Introduction

The Black Hills area is an important resource center that provides an economic base for western South Dakota through tourism, agriculture, the timber industry, and mineral resources. In addition, water originating from the area is used for municipal, industrial, agricultural, and recreational purposes throughout much of western South Dakota. The Black Hills area also is an important **recharge** area for **aquifers** in the northern Great Plains.

Population growth, resource development, and periodic droughts have the potential to affect the quantity, quality, and availability of water within the Black Hills area. Growth has resulted in competing interests for available water supplies. The Black Hills Hydrology Study was initiated in 1990 to address these concerns. This long-term study is a cooperative effort between the U.S. Geological Survey (USGS), the South Dakota Department of Environment and Natural Resources, and the West Dakota Water Development District, which represents various local and county cooperators.

Purpose and Scope

The purpose of this report is to provide a summary of the water resources of the Black Hills area that is intended primarily for a layreader audience. An overview of the Black Hills Hydrology Study also is provided. Because the Black Hills area of South Dakota and Wyoming is an important recharge area for several regional **bedrock aquifers** and various local aquifers, the study concentrated on describing **hydrogeology** and the hydrologic significance of selected bedrock aquifers. The highest priority was placed on the Madison and Minnelusa aquifers because: (1) these aquifers are heavily used and could be developed further; (2) these aquifers are connected to surface-water resources through streamflow **loss zones** and large **springs**; and (3) **hydraulic connection** between these aquifers is extremely variable. The Deadwood and Minnekahta aquifers had a lower priority because they are used less and have less influence on the hydrologic system. The **fractured Precambrian** rocks, Inyan Kara **Group**, and various local aquifers, including minor bedrock aquifers and **unconsolidated aquifers,** had the lowest priorities because: (1) the Precambrian and local aquifers are not regional aquifers with regional **flowpaths**; and (2) the Inyan Kara Group is not used as extensively in the Black Hills area as the other priority units.

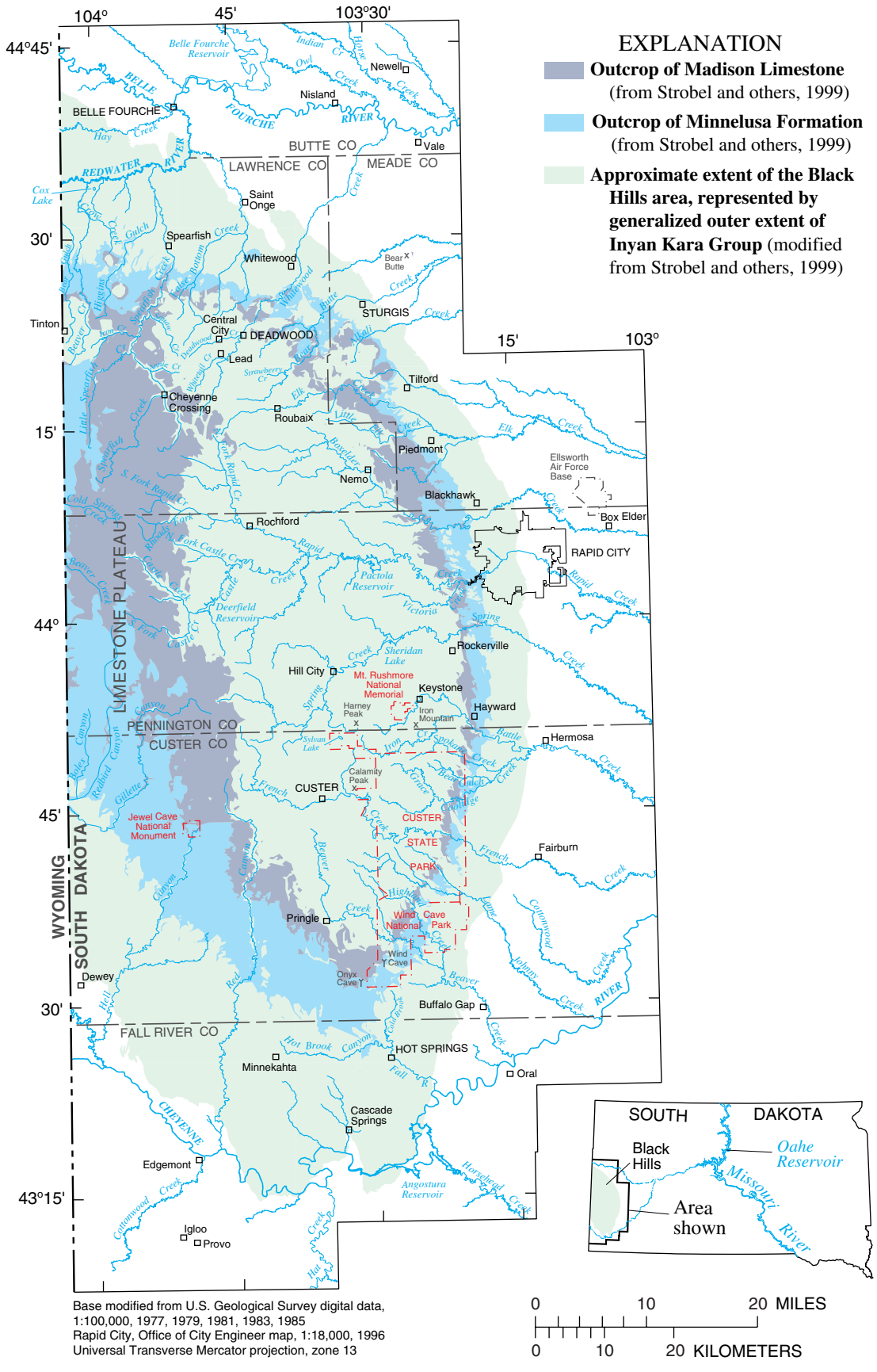


Figure 1. Area of investigation for the Black Hills Hydrology Study.

Description of Study and Study Area

The study area for the Black Hills Hydrology Study is presented in figure 1. **Outcrops** of the Madison Limestone and Minnelusa Formation, which are areas where these geologic **formations** occur at the land surface, are shown in figure 1. The generalized outer extent of the outcrop of the Inyan Kara Group, which approximates the outer extent of the Black Hills area, also is shown in figure 1. This section of the report provides an overview of the Black Hills Hydrology Study and a description of the study area.

Overview of Study

The Black Hills Hydrology Study was initiated in 1990 as a partnership among many local, State, and Federal agencies. Prior to this, preliminary studies were initiated in two counties to address a growing need for hydrologic information. Various preliminary data-collection activities were initiated in Pennington County as early as 1986. A general assessment of the water resources of Lawrence County was initiated in 1988, primarily to address hydrologic questions related to expansion of mining activities. Both of these preliminary studies were subsequently incorporated as part of the Black Hills Hydrology Study in 1990.

The West Dakota Water Development District was instrumental in expanding the preliminary studies to encompass the entire Black Hills area and served as a lead cooperator in representing the six counties within the expanded study area. West Dakota was responsible for the coordination of various local and county cooperators through a steering committee, whose membership is included in table 1. In addition, numerous individuals have provided technical assistance, guidance, and support to the study. A special thanks is extended to Dr. Phyllis Dixon, retired educator from Rapid City, who provided assistance by reviewing this document for readability by the intended audience.

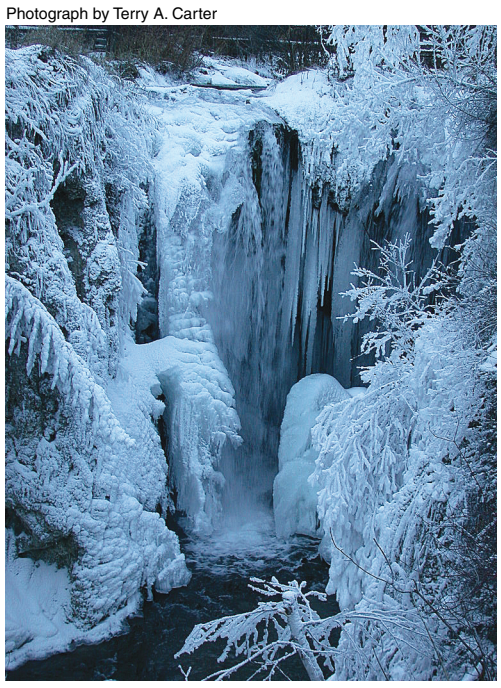
Table 1. List of individuals involved with the Black Hills Hydrology Study steering committee

[*, denotes major contribution by individual; DENR, South Dakota Department of Environment and Natural Resources]

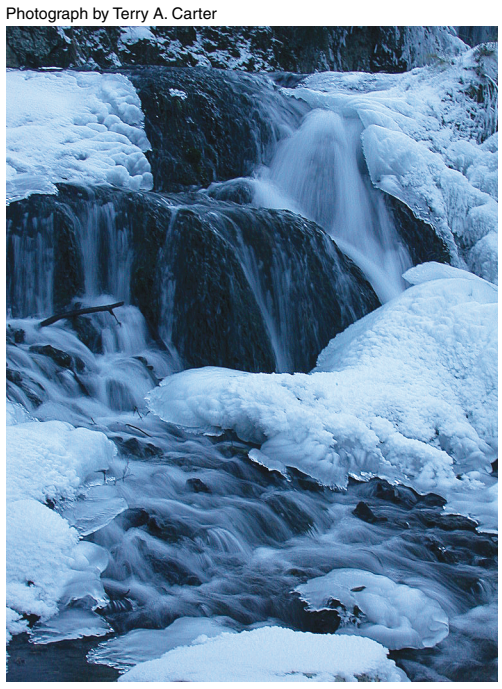
Name	Affiliation
Members of the Black Hills Hydrology Study Steering Committee	
***Daniel Bjerke**[1]	Public Works Director, Rapid City, S. Dak.
Charles (Eddie) Clay	Citizen, Hot Springs, S. Dak.
***Joseph Clinton**[1]	West Dakota Water Development District, Hill City, S. Dak.
Tom Fuller[1]	Public Works Director, Spearfish, S. Dak.
Carl Ham	South Dakota Water Congress, Caputa, S. Dak.
***Lynn Hedges**[1]	Citizen, Hermosa, S. Dak.
Robert Helmer[1]	Citizen, Belle Fourche - Rapid City, S. Dak.
***John Howard**[1]	Business representative, Rapid City, S. Dak.
William Keiry	Conservation Commission, Nisland, S. Dak.
***Jim Kissel**[1]	Citizen, Rapid City, S. Dak.
Bob Knecht	South Dakota Water Congress, Rapid City, S. Dak.
Buddy Livingston	Wyoming citizen, Newcastle, Wyo.
***Van A. Lindquist**[1]	Administrative Manager, West Dakota Water Development District, Rapid City, S. Dak.
***John Loucks**, Chairman[1]	West Dakota Water Development District, Rapid City, S. Dak.
***Larry Mann**[1]	Mining industry representative, Lead - Rapid City, S. Dak.
***George Opitz**[1]	County Commissioner, Lawrence County, S. Dak.
John Overholt	County Commissioner, Meade County, S. Dak.
Milo Rypkema	Citizen, Fairburn, S. Dak.
Henry (Hank) Scholz	Mining Consultant, Spearfish, S. Dak.
John Sheltens[1]	City Engineer, Hot Springs, S. Dak.
Marlene Simons[1]	Rancher & Wyoming Representative, Beulah, Wyo.
***Ted Vore**[1]	Public Works Department, Spearfish - Rapid City, S. Dak.
H. Edward Yelick[1]	West Dakota Water Development District, Rapid City, S. Dak.
Technical Advisors to Black Hills Hydrology Study Steering Committee	
Assad Barari	DENR, Geological Survey Program, Vermillion, S. Dak.
Jim Bell	South Dakota Board of Water and Natural Resources, Rapid City, S. Dak.
***Ken Buhler**[1]	DENR, Water Rights Program, Pierre, S. Dak.
***Laurie Gates**	DENR, Water Resources Assistance Program, Pierre, S. Dak.
John Hatch	DENR, Water Rights Program, Pierre, S. Dak.
***Lynn Hedges**	DENR, Geological Survey Program, Rapid City, S. Dak.
***Derric Iles**[1]	State Geologist, DENR, Geological Survey Program, Vermillion, S. Dak.
***J. Foster Sawyer**[1]	DENR, Geological Survey Program, Rapid City, S. Dak.
Mike Wiles[1]	National Park Service, Jewel Cave National Monument, Custer, S. Dak.
Various	South Dakota Department of Game Fish and Parks, Rapid City, S. Dak.
Various	DENR
Various	U.S. Forest Service
Various	Wyoming State Engineer's Office, Cheyenne, Wyo.
Other Parties Involved With the Black Hills Hydrology Study Steering Committee	
Jerry Apa	State Senator, Lead, S. Dak.
Michael Derby	State Representative, Rapid City, S. Dak.
Jim Dunn	Former State Senator, Lead, S. Dak.
James Emery	Former State Senator, Custer, S. Dak.
Kay Jorgensen	Former State Representative, Spearfish, S. Dak.
Marguerite Kleven	State Senator, Sturgis, S. Dak.
Kenneth McNenny	Former State Representative, Sturgis, S. Dak.
Judith Olson	Former State Senator, Rapid City, S. Dak.
Neal Strand	Former State Representative, Rapid City, S. Dak.
Linda Lea Viken	Former State Representative, Rapid City, S. Dak.
Della Wishard	Former State Representative, Prairie City, S. Dak.
Various	DENR, Water Resources Assistance Program, Pierre, S. Dak.
Various	Pennington County Drainage Commission
Various	Resource and Conservation Development Program
Various	South Dakota School of Mines and Technology
Various	Bureau of Reclamation, U.S. Department of the Interior

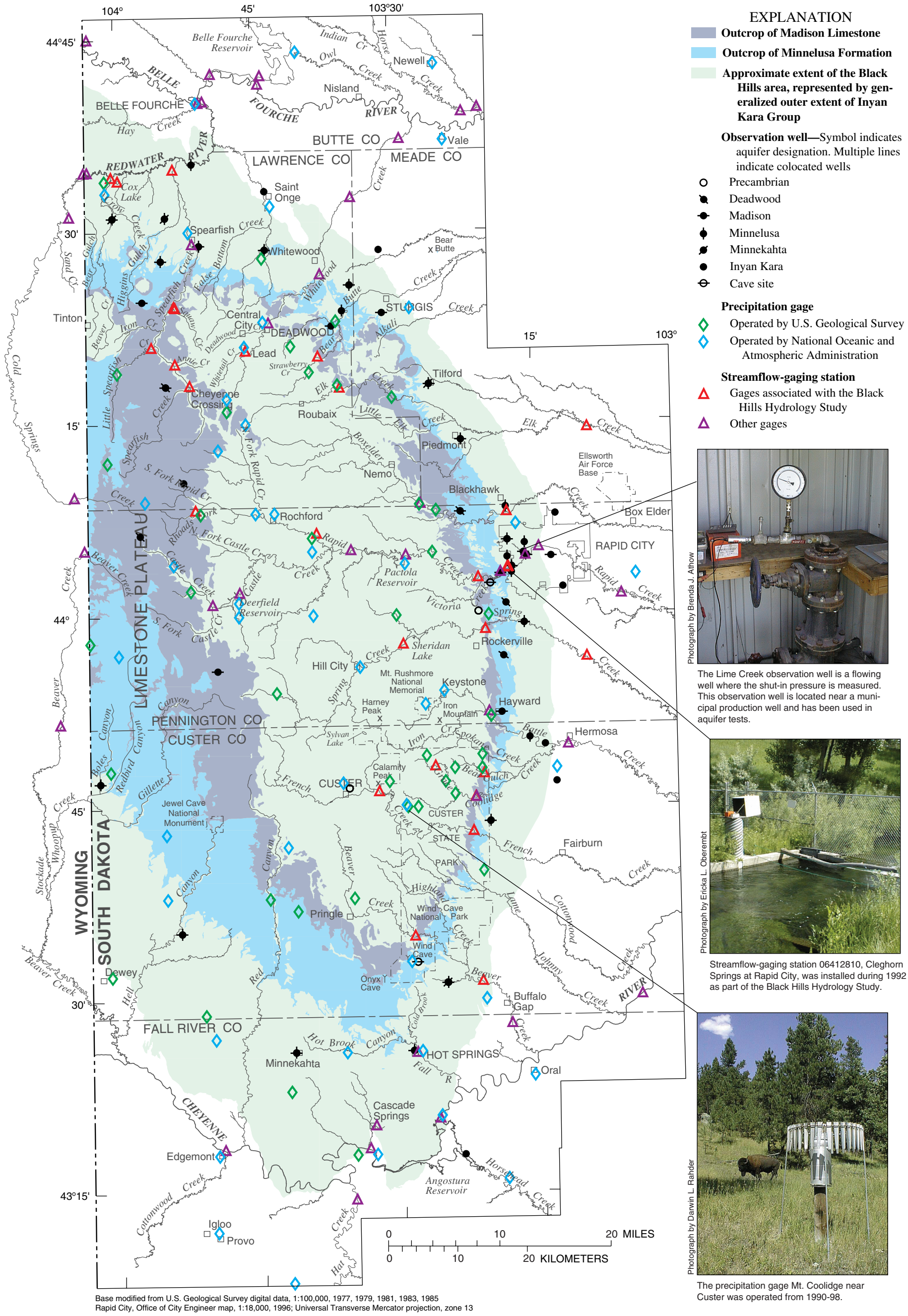
[1]Denotes current (2002) member or advisor.

Photograph by Terry A. Carter



Photograph by Terry A. Carter





Base modified from U.S. Geological Survey digital data, 1:100,000, 1977, 1979, 1981, 1983, 1985
Rapid City, Office of City Engineer map, 1:18,000, 1996; Universal Transverse Mercator projection, zone 13

EXPLANATION

Outcrop of Madison Limestone

Outcrop of Minnelusa Formation

Approximate extent of the Black Hills area, represented by generalized outer extent of Inyan Kara Group

Observation well—Symbol indicates aquifer designation. Multiple lines indicate colocated wells

- Precambrian
- Deadwood
- Madison
- Minnelusa
- Minnekahta
- Inyan Kara
- Cave site

Precipitation gage

- Operated by U.S. Geological Survey
- Operated by National Oceanic and Atmospheric Administration

Streamflow-gaging station

- Gages associated with the Black Hills Hydrology Study
- Other gages

Photograph by Brenda J. Athow

The Lime Creek observation well is a flowing well where the shut-in pressure is measured. This observation well is located near a municipal production well and has been used in aquifer tests.

Photograph by Ericka L. Oberembt

Streamflow-gaging station 06412810, Cleghorn Springs at Rapid City, was installed during 1992 as part of the Black Hills Hydrology Study.

Photograph by Darwin L. Rahder

The precipitation gage Mt. Coolidge near Custer was operated from 1990-98.

Figure 2. Data-collection network for the Black Hills Hydrology Study.

The purpose of the Black Hills Hydrology Study was to assess the quantity, quality, and distribution of **surface water** and **ground water** in the Black Hills area of South Dakota (Driscoll, 1992). Specific objectives of the study included:

1. Inventorying and describing precipitation amounts, **streamflow** rates, **ground-water levels** of selected aquifers, and selected water-quality characteristics for the Black Hills area;
2. Developing **hydrologic budgets** to define relations among precipitation, streamflow, and aquifer response for selected Black Hills **watersheds**;
3. Describing the significance of the bedrock aquifers in the Black Hills area, with an emphasis on the Madison and Minnelusa aquifers; and
4. Developing **conceptual models** of the hydrology in the Black Hills area.

The purpose of the Black Hills Hydrology Study was to assess the quantity, quality, and distribution of surface water and ground water in the Black Hills area.

The study consisted of two primary phases—data collection and interpretation. An extensive network (fig. 2) of **streamflow-gaging stations**, precipitation gages, and **observation wells** was used during the data-collection phase. Other streamflow-gaging stations and precipitation gages located outside of the study area also were used for the study. Critical components of this network (primarily streamflow-gaging stations and observation wells) have been maintained for long-term purposes.

A large number of USGS reports and maps were published as part of the study (table 2). In addition, numerous theses and dissertations by graduate students at the South Dakota School of Mines and Technology have been produced, and proceedings of a 1999 conference on the hydrology of the Black Hills were published (Strobel, Davis, and others, 2000). Various products from a companion water management study for the Black Hills area conducted by the Bureau of Reclamation also are available or forthcoming.

Various other site-specific studies in the Black Hills area have contributed to knowledge of the hydrogeology of the area. Numerous reports associated with these studies have been published in various outlets. In particular, studies of the Madison and Minnelusa aquifers in the Rapid City and Spearfish areas have been especially relevant.

Additional information concerning the Black Hills Hydrology Study is available at http://sd. water.usgs.gov/projects/bhhs/BHHS.html. Proceedings of a 1999 conference on the hydrology of the Black Hills were published by the South Dakota School of Mines and Technology.

Table 2. List of U.S. Geological Survey reports published as part of the Black Hills Hydrology Study

Report title	Reference
Plan of study for the Black Hills Hydrology Study, South Dakota	Driscoll, 1992
Compilation of selected hydrologic data through water year 1992, Black Hills Hydrology Study, western South Dakota	Driscoll and Bradford, 1994
Black Hills Hydrology Study	Driscoll, 1994
Arsenic loads in Spearfish Creek, western South Dakota, water years 1989-91	Driscoll and Hayes, 1995
Selected hydrologic data through water year 1994, Black Hills Hydrology Study, South Dakota	Driscoll and others, 1996
Streamflow characteristics for the Black Hills of South Dakota, through water year 1993	Miller and Driscoll, 1998
Streamflow losses in the Black Hills of western South Dakota	Hortness and Driscoll, 1998
Episodic sediment-discharge events in Cascade Springs, southern Black Hills, South Dakota	Hayes, 1999
Distribution of hydrogeologic units in the Black Hills area, South Dakota (map)	Strobel and others, 1999
Altitude of the top of the Inyan Kara Group in the Black Hills area, South Dakota (map)	Carter and Redden, 1999a
Altitude of the top of the Minnekahta Limestone in the Black Hills area, South Dakota (map)	Carter and Redden, 1999b
Altitude of the top of the Minnelusa Formation in the Black Hills area, South Dakota (map)	Carter and Redden, 1999c
Altitude of the top of the Madison Limestone in the Black Hills area, South Dakota (map)	Carter and Redden, 1999d
Altitude of the top of the Deadwood Formation in the Black Hills area, South Dakota (map)	Carter and Redden, 1999e
Selected data for wells and test holes used in structure-contour maps of the Inyan Kara Group, Minnekahta Limestone, Minnelusa Formation, Madison Limestone, and Deadwood Formation in the Black Hills area, South Dakota	Carter, 1999
Selected hydrologic data, through water year 1998, Black Hills Hydrology Study, South Dakota	Driscoll, Bradford, and Moran, 2000
Potentiometric surface of the Inyan Kara aquifer in the Black Hills area, South Dakota (map)	Strobel and others, 2000a
Potentiometric surface of the Minnekahta aquifer in the Black Hills area, South Dakota (map)	Strobel and others, 2000b
Potentiometric surface of the Minnelusa aquifer in the Black Hills area, South Dakota (map)	Strobel and others, 2000c
Potentiometric surface of the Madison aquifer in the Black Hills area, South Dakota (map)	Strobel and others, 2000d
Potentiometric surface of the Deadwood aquifer in the Black Hills area, South Dakota (map)	Strobel and others, 2000e
Selected hydrogeologic data for the Inyan Kara, Minnekahta, Minnelusa, Madison, and Deadwood aquifers in the Black Hills area, South Dakota	Galloway, 2000a
Digital data sets for map products produced as part of the Black Hills Hydrology Study, western South Dakota	Williamson and others, 2000
Summary of precipitation data for the Black Hills area of South Dakota, water years 1931-98	Driscoll, Hamade, and Kenner, 2000
Water-quality characteristics for selected streams in Lawrence County, South Dakota 1988-92	Williamson and Hayes, 2000
Estimated recharge to the Madison and Minnelusa aquifers in the Black Hills area, South Dakota and Wyoming, water years 1931-98	Carter, Driscoll, and Hamade, 2001
Hydrologic budgets for the Madison and Minnelusa aquifers, Black Hills of South Dakota and Wyoming, water years 1987-96	Carter, Driscoll, Hamade, and Jarrell, 2001
Geochemistry of the Madison and Minnelusa aquifers in the Black Hills area, South Dakota	Naus and others, 2001
Hydrologic conditions and budgets for the Black Hills of South Dakota, through water year 1998	Driscoll and Carter, 2001
Water-quality characteristics in the Black Hills area, South Dakota	Williamson and Carter, 2001

Description of Study Area

The study area for the Black Hills Hydrology Study (fig. 1) consists of the topographically defined Black Hills and adjacent areas located in western South Dakota. The Black Hills are situated between the Cheyenne and Belle Fourche Rivers. The Belle Fourche River is the largest **tributary** to the Cheyenne River. The study area includes most of the larger communities in western South Dakota and contains about one-fifth of the State's population. About 45 percent of the recent population growth in the Black Hills area (fig. 3) has occurred in unincorporated areas where water supply and waste-water disposal systems are not necessarily provided by municipalities.

The Black Hills uplift formed as an elongated **dome** about 60 to 65 million years ago (Darton and Paige, 1925). The dome is about 120 miles long and 60 miles wide. Land-surface altitudes range from 7,242 feet above sea level at Harney Peak to about 3,000 feet in the adjacent plains.

Beginning in the 1870's, the Black Hills have been explored and mined for many commodities including gold, silver, tin, tungsten, mica, feldspar, bentonite, beryl, lead, zinc, uranium, lithium, sand, gravel, and oil (U.S. Department of Interior, 1967). Mines within the study area have used various techniques including underground mining and open-pit mining. Many of the large open-pit mines and also rock outcrops that essentially are devoid of vegetation (fig. 4) are included in the barren land classification in figure 5.

About 43 percent of the study area is forest land (fig. 5), and most of the higher altitudes are heavily forested with ponderosa pine, which is the primary product of an active timber industry. White spruce, quaking aspen, paper birch, and other native trees and shrubs are found in the cooler, wetter areas of the Black Hills (Orr, 1959). The lower altitude areas surrounding the Black Hills primarily are rangeland, agricultural, and urban (fig. 5). Numerous deciduous species such as cottonwood, ash, elm, oak, and willow are common along streams in the lower altitudes. Rangeland, hayland, and winter wheat farming are the principal agricultural uses for dryland areas. Alfalfa, corn, and vegetables are produced in bottom lands and in irrigated areas. Various other crops, primarily for cattle fodder, are produced in both dryland areas and in bottom lands.

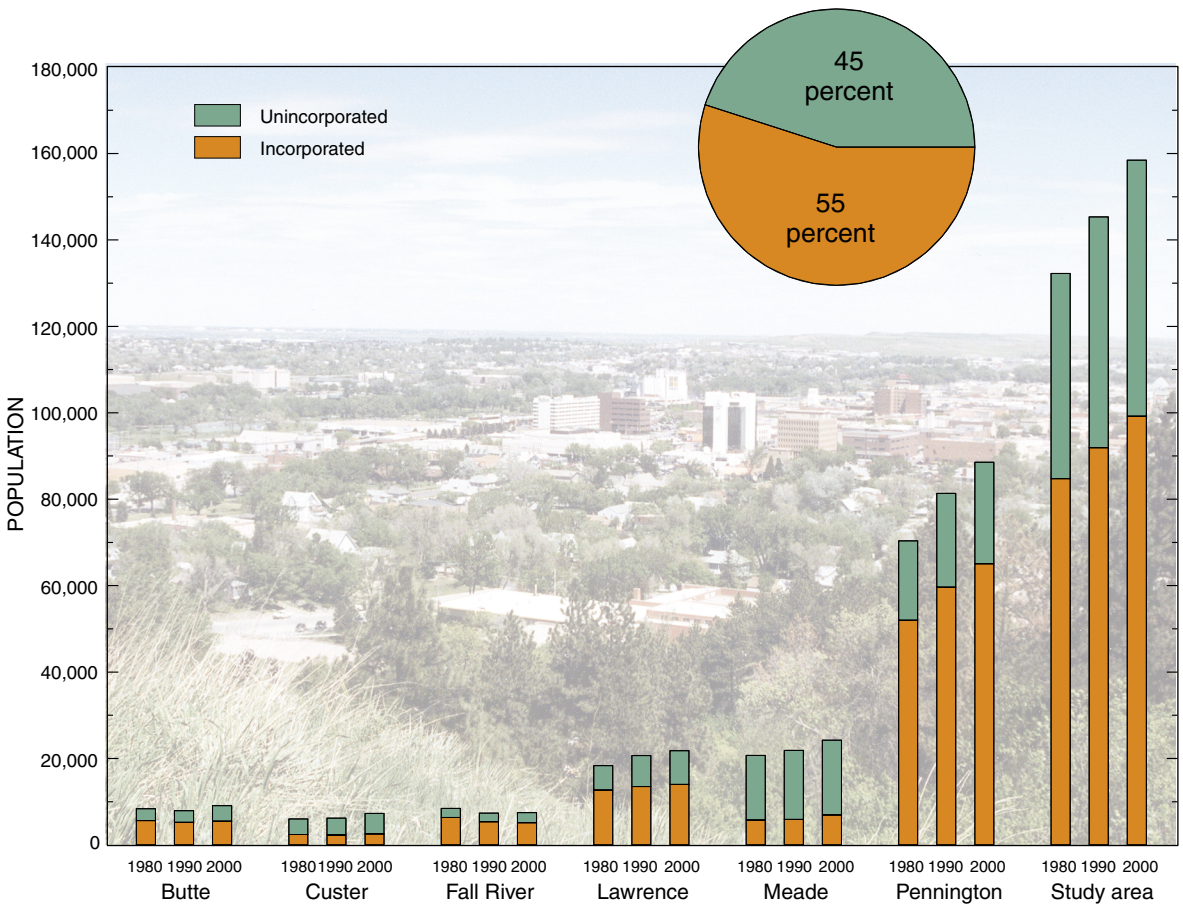
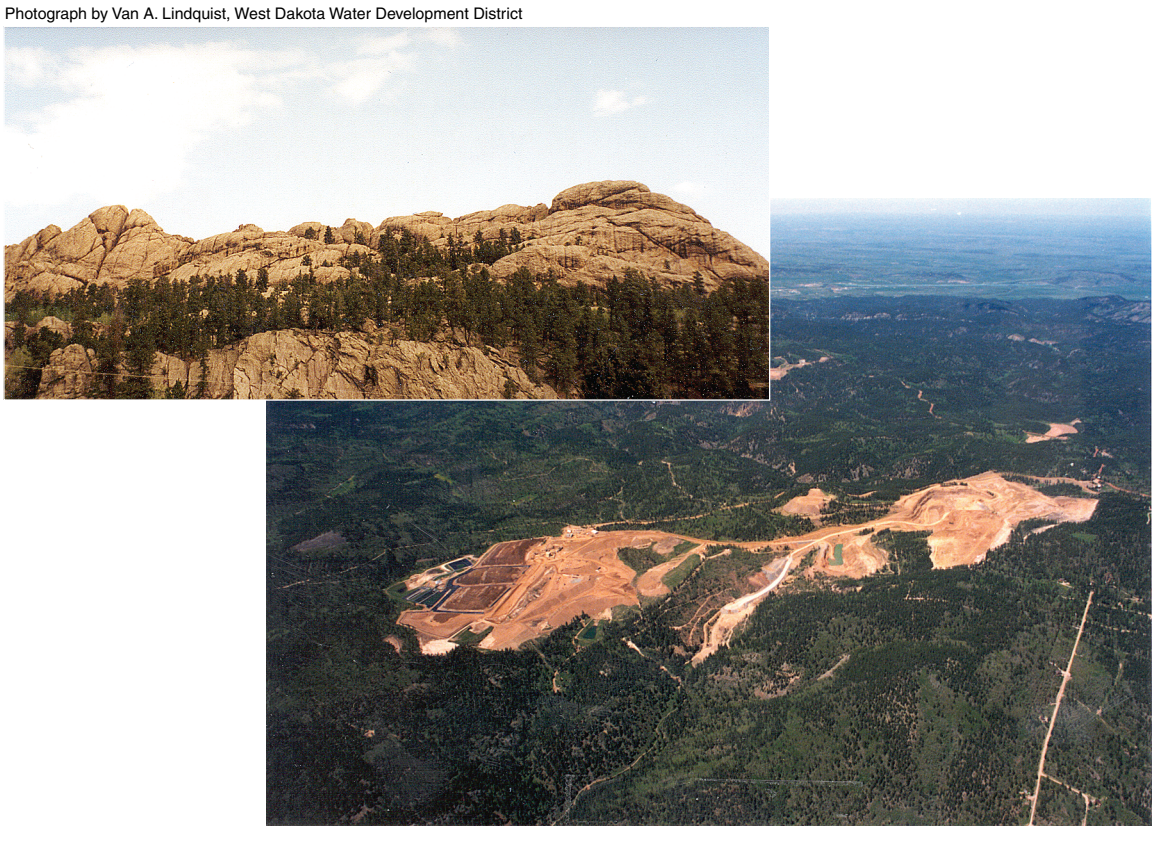


Figure 3. Population growth, by county, for incorporated and unincorporated areas (data from U.S. Census Bureau). Growth in the study area is estimated as 26,214 between 1980 and 2000. Pie chart shows percentages of that growth associated with incorporated and unincorporated areas. The largest growth occurred in incorporated areas in Pennington County, of which Rapid City (background photograph) is the largest municipality.

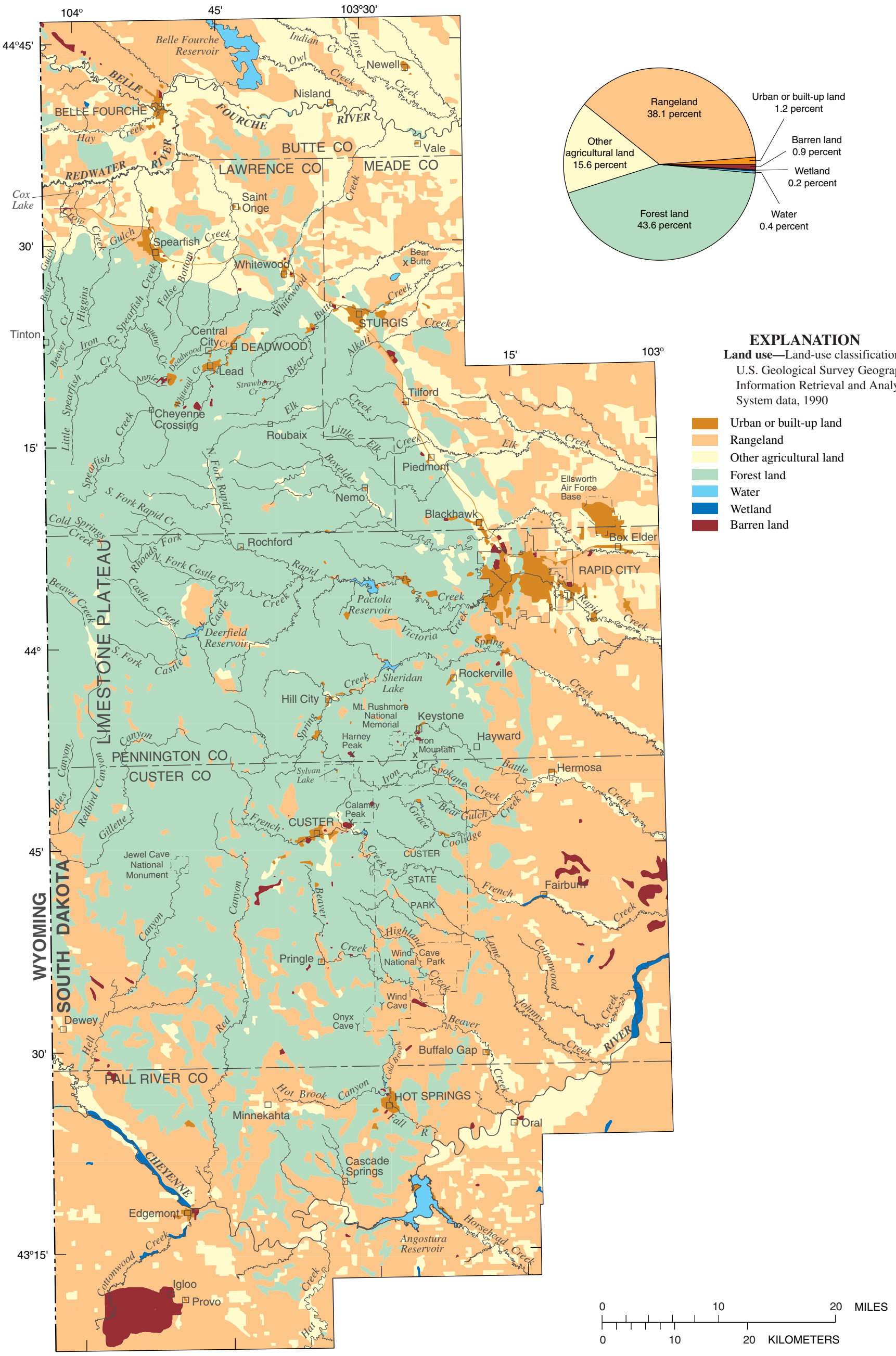
Figure 4. Calamity Peak near Custer (upper photograph) is an example of the "barren land" land-use classification. Large-scale mines (lower photograph) also are considered barren land.

Photograph by Van A. Lindquist, West Dakota Water Development District



Photograph by Mark A. Keenihan, South Dakota Department of Environment and Natural Resources

About 45 percent of the recent population growth in the Black Hills area has occurred in unincorporated areas where water supply and wastewater disposal systems are not necessarily provided by municipalities.



EXPLANATION

Land use—Land-use classification from U.S. Geological Survey Geographic Information Retrieval and Analysis System data, 1990

- Urban or built-up land
- Rangeland
- Other agricultural land
- Forest land
- Water
- Wetland
- Barren land

Base modified from U.S. Geological Survey digital data, 1:100,000, 1977, 1979, 1981, 1983, 1985
Rapid City, Office of City Engineer map, 1:18,000, 1996; Universal Transverse Mercator projection, zone 13

Figure 5. Distribution of 1990 land use in the Black Hills area.