 Land and Resource Management Plan (LRMP) pertain in some fashion to the transportation system:

> *Goal 1. Protect basic soil, air, water and cave resources.*
>
> *Goal 2. Provide for a variety of wildlife through management of biologically diverse ecosystems.*
>
> *Goal 3. Provide for sustained commodity uses in an environmentally acceptable manner.*
>
> *Goal 4. Provide for scenic quality, a range of recreational opportunities, and protection of heritage resources in response to the needs of the BHNF visitors and local communities.*
>
> *Goal 5. In cooperation with other landowners, strive for improved landownership and access that benefit both public and private landowners.*
>
> *Goal 6. Improve financial efficiency for all programs and projects.*
>
> *Goal 7. Emphasize cooperation with individuals, organizations, and other agencies while coordinating planning and project implementation.*
>
> *Goal 8. Promote rural development opportunities.*
>
> *Goal 9. Provide high-quality customer service.*
>
> *Goal 10. Establish and maintain a mosaic of vegetation conditions to reduce occurrences of catastrophic fire, insect, and disease events, and facilitate insect and disease management and firefighting capability.*

Goal 11. Enhance or maintain the natural rate of recovery after significant fire and other natural events while maintaining a mosaic of fuel-loading conditions to facilitate future fire suppression activities.

Watershed Condition Assessment

Please refer to the *Soil and Water* assessment for more detail.

In 2010, every national forest and grassland in the United States completed a Watershed Condition Assessment at the subwatershed (HUC-6, about 10,000 to 40,000 acre) scale. This was conducted using a national watershed condition model that rated various factors influencing watershed conditions. The model was based on 12 watershed condition indicators, each consisting of multiple attributes. Each attribute was rated as good, fair, or poor for each subwatershed on the basis of 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 (USDA Forest Service 2011). Results of the Watershed Condition Classification for the Rocky Mountain Region are shown in figure 18 and for the Black Hills in figure 19.

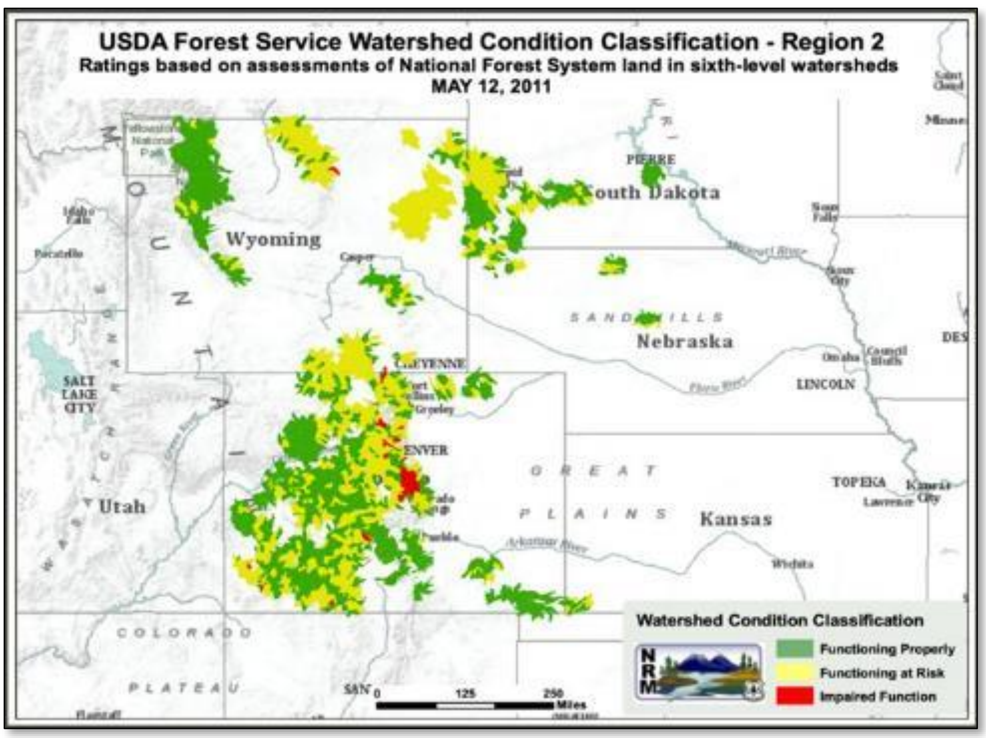


Figure 18. Results of the Watershed Condition Classification for the Rocky Mountain Region

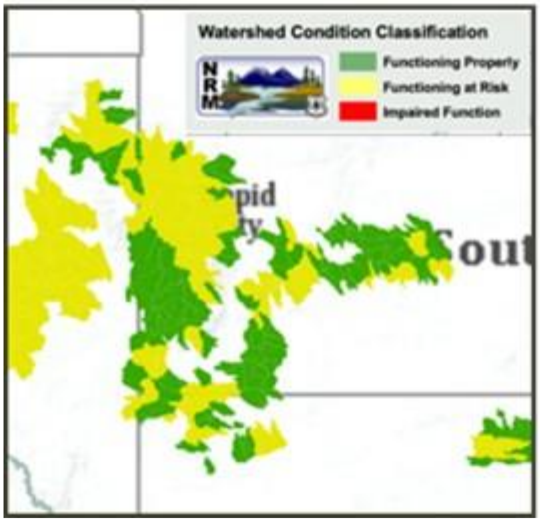


Figure 19. Results of the Watershed Condition Classification clipped for the Black Hills National Forest

Best Management Practices and Monitoring

Implementing, monitoring, and improving practices for water quality management and watershed health are central to land stewardship. The publication *National Best Management Practices for Water Quality Management on National Forest System lands, Volume 1: National Core BMP Technical Guide* (USDA Forest Service 2012) provides a set of best management practices (BMP) for most aspects of forest management, including roads, trails, and recreation. A system of BMP monitoring protocols (USDA Forest Service 2022a) based on a core set of national best management practices has been implemented. These technical guides that contain national directives and data management structures should be used in new planning efforts, National Environmental Policy Act (NEPA) analysis, design, implementation, maintenance, and evaluation of proposed activities, particularly if projects affect water resources.

Regionwide Vulnerability Assessment

A regional infrastructure climate change vulnerability assessment was conducted in 2016.

Natural Resource Manager and other Forest Service Databases

The Forest Service has implemented a wide range of databases (USDA Forest Service 2022b) to track the conditions of, investments in, and activities within national forests. The Natural Resource Manager (NRM) database is used to track infrastructure.

2019 Facilities Master Plan for the Black Hills National Forest

The Facility Master Plan, available at the Black Hills National Forest Supervisor's Office, covers fire, administration, and other facilities, quarters, lookouts, communications towers, water/wastewater systems, and dams. The latest version was signed in August 2019. This plan lists all non-recreational facility assets, with general planning to address the needs of current and future facilities.

Chapter 5. Potential Need for Plan Changes to Respond to Infrastructure Issues

- Prioritize subwatersheds for detailed inventory and analysis of road problems and risks.
- Consider limitations on total road length and density by subwatershed.

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