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# Black Hills National Forest

## Revised Forest Assessment:

## Aquatic, Riparian, and Groundwater-Dependent Ecosystems

Hikers exploring Little Spearfish Trail, Black Hills National Forest (photo courtesy of the USDA Forest Service).

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# Chapter 1. Introduction

The Black Hills National Forest is managed by the U.S. Forest Service (USFS), an agency of the U.S. Department of Agriculture (USDA). The mission of the USFS is to sustain the health, diversity, and productivity of the Nation's forests and grasslands to meet the needs of present and future generations. The National Forest Management Act requires all National Forests to develop a land management plan (forest plan) to guide management actions and decisions. The National Forest Management Act requires those forest plans be periodically updated. The current forest plan for the Black Hills National Forest was approved in 1997. Substantial plan amendments were last approved in March 2006, and minor amendments occurred through 2018. The latest version can be found on the Black Hills National Forest website (USDA Forest Service 2006).

In order to revise the current forest plan, the Black Hills National Forest has identified and evaluated existing information about relevant ecological, economic, and social conditions, as well as trends, and sustainability and how those conditions relate to management direction in the forest plan. This assessment report documents findings for aquatic, riparian, and groundwater-dependent ecosystems.

## Aquatic, Riparian, and Groundwater-Dependent Ecosystems on the Black Hills National Forest

Aquatic, riparian, and groundwater-dependent ecosystems are quite productive and biologically diverse lands on the Black Hills National Forest and provide living conditions for a greater variety of aquatic and terrestrial wildlife than any other habitat type (Montgomery 1996). The quality and extent of these riparian/wetland habitats have a direct influence on the associated aquatic ecosystem that is home to fish and amphibians and support the upland terrestrial ecosystem.

This document is an assessment of the current known aquatic, riparian, and groundwater-dependent ecosystems in the Black Hills National Forest, which comprises the "plan area." These are the ecosystems dependent on accumulations of surface water or access to groundwater, whether via a shallow water table, plant roots that can access shallow groundwater, or springs that discharge groundwater at the surface. In general, these areas tend to support diverse living communities distinct from the surrounding terrestrial areas that depend solely on precipitation and surface water runoff. For this assessment, these ecosystem types are as follows:

- Aquatic ecosystems include the biotic communities that inhabit lakes, ponds, rivers, and perennial streams. Due to their size and accessibility, they offer a dependable source of water for living organisms.
- Riparian ecosystems include the unique mix of flora and fauna that flourish at the interface between aquatic and terrestrial ecosystems.
- Groundwater-dependent ecosystems include a wide range of plants and animals supported by access to groundwater. The water-based features supporting these ecosystems include springs and seeps, caves and karst systems. In many cases, rivers, wetlands, and lakes are also considered groundwater-dependent ecosystems. Where groundwater meets the surface, unique communities of plants and animals may be present, including endangered or threatened species.

In this document, groundwater-dependent ecosystems are further categorized by depth of the water source and include (a) subsurface systems that reside within groundwater, consisting of caves, karsts, and aquifers that can occur well below the surface and are not reached by surface vegetation; (b) shallow water table deep rooted ecosystems of vegetation that depend on a constant subsurface source of water; and (c) discharge ecosystems including springs, fens, marshes, and wet meadows, as well as groundwater-

dominant slow moving and fast running systems. In discharge systems groundwater reaches to within one foot of the ground surface during part or all of the year.

The Black Hills National Forest Land and Resource Management Plan (forest plan) provides conservation and protection measures for streams and wetlands encompassed in the plan area (USDA Forest Service 2006). It states the Black Hills National Forest will be managed so the rivers, streams, wetlands, lakes, riparian areas, and caves of the plan area reflect healthy functioning ecosystems.

While rivers, streams, and wetlands are essential components of watersheds, consideration of the landscape at the watershed scale is not included as part of this document. Please see the *Forest Plan Assessments: Soils and Watersheds* for the watershed assessment. Similarly, while the living communities of ecosystems featured in this assessment are comprised of myriad plant and animal species, detailed information for specific at-risk species can be found in the *Forest Plan Assessment: At-Risk Species Status*.

# Chapter 2. Conditions and Trends

This chapter presents a discussion of the constituent elements of aquatic, riparian, and groundwater-dependent ecosystems of the Black Hills National Forest and an assessment of the current conditions and trends based on available data.

## Best Available Scientific Information

This assessment was prepared based on scientific data, reports and prior analyses provided by the Black Hills National Forest. Internet searches of publicly available information provided additional resources. To the extent possible, reasonable efforts to verify that the information used here represents the best publicly available, science-based evidence. Data gaps are identified when science-based data was not available.

## Data Gaps Identified

Data gaps were identified during the process of drafting this assessment – data and information that would add to the understanding or reduce uncertainty about conditions and trends related to aquatic, riparian, and groundwater-dependent ecosystems. The overall status of rare aquatic, riparian, and groundwater ecosystems is unclear, which is primarily due to the lack of multi-year watershed scale monitoring. Discrete trends are available from plant species monitoring reports; however, these efforts do not consider the forest-wide processes and the relative condition of these systems. A group of watershed studies of regionally significant systems would help to understand the state and trends of aquatic and riparian systems, as well as the influence of watershed-scale processes on receiving bodies of water. Specifically, the following data gaps/needs:

- An updated assessment of watersheds utilizing the Watershed Condition Framework (USDA Forest Service 2011).
- Inventory, classification, and assessment of riparian systems, predictive modeling of riparian areas and wetlands using the Riparian Solutions national mapping model for Riparian Buffer Delineation Model developed by USDA and partners.
- Data on the effects that private land development has on groundwater recharge in the national forest.
- Information on the impacts that large storm systems have on riparian systems of the Black Hills National Forest.

The continuation of these current efforts would aid management of the ecosystems considered in this report:

- Continuance and consolidation of Forest inventory and mapping of springs, streams, and wetlands updated into the national datasets (USGS National Hydrography Dataset (NHD) and USFWS National Wetlands Inventory (NWI))
- Continuation of inventory and assessment of peatland ecosystems and assessment of conditions and stressors.
- Continuation of groundwater-dependent ecosystem inventories (full Level 1 and Level 2).
- Floristic inventory of wetland and riparian plant species.

# Overview of Aquatic, Riparian, and Groundwater-Dependent Ecosystems

## Aquatic Ecosystems

Prior assessments and forest plans have distinguished two main types of aquatic ecosystems in the Black Hills National Forest: lake ecosystems and stream ecosystems.

### *Lakes and Reservoirs*

There are 38 named lakes, ponds, and reservoirs among the approximately 808 surface waterbody features within the Black Hills National Forest (U.S. Geological Survey [USGS] 2021); however, it is important to note virtually all of the lakes are in fact reservoirs created by humans by impounding water behind dams and other structures that allow for control of the water levels and outflow. The Black Hills National Forest maintains a database of known waterbodies, which includes water features not listed in the USGS NHD database. Total surface area of reservoirs within the Black Hills National Forest is approximately 2,000 acres, and the major waterbodies (i.e., greater than 100 acres) include Angostura Reservoir, Pactola Reservoir, Sheridan Lake, Deerfield Lake, and Stockade Lake. Due to their size and depth, large and deep reservoirs (such as Pactola and Deerfield reservoirs) are typically more resilient to fluctuations in temperature, dissolved oxygen, pollution inputs and sedimentation rates than smaller lakes and reservoirs such as Sheridan and Angostura reservoirs. The recreational fisheries in these waterbodies are managed by the respective states and a description of these practices is below:

- Sheridan Lake is managed by The Forest Service and is in part driven by the goal of maintaining "cold water permanent fisheries." The South Dakota Department of Agriculture and Natural Resources (SD DANR) defines cold water permanent fisheries as waters capable of supporting aquatic life and permanent populations of cold-water fish (SD Department of Environment and Natural Resources 2005).
- Pactola and Deerfield are managed by the U.S. Bureau of Reclamation (USBR) and manages releases to provide for irrigation needs, domestic water supply, as well as cold water permanent fisheries (USDA Forest Service 2005a).
- Angostura Reservoir is also managed by USBR and operated by the Angostura Irrigation District. Although this reservoir is not on USFS managed lands, it is adjacent to USFS managed lands and a receiving body from USFS lands.
- Stockade Lake is managed for cold water and warm water species by South Dakota Game, Fish, and Parks (SDGFP).

In addition, there are other lakes present in the Black Hills National Forest such as Cook Lake in Wyoming, and forty-seven smaller lakes and ponds in the South Dakota portion of the Black Hills National Forest are stocked and managed for trout (SDGFP 2020).

### *Streams*

There are over 3,500 miles of drainages within the plan area, with an estimated 950 miles of perennial streams within the boundaries of the Black Hills National Forest. Major river and stream systems include Spring Creek, Beaver Creek, Stockade-Beaver Creek, Spearfish, Creek, Bear Butte Creek, Rapid Creek, Battle Creek, Elk Creek, and French Creek, with most surface drainage features draining from west to east. All Black Hills streams eventually drain into either the Belle Fourche River in the north, or the Cheyenne River in the south (USDA Forest Service 1996).

One feature of particular significance to watershed management is the diminution or complete disappearance of flow where streams cross limestone sedimentary formations (Brown 1944, Orr 1975). These channel segments are recharge zones to aquifers, which can be an important ground-water sources. At the same time, the diminution or disappearance of flow means that surface water yields can be significantly increased only in areas upstream from the loss zones—except in the case of floods or other high flows.

Most streams, when at their base flow level, go completely dry downstream of where they cross the Minnelusa and Madison outcrops (Carter et al. 2002, Carter et al. 2003, USDA Forest Service 2005a). Only Rapid Creek, Whitewood Creek, and Spearfish Creek consistently maintain perennial flows through the loss zone on the South Dakota portion of the Forest (Carter et al. 2002a). Many miles of Forest streams disappear during drought cycles. The major flow loss zones include Box Elder Creek (50 cubic feet per second (cfs)), Spring Creek (28 cfs), Spearfish Creek (23 cfs), Grace Coolidge Creek (21 cfs), Elk Creek (19 cfs), False Bottom Creek (15 cfs), Highland Creek (10 cfs), and Rapid Creek (10 cfs). Stream sections below these loss zones are often dry because the amount of loss exceeds stream inputs (SDGFP 2020).

As reported in the *Soils and Watersheds Assessment*, ninety-five sub-watersheds that lie either completely or partially in the Black Hills National Forest were evaluated in 2010 using the Watershed Condition Framework (USDA Forest Service 2011). The Watershed Condition Framework is a 12-indicator model that considers both aquatic and terrestrial physical and biological indicators and rates each watershed as functioning properly (class 1), functioning at risk (class 2), or impaired function (class 3) according to a standardized rule set. Under this framework, watersheds that are classified as “functioning properly” provide a high degree of biotic integrity, are resilient, exhibit a high degree of connectivity longitudinally along a stream as well as across the floodplain, provide ecosystem services, and maintain long-term soil productivity. A watershed classified as “functioning at risk” is in fair condition with moderate water quality problems, various dams and diversion facilities, and moderate habitat fragmentation. Forty-three sub-watersheds on the Black Hills National Forest were considered functioning properly in 2010, with the remaining fifty-two sub-watersheds classified as functioning at risk. There were no impaired function sub-watersheds identified on the Black Hills National Forest (USDA Forest Service 2021). Also as reported in *the Soils and Watershed Assessment*, aquatic habitat condition and aquatic biota condition was considered good in more than half of the sub-watersheds. Riparian and wetland vegetation condition was rated as good condition in only 4 percent of the sub-watersheds (USDA Forest Service 2011). The ratings were updated on four sub-watersheds in 2015 and 2016 (the ratings on those four watersheds remained functioning at risk), but more updates are needed, as monitoring data indicate there has been an improvement in riparian vegetation conditions (discussed further below), but there has also been an increase in the amount of invasives on the forest. Sediment, bed and bank stability, and temperature are among the primary components of concern to all streams located in the plan area (USDA Forest Service 2010a).

### *Biotic Communities within Aquatic Ecosystems*

Fish communities in the lakes and streams of the Black Hills National Forest can be grouped into the following broad categories: native/indigenous species, cold-water trout species, warm-water game species, and invasive species. Native fish species include suckers, chubs, and dace (Bailey and Allum 1962). Trout were not present in the Black Hills prior to European settlement but have been stocked since the late 1800s and are now abundant in many of the lakes and streams that provide consistent flow and appropriate habitat (Barnes 2007). Trout species include brown (*Salmo trutta*), brook (*Salvelinus fontinalis*), rainbow (*Oncorhynchus mykiss*), cutthroat (*Oncorhynchus clarkia*), lake (*Salvelinus namaycush*), and tiger (*Salmo trutta x Salvelinus fontinalis*). Warm-water game species have also been introduced, propagated, and managed to provide fishing opportunities. Warm-water species include smallmouth bass (*Micropterus dolomieu*), largemouth bass (*Micropterus salmoides*), walleye (*Sander vitreus*), black crappie (*Poximus nigromaculatus*), bluegill (*Lepomis macrochirus*), yellow perch (*Perca flavescens*), and northern pike (*Esox lucius*).

The South Dakota Department of Game, Fish and Parks South Dakota Natural Heritage Program has listed the following native fish species as species of greatest conservation concern: mountain sucker (*Catostomus platyrhynchus*), longnose sucker (*Catostomus Catostomus;* also listed as threatened by the state of South Dakota), lake chub (*Couesius plumbeus*), and finescale dace (*Chrosomus neogaeus;* also listed as endangered by the state of South Dakota).

Invasive species are present in the aquatic ecosystems of the Black Hills National Forest. Didymo (*Didymosphenia geminata*) is known to be present in Rapid Creek and a portion of Castle Creek. Curlyleaf pondweed (*Potamogeton crispus*) is classified by the Black Hills Invasive Plant Partnership as Class C, meaning it is established in the region. These and other invasive species are further discussed in the stressors section below and in further detail in the *Assessment: Insects, Diseases, and Invasive Species*.

## Riparian Ecosystems

Riparian ecosystems are defined in this assessment as those areas situated adjacent to rivers, lakes, and streams. These systems are characterized by periodic flooding that reorganizes sedimentary soils and provides a seed bed for various riparian plant species. Riparian ecosystems are comprised of a variety of tall and low deciduous trees, shrub species and herbaceous plants. Additional phreatophytic plant communities are addressed in the groundwater-dependent ecosystems section.

The Phase II forest plan amendment noted riparian areas account for approximately 1 percent of all lands within the administrative boundary of the forest, with about 70 percent of the riparian acres occurring on National Forest System Lands. Riparian areas on the forest vary ranging from sedge/grass/forb communities to shrub/deciduous/tree communities. The biotic community varies across the stream systems in the plan area with high gradient first and second order streams supporting lower stature floodplain forest consisting of an of various willow species (*Salix* spp.), American elm (*Ulmus americana*), green ash (*Fraxinus pennsylvanica*), boxelder (*Acer negundo*), American hophornbeam (*Ostrya virginiana*), hackberries (*Celtis* spp.), with scattered occurrences of bur oak (*Quercus macrocarpa*). Some sites may include of coniferous species including ponderosa pine (*Pinus ponderosa*) and white spruce (*Picea glauca*). Stands of eastern cottonwood (*Populus deltoides*) were formerly common along lower gradient stream systems, however these habitat types have undergone significant declines (Hoffman and Alexander 1987). Stands of Scouler's willow (*Salix scoulerlana*) may occur between transition zones from riparian to upland areas.. Back channels, also referred to as oxbows and cut-off meanders, and other wetlands support emergent wetland-obligate species. Common species in

wetter sites that overlap with aquatic areas include arrowheads (*Sagittaria* spp.) bulrush (*Schoenoplectus* spp.), bur-reed (*Sparganium* spp.), sedges (*Carex* spp.), and cattails (*Typha* spp.).

Outside of floodplains, forests of quaking aspen (*Populus tremuloides*) and birch (*Betula* spp.) are located where groundwater produces adequate soil moisture to support deciduous trees. Riparian hardwood species include paper birch (*Betula papyrifera*), Paper birch are often found in association with quaking aspen over burn scars, which may colonize smaller stream and drainage areas. High elevation riparian areas contain willows and water birch (*Betula occidentalis*). The general elevation threshold between 4,000 and 6,240 feet may contain mixed stands of oak, ash, box elder, elm, and hawthorn (*Crataegus* spp.). Lower elevation riparian shrublands contain western snowberry (*Symphoricarpos occidentalis*), gooseberries and currants (*Ribes* spp.), and rose (*Rosa* spp.), with silver sagebrush (*Artemisia cana*) occurring on floodplains (Hoffman and Alexander 1987).

Riparian areas support many wildlife species including native grazing ungulates such as Rocky Mountain elk (*Cervus elaphus nelsoni*), white-tailed deer (*Odocoileus virginianus dakotensis*) and mule deer (*Odocoileus hemionus*). Merriam's Turkey (*Meleagris gallopavo merriami*) are associated with aspen and paper birch habitats.

Aspen and paper birch habitats support MacGillivray's warbler (*Oporornis tolmiei*), ovenbirds (*Seiurus aurocapillus*), western tanager (*Piranga ludoviciana*), chipping sparrows (*Spizella passerina*), Swainson's thrush (*Catharus ustulatus*), dusky flycatcher (*Empidonax oberholseri*), warbling vireo (*Vireo gilvus*), American robins (*Turdus migratorius*), mountain bluebird (*Sialia currucoides*), black-capped chickadee (*Parus atricapillus*), northern flickers (*Colaptes auratus*), downy woodpecker (*Picoides pubescens*), hairy woodpeckers (*Picoides villosus*), and red-naped sapsucker (*Sphyrapicus nuchalis*) (Shepperd 2002).

### *Unique Riparian and Wetland-Supported Vegetation Communities*

Vegetation communities within the Black Hills National Forest are regionally distinct by definition and occur in a region that is otherwise primarily composed of grasslands. The Black Hills primarily lie within the Middle Rockies (6.2) Level III Ecoregion, which is a dry-domain, temperate-steppe ecoregion, and is unique enough to require its own province type: M334 Black Hills Coniferous Forest Province. The Black Hills are surrounded by, and a small portion of the Black Hills National Forest is within, the Northwestern Great Plains (9.3) Level III ecoregion (Omernik 1987). The essential feature of a dry climate is that annual evaporative water loss is greater than what is received from precipitation (Bailey 1995). As a result, the availability and dependence on groundwater is a driving force of ecosystem development and sustainability throughout the plan area.

The dependence on groundwater partially stems from the Black Hills National Forest's lack of slow melting winter snow that provides surface water throughout summer months in other parts of the west. Numerous streams and subsurface waterways originate flow radially away from the forest into the surrounding landscape, although most major streams flow west to east, with the exception of those streams located in the Bearlodge Ranger District.

This portion of the Black Hills National Forest in Wyoming covers less than 5 percent of the state but contains 38 percent of the vascular plant species in the state (Fertig and Oblad 2000). Moreover, the aquatic, riparian, and groundwater-dependent ecosystems within the Black Hills National Forest are more likely to support rare plant species. In general, riparian and associated aquatic ecosystems support a higher level of biodiversity as compared to adjacent upland areas (Goebel et al. 2003). Several rare plant and animal species have been identified in association with these ecosystems and are addressed elsewhere. Monitoring of USFS Region 2 sensitive species and species of local concern is ongoing on the Black Hills National Forest. A review of these monitoring reports indicates the ecosystems supporting these species are stable with local grazing and off-highway vehicle (OHV) use causing degradation at some sites (USDA Forest Service 2010b).

## Groundwater-Dependent Ecosystems

In addition to the aquatic and riparian ecosystems described above, the Black Hills National Forest also supports a variety of inland freshwater groundwater-dependent ecosystems (table 1). These include ecosystems that are formed entirely underground or that require the above surface features such as springs and wetlands. They include the ecosystems that develop due to groundwater presence, those that are entirely dependent on groundwater (obligate), and to those that can survive fluctuating water amounts (proportional dependency; Eamus et al. 2016). The groundwater-dependent ecosystems and associated wetland and riparian ecosystems supported by ground water are critical components of Rocky Mountain and Great Plains landscapes. These ecosystem areas occur at all elevations and latitudes and provide a number of economic and ecological functions. They are critical as wildlife habitat and as centers of biodiversity, and these ecosystems support many unique biogeochemical, physical, and ecological processes (Gage and Cooper 2013).

**Table 1. Groundwater-dependent ecosystem categories in the Black Hills National Forest plan area**

| Groundwater-Dependent Ecosystem Categories | Location and Water Dependence | Examples in the Plan Area |
|---|---|---|
| Subsurface | Karst and Aquifers are obligate ecosystems occurring below the surface and may convey waters to the surface at specific locations. | Deadwood, Madison, Minnelusa, Minnekahta, and Inyan Kara Aquifers |
| Phreatophytic | Phreatophytic Ecosystems depending on shallow subsurface groundwater occurring close enough to the surface for vegetation with deep tap roots to reach but does not reach the upper foot of the ground surface. | Vegetation communities whose root systems obtain water from the groundwater or the soil above groundwater. Includes some riparian systems. |
| Discharge | Surface water ecosystems that depend on groundwater that reaches or comes within one foot of the ground surface. | Springs, peatland, wetlands, lakes, streams, and riparian habitats |

Source: Eamus et al. 2016, USDA Forest Service 2012.

### *Subsurface*

#### *Karst Ecosystems*

An extensive network of caves has formed beneath the Black Hills National Forest, a result of the presence of water-soluble rocks in the rock layers below. As water falls on the surface, it enters the subsurface through cracks, fractures, and holes. There, it further dissolves soluble rock and can carve out enlarged flow paths, creating karst systems that includes caves (Palmer et al. 2016). The most well-known caves of the Black Hills region are Jewel and Wind Caves located in the water worn rocks of limestone and dolomite that comprise the Madison Formation (Palmer 2016). Jewel Cave contains 210 miles, and Wind Cave contains 149 miles of mapped passages. They are the third and sixth longest known caves in the world. While these two features are not managed by the Forest Service, impacts on them are considered during planning because of the underground linkages between karst resources under the Forest Service's purview and the National Park Service management of Jewel and Wind Caves.

Karst ecosystems are delicate and finite. It is assumed that the formation of new caves has slowed in the recent age and protection of caves like Jewel and Wind Cave is essential to their longevity. Threats related to karst ecosystems include groundwater contamination (Whallon and Crawford 1985).

The Black Hills National Forest has identified potential karst features within the forest via LIDAR (Light Detection and Ranging), a remote sensing method. Those features are routinely ground-verified during project design, with a standard 100-foot no-disturbance buffer for feature protection during project implementation, but that design feature is not included in the current forest plan.

### *Aquifers*

The Black Hills is a major recharge zone for several aquifers, including the Deadwood, Madison, Minnelusa, Minnekahta, and Inyan Kara aquifers. Aquifers primarily receive recharge from infiltration of precipitation, and the Madison and Minnelusa aquifers also receive substantial recharge from streamflow losses (Carter et al. 2003). A Precambrian aquifer is also present at the deepest layers of geologic formation. Major aquifers are associated with the Limestone Plateau and outcrops along the Hogback encircling the Black Hills region, (such as the Madison and Minnekahta aquifers); and the Precambrian aquifers are associated with the granite and metamorphic central core of the Black Hills.

In South Dakota, approximately 52 percent of the public drinking water systems rely solely on ground water and approximately 74 percent of South Dakota's citizens use ground water as their source of drinking water (Iles 2008). The South Dakota Department of Agriculture and Natural Resources (SDDANR) Drinking Water Program's mission is to protect public health and the environment. In Wyoming the Department of Environmental Quality, Water Quality Division works to keep Wyoming's water clean by monitoring and protecting surface- and groundwater in the state, while the Wyoming State Engineer's Office permits the appropriation of water within the state. According to SDDANR Drinking Water Program, approximately 150 public drinking water systems in the Black Hills National Forest exist. The majority of these public water systems are privately owned and operated. Most feed campgrounds, summer camps, horse and other recreational camps, ranches, and stores. Several small municipal water systems exist as well (SDDANR 2021). Because shallow water aquifers are used extensively for drinking water supplies, a primary concern is groundwater quality. A study of groundwater flow, quality, and mixing in relation to Wind Cave National Park conducted in 2007–2010 to evaluate water-quality issues and to determine sources of groundwater contamination that may affect drinking water quality (Long et al. 2012). The study indicated there were no contaminant concerns derived from sampled springs, sinks, or cave drips for the constituents analyzed (arsenic, nitrate plus nitrite, trace metals, tritium, and chlorofluorocarbons). Higher arsenic levels found in springs are the result of natural conditions from existing shale layers. Additional information is available in assessments from the USGS publications by Carter and others (2002 and 2003) in the Water Resources of the Black Hills Atlas and Groundwater atlas, which summarize conditions and concerns for both quantity and quality of groundwater resources in the region. Water use, including more detailed public water supply information for both South Dakota and Wyoming, is discussed in more detail in the *Soils and Watersheds* assessment.

Lowering of the water table is also a concern, as availability of groundwater is dependent on being able to reach it with wells, and the population of the area is increasing. Aquifer observation wells in South Dakota show that water levels have fluctuated during the period of record (previous 30-50 years), but that the average water table elevation has not changed in the aquifers monitored. Some aquifers were higher in 2020 than in previous years (South Dakota Department of Natural Resources 2021). The USGS also maintains a system of groundwater monitoring wells that may be referenced (USGS 2022).

Although the Black Hills have ample ground water, it is not always available. Water-producing units may be deep and difficult or expensive to access, may have undesirable water quality, or may not produce the amount of water needed or in the area needed.

## Phreatophytic Ecosystems

Phreatophytic or deep-rooted ecosystems are unique due to the type of vegetation species they support; they include riparian as well as other phreatophytic ecosystems in the Forest. This broad category of ecosystem types is comprised of plant species that rely on a groundwater table through deep tap roots. Often situated near aquatic ecosystems, phreatophytic vegetation is always dependent on ground water and is therefore well correlated with the distribution of groundwater. The root systems of phreatophyte species are capable of penetrating to depths ranging from just over one foot to more than one hundred feet below the surface.

## Discharge Ecosystems

Discharge ecosystems occur where groundwater emerges or reaches the upper twelve inches of the ground surface. These include springs, wetlands, lakes, streams, and some riparian habitats where ground water is closer to the surface. Consequently, they are often associated with the riparian systems described above.

Hydrological changes are the primary influence on plant communities in this group. They typically support vegetation with low to dense cover dominated by sedges, with cattails and bulrush more prevalent in larger and deeper open water areas such as ponds and lakes. Wet meadows and prairies are comparatively drier, particularly in late summer. These sites support narrow small-reed (*Calamagrostis stricta*), sedges, and prairie cordgrass (*Spartina pectinate*). Depressional wetlands are located in the low parts of floodplains where water collects. These sites may also occur with strongly saline soils with salt tolerant plant species such as Saltgrass (*Distichlis spicata*), alkali sacaton (*Sporobolus airoides*), and foxtail barley (*Hordeum jubatum*). Floodplain forests may have an open to closed canopy dominated by deciduous trees including plains cottonwood, green ash, and various willow species in the lower and midstory areas.

### Springs

Thousands of springs are present in the Black Hills National Forest, hundreds of which are free flowing, originating from confined aquifers around the periphery of the Black Hills. Collectively, these springs are a large source of groundwater discharge, contributing to the flow of streams, creation of wetlands, and volume of lakes in the region.

Artesian springs emerge from or near outcrop areas of the Spearfish Formation, which is a low permeability hydrogeologic unit (Long et al. 2012). This formation has a high shale content, has flowing groundwater in fractures, and has many cavities created by dissolved gypsum. Artesian springs in the southern Black Hills may flow upward through breccia pipes vertical cylindral cavities that allow groundwater from deep bedrock aquifers to emerge from overlying formations (Hayes 1999). Springs can be differentiated from waters originating in aquifers through temperature and hydro chemical conditions. A detailed account of spring types and geologic descriptions can be found in USGS publications by Carter and others (2002 and 2003).

Warm, or geothermal, springs are a unique feature of the plan area and a popular destination for tourism. Many of the warm springs in the area, such as those at Hot Springs, SD, have become resorts, where waters are funneled into retention ponds or into buildings. Warm springs, recognized as a unique biological feature, since these habitats support several rare plant species. The only warm spring currently managed by the Black Hills National Forest is the spring complex associated with the J.H. Keith picnic site at Cascade, SD (Cascade Springs).

On the Bearlodge portion of the Black Hills National Forest, where there is higher potential for mass movement or downslope movement of erosion. Limnocrene springs, or ‘sag ponds’ often form at the base of these eroded soils.

### *Peatlands*

Peatlands which include the subtype features of fens and bogs, occur where enriching groundwater emerges at the surface, such as at the lower slopes of a hill or cliff or in floodplains, and are characterized by saturated soil conditions due to an elevated water table and the accumulation of organic material. Accumulation of organic matter in peatlands can be extremely slow. Some fens in Colorado are over 10,000 years old with organic soil accumulation rates ranging from 4.3 to 16.2 inches per thousand years (US Fish and Wildlife Service 1999). Due to these slow accumulation rates, these resources should not be considered renewable resources; Region 2 Forest Service Handbook (FSH) 2509.25 notes springs and fens/peatlands are rare, irreplaceable water features. There are over 2,400 known peatlands on the Black Hills National Forest (USFS 2022). The inventory of peatlands is an ongoing process; the Black Hills National Forest maintains a database of suspected (based on photo interpretation) peatlands that are ground verified as possible. Two notable examples include the McIntosh Fen and a small area on Middle Boxelder Creek. Plants and animals associated with springs and fens, such as Autumn willow (*Salix serissima*), are discussed in the *At-Risk Species assessment*.

### *Wetlands*

Wetlands are areas where water is present at the subsurface or at the surface for some period of the year. These saturated conditions produce hydric soils and support wetland-specific plant communities (hydrophytes). Wetlands typically occur within floodplains adjacent to river or stream systems, or along the margins of lakes and ponds. In mountainous settings, depressional wetlands, wet meadows, slope wetlands, and fens are other wetland types that may be present. In general, wetlands provide a buffer to control runoff and improve water quality. Wetlands also contribute to groundwater recharge and support special habitat types. A summary of wetland types, counts, and total area identified by the USFWS National Wetlands Inventory (NWI) within the Forest is presented in table 2.

**Table 2. Summary of NWI features in the Black Hills National Forest**

| Wetland Type | Definition | Average Size (acres) | Count | Acres |
|---|---|---|---|---|
| Palustrine | Marshes, swamps, fens, and ponds | 1.40 | 3,054 | 4,254 |
| Lacustrine | Permanently flooded lakes and reservoirs | 3.18 | 2,162 | 6,862 |
| Riverine | Rivers and creeks (flowing water) | 3.13 | 4,662 | 14,581 |
| Total | | | 9,878 | 25,697 |

The Forestwide standards and guidelines for riparian areas, water influence zones and wetlands apply wherever those ecosystems occur (USDA Forest Service 2006). USFS National Best Management Practices (BMPs; USFS 2012) also directs at a minimum a 100-foot disturbance buffer around water features known as the Aquatic Management Zone. These areas are defined in the current forest plan as follows:

- Riparian ecosystems are “the moist transition zone between the aquatic ecosystem and the drier, more upland, terrestrial ecosystem(s). This transition zone can extend both laterally and longitudinally away from aquatic ecosystems, sometimes into headwater depressions that have no defined stream

channel. The riparian ecosystem is the area whose soil is moister than the adjacent upland and whose vegetation growth reflects more available water."

- Water Influence Zones include "the land next to streams and lakes where vegetation plays a key role in sustaining the long-term integrity of aquatic ecosystems. This includes the geomorphic floodplain, riparian ecosystem, and inner gorge, and has a minimum horizontal width (from top of each bank) of one hundred feet or the mean height of mature dominant secondary vegetation, whichever is greater."
- Wetlands include "those areas that are inundated by surface water or groundwater with a frequency sufficient to support a prevalence of vegetative or aquatic life that requires saturated or seasonally saturated soil conditions for growth and reproduction. Wetlands include swamps, marshes, bogs, fens, and similar areas such as sloughs, potholes, wet meadows, river overflows, mud flats, and natural ponds."

A list of specific lakes, streams, and open-water wetlands to which riparian direction would (or would not) apply are not in the forest plan, because plan riparian direction applies unilaterally to all water features. Instead, a description of conditions identifies areas on the ground where plan direction applies.

# Ecological Function of Aquatic, Riparian, and Groundwater-Dependent Ecosystems

This section assesses the general level of ecological function of each aquatic, riparian, and groundwater-dependent ecosystem and determines if the disturbance processes are operating within the desired range of variation. Human influences on ecosystems and changes induced from modifications are addressed. Water requirements vary across groundwater-dependent ecosystems. Ecosystems entirely dependent on groundwater are obligate groundwater-dependent ecosystems. These communities may be affected by changes in groundwater availability or quality.

The main characteristics of aquatic and associated riparian ecosystems include the presence of perennial, intermittent, or ephemeral surface water associated with lakes, ponds, and various channel type features. The presence of surface and shallow groundwater supports a variety of specific plant communities of numerous vegetation types, which in turn support a diverse group of fauna. The characteristics of these ecosystems vary widely from mature deciduous riparian forests to permanently or seasonally saturated wetlands dominated by herbaceous plant species.

Aquatic, riparian, and groundwater-dependent ecosystems play a significant ecological role, typically supporting elevated levels of plant and wildlife biodiversity, and contribute to desired function of aquatic systems. Specific ecological functions of riparian systems include the presence of root systems that provide bank stability and reduce erosion, and riparian buffers that provide biological filtering and improved water quality (Anbumozhi 2005).

The principal driver of riparian and aquatic ecosystems is the presence of water in greater quantities as compared to upland areas. The relative abundance of water in these ecosystems results in highly diverse habitats. Examples of drivers of riparian ecosystems include floods and drought, which interact with plant regenerative dynamics. Flooding mobilizes sediment, scours substrates, removes bank and floodplain vegetation, and creates the seedbed for plant colonization.

In the Black Hills, the generalized pathway of forest succession includes mid-intermediate stage aspen and other deciduous forests eventually becoming late-intermediate stage ponderosa pine and white spruce dominated forests, barring any disturbance. Two natural sources of disturbance, fire and beavers historically maintained the presence of hardwood forests across the landscape.

Beavers may have been the most important biological influence on the Black Hills riparian ecosystems, particularly in low-gradient drainages that supported abundant deciduous woody species. The effect of

beavers in maintaining mid-intermediate stage riparian plant communities through hydrologic alteration and frequent disturbance was profound (Parrish et al. 1996). The cycle of riparian succession caused by beavers begins with colony establishment and dam building to impound water and raise the water table, which improves growing conditions for willows and other deciduous species. However, eventually over browsing causes the beavers to migrate, which results in unmaintained dams that fail and expose nutrient rich soils to support reestablishment of riparian and transitional modertately moist soils and associated plant communities. The removal of beavers from the landscape has led to less frequent disturbance and encroachment of coniferous tree species (Hoffman and Alexander 1987). The decline in beaver populations has contributed to the conversion of historical wetlands to drier sites.

Riparian ecosystems represent the interface between terrestrial and aquatic ecosystems and are affected by changes to either one. In 1987 it studies noted most riparian systems in the Black Hills have been severely degraded, with decreases in *Populus* and *Salix* cover (Hoffman and Alexander 1987). Marriot and Faber-Langendoen (2000b) stated *with the heavy human use riparian systems in the Black Hills are subjected to few riparian areas remain that are undisturbed, with many sites subjected to complete changes is species composition as a result of human impact*. These declines are attributed to historic gold and hydro mining operations, historic and current water diversions, concentration of livestock and wildlife use, and invasion by exotic (invasive) plant species.

In 2005 the effects analysis conducted for the phase II forest plan amendment (USDA Forest Service 2005a) concluded the selected alternative contained measures to minimize direct and indirect impacts to riparian and wetland habitats; and the most recent forest plan monitoring report (USDA Forest Service 2015) noted progress towards achieving the riparian objectives identified.

Since the implementation of the current forest plan, site-specific allotment management grazing management) has occurred and Multiple Indicator Monitoring (Burton et al. 2011) data show improvements in plant species composition, streambank stability, greenline width and overall wetland ratings. Timber harvest and road building can lead to changes in sediment delivery and erosion within riparian areas, but best management practices are employed to reduce that risk.

Beaver trapping and dam removal (described above), and reservoir construction and operation activities have resulted in withdrawals for irrigation and other uses and changes in the quantity, quality, and timing of water flows in downstream reaches. However, in general, there is little indication of long-term water-level declines from groundwater withdrawals in any of the bedrock aquifers in the Black Hills area (Carter et al. 2002b). This is supported by the long-term hydrograph for the Redwater Minnelusa well (USGS 2003).

Karst formation in the planning area occurs when soluble rock is dissolved forming intertwined groundwater features. The rate of karst formation is influenced by climate, including periods of increased precipitation and drought (USDA Forest Service 2018). Karst formation is particularly sensitive to climate and changes in precipitation (Theilen-Willige 2018).

## Wildland Fire Effects on Aquatic, Riparian, and Groundwater-Dependent Forest Ecosystems

Fire hazards in the vicinity of aquatic, riparian, wetland, and groundwater-dependent ecosystems may serve as a stressor to these systems when fire events in adjacent uplands spread into bottomlands.

The role of fire in the aquatic, riparian, and groundwater-dependent ecosystems described in this report is less clear and is influenced by fuel conditions in adjacent pine forests. Although the ecosystems considered in this section are wetter and less prone to catastrophic fire as compared to their general surroundings, the drying of these areas and conifer encroachment into riparian bottomlands may contribute to a higher fire recurrence interval. Fuel reductions in adjacent pine forest areas can contribute

to a reduced probability of catastrophic fire impacting the areas considered in this section (USDA Forest Service 2005a).

### *Adaptations to Wildfire*

Although the aquatic, riparian, and groundwater-dependent ecosystems considered in this report are not typically prone to regular fire disturbance, post-fire flooding and other upland post-wildfire processes may contribute to significant alterations to stream integrity and function. Watershed conditions after high-severity fire events may transport undesirable amounts of sediment into aquatic systems, leading to decreased channel stability, more variable discharge, increased suspended sediment, removal of riparian vegetation, and negative impacts to fish populations (Driscoll et al. 2004). Hydrologic responses from post-fire precipitation events are dependent on the burn severity and resulting soil conditions. High-severity fire events are more likely to reduce canopy interception and increase the water repellency in soils, leading to increased runoff generation and potential impacts to stream systems (Hallema et al. 2017). Post-fire assessments of Black Hills National Forest fires consistently find a thin (2 mm or less) water repellent layer at the soil-ash interface in a mosaic pattern created by freeze-thaw cycling. Impacts to aquifers and other subsurface systems are not well studied (Rhoades et al. 2019) However, aerial observations of post-fire flooding have shown ash-laden waters flowing through streams until they abruptly end surface flows into potential underground cave and karst features (USFS 2012).

Fire impacts to karst systems is dependent on the severity of the burn event; however, the effects are not well studied. High severity fire and resulting soil sterilization reduces the concentration of CO2 in soil, which is a vital component of the dissolution process. The removal of vegetation following a fire event may also change the surface hydrological inputs (Coleborn et al. 2015).

## Insects, Disease, and Invasive Species within Aquatic, Riparian, and Groundwater-Dependent Ecosystems

In watersheds that are not snow influenced, tree mortality caused by the mountain pine beetle (*Dendroctonus ponderosae;* MPB) has minimal direct effects on the watersheds, and therefore minimal effect on the riparian and aquatic ecosystems. There are increases in understory vegetation and tree regeneration in areas affected by the MPB, which filters run-off and minimizes changes to streamflow during normal or dry climactic conditions (Thom et al. 2020). Conversely, in watersheds that are snow influenced, the reductions of the forest canopy result in an earlier snow melt and increased runoff during periods when transpiration is low (Sheppard and Battaglia 2002). However, beetle-killed trees add fuels and change the fuel profile that can lead to larger and higher severity wildfires, which can impact water flow and sediment delivery. Watersheds experiencing post-fire effects can have potentially devastating effects to aquatic and riparian habitat either directly or due to erosion and sediment runoff.

The effects of MPB, and other insect species is covered in more detail in the *Insects, Disease, and Invasive Species Assessment*.

Aquatic nuisance species (ANS) are nonindigenous species that threaten the diversity or abundance of native species, the ecological stability of infested waters, or commercial, agricultural, aquacultural, or recreational activities dependent on such waters. The Black Hills National Forest has developed an ANS Action Plan (USDA Forest Service 2014). An overview of ANS is provided in the *Insects, Disease, and Invasive Species Assessment* which also provides a list of potential ANS that may occur in Black Hills National Forest.

Infestations of didymo *(Didymosphenia geminata),* a diatom, in waterways of the Black Hills National Forest can have harmful effects on the native biota of these areas. Didymo, commonly called “rock snot” can form thick, mat-like growths that last for months. These mats often inhibit growth of native organisms that live on stream bottoms, and can have devastating impacts on aquatic food chains, such as desirable

game fish like trout (James 2015). There are indications that the didymo infestation in Rapid Creek is not impacting trout there. Since aquatic invertebrates are physically smaller in Rapid Creek than in comparable non-infested streams, trout are able to consume enough of them to maintain healthy growth and energy reserves (James 2015).

Another ANS, red-rimmed melania (*Melanoides tuberculata* a snail native to Africa and introduced to the U.S. by the aquarium industry), poses a risk to native aquatic ecosystems because it is a host to several pathogens that threaten native fish (Daniel et al. 2019). Chytrid fungus (*Batrachochytrium dendrobatidis*) is easily transferred from one waterbody to another and can cause disease in amphibian species. Other examples of ANS present within the Black Hills National Forest include zebra mussel (*Dreissena polymorpha*), New Zealand mud snail (*Potamopyrgus antipodarum*), and Asian clam (*Corbicula fuminea*).

The Watershed Condition Framework used to evaluate watersheds in 2010 includes an aquatic biological indicator, which includes a sub-indicator for exotic and/or invasive species. In 2010 the sub-indicator ratings indicated 53 percent of watersheds (50 of 95) were functioning properly, 27 percent of watersheds (26 of 95) were functioning at risk, and 20 percent of watersheds (19 of 95) were impaired. Based on the 2010 data, aquatic invasive species are potentially more of an impairment than terrestrial invasive species, and 20 percent of sub-watersheds are considered impaired with aquatic invasive species versus 2 percent for terrestrial invasive species. These ratings are based on data collected in 2010, they do not account for the increase in terrestrial invasives plants that has occurred, nor the presence of zebra mussels. An analysis of the South Dakota 'Least Wanted' ANS could provide further detail regarding high priority ANS species to consider in the Black Hills National Forest.

## Human Influences on Aquatic, Riparian, and Groundwater-Dependent Forest Ecosystems

Human influences, including Forest Service management, can have effects on the processes that sustain aquatic, riparian, and groundwater-dependent forest ecosystems. This section explores the effects on three specific components: water quality, fish migration barriers, and sediment transport.

Human influences play a role in determining the current composition, structure, function, and connectivity of aquatic, riparian, and groundwater-dependent ecosystems in the Black Hills National Forest. These influences are noted across different geographic areas over time. . While a comprehensive list of these human influences is not possible , the general categories include water use (stream diversions, reservoirs, ditches, groundwater extraction), mineral extraction, transportation (roads, trails, culverts), recreation, biological control (invasive species, beaver removal, pesticides), vegetation management (timber harvest, livestock grazing, wildland fire management), and urbanization (Gage and Cooper 2013).

Water temperature in aquatic systems can be altered by increases in air temperature caused by a changing climate, the impoundment of water in large reservoirs, the reduction of summer flows in streams due to diversion for agricultural, municipal, or industrial uses, the loss of riparian vegetation that reduces shade along the water's edge, and changes in stream and wetland characteristics that alter the dimension, pattern or profile of their features.

The Black Hills region traditionally includes high surface water quality. This is due in large part to the cooler climate, higher precipitation and less erosive bedrock than the surrounding plains (USDA Forest Service 2018). The Black Hills National Forest works cooperatively with the states to conduct project-level monitoring and employ best management practices in compliance with state mandates and the Clean Water Act (USDA Forest Service 2009, USDA Forest Service 2013). Beyond the project-level practices employed to maintain water quality, the focus of water quality monitoring is on water bodies that may not be meeting established beneficial uses or are listed as impaired on the State's 303(d) list. The chemical composition of water can be affected by potential acid mine drainage from legacy mining operations in

the region. This drainage can lead to elevated concentrations of heavy metals, although, according to state water monitoring, this is not a major source of pollution in the Forest. In general, pesticide treatments to the surrounding landscape, other pollution inputs from urbanized areas (including an increased number of septic systems in the area due to land development), and elevated bacteria levels from high densities of livestock near water features also result in adverse effects. Water quality is discussed in more detail in the *Soils and Watersheds* assessment.

Barriers in water courses occur across the stream networks of the Black Hills National Forest and can affect the distribution of fish species. In addition to natural barriers (e.g., waterfalls or seasonally dry reaches), anthropogenic barriers include dams, road culverts, and diversion structures. Barriers may result in adverse effects to native fish populations by preventing migration to productive habitat; however, they can also be useful for managers to prevent dispersal of non-native species that may otherwise compete with sensitive native fish. The presence of stream barriers may preserve the genetic integrity of certain fish species and therefore be beneficial to the system, whereas other fish barriers may restrict the spawning migrations of fish. The presence or absence of these features is considered on an individual stream basis, and road-stream crossings are considered during project implementation.

The rate of sediment delivery to aquatic and riparian ecosystems has been altered by human actions, in many cases leading to adverse effects on fish habitat. Direct removal of vegetation (timber harvest), improper livestock grazing practices, roads, and urbanization all have the potential to increase the rate of sediment entering streams. Long-term suppression of the natural wildland fire regime has resulted in high-intensity fires that also lead to loss of vegetation and alteration of soil properties, making them more susceptible to erosion post-fire.

### *Adaptations to Human Influence*

The extensive nature of human influences on aquatic, riparian, and groundwater-dependent ecosystems in the Black Hills National Forest have resulted in permanent changes to the landscape. Climate change has influenced the landscape, and current forest plan objectives analysis is vital. In areas where humans have altered the ecosystems to the point they are not meeting forest plan objectives, restoration actions should be taken to reestablish historic conditions. The effectiveness of management actions within the Forest are monitored and evaluated (USDA Forest Service 2015), but the degree to which ecosystems on the forest are withstanding and recovering from human influence is difficult to determine. Comparative studies and additional monitoring programs would help assess the condition and trend of these systems.

In general, the composition, structure, function, and connectivity of riparian ecosystems have varying abilities to withstand levels of disturbance, whether from natural or human sources. The *Final Environmental Assessment and Record of Decision for Black Hills National Forest Phase II Amendment to 1997 Land and Resource Management Plan* suggests that riparian conditions have improved across the Black Hills National Forest in response to ongoing efforts to implement best management practices, reduce sediment delivery from roads, livestock grazing management, and re-plant woody shrubs (USDA Forest Service 2005a). As noted previously, the most recent forest plan monitoring report (USDA Forest Service 2015) noted progress is continuing to be made towards achieving the riparian objectives identified in the current forest plan. Changes in grazing management since 2005 have resulted in improvements in plant species composition, streambank stability, greenline width and overall wetland ratings, according to the Multiple Indicator Monitoring data. However, it will take years of continued monitoring and data collection to determine if these treatments are successful and to reveal the long-term effects of human influences on the hydrology, fire regime, and other drivers/stressors of riparian ecosystems. These ecosystems should be able to recover within the range of natural variation with a reduction in human created stressors.

### Restoration Opportunities

As mentioned above, post-fire flooding and other post-wildfire processes may contribute to alterations to stream and riparian integrity and function, making restoration necessary. A total of 664 acres of riparian habitat were restored or enhanced from 2003 to 2014. The latest forest plan monitoring report indicated progress in restoring riparian shrub communities throughout the Black Hills National Forest was ongoing (USDA Forest Service 2015). Although a more current forest plan monitoring report has not been published, activities to enhance riparian areas have continued since 2015. Data from Multiple Indicator Monitoring on riparian sites that are grazed show improvements in most indicators monitored, as a result of improved grazing management on those sites.

Large-scale, landscape restoration of riparian ecosystems involves modifications to the flood regime and floodplain as well as terrestrial and aquatic/riparian treatments. Specific watersheds are described in the Watershed Condition Framework, in which priority watersheds (sixth level HUC12) are identified. Subsequently, projects are implemented across the watershed to improve conditions. Interactions between floodplain disturbance via periodic flooding of riparian zones and riparian regenerative processes are vital to restoring natural function to these corridors. Under the natural disturbance regime, fire is typically not a major disturbance factor. Impacts to the structure and functioning of riparian areas through impacts related to human settlement, land use, and the modifications of natural flooding regimes by dams and other impoundments have been documented. Alterations to river hydrology have resulted in changes in geomorphic structure with considerable impacts to the physical and biological character of riparian areas. Additionally, there is a need to continue broad scale assessment and to continue improvement of road-stream crossings for aquatic organism passage and flood flow passage.. An effort is underway to evaluate and identify priority watersheds; a watershed restoration action plan will assess needs to restore/improve the watershed for each. Several Rapid Creek and Spring Creek basins have been reviewed.

## Landscape Level Conditions and Adaptations Within Aquatic, Riparian, and Groundwater-Dependent Ecosystems

Due to their position on the landscape, the health of aquatic, riparian, and groundwater-dependent ecosystems reflects, and is often an amplification of, the ecological conditions of the surrounding watersheds, whether or not those areas are within or outside of the Black Hills National Forest boundaries. The sustainability of the ecosystems within the plan area are influenced by conditions of the broader landscape, especially considering the extensive in-holdings of private and non-Forest lands within the Black Hills.

The conditions of the broader landscape are determined by a combination of natural processes and human management actions. This section addresses the natural aspects of these conditions. The quantity, quality and timing of precipitation and surface water runoff are fundamental characteristics of lake, stream, and wetland ecosystems, and these are determined by conditions upslope and upstream. Similarly, groundwater availability is also a product of natural variation driven by conditions across the broader landscape, such as the characteristics of the underlying geologic formations, rates of aquifer recharge, etc. The health of riparian and phreatophytic or dee- rooted vegetation communities is closely related to landscape-scale conditions in the upland forests and terrestrial ecosystems, affected by the fire regime, intensity of drought and flooding, invasive species, insects and diseases, etc.

The aquatic, riparian, and groundwater-dependent ecosystems of the Black Hills National Forest are dynamic and experience a constant influx of drivers from the surrounding landscape. Lake levels are determined by a balance of inputs from surface and groundwater with outputs from evaporation, percolation and released reservoir flows. The morphology of streams is dictated by the amount and timing of flow, along with sediment, wood, and nutrient inputs. Phreatophytic vegetation communities are

structured by the availability of water that can vary seasonally and year to year. All of these ecosystems have adapted over millennia to a range of variation in these dynamic landscape-scale drivers.

Natural riparian ecosystems, particularly in floodplains, are typically composed of a patchwork of early- to mid-seral stage plant communities that includes by a frequent hydrologic disturbance regime. The primary source of disturbance is flooding and seasonal flow fluctuation that can alter a river or stream, erode banks, deliver water to off-channel features and reset plant growing conditions on a regular basis. Riparian disturbances are caused by other influences such as fire and insect infestation, along with a host of human caused disturbances such as grazing and development. These upland disturbances and land use practices can alter watershed hydrologic processes, and create uncharacteristic fire events, which may lead to channel degradation and water quality impairments.

## Effects of Climate Change on Aquatic, Riparian, and Groundwater-Dependent Forest Ecosystems

Climate trends and projections of future climate are discussed in *Climate Change Vulnerability in the Black Hills National Forest* (Timberlake et al. 2022). Altered snowpack and hydrologic regimes may exert stress on riparian ecosystems in the Black Hills. In general, a warmer climate and reduced soil moisture may cause riparian areas to decrease in size over time. Additionally, riparian areas are expected to experience secondary effects from increasing fire events and the expansion of invasive plant species (Dwire et al. 2018).

Riparian systems are impacted by the environmental stress resulting from a warmer climate and an altered hydrologic regime. Land management techniques related to resiliency help mitigate the effects of climate change. Land management proposals include fire-hazard reduction in upland conifer-dominated settings to prevent the spread of fire into riparian areas. These treatments include reducing fuel loads and prescribed burning where low to moderate severity fire protects soil characteristics and allows for the rapid recovery of organic materials and vegetative ground cover.

## Considerations for Managing Multiple Use within Aquatic, Riparian, and Groundwater-Dependent Forest Ecosystems

Riparian areas support multiple uses such as recreation, livestock use, and irrigation, while also providing important ecosystem services. These areas support wildlife habitat, improve water quality through pollutant filtering, and provide flood dampening and maintenance of water tables. prevent degradation and preserve ecosystem services, riparian areas require best management practices (BMPs). BMPs for riparian systems are designed to preserve or enhance ecosystem services. BMPs are implemented to maintain water quality, manage wildlife and rare plant habitats, and enhance floodplain interaction with the channel. Additionally, restoration and maintenance of riparian features will prevent degradation and continue to support multiple uses.

Multiple sources of nonpoint source pollution can lead to water quality problems Including sediment, the most common of these. Various management practices can address nonpoint sources, including riparian buffers, removal of stream crossings, and the closure of high value riparian areas to public use (Philips et al. 2000). The potential for dispersed and developed recreation impacts is high in riparian areas and groundwater-dependent ecosystems.

Impacts to riparian and wetland ecosystems result from direct disturbances such as the removal of vegetation, improper livestock grazing practices, development of roads, or trails (e.g., stream crossings), placement of fill material (e.g., development in a floodplain), and wildfire. Indirect disturbances on riparian resources can result from upstream and downstream activities in the Black Hills National Forest. These disturbances may include channelization downstream that causes stream channel adjustments

upstream; post fire flooding from burned hillslopes upstream; dewatering due to construction of impoundments upstream that capture spring-fed source water; and loss of riparian habitat and channel features due to dewatering activities.

The compatibility of multiple uses and maintaining ecosystem integrity is uncertain. Recreational uses adversely impact riparian ecosystem integrity. Riparian corridors and associated surface water features support biodiversity and also attract human disturbance. Aquatic and groundwater-dependent habitats attract a unique assemblage of fish and wildlife, which in turn attracts human interest, including recreational uses such as hunting, fishing, birdwatching, photography, and enjoyment of nature.

# Chapter 3. Current Management

## Forest Plan Direction

The Black Hills National Forest 1997 Land and Resource Management Plan contained management direction to manage for aquatic, riparian, and groundwater-dependent ecosystems. Original direction was revised in 2005 during the Plan II amendment process in order to better provide for species conservation and fire and insect hazard reduction. The current management direction for these ecosystems is below.

### Forest wide Goals and Objectives

- Protect basic soil, air, water and cave resources (Forest wide Goal 1),
- Use a qualitative survey which emphasizes riparian condition, such as the Proper Functioning Condition methodology, to refine the preliminary watershed health assessments (FP-FEIS, Appendix J) within the next planning period. This survey would focus first on Class III watersheds, and could include additional quantitative methods, as needed, for the design of watershed improvements. Class I watersheds do not need surveys unless information becomes available which suggests there was an error in classification (Forest wide Objective 102),
- Maintain or improve long-term stream health. Achieve and maintain the integrity of aquatic ecosystems to provide stream-channel stability and aquatic habitats for water quality in accordance with state standards (Forest wide Objective 103),
- Maintain or enhance watershed conditions to foster favorable soil relationships and water quality.
    - Implement projects to improve watershed conditions on an average of at least three hundred acres annually over the plan period.
    - Achieve and maintain stable stream beds and banks, diverse riparian vegetation, and effective ground cover that controls runoff and erosion (Forestwide Objective 104),
- Prohibit motorized vehicle use in wetlands, wet meadows and riparian areas, except at specified locations and times of the year (Forest wide Objective 105),
- Manage water-use facilities to prevent gully erosion of slopes and to prevent sediment and bank damage to streams (Forest wide Objective 106),
- Restore degraded wetlands except where exemptions are allowed by a Clean Water Act Section 404 permit (Forest wide Objective 107),
- Manage for sustained or improved water flows (Forest wide Objective 108),
- Maintain or enhance existing riparian area biodiversity, physical structure and size.
- Restore riparian shrub communities across the forest by five hundred acres during the Plan period on sites capable of supporting this community (Forest wide Objective 214),

- Manage for at least five stream reaches in a rehabilitated condition during the Plan period. Select reaches where the water table has receded, and plant species composition has changed as a result of human activities. Coordinate planning and implementation with state game and fish agencies and downstream private landowners. Use Objective 215 a through d in designing the projects.
    - a. Raise the water table to saturate historically inundated soils.
    - b. Convert drier-site vegetation to native wet-meadow species.
    - c. Reintroduce beaver into the drainage once suitable habitat is developed.
    - d. Design management to maintain wet-meadow conditions (Forest wide Objective 215),
- Maintain or improve instream fisheries habitat. Cooperate with state agencies in aquatic ecosystem improvements to meet mutually agreed-upon objectives (Forest wide Objective 219), and
- Manage and/or install structures to provide water for livestock and to protect the aquatic, shoreline and upland vegetation around ponds or water catchments containing leopard frogs (Forest wide Objective 240).

## Forest wide Standards and Guidelines for Water

- Conduct actions so that stream pattern, geometry, and habitats are maintained or improved toward robust stream health (Forest wide Standard 1201),
- Move stream channels only if all other practical alternatives to protect critical resources or capital investments have been exhausted and other legal requirements have been met. If streams are put in channels:
    - a. Use methods that create stable beds and banks and beneficial aquatic habitat features; and
    - b. Use stream geometry relationships to reestablish meanders, width/depth ratios, etc. consistent with each major stream type (Forest wide Guideline 1202),
- Design and construct all stream crossings and other instream structures to provide for passage of flow and sediment, withstand expected flood flows, and allow free movement of resident aquatic life (Forest wide Standard 1203),
- Naturally occurring debris will not be taken from stream channels unless it is a threat to life, property, significant resource values, or otherwise covered by legal agreement (Forest wide Guideline 1204),
- When projects occur which affect large, woody debris, retain natural and beneficial volumes of large, woody debris for fish habitat, stream energy dissipation, and as sources of organic matter for the stream ecosystem (Forest wide Guideline 1205),
- When stabilizing damaged stream banks, preferentially use methods that emphasize vegetative stabilization. Use native vegetation for streambank stabilization whenever possible (Forest wide Guideline 1206),
- Manage water-use facilities to prevent gully erosion of slopes and to prevent sediment and bank damage to streams (Forest wide Standard 1207),
- Design water developments to minimize damage to channel capacity, aquatic habitat and riparian vegetation (Forest wide Guideline 1208),
- Manage vegetation treatments so that stream flows and long-term stream health is not degraded (Forest wide Standard 1209),
- Maintain enough water in perennial streams to sustain existing stream health. Return water to dewatered perennial streams when needed. Comply with Section 505 of the FLPMA and 36 CFR 251.56 when issuing and re-issuing authorizations for water storage and diversion facilities (Forest wide Standard 1210),
- Place new sources of chemical and pathogenic pollutants where such pollutants will not reach surface or ground water (Forest wide Standard 1211),

- Apply runoff controls to disconnect new pollutant sources from surface and ground water (Forest wide Standard 1212),
- Apply chemicals using methods which minimize risk of entry to surface and ground water (Forest wide Standard 1213),
- Where natural background water pollutants cause degradation, it is not necessary to implement improvement actions. Short-term or temporary failure to meet some parameters of the applicable federal or state standard, such as increased sediment from road crossing construction or water resource development, may be permitted in particular cases (Forest wide Guideline 1214),

## Forest wide Standards and Guidelines for Riparian Zones, Water Influence Zones, and Wetlands

- In the water influence zone next to perennial and intermittent streams, lakes, and wetlands, allow only those actions that maintain or improve long-term stream health and riparian ecosystem condition (Forest wide Standard 1301),
- Maintain long-term ground cover, soil structure, water budgets, and flow patterns in wetlands to sustain their ecological function, per 404 regulations (Forest wide Standard 1302),
- Vegetative type conversion should only occur in riparian areas to reestablish riparian vegetation for the protection and/or enhancement of those ecosystems (Forest wide Guideline 1303),
- As opportunities arise, and need dictates, relocate or implement mitigation measures for roads, trails, watering tanks, ponds, water catchments, and similar facilities currently located within the Water Influence Zone (Forest wide Standard 1304),
- Locate camping sites for contractual purposes (e.g., mining, logging, etc.) in order to lessen channel and riparian area impacts (Forest wide Standard 1305), and
- Prohibit log landing, decking areas and mechanical slash piling within riparian areas unless the integrity of the riparian area is maintained (e.g., frozen, snow-covered ground conditions) (Forest wide Standard 1306).

## Forest wide Standards and Guidelines for Managing Rangeland Activities in Wetlands and Riparian Areas

- Residual levels (or remaining height of key plant species) is prescribed for riparian areas in the allotment management plan (AMP) or the annual letter of operating instructions (AOI) to the livestock permittee. Residual levels will be based upon specific objectives for the location in question and will consider season of use and range conditions (Forest wide Standard)
- Allowable use and/or residual levels:
    - c. Utilization of willows, shrubs, woody vines or young deciduous trees (such as aspen, birch and oak) in any year by livestock or wildlife browsing includes 40 percent of the total individual leaders produced in that year (not to be confused with 40 percent use on each and every leader produced).
    - e. No authorized utilization will occur by domestic livestock on known occurrences of willow emphasis species (e.g., *Salix candida*, *Salix serissima*, *Salix lucida*).
    - f. Implement additional measures to assure avoidance of livestock use on *Carex alopecoid*. Restrict livestock use of all or portions of five of the largest geographically spaced occurrences at site numbers: CAAL8-19, CAAL8-20, CAAL8-22, CAAL8- 30, CAAL8-31. STANDARD (Forest wide Standard).

- Allow use of forage by livestock and wildlife in fenced riparian pastures so long as it meets the objectives of maintaining, enhancing, or conserving the riparian ecosystem and emphasis species persistence (Forest wide Standard 2507).

## Forest wide Standards and Guidelines for Endangered, Threatened or Sensitive Species – Protection and Management

- Do not develop springs or seeps as water facilities where sensitive species or species of local concern exist unless development mitigates an existing risk (Forest wide Standard 3104),
- Riparian areas or wetlands where populations of sensitive species are located are off-limits during ground disturbing activities. Use one or more of the following (or other mitigation measures) tied to the site-specific conditions for disturbances adjacent to known occurrences:
    - a. Avoid removing riparian or wetland vegetation; filling or dredging the riparian area or wetland; diverting stream flow from the current channel.
    - b. Prevent storm runoff from washing silt into the stream or wetland.
    - c. Reseed and/or replant cut and fill slopes with native seed and/or native plants promptly to control erosion and for prevention of noxious-weed infestations. Use appropriate measures to control erosion on disturbed areas that are steep, are highly erosive, and/or adjacent to the riparian area.
    - d. Timing, placement, and installation of temporary stream diversions shall allow passage of aquatic life and protect sensitive and species of local concern (Forest wide Standard 3106).

## Forest wide Standards and Guidelines for General Wildlife and Fish in Riparian Areas

- Provide riparian habitat by maintaining or establishing riparian shrub and tree species, and protect riparian habitat from animal damage if needed (Forest wide Guideline 3210),
- Provide riparian habitat diversity through vegetation treatments or in conjunction with other resource activities designed to maintain or improve wildlife or fisheries habitat and stream stability (Forest wide Guideline 3211),
- Manage for high quality riparian communities.
    - a. Provide stable stream banks.
    - b. Retain woody vegetation along streams and lakes to provide shading for aquatic life and habitat for terrestrial species.
    - c. Provide large woody material for aquatic life (Forest wide Guideline 3212), and
- Plan and implement lake- and stream-habitat improvement projects so that they harmonize with the visual setting and incorporate discussions with other federal and state agencies. Include dredging lakes and ponds among potential projects when appropriate and cost-effective to enhance or maintain resources. Plan projects using site-by-site analysis (Forest wide Guideline 3213).

## Forest wide Standards and Guidelines for Transportation and Travel Management in Riparian Areas

- Prohibit land vehicles from entering perennial streams where resource damage would occur except to cross at specified points (Forest wide Guideline 9107),
- Vehicular traffic, except for snowmobiles, will be restricted to roads and trails in riparian areas (Forest wide Guideline 9108), and
- Walk-in fisheries are will be closed to motorized travel (Forest wide Guideline 9109).

Additional forest plan management direction applies to specific management areas, as detailed in the 1997 Black Hills National Forest Land and Resource Management Plan (USDA Forest Service 2006).

A more recent large project, the Black Hills Resilient Landscapes Project, is designed to respond to recent mountain pine beetle infestations in the Black Hills National Forest. Individual site-specific projects implemented under this landscape project are oriented towards the extensive pine landscapes in the Black Hills National Forest, however, the implementation of these treatments is expected to reduce the risk of impaired water quality that may result from wildfire (USDA 2018).

## Other Forest Service Direction

Forest Service Manual and Handbook Directives contain legal authorities, objectives, policies, responsibilities, instructions, and guidance for resource management on National Forest System lands. Forest Service Manual Series 2000 contains specific chapters that address aquatic, riparian, and groundwater-dependent ecosystems. Forest Service Handbook 2500, Watershed and Air Management and Forest Service Handbook 2600, Wildlife, Fish, and Sensitive Plant Habitat Management contain additional guidance.

## Other Federal Laws, Policies, and Executive Orders

Additional pieces of guidance exist, including the National Environmental Policy Act, the Clean Water Act, Executive Order 11988 Floodplain Management, and Executive Order 11990 Wetlands that direct Forest Service activities in aquatic, riparian, and groundwater-dependent ecosystems.

## Actions of Others

The management of surface and groundwater resources may impact the functioning and integrity of the ecosystems discussed in this assessment. Surface water quality and groundwater regulation is managed by two state agencies: the South Dakota Department of Agriculture and Natural Resources (DANR) and the Wyoming Department of Environmental Quality. Coordination with these regulatory bodies regarding the protection and enforcement of water quality standards and the protection of water resources is critical. The DANR conducts a biennial assessment of South Dakota's lakes that delineates areas of source water, lists an inventory of contaminants, and provides vulnerability ratings from aquifers throughout the state (DENR 2020). The Wyoming Department of Environmental Quality also conducts a biennial assessment of Wyoming's aquatic resources.

# Chapter 4. Potential Need for Forest Plan Changes

The current forest plan direction (as outlined above) is fairly strong for aquatic, riparian and groundwater-dependent ecosystems, however, updates may be beneficial. The focus should be on managing to maintain resiliency to provide for ecosystem services and buffer anticipated impacts from climate change. Potential changes to consider:

- The current forest plan defines a fen as "low-lying marshy land, partially covered with water." Consider updating that definition to include the peat-accumulating feature of fens.
- Consider incorporating forest plan components that recognize fens as nonrenewable resources and provide specific protections.
- Consider incorporating forest plan components that would protect vulnerable karst features from ground-disturbing, or potentially groundwater contaminating, activities.
- Consider incorporating forest plan components that recognize the need to protect aquatic, riparian and groundwater-dependent ecosystems from the increased pressure from recreation.
- Consider incorporating forest plan components to address the uncertainty accompanying climate change.
    - For example, the Black Hills may be warmer and drier in the summers, which could result in more water loss via evapotranspiration further stressing ecosystems. Since most water resources in the Black Hills National Forest are groundwater fed, there may be opportunities for water managers to alter current water operations. Through conserving more water in the winter, it may be possible to balance the decreased runoff expected in the drier summer months and keep rivers and streams wetter over time.
    - Climate change could potentially reduce flows in the summer months and impair aquatic habitat. There are opportunities to remove instream barriers at road stream crossings to promote connectivity. These actions can improve aquatic habitat by creating passage for fish and create more suitable habitat.
- Consider if forest plan components address the effects from a continued population increase, increased demand for water use, as well as the potential for ground water contamination from an increase in the number of septic systems.
- Zebra mussels are a new occurrence on the forest, consider the need for forest plan components to help limit their spread.

# References

Anbumozhi, V., J. Radhakrishnan and E. Yamaji. 2005. Impact of riparian buffer zones on water quality and associated management considerations. Ecological Engineering, 24(5), 517-523.

Bailey, R.M. and M.O. Allum. 1962. Fishes of South Dakota. Miscellaneous Publications, Museum of Zoology, University of Michigan, No. 119. Available from: http://www.nativefishlab.net/library/textpdf/17260.pdf. Accessed January 2022.

Bailey, R.G. 1995. Descriptions of the ecoregions of the United States: U.S. Department of Agriculture, Forest Service, Miscellaneous Publication 1391, 108 pp.

Barnes, M.E. 2007. Fish hatcheries and stocking practices: past and present. Pages267-294 in C. Berry, K. Higgins, D. Willis, and S. Chipps, eds. History of fisheries and fishing in South Dakota. South Dakota Department of Game, Fish and Parks, Pierre.

Brown, C.B., 1944, Report on an investigation of water losses in streams flowing east out of the Black Hills, South Dakota: U.S. Soil Conservation Service, Special Report 8, 45 pp.

Brown, P. M., Ryan, M. G., and Andrews, T. G. 2000. Historical surface fire frequency in ponderosa pine stands in research natural areas, central Rocky Mountains and Black Hills, USA. Natural Areas Journal, 20(2), 133-139.

Burton, T.A., Smith, S.J, and Cowley, E.R. 2011. Multiple Indicator Monitoring (MIM) of Stream Channels and Streamside Vegetation. Technical Reference 1737-23.

Carter, J. M., Driscoll, D. G., and Williamson, J. E. (2002a). Black Hills Hydrology Study. US Department of the Interior, US Geological Survey.

Carter, J.M., D.G. Driscoll, J.E. Williamson and V.A. Lindquist. 2002b. Atlas of water resources in the Black Hills area, South Dakota. Hydrologic Investigations Atlas HA-747. http://water.usgs.gov/pubs/ha/ha747/index.html

Carter, J.M., D.G. Driscoll, and J.F. Sawyer. 2003. Ground-Water Resources in the Black Hills Area, South Dakota. Water-Resources Investigations Report 03-4049. Rapid City, South Dakota. Prepared in cooperation with the Bureau of Reclamation, South Dakota Department of Environment and Natural Resources, and the West Dakota Development District. Available from: https://pubs.usgs.gov/wri/wri034049/wri034049_files/wri034049p0_10.pdf. Accessed November 2021.

Coleborn, K., A. Lupingna, I. Flemons, G. Nagra, P.C. Treble, M.S. Andersen and S. Meehan. 2015. Wildfire on Karst: An Overview. Presentation to the American Geophysical Union Fall 2015 Meeting. Abstract available from: https://agu.confex.com/agu/fm15/meetingapp.cgi/Paper/76979. Accessed January 2022.

Daniel, W. M., A.J. Benson, and M. E. Neilson. 2019. Melanoides tuberculata (Muller, 1774): U.S. Geological Survey, Nonindigenous Aquatic Species Database, Gainesville, FL. Available from: https://nas.er.usgs.gov/queries/factsheet.aspx?SpeciesID=1037. Accessed January 2022.

Driscoll, D.G., J.M. Carter, J.E. Williamson and L.D. Putnam. 2002. Hydrology of the Black Hills Area, South Dakota. Water-Resources Investigations Report 02-4094. U.S. Department of the Interior, U.S. Geological Survey. Prepared in cooperation with the South Dakota Department of Environment and Natura. Resources and the West Dakota Water Development District. Available from: https://pubs.usgs.gov/wri/wri024094/pdf/wri024094.pdf. Accessed January 2022.

Driscoll, D.G., J.M. Carter and D.O. Ohlen. 2004. Hydrologic Effects of the 1988 Galena Fire, Black Hills Area, South Dakota. Water-Resources Investigations Report 03-4323. U.S. Department of the

Interior, U.S. Geological Survey. Prepared in cooperation with the State of South Dakota, West Dakota Water Development District, and the U.S. Department of Agriculture Forest Service. Available from:. https://pubs.usgs.gov/wri/wri034323/pdf/wri034323.pdf. Accessed January 2022.

Dwire, K.A., S. Mellmann-Brown and J.T. Gurrieri. 2018. Potential effects of climate change on riparian areas, wetlands, and groundwater-dependent ecosystems in the Blue Mountains, Oregon, USA. Climate Services 10: 44-52.

Eamus D., B. Fu, A.E. Springer and L.E. Stevens. 2016. Groundwater Dependent Ecosystems: Classification, Identification Techniques and Threats. In: Jakeman A.J., Barreteau O., Hunt R.J., Rinaudo JD., Ross A. (eds) Integrated Groundwater Management. Springer, Cham.

Fertig, W. and B. Oblad. 2000. Protection status and checklist of the vascular plant flora of the Wyoming Black Hills. Wyoming Natural Diversity Database, Laramie, Wyoming. Prepared for The Nature Conservancy, Midwest Science Division. Available from: https://www.uwyo.edu/wyndd/_files/docs/reports/wynddreports/u00fer11wyus.pdf. Accessed January 2022.

Froiland, S. G. 1962. The genus Salix (Willows) in the Black Hills of South Dakota. Technical Bulletin No. 1269. U.S. Department of Agriculture, Forest Service.

Gabel, A.C. and M.L. Gabel. 2007. Comparison of diversity of macrofungi and vascular plants at seven sites in the Black Hills of South Dakota. The American Midland Naturalist, 157(2): 258-296.

Gage, E. and D.J. Cooper. 2013. Historical range of variation assessment for wetland and riparian ecosystems, U.S. Forest Service Rocky Mountain Region. Gen. Tech. Rep. RMRS-GTR-286WWW. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 239 p. Available from: https://www.fs.fed.us/rm/pubs/rmrs_gtr286.pdf. Accessed November 2021.

Goebel, P. C., BJ. Palik and K.S. Pregitzer. 2003. Plant diversity contributions of riparian areas in watersheds of the northern Lake States, USA. Ecological Applications, 13(6): 1595-1609.

Graham, R.T., M.A. Battaglia and T.B. Jain. 2021. A Scenario Based Assessment to Inform Sustainable Ponderosa Pine Timber Harvest on the Black Hills National Forest. United States Department of Agriculture Forest Service, Rocky Mountain Research Station.

Halofsky, J.E., D.L. Peterson, J.J. Ho, N.J. Little and L.A. Joyce. 2018. Climate change vulnerability and adaptation in the Intermountain Region: Part 2. Gen. Tech. Rep. RMRS-GTR-375. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. Available from: https://www.fs.fed.us/rm/pubs_series/rmrs/gtr/rmrs_gtr375_2.pdf. Accessed January 2022.

Hallema, D.W., G. Sun, K.D. Bladon, S.P. Norman, P.V. Caldwell, Y. Liu and S.G. McNulty. 2017. Regional patterns of post wildfire streamflow response in the Western United States: The importance of scale-specific connectivity. Hydrological Processes 31(14): 2582-2598.

Hayes, T.S. 1999, Episodic Sediment-Discharge Events in Cascade Springs, Southern Black Hills, South Dakota: U.S. Water-Resources Investigations Report 99-4168. U.S. Department of the Interior, U.S. Geological Survey. Prepared in cooperation with the South Dakota Department of Environment and Nature Resources and the West Dakota Water Development District. Available from: https://pubs.usgs.gov/wri/wri994168/pdf/wrir99.4168.pdf. Accessed January 2022.

Hoffman, G.R., and R.R. Alexander. 1987. Forest Vegetation of the Black Hills National Forest of South Dakota and Wyoming: A Habitat Type Classification. Available at https://www.fs.fed.us/rm/pubs_exp_for/black_hills/exp_for_black_hills_1987_hoffman.pdf. Accessed November 2021.

Hornbeck, J.H., C.Hull Sieg, and D.J. Reyher. 2003. Conservation Assessment for the Autumn Willow in the Black Hills National Forest, South Dakota and Wyoming. Custer, SD: US Department of Agriculture, Forest Service, Rocky Mountain Region, Black Hills National Forest. Available from: https://www.fs.fed.us/rm/pubs_other/rmrs_2003_hornbeck_j001.pdf. Accessed January 2022.

Iles, DL. 2008. South Dakota's Aquifers. Geological Survey Program. South Dakota Department of Environment and Natural Resources. Available from: http://www.sdgs.usd.edu/pdf/SD_Aquifers_article.pdf. Accessed November 2021.

James, D.A. 2015. South Dakota Conservation Digest: Do-wah-didymo. South Dakota Game, Fish and Parks. Fort Pierre, SD. March/April. Available from: https://sdleastwanted.sd.gov/docs/conservationdigest/Didymo.pdf. Accessed January 2022.

Long, A.J., M.J. Ohms and J.D.R.G. McKaskey. 2012. Groundwater flow, quality (2007-10), and mixing in the Wind Cave National Park area, South Dakota: U.S. Geological Survey Scientific Investigations Report 2011–5235, 50 p. Available from: https://pubs.usgs.gov/sir/2011/5235/pdf/sir2011-5235.pdf. Accessed November 2021.

Marriott, H.J. and D. Faber-Langendoen. 2000a. Black Hills Community Inventory. Volume 2: Plant Community Descriptions. The Nature Conservancy, Midwest Conservation Center. Minneapolis, Minnesota. 326 pp.

Marriott, H.J. and D. Faber-Langendoen. 2000b. Riparian and Wetland Plant Communities of the Black Hills. The Nature Conservancy Midwest Conservation Science Center and Association for Biodiversity Information. Minneapolis, Minnesota.

May, T.W. R.H. Wiedmeyer, J. Gober and S. Larson. 2001. Influence of mining-related activities on concentrations of metals in water and sediment from streams of the Black Hills, South Dakota. Archives of Environmental Contamination and Toxicology 40(1): 1-9.

Miller, W. and G. Galinat. 2009. State Fisheries Surveys, 2008 Surveys of Public Waters Part 1 Lakes. South Dakota Department of Game, Fish and Parks, Annual Report, 09-10.

Montgomery, G.L. 1996. RCA III, Riparian Areas: Reservoirs of Diversity (No. 13). US Department of Agriculture, Natural Resources Conservation Service.

National Park Service. 2021. Karst Landscapes (website). Available from: https://www.nps.gov/subjects/caves/karst-landscapes.htm. Accessed November 2021.

Omernik, J.M. 1987. Ecoregions of the conterminous United States. Annals of the Association of American Geographers. 77(1): 118–125.

Orr, H.K. 1975. Watershed Management in the Black Hills: The Status of Our Knowledge. U.S. Department of Agriculture, Forest Service, Research Paper RM-141. Available from: https://www.fs.fed.us/rm/pubs_exp_for/black_hills/exp_for_black_hills_1975_orr.pdf. Accessed November 2021.

Palmer, A.N. 2016. Karst and Caves of the Black Hills, South Dakota, USA. Boletin Geologico y Minero 127(1): 67-78. Available from: http://www.igme.es/boletin/2016/127_1/BG_127-1_Art-5.pdf. Accessed November 2021.

Palmer, A.N., M.V. Palmer, J.B. Paces, J. Feinberg, Y. Gao, Y., and E.C. Alexander. 2016. Geologic history of the Black Hills caves, South Dakota. Caves and Karst Across Time: Geological Society of America Special Paper, 516, 87-101.

Parrish, J. B., D.J. Herman, D.J. Reyher and F.R. Gartner. 1996. A Century of Change in Black Hills and Riparian Ecosystems. Research Bulletins of the South Dakota Agricultural Experiment Station (1887-2011). 726.Available from:

https://openprairie.sdstate.edu/cgi/viewcontent.cgi?article=1725&context=agexperimentsta_bulletins. Accessed January 2022.

Phillips, M.J., L.W. Swift and C.R. Blinn. 2000. Best management practices for riparian areas. In: Verry, Elon S.; Hornbeck, James W.; Dolloff, C. Andrew, eds. Riparian management in forests of the continental Eastern United States. Boca Raton, FL: Lewis Publishers, CRC Press LLC: 273-286.

Rhoades, C.C., J.P. Nunes, U. Silins, and S.H. Doerr. 2019. The influence of wildfire on water quality and watershed processes: new insights and remaining challenges. International Journal of Wildland Fire 28(10): 721-725.

Sheppard, W.D. and M.A. Battaglia. 2002. Ecology, Silviculture, and Management of the Black Hills Ponderosa Pine. Gen. Tech. Rep. RMRS-GTR-97. Fort Collins, CO: U.S. Department of Agriculture Forest Service, Rocky Mountain Research Station. Available from: https://www.fs.fed.us/rm/pubs/rmrs_gtr097.pdf. Accessed January 2022.

Shepperd, W.D. 2002. Ecology, silviculture, and management of Black Hills ponderosa pine. USDA Forest Service, Rocky Mountain Research Station.

South Dakota Department of Environment and Natural Resources. 2005. Targeting impaired lakes in South Dakota. South Dakota Watershed Protection Program. Available from: https://danr.sd.gov/Conservation/WatershedProtection/ReportsPublications/impairedlakes.pdf

South Dakota Department of Game, Fish and Parks. 2014. South Dakota Wildlife Action Plan. Wildlife Division Report 2014-03. South Dakota Department of Game, Fish and Parks, Pierre, South Dakota.

South Dakota Department of Game, Fish and Parks, Wildlife Division. 2020. Fisheries and Aquatic Resources Adaptive Management System. 2020-2024 Black Hills Fish Management Area. Available from: https://gfp.sd.gov/UserDocs/docs/BHFMA_Plan_2020-2024_DRAFT_for_Public_Comment.pdf. Accessed January 2022.

South Dakota Department of Agriculture and Natural Resources. 2020. The 2020 South Dakota Integrated Report for Surface Water Quality Assessment. 201 pp.

South Dakota Department of Agriculture and Natural Resources. 2021. Interactive map of groundwater levels in South Dakota. Powered by ESRI. Available from: https://apps.sd.gov/nr69obswell/default.aspx. Accessed November 2021.

South Dakota Department of Agriculture and Natural Resources. 2021. Drinking Water Program. Map application available from: https://danr.sd.gov/OfficeOfWater/DrinkingWater/default.aspx. Accessed January 2022.

South Dakota Natural Heritage Program. 2018. Rare Animals of South Dakota. South Dakota Game, Fish and Parks, Pierre, South Dakota. https://gfp.sd.gov/rare-animals/. Accessed (January 2022).

Stamm, J.F., M.F. Poteet, A.J. Symstad, M. Musgrove, A.J. Long, B. Mahler, B., and P.A. Norton. 2014. Historical and projected climate (1901–2050) and hydrologic response of karst aquifers, and species vulnerability in south-central Texas and western South Dakota. U.S. Geological Survey Scientific Investigations Report 2014–5089, 59 p., plus supplements. Available from: https://pubs.usgs.gov/sir/2014/5089/sir20145089.pdf. Accessed January 2022.

Theilen-Willige, B. 2018. Detection of karst features in the Black hills area in South Dakota/Wyoming, USA, based on evaluations of remote sensing data. Geosciences 8(6): 192.

Thom, D., M. Warnke, B. Garbisch, G. Josten, J. Ball, D. Buehler, K. Allen, B. Cook, S. Jacobson, B. Wudtke, D. Terry, J. Dedic, J Sloan, S Guffey and B. Doten, B. 2020. Black Hills Mountain Pine Beetle Strategy Collaborative Accomplishments. United States Department of Agriculture Forest

Service. Available from: https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fseprd721758.pdf. Accessed January 2022.

Timberlake ,T.J., J.E. Halofsky, L.A. Joyce, and D.L. Peterson. 2021. Climate change vulnerability in the Black Hills National Forest. U.S. Department of Agriculture, Forest Service, Western Wildland Environmental Threat Assessment Center. Unpublished report.

USDA Forest Service. 1996. Final Environmental Impact Statement for the Black Hills National Forest Land and Resource Management Plan. December 1996.

USDA Forest Service. 2005a. Final Environmental Assessment and Record of Decision for Black Hills National Forest Phase II Amendment to 1997 Land and Resource Management Plan. Available from: https://www.fs.usda.gov/detail/blackhills/landmanagement/planning/?cid=fsm9_012673. Accessed January 2022.

USDA Forest Service. 2005b. Selection of Management Indicator Species. Black Hills National Forest Phase II Plan Amendment. Prepared by SAIC, Littleton, Colorado. Prepared for USDA Forest Service, Black Hills National Forest. May 4 2005.

USDA Forest Service. 2005c. Process for Identifying Wildlife and Plant Species of Local Concern and Results - Black Hills National Forest Phase II Plan Amendment. Available from: https://www.fs.usda.gov/detail/blackhills/landmanagement/planning/?cid=fsm9_012660#3. Accessed January 2022.

USDA Forest Service. 2006. Black Hills National Forest Land and Resource Management Plan, 1997 Revision with Phase II Amendment. Available from: https://www.fs.usda.gov/detail/blackhills/landmanagement/planning/?cid=STELPRDB5112303. Accessed December 2021, January 2022.

USDA Forest Service. 2009. Monitoring Implementation Guide for the Black Hills National Forest Land and Resource Management Plan. Available from: https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5112523.pdf. Accessed January 2022.

USDA Forest Service. 2010a. Final Environmental Impact Statement: Black Hills National Forest Travel Management Plan. Available from: https://www.fs.usda.gov/nfs/11558/www/nepa/41877_FSPLT1_026126.pdf. Accessed November 2021.

USDA Forest Service. 2010b. Black Hills National Forest FY 2009 Monitoring and Evaluation Report. Available from: https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5436662.pdf. Accessed January 2022.

USDA Forest Service. 2011. Watershed Conditions Classification Technical Guide. United States Department of Agriculture Forest Service, FS-978. July 2011. Available from: https://www.fs.fed.us/biology/resources/pubs/watershed/maps/watershed_classification_guide2011FS978.pdf. Accessed January 2022.

USDA Forest Service. 2012. Groundwater-Dependent Ecosystems: Level I Inventory Field Guide. Gen. Tech. Report WO-86a. Available from: https://www.fs.fed.us/geology/GDE_Level_I_FG_final_March2012_rev1_s.pdf. Accessed November 2021.

USDA Forest Service. 2013. Black Hills National Forest FY 2012 Monitoring and Evaluation Report. Available from: https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5436659.pdf. Accessed January 2022.

USDA Forest Service. 2014. Black Hills National Forest Aquatic Nuisance Species Action Plan FY 2014-2016. Available from https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprd3805002.pdf. Accessed January 2022.

USDA Forest Service. 2015. Black Hills National Forest FY 2013-2014 Monitoring and Evaluation Report. Available from: https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fseprd475802.pdf. Accessed January 2022.

USDA Forest Service. 2018. Black Hills Resilient Landscape Project Final Environmental Impact Statement. Available from: https://www.fs.usda.gov/nfs/11558/www/nepa/103904_FSPLT3_4276956.pdf. Accessed January 2022.

USDA Forest Service. 2021. WCATT SAQ Attribute Ratings 20211203.xlsx, provided by the USFS in December 2021.

U.S. Environmental Protection Agency (USEPA). 2013. Level III ecoregions of the continental United States (revision of Omernik, 1987): Corvallis, Oregon, USEPA – National Health and Environmental Effects Research Laboratory. Available from: https://www.epa.gov/eco-research/level-iii-and-iv-ecoregions-continental-united-states. Accessed January 2022.

U.S. Geological Survey (USGS). 1985. Hydrologic Hazards in Karst Terrain. Water Fact Sheet Open File Report 85-877. Available from: https://pubs.usgs.gov/of/1985/0677/report.pdf. Accessed November 2021.

USGS. 2003. Ground-Water Resources in the Black Hills Area, South Dakota. Water-Resources Investigations Report 03-4049. Rapid City, South Dakota. Available at https://pubs.usgs.gov/wri/wri034049/wri034049_files/wri034049p0_10.pdf. Accessed November 2021.

USGS. 2021. National Hydrography Dataset (ver. USGS National Hydrography Dataset Best Resolution (NHD) for Hydrologic Unit (HU) 4 - 2001 (published 20191002)). Available from: https://www.usgs.gov/core-science-systems/ngp/national-hydrography/access-national-hydrography-products. Accessed December 2021.

USGS 2022. USGS Groundwater for Data for the Nation Database. Available from: https://waterdata.usgs.gov/nwis/gw. Accessed December 2022.

Western Regional Climate Data Center. 2022. Climate Data on Temperature and Precipitation for Pactola Dam, Lead, Mt Rushmore and Custer, South Dakota. Available from: from http://www.wrcc.dri.edu/cgi-bin/cliF302010.pl?sd2087. Accessed December 2021.

Whallon, A.J. and N.C. Crawford. 1985. Hydrologic hazards in karst terrain (Water Fact Sheet) (No. 85-677). US Geological Survey. Available from: https://pubs.usgs.gov/of/1985/0677/report.pdf. Accessed January 2022.

Williams, A.P., C.D. Allen, A.K. Macalady, D. Griffin, C.A. Woodhouse, D.M. Meko and N.G. McDowell. 2013. Temperature as a potent driver of regional forest drought stress and tree mortality. Nature Climate Change, 3(3): 292-297.